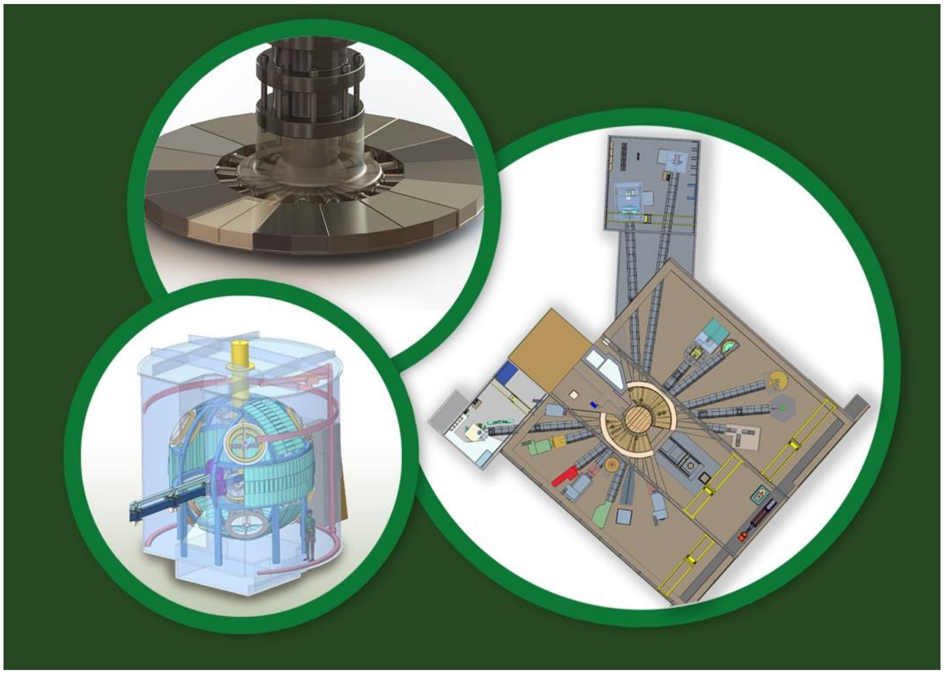
STS-S01030000-ES0002, R03 Draft

SECOND TARGET STATION (STS) PROJECT

Preliminary Hazard Analysis Report



Month XX, 2025

Not for public release

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SECOND TARGET STATION (STS) PROJECT

PRELIMINARY HAZARD ANALYSIS REPORT

Month XX, 2025

Prepared by
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for the
US DEPARTMENT OF ENERGY
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DOCUMENT APPROVAL RECORD

Spallation Neutron Source
Second Target Station Preliminary Hazard Analysis Report
SNS Document Number STS-S01030000-ES0002, R03 DRAFT

Recommended for approval:

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Steven Trotter Date
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STS Project Manager

Revision Record

Revision	Description
00	Initial Release
01	Update to incorporate design evolution 2021
02	Update to incorporate design evolution 2023
03	Update to incorporate design evolution during 2023, 2024, and early 2025

ACKNOWLEDGMENTS

The Environment, Safety, Health, and Quality (ESH&Q) team is working very closely with the members of the Second Target Station (STS) design team to integrate safety into the STS design. Therefore, the ESH&Q team wishes to acknowledge the willingness of the STS design team to work through the hazard analysis process and provide input to this interim Preliminary Hazard Analysis Report revision. Knowing that several key areas of the design are in flux at this stage of preliminary design, these designers openly engaged with the ESH&Q team as they developed their design solutions. These interactions considered the potential safety consequences that could affect their current design and, in several cases, either eliminated or mitigated the hazard through design changes.

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1. INTRODUCTION AND BACKGROUND

1.1 INTRODUCTION

This *Preliminary Hazard Analysis Report* (PHAR) has been prepared for the Second Target Station (STS) Project at the Spallation Neutron Source (SNS) at Oak Ridge National Laboratory (ORNL) as an interim update of the current project evolution since issue of the Second Target Station (STS) Project Preliminary Hazard Analysis Report (PHAR), STS-S01030000-ES0002, R02, January 12, 2023[8]. This project will construct a STS on the SNS site, an initial set of neutron scattering instruments, and the required proton beamline transport to the target. The purpose of this document is to provide an update to the preliminary qualitative evaluation of the hazards to workers and the public. This has been accomplished using extensive face-to-face reviews of the hazard evaluation (HE) tables and updates provided by the design leads in each of the STS key areas. The Hazard Evaluation (HE) tables are maintained current with the safety/design basis, and the respective postulated STS events are provided in Appendices A through S. These tables provide a snapshot in time (XX/XX/2025) of the current project safety basis and design considerations. However, design changes or evolution could impact these tables. Remote handling and event consequences associated with the target have been evaluated including the current configuration of the core vessel internal components and their removal and handling during removal and movement in the target building. The consequence analyses initially performed on the monolithic target design were determined to bound the consequences of the updated segmented target design. These tables are the result of continued interactions between the ESH&Q and the project design teams to evolve the PHAR consistent and in parallel with design evolution and assure that efforts to integrate safety into the design is documented. The tables will continue to evolve with the design throughout the project. Certain bounding events using the initial target design are being maintained as bounding evaluations in project documentation to facilitate future target design evolution or alternate target designs.

The scope of this hazard analysis is focused on the events associated with significant radiological releases/exposure and oxygen deficiency hazards that cannot be considered as standard industrial hazards. These events are categorized by event type (fire, explosion, loss of confinement/containment, ODH, external events, and natural phenomena events. Standard industrial hazards (SIH) are evaluated in the PHAR only to the extent in which they can lead to a more significant event. SIHs, whether as part of normal operations or maintenance activities are identified as part of the design process or operational planning and appropriate codes and standards are specified or a determination that the ORNL Standards Based Management System (SBMS) provides adequate direction to address the hazard. Additionally, STS will use the existing SNS Job Hazard Analysis to guide work planning and safe operations. The results during the project phase of STS are documented as part of the system, structure, or component design documentation and where warranted carried forward to operational procedures.

The facility description provided in Section 2 of this document represents a high-level presentation of the facility configuration and planning. This is an update to that documented in the STS *Conceptual Design Report*[1] and Revision 2 of this PHAR[8]. It is expected that details of the facility configuration description provided in Section 2 will continue to evolve. Some decisions are currently being evaluated that may further change the facility layout, and these will be updated as they become available..

The SNS target facility hazards for the SNS First Target Station (FTS) were extensively reviewed and are documented in the *SNS Hazard Identification and Evaluation* (SNS 102030102-ES0017),[2] developed early in the project, and later in the SNS final safety assessment document (FSAD), FSAD-NF.[3] Accelerator hazards for the SNS are documented in the SNS FSAD-PF.[4] The preliminary hazard analysis (PHA) for the STS uses an approach to the HE process similar to that used for the FTS, with the focus on ensuring that all credible scenarios have been evaluated, consequences qualitatively evaluated, and credited controls selected (where warranted) consistent with the *Second Target Station (STS) Project Policy for Selection of Safety Related Credited Controls*, S01030100-ES0001-R00,[5] January 2021.

1.2 BACKGROUND

The Department of Energy (DOE) authorized the design, construction, and operation of the SNS, an accelerator-based neutron source that provides intense pulsed neutron beams for scientific research and industrial development. The construction project was completed in 2006. After over 10 years of SNS operation, the need for a STS has been identified to provide additional and improved neutron scattering instrumentation. The eventual need for this facility was foreseen in the original National Environmental Policy Act (NEPA) Environmental Impact Statement, EIS-0247: Construction and Operation of the Spallation Neutron Source (April 1, 1999) and the respective Record of Decision (ROD) (Federal Register / Vol. 64, No. 125 / Wednesday, June 30, 1999). Furthermore, the initial design of a second target station at the SNS was included in the site layout. A proton power upgrade (PPU) was implemented to increase the proton beam energy to 1.3 GeV and total power capacity to 2.8 MW, which allows the accelerator to provide up to 2.1 MW at 45 pulses per second to the FTS and 700 kW at 15 pulses per second to the STS. Because the FTS was designed for 2.0 MW, plans are to initially limit power there to 2.0 MW. The PPU project was a separate project and not part of the STS project. The SNS FSAD-PF will be revised as needed for changes associated with the PPU Project and the STS Project.

DOE Order 420.2D,[10] *Safety of Accelerator Facilities*, states the applicability of the Order to all DOE accelerator facilities, while unambiguously confirming the distinctions between accelerator facilities and nuclear facilities. As a new accelerator project, the STS Project undergoes formal project management reviews as required by DOE Order 413.3B, *Program and Project Management for the Acquisition of Capital Assets*. Although DOE O 420.1C, Rev. 3[9] primarily addresses nuclear facilities several requirements are specifically applied to accelerators. The applicable requirements for STS are fire protection and natural phenomena hazards (NPH) mitigation.

A hazard analysis was prepared and submitted as part of the CD process and updated in 2021 and 2023. Specifically, the PHAR will evolve with the project design, commissioning, and operation as part of each of the CD process phases, along with specific revisions as needed to formally communicate the current facility hazard analysis. By the time the project reaches CD-4, the hazard analysis will be consistent with the as-built facility and the respective safety assessment documents will be prepared. This current document serves as an interim issue of the PHAR, and as the foundation for further analyses and evaluations as the project moves forward.

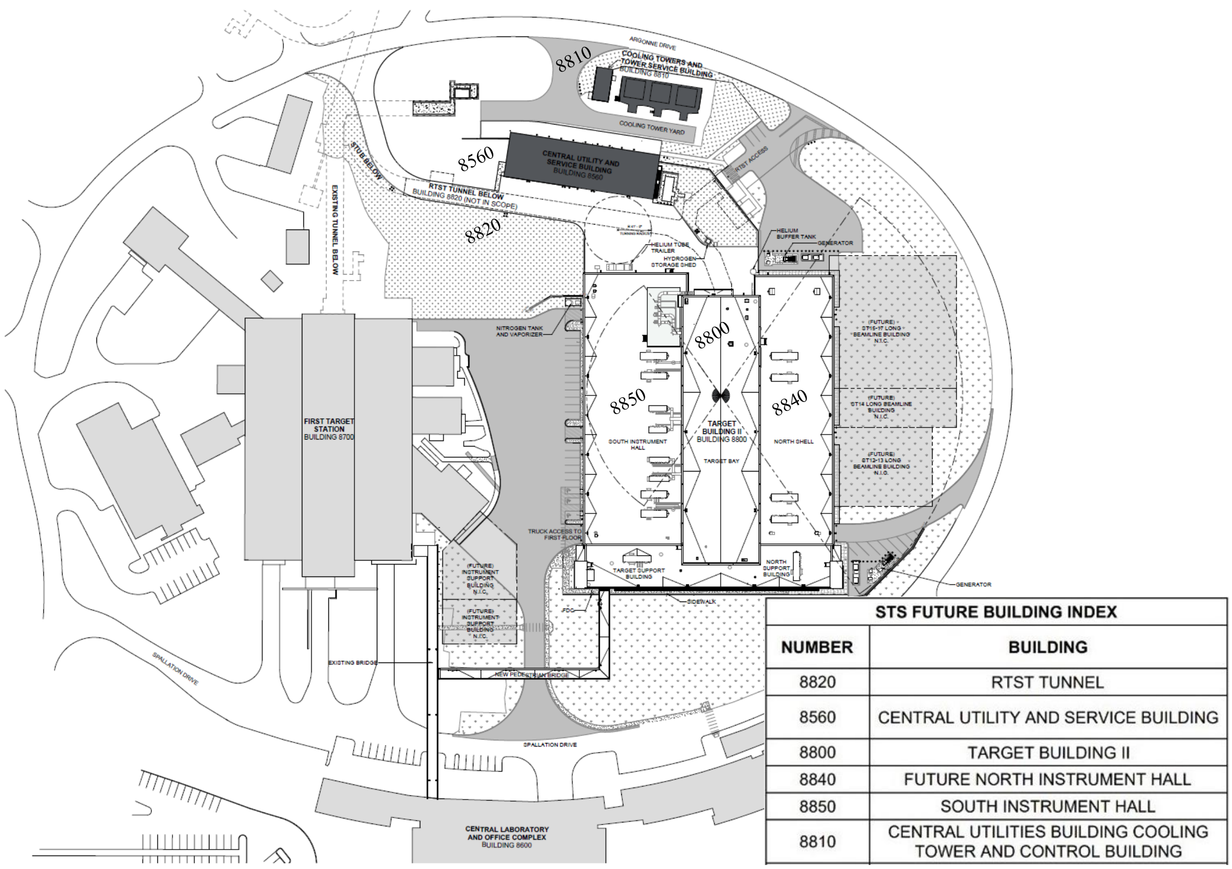
The Hazard Evaluation (HE tables) presented in this document addresses hazards associated with the Ring-to-Second Target (RTST) beamline and tunnel, neutron scattering instrument systems, target, support utilities, and support areas of the second target building. The Hazard Evaluation is intended to provide input to future development of Preliminary and Final Safety Assessment Documents (SNS PSAD-STS and SNS FSAD-STS), which are required by DOE Order 420.2D, *Safety of Accelerator Facilities*, and DOE Guide 420.2-1A,[11] *Accelerator Facility Safety Implementation Guide for DOE O 420.2C, Safety of Accelerator Facilities*, for the SNS facilities.

2. PROJECT DESCRIPTION

Overview

The SNS facility at ORNL initially included a FTS with 24 instrument beamlines. The original SNS Campus Master Plan included provision for an STS. This provision has been further developed to accommodate growth and expansion of the accelerator facilities, target facilities, instrument buildings, laboratories, offices, and secondary supporting facilities. A PPU Project was implemented, which increased the accelerator power capability from 1.4 MW to 2.8 MW at 60 Hz. This capability allows the accelerator to provide up 700 kW at 15 pulses per second to the new target station when it is available. The STS Project will provide the proton beam transport to the STS, the target station, an initial set of neutron scattering instruments, and the supporting buildings and facilities. The new facility is being designed for 18 beam ports to be capable of supporting 20 to 22 instruments. A short summary is included in this section for the key elements of the design as it currently stands.

Figure 2.1 highlights the site layout for the proposed new facilities.



STS FUTURE BUILDING INDEX	
NUMBER	**BUILDING**
8820	RTST TUNNEL
8560	CENTRAL UTILITY AND SERVICE BUILDING
8800	TARGET BUILDING II
8840	FUTURE NORTH INSTRUMENT HALL
8850	SOUTH INSTRUMENT HALL
8810	CENTRAL UTILITIES BUILDING COOLING TOWER AND CONTROL BUILDING

Figure 2.1. STS site plan.

Central Utility and Service Building

The STS will be served by a new Central Utilities and Service Building (CSB). The CSB will be located along the perimeter ring road north of the STS complex. The CSB will house utility systems, including magnet power supplies, magnet cooling systems, controls, diagnostics, and communication systems that support the RTST tunnel and proton beamline.

Ring to Second Target Tunnel

The Ring to Second Target (RTST) tunnel will house the proton beamline, shown schematically in Figure 2.2, that extends from the existing Ring-to-Target Beam Transport (RTBT) tunnel to the STS Target Building. Because of the radiological levels that will occur during operation of the proton beamline, it will be shielded with a combination of concrete and earth. The minimum bulk shielding requirement above the tunnel ceiling is 465 cm (15.25 ft) of soil. The CSB minimum bulk shielding requirement is 490 cm (16.1 ft) of soil to the beam-left of the RTST tunnel wall. The soil shielding is in addition to the concrete sidewalls and ceiling (1'-10" sidewalls, 2'-3" ceiling).

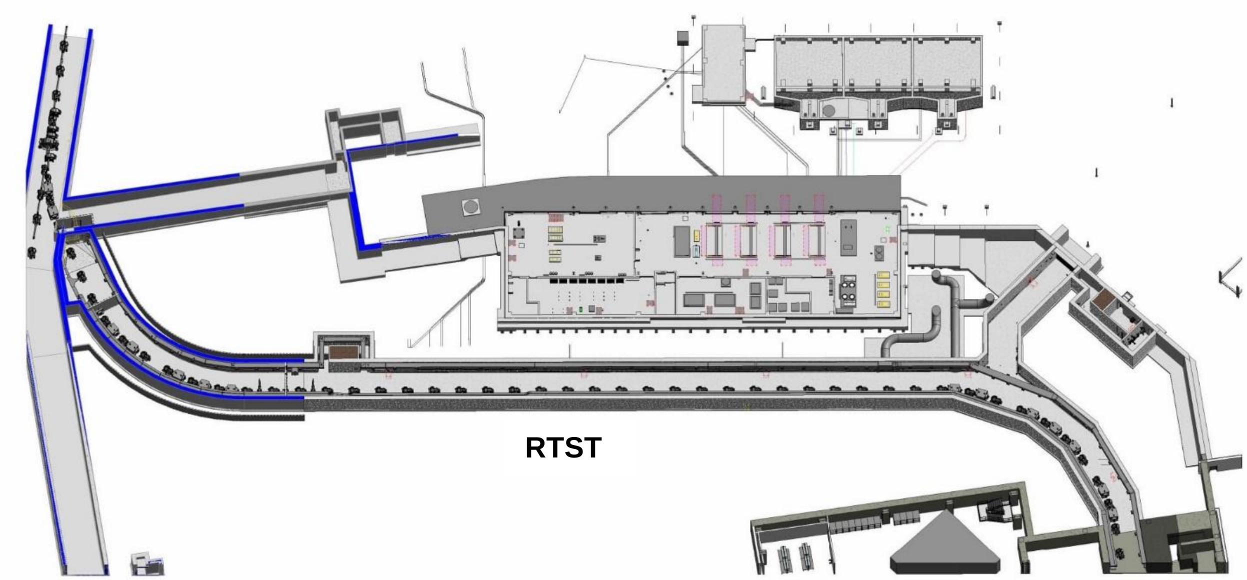


Figure 2.2. Ring-to–second target beamline.

The STS Target & Instrument Building

The STS Target & Instrument Building will house the second target monolith, target, support systems, and neutron scattering systems for the STS neutron beamlines. A perspective view from the high bay area shown in Figure 2.5. The STS Target & Instrument Building will also house all utility systems necessary to support the target, space supporting long-term maintenance of the target, and numerous other functions that are critical to operation of the target facility. Chilled water, tower water, heating water, and compressed air are supplied to the Target & Instrument Building from the CSB. The STS will include a South Instrument Hall and a North Instrument Hall Shell. The North Instrument Hall Shell allows for future expansion to accommodate long instruments. Figure 2.3 shows the initial set of instruments; located in the South Hall. An isometric view of the eight project instruments is shown in Figure 2.4.

The STS Target Building includes a service cell permitting a safe confined space for handling of activated components that come out of the monolith that require drying, reduction, or decay time prior to being declared as waste and shipped off site for disposal. The service cell includes a shear cutter station that allows for Target and Target Viewing Periscope (TVP) downsizing prior to loading the pieces into their respective casks. It also includes a location to support sluicing of the ion exchange column and handling of spent resin. Figure 2.6 shows an early concept of the Target Building Service Cell. The vertical slice of the Target Building is shown in Figure 2.8.

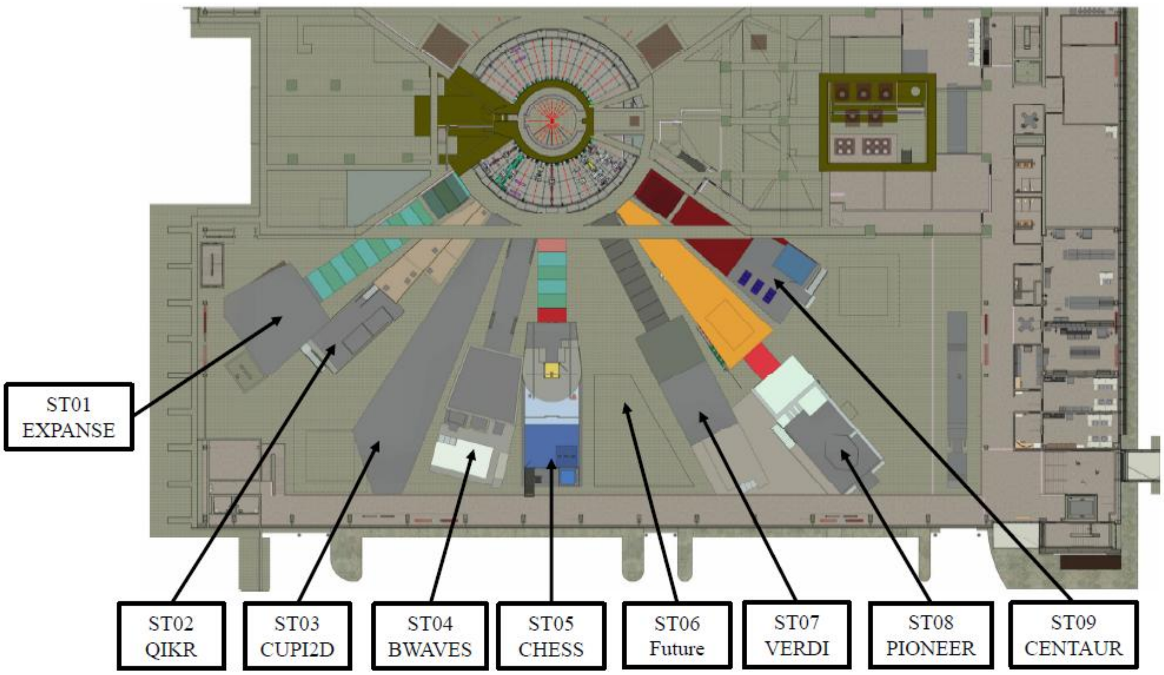


Figure 2.3. Initial Set of Instruments in South Hall.

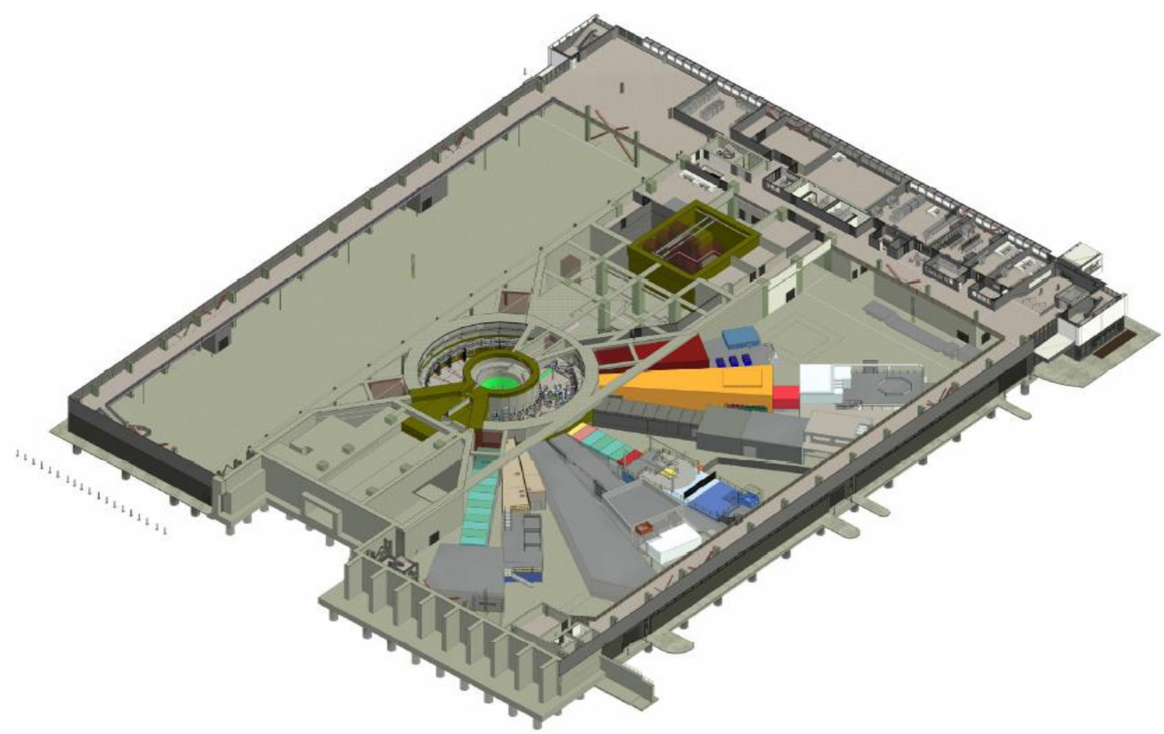


Figure 2.4. Isometric of Initial Set of Instruments in South Hall.

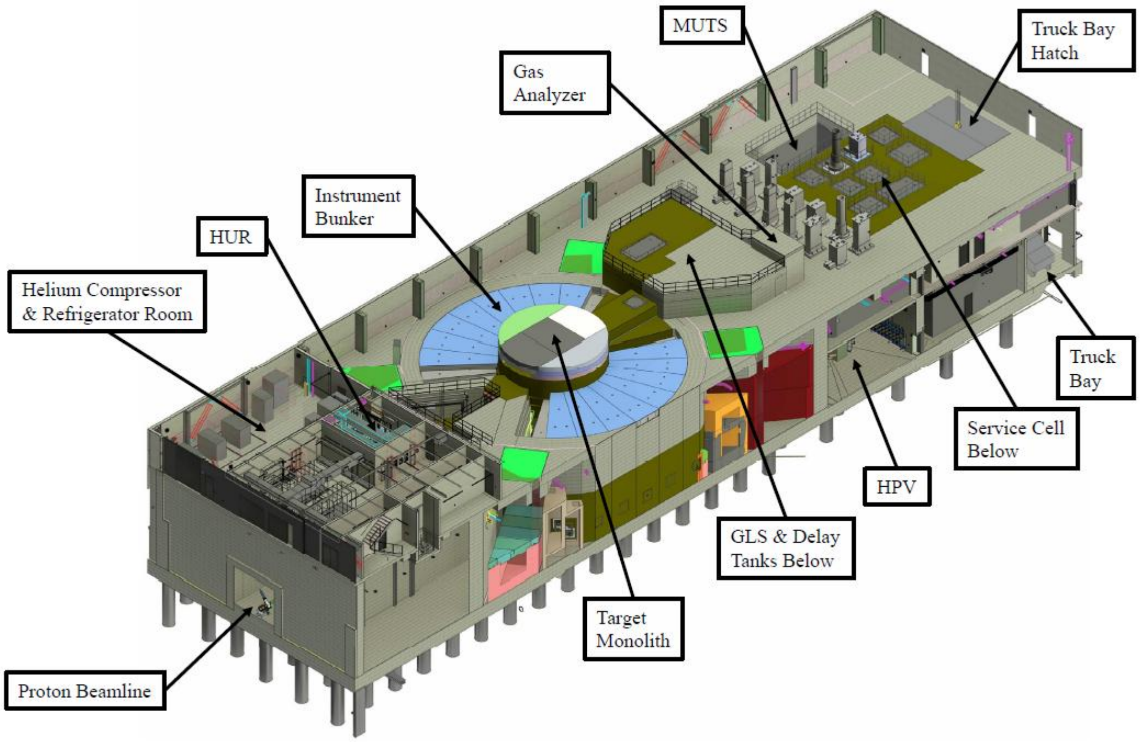


Figure 2.5. STS Target Building.

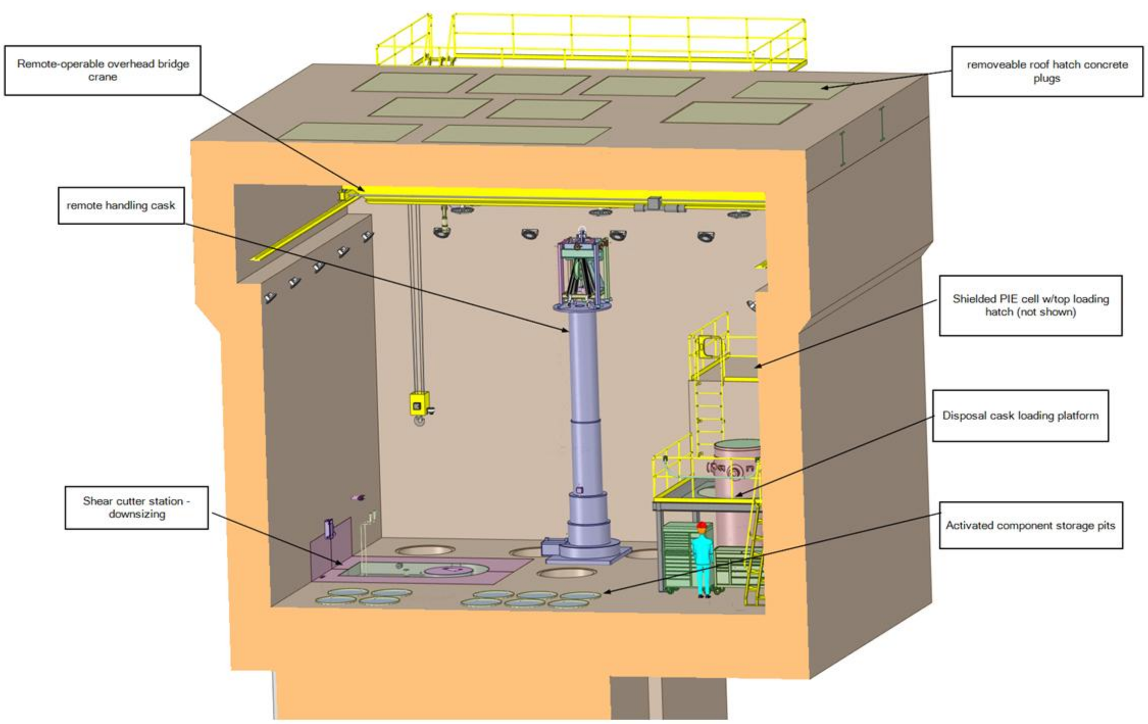


Figure 2.6. STS Target Building Service Cell

Target & Monolith

The target includes rotating target drive, target shaft, and a water-cooled rotating target assembly consisting of 20 segmented tungsten targets that will produce neutrons that will be moderated in two liquid hydrogen moderators to the energies required for the neutron instruments. The 700 kW incident proton beam will operate at 15 pulses per second with short pulses. Figure 2.7 shows a view of the central monolith and target region. The Monolith primarily consists of the targe assembly, TVP, Core Vessel, Core Vessel Shielding, Bulk Shielding, Proton Beam Window (PBW), and Moderator Reflector Assembly (MRA).

Two changes in this layout since the CDR is that there is currently one HARP in the design in the AS scope on the RTST side of the PBW. A second HARP has been approved on the target side. This HARP is on the PBW shielding and is in TS (AIC) scope. Both would drive an MPS trip. Additionally, there are three HALOs in the design and all three are in the TS (AIC) scope. One on the PBW shielding on the RTST side, one on the PBW itself, and one on the PBW shielding on the target side. MPS trips are only on the PBW HALO.

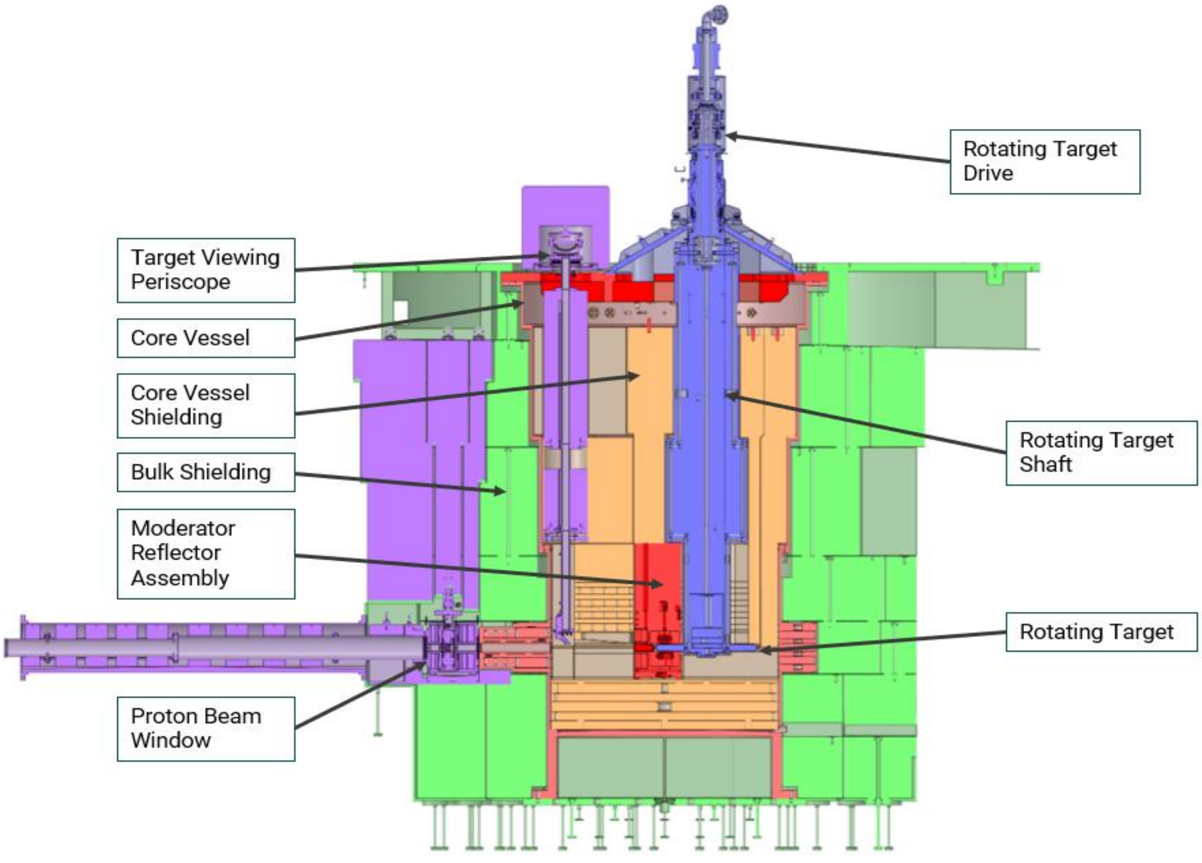


Figure 2.7. Target monolith layout.

Figure 2.8 shows a cut through the center of the Target Building.

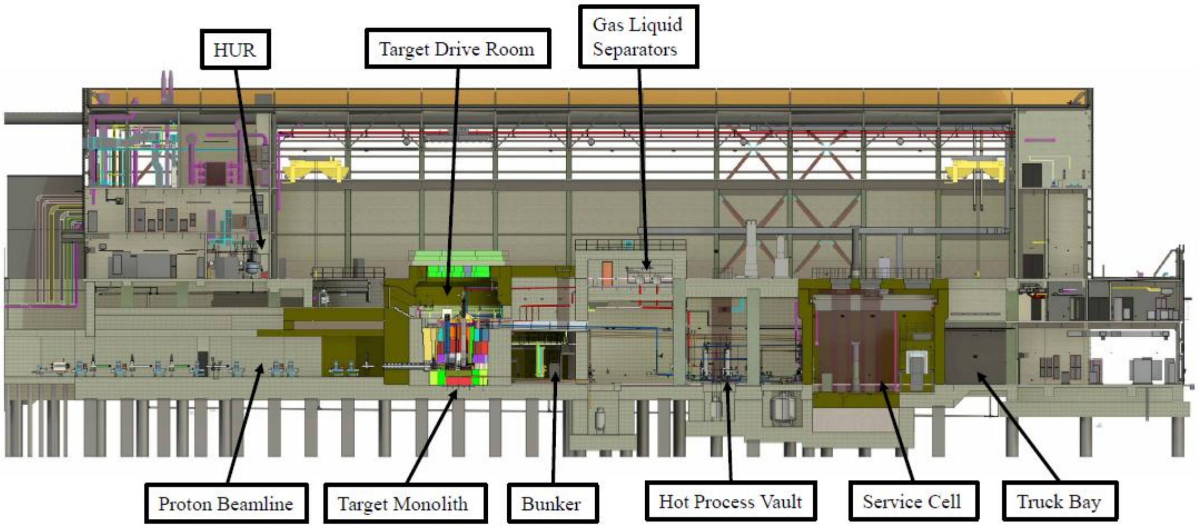


Figure 2.8. Vertical Slice of the Target Building.

Bunker

As shown in Figure 2.9, the STS incorporates a heavily shielded bunker which surrounds the 10-meter-diameter target monolith. This bunker allows for simpler installation and maintenance of the near-monolith instrument components. The bunker will be hands-on accessible during facility shutdowns but will not be accessed by personnel when the beam is on. Access to the bunker is through a shielded door and corridor/stairs from level 2 to the bunker mezzanine. Egress only is possible through a shield door from level 1 into the HPV.

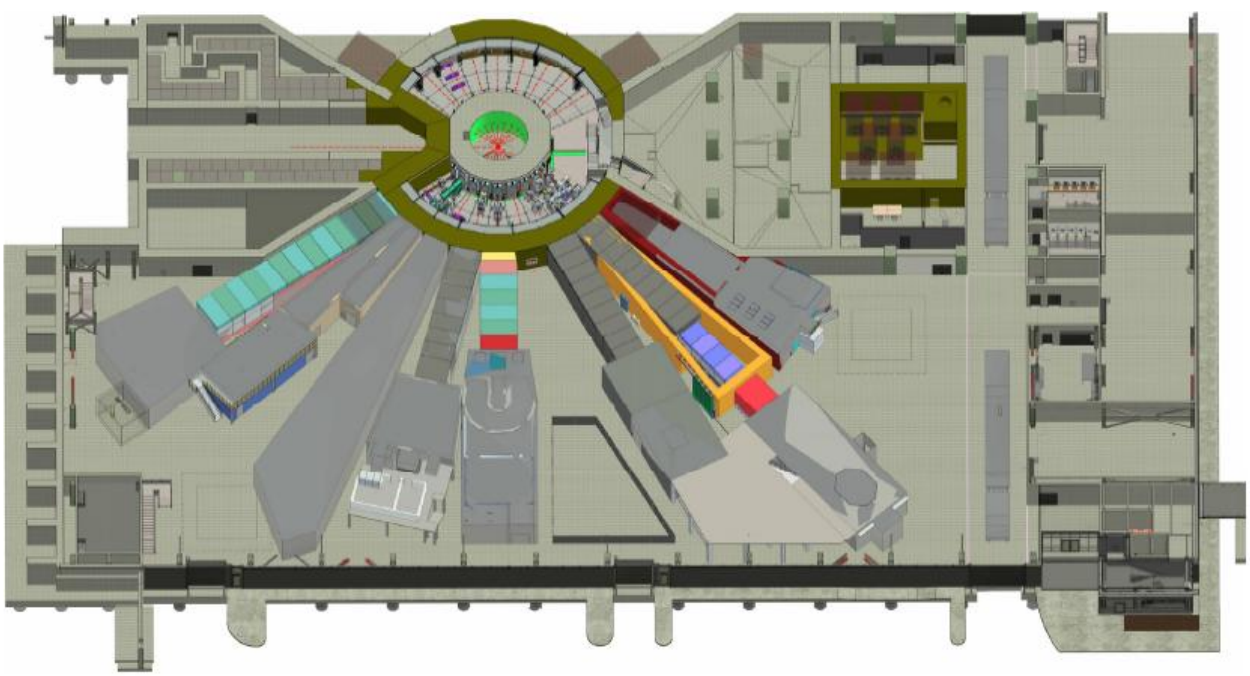


Figure 2.9. Bunker in Target Building.

Figure 2.10 shows a view of the bunker surrounding the monolith. In this view, the proton beam enters the monolith from the top. An elevated catwalk around the bunker perimeter will allow walking above the instruments, with local ladders providing bunker floor access between beamlines.

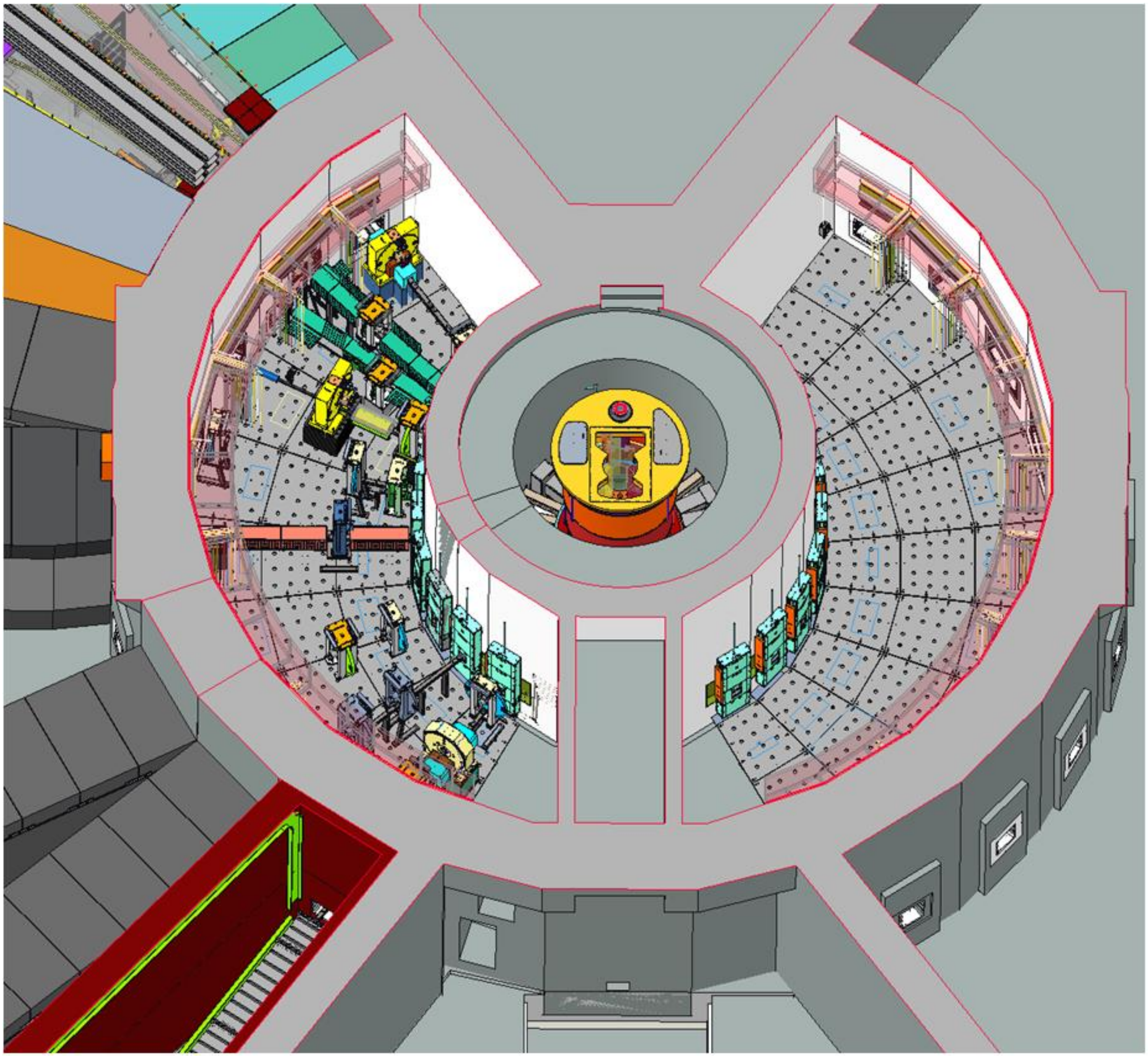


Figure 2.10. Instrument bunker surrounding target monolith.

Neutron Scattering Instrumentation

STS uses neutrons as probes to conduct materials research using a suite of neutron scattering instruments. Each neutron scattering instrument consists of unique combinations of optics and choppers to transport neutron beams from their source to experimental end stations called caves, and all these components are located under heavy radiation shielding. Within these instrument caves, the transported neutrons interact with material samples and are scattered into a group of neutron detectors arranged in specific geometries around the sample position. In some instruments, samples and/or detectors are located within a vacuum chamber, while in others sample and detectors are in air. When the STS facility is producing neutrons, each instrument functions as an independent laboratory, and no personnel are inside any shielded spaces, including the instrument caves. Users can stop the flow of neutrons to their specific instrument using a neutron shutter, and safety interlocks then allow personnel access to the instrument cave for sample changes. Most maintenance on an instrument occurs during facility shutdowns.

Control Systems

Integrated Control Systems provides the controls, data acquisition, computing infrastructure, and protection systems across all STS technical areas. Control systems integrate all the STS systems and ensures that STS functions as an integral part of the SNS.

The control systems enable remote control, monitoring, alarms, and data archiving for the STS accelerator, target, conventional facilities, and neutron scattering instruments. The instrument data acquisition system includes the software and electronics for collecting scientific data, storing those data, and making data available for analysis. Control systems include the software tools for conducting an experiment, automating data collection, and providing remote access. The protection systems provide the interlocks, monitoring, and controls enabling safe operation of the facility.

The STS control systems, like all SNS control systems, is built using the Experimental Physics and Industrial Control System (EPICS) toolkit. The STS control systems use several technologies, including programmable logic controllers, custom digital electronics, and commercial instrumentation. Software for user interfaces, archiving, and alarms are built using the CS-Studio toolkit. The control systems are highly distributed using a reliable computing and network infrastructure for transporting data

Accelerator Interface Components

The Accelerator Interface Components system (AIC) is the interface from the Accelerator Systems to the Target Systems. It consists of four distinct subsystems:

- Proton Beam Window (PBW): The core functionality of Proton Beam Window is to separate the core vessel environment from the high-vacuum accelerator environment.
- PBW Shielding: The main purpose of the PBW shielding is to provide shielding immediately around the PBW to absorb the scattered beam from the PBW.
- Proton Beam Tube Assembly (PBTA): The PBTA transports the beam from the Accelerator System to the PBW in the Monolith and provides a vacuum connection to the Accelerator System. The PBTA is the first physical interface between the Target systems and the Accelerator systems.
- Target Viewing Periscope (TVP): The primary purpose of the TVP is to view the proton beam profile on the front face of the Target. The TVP also aims to measure the temperature of the target segment face. The Proton beam profile on the target segment face is determined by scintillation of a luminescent coating that will be applied on the face of the target.

The PBW and PBW shielding are installed in the Target Station Shielding and the TVP is installed in the Core vessel. The PBTA is installed in a liner penetrating the concrete wall from the Ring to Second Target (RTST) tunnel to the Target Systems Monolith. The AIC also has three beam diagnostics - the halo monitor assemblies in the PBW and PBW Shielding, TVP and the PBW Harp.

Vessel Systems

Vessel Systems (VS) is comprised of four primary components: the Core Vessel assembly, Core Vessel Shielding assembly, Nozzle Extension assemblies and the Gamma Gate assembly. The technical components residing inside the core vessel include the Target Assembly, the Moderator Reflector Assembly, the Target Viewing Periscope, the Core Vessel Shielding and portions of the Gamma Gate assembly. The Core Vessel provides an inert environment suitable for neutron production and serves as part of a leak collection system for all water-cooled components housed within the Core Vessel. The Core Vessel Shielding is comprised of both water-cooled and uncooled shield blocks that surround the internal technical components within the Core Vessel and provide both radiation protection and thermal regulation within the Core Vessel. The Nozzle Extension assemblies provide housings that support and align the monolith insert guide optics designed and built by Instrument Systems. The gamma gate resides at the top of the core vessel shielding stack and provides additional shielding during target segment changeouts that facilitates hands-on target maintenance work.

Target Station Shielding

Target Station Shielding (TSS) is comprised of five primary components: Bulk Shielding, Removable Shielding, Core Vessel Baseplate, Bulk Shielding Liner and Pipe Pans. The Bulk Shielding resides between the concrete monolith structure and the core vessel and provides radiation shielding within the Monolith. Removable shielding resides above the pipe pans and serves as part of the floor structure for the target drive room. The Core Vessel Baseplate supports and aligns the Core Vessel and has a central drain hole for routing water leaks out of the Monolith. The bulk shielding liner is joined to the Core Vessel Baseplate, and together they provide leak collection and drainage for the lower section of the Monolith. The pipe pans reside at the top of the bulk shielding just below the floor of the target drive room. The pipe pan contains most of the water-cooling lines that enter and exit the Core Vessel and provide leak collection and drainage for any leaks in these pipes.

Target Process Systems

The STS Target Building includes a Hot Process Vault (HPV) that contains two Activated Cooling Loops (ACL), a Low Level Liquid Waste system (LLLW), and a Leak Collection System (LCS), all of which will contain activated water. The two Activated Cooling Loops provide cooling for Target Technical Components, with Loop 1 serving the Target Assembly and Loop 2 serving all other water-cooled components residing in the Monolith. These cooling loops also include features to store, and transfer spent ion exchange resin. The LLLW system receives, stores, samples, and dispositions for disposal water from activated and potentially activated sources, while the Leak Collection systems capture and direct leaks of activated water to the appropriate destinations. The HPV will be hands-on accessible during facility shutdowns but will not be accessed by personnel when the beam is on. Shielded doors will provide access to the HPV.

Target Vacuum Systems

The Target Vacuum Systems are comprised of four independent subsystems providing vacuum pumping and monitoring (through interface to the Integrated Controls System) to technical components requiring vacuum environments for operation or maintenance:

- Inflatable Seal Vacuum Systems: Provides vacuum support to the inflatable seals on the PBW and PBW Shielding assemblies to maintain separation of the Accelerator and Target environments, and to retract the seals in the event of removal of those components.
- Core Vessel Vacuum System: Provides vacuum support to the Core Vessel to maintain a rough vacuum during operation or prior to backfill with Helium.
- Cryogenic Moderator Vacuum System: Provides vacuum insulation for the CMS hydrogen transfer lines between the Hydrogen Utility Room and the MRA.
- Component Dryer Vacuum System: Provides vacuum support to Remote Handling for the evaporation of water from water-cooled technical components that have been removed from the Monolith.

3. SUMMARY OF HAZARDS

3.1 OVERVIEW

Except for events associated with the rotating segmented solid target or mercury target, many of the hazards at the STS are very similar to those at the FTS. Since the FTS has been an operating facility for over 10 years with current FSADs, these hazards are well understood. The STS project hazards for the accelerator RTST beamline are similar to those for the existing beamline. The STS instrument set also is expected to present a similar set of hazards to those identified in the FSAD-NF[3].

The primary reason for the selection of a rotating target is that the decay heat can be passively removed by thermal radiation to the surrounding shielding without reaching temperatures that could cause a significant radiological release. Although the target could be damaged and require replacement, the design precludes exacerbating the event consequences. The potential mechanisms for release associated with elevated temperatures include the tungsten target and its associated cladding/housing. The release mechanisms include oxidation of the tungsten, as well as a potential reaction between tungsten and steam. However, the current segmented target design minimizes the potential for tungsten water/steam interactions and minimizes the potential contributions to radiological release from the cladding. The tungsten produces a tungstic acid aerosol and hydrogen gas.[6,7] The tungsten-steam reaction starts at approximately 800°C. Preliminary evaluations of the baseline design showed that with no cooling except thermal radiation to the surrounding shielding, the peak tungsten temperature was on the order of 400°C or less, which is well below the threshold for a tungsten/steam reaction.[6,7] The initial hazard event evaluations identified two primary types of unmitigated events as bounding for radiological dose exposure to workers or the public. The first primary type is a loss of cooling with continued beam operation, and the second is a seismic event followed by a hydrogen detonation adjacent to the target. These are summarized in the following sections. The current bounding accident scenarios are based on the previous target design of tungsten clad with tantalum. The contribution of tantalum to the radiological releases and associated consequences makes this analysis clearly more severe than the associated consequences from the current segmented design. When the target design is finalized, these analyses will be updated. No changes to current credited controls are expected. However, the calculated unmitigated consequences are expected to be much less. Although the current segmented target design provides a significant reduction in postulated consequences for these bounding events, the bounding events using the initial target design are being maintained as facility bounding evaluations in project documentation to facilitate future target design evolution or alternate target designs.

3.2 STS FACILITY BREAKDOWN FOR EVENT EVALUATIONS

To facilitate communication within the team and to ensure that the proper personnel are involved with the hazard evaluations performed within the integrated design and Environment, Safety, and Health (ES&H) staff, the hazard tables have been broken down generally by WBS element. The HE tables for each facility segment are provided in Appendices A through S within this document. They are presented alphabetically by the pneumonic assigned to each section, as shown in Table 3.1. On-site transfer of remotely handled components and waste has not been specifically evaluated in this PHAR, as it will be determined by pending decisions on remote handling of components within the facility and waste handling and shipping.

Even with the above organization and breakdown of systems and event scenarios, some scenarios involve multiple systems and some systems interface with multiple systems and therefore are potentially impacted by the same event scenario. Therefore, a complete set of events for single system may be captured in multiple tables. For example, facility wide events (e.g., seismic event) are captured in Appendix C

(Building General). However, they are also captured in system specific tables in Appendix A (Accelerator Interface Components) and Appendix D (Cryogenic Moderator System and Moderator Reflectors Assembly).

Table 3.1. STS facility breakdown.

Appendix	Designator	System
A	AIC	Accelerator Interface Components
B	AS	Accelerator Systems
C	BG	Building General
D	CMS/MRA	Cryogenic Moderator System/Moderator Reflector Assembly
E	CW	Cooling Water
F	GW	Gas Waste Processing
G	HB	High Bay
H	HPV	Hot Process Vaults
I	HV	Secondary and Primary Confinement Systems
J	IS	Instrument Systems and Bunker
K	LCS	Leak Collection Systems
L	PW	Process Waste
M	RH	Remote Handling
N	RW	Contact and Remote Handling and Decontamination Area
O	SP	Storage Pad (Not currently part of the project scope)
P	SS	Service Cell
Q	TB	Truck Bay
R	TS	Target, Drive, and Support Systems/Buildings
S	VS	Vessel Systems

3.3 HAZARD EVENT CATEGORIES

The hazard event tables in each section are broken down into event types, as presented in Table 3.2.

Table 3.2. Hazard event categories.

Event category	Event type description
E-1	Fire events
E-2	Explosion events
E-3	Loss of confinement/containment events
E-4	Direct radiation exposure/chemical exposure events
E-5	Cryogenic oxygen deficiency hazard events
E-6	External events
E-7	Natural phenomena events

3.4 SAFETY INTERFACES BETWEEN FTS AND STS

There are several interfaces between the FTS and STS, as they will share the proton beam pulses from the ring and use some of the same site infrastructure, procedures, and programs. The following are some examples:

- A magnet switching system will be added in the transport line to divert pulses at 15 pulses per second to STS; the remaining 45 pulses per second will be sent to FTS. One safety feature will be the design of the switching system to limit the repetition rate to 15 pulses per second so that pulses of more than 15 pulses per second cannot be sent to STS. In addition, the accelerator will have a pulse frequency measurement for the FTS and STS and a credited device to prevent excess power to either target.
- The specific hazards identified for STS that warrant procedures, and training must ensure that they do not create operational conflicts or "traps" for workers moving from one facility to the other. Although common requirements and procedures are expected for waste handling, remote operations, and so on, the STS identified administrative controls will be evaluated against those in the FTS for possible consolidation or modification as appropriate.
- Common fire protection requirements and sharing of the site water supply for fire suppression are expected.

Therefore, the preliminary STS design will include a review of FTS programs and procedures to incorporate or modify them as needed for STS. Common-use facilities will be identified, and any additional capabilities required for STS will be documented. As the STS will operate as a separate facility until CD-4 is completed, operating procedures will be maintained as STS procedures and practices. Evaluating consistency between STS and FTS is ongoing and will be evaluated to permit integration of STS procedures into SNS operations as part of the transfer to operations planning process.

3.5 BEAM CONTROL BETWEEN FTS AND STS

Machine Protection System

The Machine Protection System's (MPS) function is to limit physical damage to components in the accelerator and target areas from beam-related damage. The MPS is a high-reliability protection system but is not a safety system. The MPS provides the second layer of defense for the SNS facility, responding to out-of-bound operating conditions by interrupting the proton beam. It contributes to layered protection because it prevents challenges to the Personnel Protection System radiation monitoring function by cutting off beam quickly when elevated beam losses occur.

The MPS monitors more than 1000 devices, including magnet power supplies required to steer or focus the beam, RF systems required to accelerate the beam, and beam loss monitors that detect elevated beam loss. Whenever any of these monitored devices indicates a problem, the MPS will stop the beam.

The individual MPS channels can be configured to latch on fault or to automatically reset up-to a configurable number of faults. Some devices like power supplies are typically configured to require operator intervention to re-enable them. Other devices like beam loss monitors can recover within a machine cycle, unless the MPS detects that the device has indicated more than a configurable number of faults within the last second, whereupon the MPS will declare a "chatter fault" on the device which requires operator intervention. If at least one device continues to fault, or a "chatter fault" has been detected, the MPS will continue to prevent beam.

The MPS prevents beam by shifting or stopping the timing triggers to the devices located in the Front-End (FE):

1) MPS shifts the timing gate to the Ion Source, which effectively prevents the ion source from generating beam.
2) MPS stops the timing gate to the Low Energy Beam Transport (LEBT) chopper system, which effectively deflects the beam from entering the accelerator.
3) MPS stops the timing gate to the Radio Frequency Quadrupole (RFQ) Low Level Radio Frequency (LLRF), preventing it from accelerating the beam.

In this situation the source will continue to generate beam, but the chopper and RFQ will block that beam, which is considered sufficient for machine protection. This continued operation of the ion source is necessary to avoid an ion source shutdown which would require a lengthy restart. As soon as all monitored devices recover and potential chatter faults are reset, the MPS re-enables the three timing gates.

For each monitored device, the MPS is aware of the device location and applicable machine configurations. For example, devices required to accelerate beam to the ring are checked regardless of the target beam destination. Magnet power supplies that steer the beam from the ring to the FTS are checked when beam is destined to the FTS but ignored when beam is STS-bound. This “mode-masking” is performed for each 60 Hz machine cycle. A faulted magnet power supply in the ring-to-FTS area of the machine will thus cause the MPS to stop beam on FTS machine cycle but be ignored on STS machine cycles.

Personnel Protection System

The Personnel Protection System (PPS) is an active Credited Engineered Control (CEC) system that spans the entire SNS facility, including the new STS proton and neutron buildings. Included in the STS PPS are the Accelerator (RTST), Target, and Instruments sections. The PPS provides the prompt radiation safety and access controls. The STS PPS is also involved with non-credited environmental monitoring systems that only notify personnel but do not shut off the beam. Some examples of non-CEC systems are oxygen deficiency and process control radiation systems. The PPS uses a variety of hardware connected to safety-rated Programmable Logic Controllers (PLCs). This hardware includes gamma/neutron monitors, keyed access control, door/gate switches, search & secured hardware, emergency stops, beam inhibit devices, status stack lights, warning lights, and warning horns/speakers. The STS PPS also provides statuses to the Machine Protection System (MPS) for defense in depth safety (second layer).

The PPS shuts off the beam at the accelerator Front-End (FE) area. There are three Critical Devices located in the FE that are normally used to stop beam production:

1) The negative 65 kV extraction power supply (Ion source).
2) The RF supply to the Radio Frequency Quadrupole (RFQ).
3) The RF power supply for the ion source plasma antenna.

Eliminating any of these three energy sources effectively terminates beam production. These devices are used to shut off the beam and are referred to as the Front-End Critical Devices.

Target Protection System
The Target Protection System (TPS) is an active CEC system that prevents beam to STS from identified hazard events associate with the target assembly only (ACL1 hazards). The TPS has a bypass mode that is selected by operators but it’s only valid if the power supplies to the Pulsed dipoles and transport dipoles (critical devices for STS), which prevents beam to the RTST, are disabled by PPS. The TPS shuts off two of the FE critical devices located in the Front-End area of the accelerator using two redundant, channels:

1) Channel A and B: Interrupts the negative 65 kV extraction power supply (Ion source).
2) Channel A and B: Interrupts the 2,100 V AC power input to the Radio Frequency Quadrupole power supply (located in the klystron building adjacent to the front-end building).

Eliminating any of these two critical devices effectively terminates beam production.

4. HAZARD EVENTS AND CONTROLS

4.1 HAZARD EVENT TABLE DESCRIPTION

Event Description: The event description provides a simplified description of the event being considered that could lead to the release of hazardous material. Further details of the event are included in the Assumptions and Initial Conditions and Causes sections. The events evaluated include standard industrial hazards only to the extent that they could lead to a release of hazardous material that is not addressed in national consensus codes and standards or the ORNL Standards-Based Management System.

Assumptions and Initial Conditions: This section provides general assumptions and initial conditions that provide specific guidance regarding the conditions under which the event is being evaluated. Where the Initial Condition is critical for understanding the event, or potentially represents a safety credited control needed to provide a realistic event scenario, those items are labeled "IC." Where the condition represents a design feature that is crucial to the event and the safety basis it is identified as a design feature (DF) that is required to be in the facility and is an inherently credited control (See Section 4.2.1).

The requirement for design feature (DF) selection in the PHAR event tables is that it is a passive item required to be in the facility to perform an operational or mission function that is also available to prevent or mitigate a postulated event. Design features are passive items that normally do not require regular surveillance or testing to assure that the identified safety function is met. Only if the PHAR identifies specific additional requirements (e.g., design code, specification, feature) that are above and beyond the operational or mission function does the PHAR add design requirements to the design feature.

Causes: This section lists all postulated causes for the event being evaluated. It guides consideration of the identified mitigators and preventers to ensure that all possible causes of the event are addressed in these sections.

Initiating Event Frequency: This section provides the qualitatively and conservatively assigned frequency of each initiating event (not the event progression). The assigned frequencies are based on Table 4.1. The selected probability of occurrence for each event was based on a best estimate for that event and was considered the nature of the failure within the specific design configuration.

Table 4.1. Event frequency ranges.

Event frequency level	Estimated annual likelihood of occurrence	Description
Anticipated (A)	$10^{-1} > p > 10^{-2}$	Incidents that may occur several times during the lifetime of the facility. (Incidents that commonly occur)
Unlikely (U)	$10^{-2} > p > 10^{-4}$	Events that are not anticipated to occur during the lifetime of the facility.
Extremely Unlikely (EU)	$10^{-4} > p > 10^{-6}$	Events that will probably not occur during the life cycle of the facility.
Beyond Extremely Unlikely (BEU)	$10^{-6} > p$	All other events

Unmitigated Impact on Systems: This section identifies possible systems in the facility that may be impacted by the event.

<u>Unmitigated Consequences</u>: This section identifies the conservatively estimated consequences to each receptor with no credit taken for control provided in the facility (both credited and noncredited). The consequences cover radiological, chemical, and oxygen deficiency hazards. The consequence levels (High, Moderate, Low, and Negligible) for each receptor (WG1, WG2, and Public) are defined in Table 4.2 – Table 4.4. Hazard receptors are defined as follows:

- Offsite receptors are individuals outside the reservation boundary.

- Onsite-1 receptors (WG1) are workers inside the facility. This category of receptors includes those workers in the immediate area of the hazard and those workers in the same room or building who may not be aware of the hazardous condition. It includes anyone within 100 m of the release.

- Onsite-2 (WG2) receptors are workers outside the facility but within the site boundary. For evaluation purposes, these workers are located outside the last possible barrier from the hazard and at the worst possible location. Doses are evaluated for the WG2 receptor at a distance of 100 m from the hazard and are used to guide the evaluation of worker consequences depending on the location, consistent with the policy for selection of credited controls.

- Note that anyone within the site boundary is evaluated as a worker.

Table 4.2. Radiological consequence evaluation level for hazard receptors.

Consequence level	Off-site receptor	On-site receptor
High (H)	≥25 rem	≥100 rem
Moderate (M)	5 ≤ C < 25 rem	25 ≤ C < 100 rem
Low (L)	0.5 ≤ C < 5 rem	5 ≤ C ≤ 25 rem
Negligible (N)	<0.5 rem	<5 rem

Table 4.3. Chemical consequence evaluation levels for hazard receptors.

Consequence level	Off-site receptor	On-site receptor
High (H)	> PAC 2	> PAC 3
Moderate (M)	PAC 1< C ≤ PAC 2	PAC 2 < C ≤ PAC 3
Low (L)	< PAC 1	PAC 1< C ≤ PAC 2
Negligible (N)	<< PAC 1	≤ PAC 1

Table 4.4. Oxygen deficiency hazard consequence evaluation levels vs. oxygen concentration by volume for workers.

Consequence level	Worker receptor
High (H)	< 12.5%
Moderate (M)	12.5% ≤ C < 15%
Low (L)	15% ≤ C < 19%
Negligible (N)	≈ 19.5% – 21%

<u>Safety Function</u>: This section describes the general safety function(s) required to prevent or mitigate an event. The safety function in this entry should not specify a system, structure, or component (SSC) or otherwise state how the safety function is satisfied. It provides input to the designer as to the safety function that must be met, but not the specific approach to providing the function. The designer must provide a solution such that the specific functional and design attributes for a selected SSC fulfill the defined higher-level safety function identified for the event.

Method of Detection: This section documents that the event can be detected and the method by which the event is detected so that appropriate actions can be taken to mitigate the event.

Preventive Features—Attributes and Mitigative Features—Attributes: These sections list all engineered controls (ECs), design features (DFs), and administrative actions/controls (ACs) that are available to either prevent or mitigate the identified event. ECs are generally active systems or components or are items that are expected to be replaced. DFs are passive features in the design. These controls are currently assumed to be part of the system design and operation, but only those items identified as **Credited** are used to determine the mitigated or prevented consequences for the event. These Credited items must be protected within the STS Safety Assessment Document and Accelerator Safety Envelope when they are generated.

Planned Analysis, Assumption Validation, and Risk/Opportunities: This section includes all items that need to be followed or closed to ensure that the event has been properly characterized, is properly mitigated or prevented, and any items that need to be addressed in design, testing, commissioning, or operation. It also includes both design/safety specific risks and opportunities for the project to consider. Documentation sufficient to satisfy considerations for the specific event, including event characterization, event mitigation, or event prevention includes, but is not limited to, the following:

- Analyses
- Calculations
- Qualitative Evaluations
- Reports by the project or other facilities
- Specifications
- Drawings
- Studies applicable to the specific event
- Position/White Papers
- Procedures
- Manuals
- Test Results
- Measurement Results

In all cases the applicable documentation or plan for addressing the consideration must be reviewed and approved by project management. If the documentation includes analyses or calculations these must also be reviewed and signed by an independent SME.

NOTE: Not all planned analyses, assumption validations, and risk/opportunities need to be resolved prior to the evolution from the PHAR to the HAR. For instance, some events will be reconciled during the design phase of the project, while others are validated following CD3 or during facility testing, commissioning, or operation activities.

Mitigated Consequences and Mitigated Frequency: This section identifies the conservatively estimated consequences and event frequency after the credited controls have been included in the evaluation. Note that if no credited controls are required, the mitigated conditions are identical to the unmitigated conditions. This section also provides a representation of the level of “defense-in-depth” included in the design. If preventers are selected, then the mitigated frequency is listed as "prevented." This does not mean that the event is incredible, but that the selected control has a high reliability of preventing the event. In a few cases, a combination of preventers and mitigators were selected as credited controls for that event scenario, and the mitigated conditions represent both a prevented frequency and a reduced consequence.

Notes: This section provides a catch-all section for notes about the event.

4.2 HAZARD EVENT CREDITED CONTROL

The credited controls identified at this point in the safety/design evolution are presented below. The credited controls identified in the HE tables are based on a joint effort between the system designers and the ESH&Q as the HE process was executed. The control selections have not been consolidated to determine whether a control selected in one section may be a replacement for one selected in another section, and thus reduce the number of credited controls while maintaining the same level of safety. The controls are presented in Table 4.5 – Table 4.7. As the adequacy of each control is dependent on meeting the identified safety function, in a number of cases, the single credited control involves controls from multiple categories (e.g., engineered control and administrative control). These are identified in the individual HE tables where the credited control is identified. Credited Controls: Are controls determined through Safety Analysis to be essential for safe operation directly related to the protection of workers, the public and the environment.[10]

Table 4.5. Credited engineered controls.

Engineered Controls are active controls that must function to provide the identified safety function. They will require periodic testing and verification that they are capable of performing the identified safety function.

Credited control	Description	Associated events
Engineered controls		
	Active venting of the core vessel atmosphere to maintain a slightly negative pressure in the core vessel.	CMS2-2c
	Use of a portable hoist with an installed load cell will alert the hoist operator that there is an issue, so that the lift can be stopped. This prevents the potential exposure to a worker to a direct shine from the component.	RH3-8
	Service Cell Crane lateral travel limit	SSP4-2
	Service Cell Crane speed limits/governor	SSP4-2
Target Protection System		
	TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel, including during an SDC-2 level event. Fail safe design for the TPS and MPS.	BG1-1; BG3-2; BG6-1; BG7-4; BG7-5; BG7-11; BG7-12; CMS7-3; CMS7-5
	TPS beam trip due to TPS fail safe design providing a trip on loss of power to the TPS panel, including during an SDC-2 level event.	BG1-1; BG3-2; BG6-1; BG7-4; BG7-5; BG7-11; BG7-12; CMS7-3; CMS7-5
	TPS beam trip for abnormal Loop 1 return flow	BG3-2; BG7-11; BG7-12; CW3-1a; CW3-7a; TS3-4
	TPS beam trip for abnormal Loop 1 return temperature	BG7-9a; TS3-5
	TPS beam trip on Loop 1 cooling water out of range condition	CW3-2a
	TPS beam trip on high-high level in the Core Vessel Drain Line	CW3-2a; TS3-3; TS3-7; TS3-12
	TPS beam trip if target rotation stops or slows beyond limits	TS3-2; TS3-3; TS3-16
	TPS beam trip if target rotation increases beyond limits.	TS3-14
	TPS beam trip if low beam power limits exceeded.	TS3-15
	TPS beam permit system	TS4-1
	TPS beam trip for differential Loop 1 bulk flow across the target out of range	CS3-1a; CW3-2a; CW3-7a; TS3-2; TS3-3; TS3-4; TS3-13; TS3-14; TS3-15; TS3-16

Table 4.5. Credited engineered controls (continued).

Credited control	Description	Associated events
Personnel Protection System		
	PPS Access Control to the Target Drive Room	AIC4-2
	PPS interlocked radiation monitors (IRM).	AIC4-2
	PPS Audible and visible alarm of impending beam operation.	AS4-3; HPV4-3; TS4-5
	E-Stop Buttons	AS4-3; HPV4-3; ISB4-3
	PPS – to detect the fault and terminate beam operation on high radiation alarm.	AS4-5; AS4-8
	PPS Interlocked Radiation Monitoring (IRM) – detection and alarm for increased radiation in occupied areas outside the tunnel.	AS4-5; AS4-8; AS4-11; AS4-12; AS4-13; AS4-16
	Provide a lock on the RTST access door preventing entry until authorized by mode change from the control room	AS4-6; AS4-7; AS4-19
	PPS Limits access to authorized personnel during controlled access mode	AS4-6: AS4-19
	PPS to detect the RTST Gamma Blocker position and terminate beam operation if the RTST Gamma Blocker is out of position.	AS4-11
	PPS prevents workers from entering the labyrinth from the RTST permitted location.	AS4-13
	PPS prevents Pulsed dipoles (25D50) from turning ON to allow beam to enter the RTST.	AS4-16
	PPS prevents the first transport dipoles (17D120) from turning ON to allow beam to enter the RTST	AS4-16
	TPPS alarm on area doorway to Target Drive Room	CW4-1
	TPPS alarm on area doorway to HPV	HPV1-3; HPV3-9: HPV4-1
	Target Personnel Protection System (TPPS) – prevents personnel access to the HPV during beam operation and until authorization is provided.	HPV4-2
	PPS - Corridor 202 access control.	ISB4-6
	TPPS shutter gamma blocking mode detection and alarm	ISB4-1
	Area Radiation Monitors are located in the High Bay to alarm locally and provide TPPS trip for the beam if elevated radiation levels are detected	ISB4-2
	TPPS - Bunker access control	ISB4-4

Table 4.5. Credited engineered controls (continued).

Credited control	Description	Associated events
Personnel Protection System (Continued)		
	IPPS - triggers the operations shutter on the affected beamline to close if it detects the door open while neutrons are authorized	ISC4-1
	IPPS - If the shutter fails to close in a TBD time period, the IPPS issues a fault to the TPPS and it trips the proton beam, terminating all beam capability.	ISC4-1
	Area Radiation Monitors and alarms	ISC4-5
	Controlled access to LLLW locations and Worker training	LCS4-1
	PPS Service Cell Door interlock system prevents door operation when a source is present.	SS4-3
	Service cell radiation monitors	SS4-6

Table 4.6. Credited design features.

The requirement for design feature (DF) selection in the PHAR event tables is that it is a passive item required to be in the facility to perform an operational or mission function that is also available to prevent or mitigate a postulated event. Design features are passive items that normally do not require regular surveillance or testing to assure that the identified safety function is met. Only if the PHAR identifies specific additional requirements (e.g., design code, specification, feature) that are above and beyond the operational or mission function does the PHAR add design requirements to the design feature.

Credited control	Description	Associated events
Design features		
	RTST Tunnel Design – provides shielding to the personnel outside RTST tunnel based on normal operational losses.	AS4-5
	Provides shielding adequate for normal operation of the RTBT with personnel in the RTST	AS4-13
	RTST Tunnel Design – provides shielding personnel outside RTST tunnel based on normal operational losses.	AS4-8; AS4-12
	Shielding – If a beam stop is used, adequate shielding is provided	AS4-8
	Labyrinth shields worker permitted areas when beam is only going to the FTS.	AS4-13
	Installed local shielding or temporary shielding as determined by RCT entry survey	AS4-19
	Prohibition for parking spaces or charging stations for electric cars/trucks or hybrids with lithium-ion batteries near the target building.	BG1-1; BG6-10
	The neutron beamline bunkers in target building and neutron beamlines radiating outward in the instrument hall provide significant protection against impact reaching the monolith	BG6-9
	The monolith shielding protects the core vessel and the shielding inside the core vessel, in turn, protects the target	BG6-9
	Large components are structurally anchored and building structures seismically qualified to prevent collapse, protect evacuation paths, and protect applicable confinement of hazardous material (applicable SSCs meet SDC-2 and applicable Limit State B or C requirements)	BG7-1a; BG7-2; BG7-10; BG7-11; BG7-12
	Target building design to meet SDC-2 criteria provides inherent protection from collapse during this WDC-2 level event	BG7-4
	Spent target transfer cask and highly activated disposable components will be in a local confinement (service cell). The components are located in Service Cell pits during component drying operation and in a sealed container. The service cell is located in a place where the cask and components are protected from tornado generated loads	BG7-4; BG7-5

Table 4.6. Credited design features (continued).

Credited control	Description	Associated events
Design features (Continued)		
	The stack is constructed with features that meet WDC-2 level conditions preventing collapse in high winds short of a tornado	BG7-5
	Target building design to meet SDC-2 criteria provides inherent protection from collapse during this WDC-2 level event	BG7-5
	Building roof designed to meet NDC-2 criteria (200-year return period) provides structural loads for protection from collapse during this event consistent with the climate in Tennessee (DOE-STD-1020-2016) and to support heavy snow and ice loads, consistent with best practices for climate in Tennessee and code requirements.	BG7-8
	Double walled heat exchanger eliminates freezing of intermediate loop.	BG7-9a; BG7-9b
	The stack is constructed with features that prevent collapse during an SDC-2 level seismic event.	BG7-10
	Target segment attachment points designed to withstand an SDC-2 seismic event with a design margin of TBD	BG7-11; BG7-12; CMS7-3
	Target Drive Room design for passive venting to prevent hydrogen build up in this space.	BG7-11
	Seismic event will inherently cause a beam trip.	BG7-12; CMS7-5
	Moderator and Hydrogen transfer line designed to meet SDC-2 loads	BG7-12
	CMS Transfer line routing	CMS2-2c
	Transfer lines are vacuum jacketed from the core vessel to the HUR.	CMS2-5
	Robust design of ortho-para converter with screen and filter to retain the Fe2O3 powder	CMS4-3
	Building structures seismically qualified to prevent collapse, protect evacuation paths, and protect applicable confinement of hazardous material (applicable SSCs meet SDC-2 and applicable Limit State B or C requirements)	BG7-1a; BG7-2; BG7-10; BG7-11; BG7-12; CMS7-1; CMS7-3; CMS7-5; CMS7-6; CMS7-7
	Monolith concrete shielding and building steel structures seismically qualified to prevent gross displacement (SDC-2 and applicable Limit State B or C requirements). Enough iron shielding is in place to provide a heat sink and keep the target below 800 C in all configurations.	CMS7-3; CMS7-5; CMS7-7
	Massive monolith shielding assembly outside the core vessel with positive retention protects the target from the facility fire.	CMS7-3; CMS7-7

Table 4.6. Credited design features (continued).

Credited control	Description	Associated events
Design features (Continued)		
	Hydrogen transfer lines designed and built to applicable portions of AMSE B31.12 and ASME B31.3 and provide Limit State C protection during an SDC-2 event.	CMS7-5
	High Bay Crane certification and preventive maintenance and Rigging Design	HB2-2; HB2-3; HB3-2; RH4-11; SS4-2
	Bunker roof panels are designed to provide adequate shielding for a T0 chopper or a shutter dropping into the beam line.	ISB4-2
	Target Drive Room roof hatch/plug design prevents it passing through the opening in the Target Drive Room roof	RH3-1
	Cask material specification and design (monolith shutter insert removal)	RH4-6
	Adequate shielding above target or other core vessel component to reduce dose and activation to acceptable levels	RH4-7; RH4-8; RH4-10
	Required temporary shielding in place	RH4-7; RH4-8; RH4-10
	Spent waste cask/container design including Confinement features.	RW1-3
	Low thermal loading of resin and resin storage tank design precludes drying in short time periods. Ion exchange resin is not required to be maintained wet to prevent autoignition of the resin. The radionuclide inventory is not high enough for this to occur.	RW2-2
	Location of LLLW tanks in covered pits in the HPV without normal access	RW4-2; RW4-3
	IX columns are in a shielded area of the HPV and the resin storage tank is in a covered pit in the HPV	RW4-4
	PIE and Service Cell design minimizes the potential for spreading the fire	SS1-1; SS5-1; SSP1-1; SSP5-1
	Component design (shell material and construction) minimizes the potential for spreading the fire and release of material	SS1-1; SS5-1; SSP1-1; SSP5-1
	Lack of explosive materials in the Service Cell.	SS2-1; SSP2-1
	SCE in the service cell and the HOG confinement in pit design.	SS3-2
	Service Cell crane and rigging design	SS4-2
	Shield walls between the truck bay and vaults/rooms with increased levels of radiological material.	TB1-3
	Inlet screen in Loop 1 header to target segment	TS3-6; TS3-12

Table 4.6. Credited design features (continued).

Credited control	Description	Associated events
Design features (Continued)		
	Target cooling system includes a physical barrier that ensures the proper orientation of the target cooling water valves prior to operation	TS4-4
	Target design interface with the target support system requires the target segment to be fully inserted and in the right position for the operator to insert the locking screw to attach the target.	TS4-3; TS4-4
	Steel shielding within and outside the core vessel but within the concrete shell designed to reduce streaming paths and external dose	VS4-1

Table 4.7. Credited administrative controls.

Credited control	Description	Associated events
Administrative controls		
	Tunnel access training including how to use the E-stop buttons & what is the meaning of the audible and visual alarms for impending beam.	AS4-3
	Sweep and Evict Procedure - Proper procedures and training for the sweep and evict protocols prior to closing the tunnel before beam operations (Includes the HPV and TDR)	AS4-3; HPV4-3; TS4-5
	Shielding – If a beam stop is used, adequate shielding is provided	AS4-8
	RTST Entry Program – requires controls to prevent workers from entering the tunnel prior to defining access limitations.	AS4-10
	Radiation Safety Program – • Radiological Work Permit (RWP). (AC) • RTST Entry Program – requires controls to prevent workers from entering the tunnel prior to activated components cool down or proper controls (e.g., local shielding) are in place. (AC) • Installed shielding and RWP postings	AS4-19; HPV3-8; RH4-3; RH4-9a; RW4-4; SS4-3; SS4-6; SSP4-1; VS4-1
	Installed local shielding or temporary shielding as determined by RCT entry survey	AS4-19
	Prohibition for electric cars/trucks or hybrids with lithium-ion batteries from entering or having access near the target building.	BG1-1; BG6-10
	Combustible Material Control Program Including: (AC) • Metallic covering of large quantities of hydrogenous shielding material to slow the ignition and propagation of a large hydrogenous shielding fire throughout the instrument hall. • Low combustibility hydraulic fluid.	BG1-1
	Emergency procedures and training, including specific guidance on response to a seismic event	BG7-1a; BG7-2; BG7-10; BG7-11; BG7-12; CMS7-1; CMS7-3; CMS7-7
	Spent target storage cask will be in a local confinement (service cell pit) during component drying operation and then in a sealed container. The service cell is located in a place where the cask will withstand tornado generated loads	BG7-4
	Inert core vessel atmosphere with helium or vacuum mode of core vessel operation	CMS2-2b; VS1-1; VS2-1a
	Active venting of the core vessel atmosphere to maintain a slightly negative pressure in the core vessel.	CMS2-2c
	Ortho-para converter screen and filter installation surveillance procedures	CMS4-3

Table 4.7. Credited administrative controls (Continued)

Credited control	Description	Associated events
Administrative controls (continued)		
	RCT survey prior to entering the HPV or Target Drive Room for work.	CW4-1
	RCT survey detection in pump room	CW4-2
	Emergency response procedures (fire and radiation alarm)	HB1-2; HPV1-2; ISC4-5
	Critical Lift procedures	HB2-2; HB2-3; HB3-2; HB4-1; RH4-11; SS4-2
	Hoisting and rigging program.	HB2-2; HB2-3; HB3-2; HB4-1; RH4-11; SS4-2
	Crane inspection and certification program	HB2-2; HB2-3; HB3-2; HB4-1; RH4-11; SS4-2
	Cask lift procedures, including lift height and load path	HB3-2; HB4-1
	Radiation Control Procedures	HPV3-2
	Filter replacement procedures to limit filter buildup of radiological inventory and worker training	HPV3-8
	Workers are trained to evacuate if elevated radiation levels are detected or if the TPPS warns them of a hazard	ISB4-1
	TPPS Sweep and Evict Procedure - Proper procedures and training for the sweep and evict protocols prior to securing Corridor 202 before beam operations	ISB4-5
	Configuration Management Program – RSO verification that shielding is in place and secured prior to beam operation.	ISC4-2; ISC4-4
	Sample activation calculation predicts activation level of samples based on sample makeup and exposure parameters.	ISC4-3
	Appropriate software V&V applied sample calculator	ISC4-3
	Instrument test procedures controlling test articles placed in the sample location.	ISC4-4
	Controlled access to LLLW locations and Worker training	LCS4-1
	Component specific lifting procedures will be in place to direct the hoist operator if the load cell give a high reading.	RH3-8
	STS activated component removal procedures	RH4-4; RH4-11
	Monolith & guide insert and shutter replacement procedures.	RH4-6
	Operating Procedures and Training	RH4-6; RH4-7; RH4-8; RH4-10

Table 4.7. Credited administrative controls (Continued)

Credited control	Description	Associated events
Administrative controls (continued)		
	Cleaning agents (e.g., strong oxidizer) are permitted in either the HPV or Service Cell only after evaluation of specific use and potential for interaction with resin	RW2-2
	Maintenance/operating Procedures – to ensure the integrity of all components of the piping loop	RW3-10
	Lack of explosive materials in the Service Cell.	SS2-1; SSP2-1
	Procedures and RCT Holds to ensure the access hatch/plug remains shut when a source is present within the service cell and not secured in a pit with the pit lid in place or a transfer cask is in place, or other radiological controls are in place to provide adequate shielding.	SS4-1
	Shielding or access limitations on personnel when the crane removes the access hatch/plug.	SS4-1
	RCT Hold prior to PIE Cell access hatch opening	SSP4-1
	Prohibition of EVs and Hybrid vehicles with lithium-ion batteries from entering the target building.	TB1-3
	Prior to trucks entering the target building they are required to all time for breaks to cool and an inspection of the truck for potential fuel leaks and hot spots	TB1-3
	Hydrogen in the CMS/MRA have been removed for this operation Events associated with the hydrogen in the CMS/MRA are addressed separately in the CMS/MRA events)	VS2-1b
	Initial power ramp-up planning with RCT survey	VS4-1
	TPPS Sweep and Evict Procedure - Proper procedures and training for the sweep and evict protocols prior to securing the TDR before beam operations.	AIC4-2
	RS hold to prevent beam operations if any target segment, the PBW, or core vessel component is not in place by locking out critical devices.	TS4-1
	RSO performs independent visual verification that all target segments have been properly installed prior to operation.	TS4-3
	RSO performs independent visual verification that all target cooling water vales are in the correct orientation and that the physical barrier (that ensures valve alignment) is properly installed prior to operation.	TS4-4
	TPPS Sweep and Evict Procedure - Proper procedures and training for the sweep and evict protocols prior to closing the Bunker before beam operations	ISB4-3

4.2.1 ASSUMPTIONS AND INITIAL CONDITIONS INHERENTLY CRITICAL TO THE HAZARD EVENTS

To effectively evaluate the response of the STS to certain events, design features (DF)[1], engineered controls (EC), administrative controls (AC), and initial conditions (IC) that are in the facility are assumed to be in place and are identified in the events under the "Inputs and Assumptions" section of the event scenario. These represent features of the design and operation that are required and are an inherent part of the facility, are important in evaluating the specific event, and identified in the event tables. These are identified in the safety analysis as critical to the evaluation of specific events but not called out separately in the "Credited Control" column in the events.

In some cases, the critical control documents the design as it is or provides notification that the action is permitted to provide scope for the identified events, as these inputs and assumptions are an important part of the evaluation of the specific events identified for that control, they must be under project configuration control to assure that should they be modified, the PHAR can be updated, and the specific events reevaluated to assure that there is no impact on the facility safety basis. Those critical controls that must be protected to assure the safety of the facility will be specifically identified as "Credited Controls" in the next revision of the PHAR.

Inputs and assumptions critical to the hazard tables in Appendices A through S are identified in Table 4.8 below.

Table 4.8. Critical Assumptions and Initial Conditions.

Critical control	Description	Associated events
General	Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1	Remote Handling Events
Engineered Controls Critical to Event Evaluations		
EC	Design shielding is in place between the RTBT and RTST tunnel for normal operation of the beam to the RTBT with personnel in the RTBT.	AS4-13
EC	Personnel are not permitted in the Target Drive Room during beam operation	CMS1-4; CMS2-5
EC	Personnel are not permitted in the HPV during beam operation.	CW2-1b
EC	Before a worker could enter the bunder with the beam on they must pass through Corridor 202 which also has TPPS access controls	ISB4-4
EC	The LCS collection tank is located in a controlled and shielded locations the HPV. Access to the HPV requires PPS release for access.	LCS4-1; RW2-3

[1] Section 4.1, HAZARD EVENT TABLE DESCRIPTION, ASSUMPTIONS AND INITIAL CONDITIONS, requirement for design feature (DF).

Table 4.8. Critical Assumptions and Initial Conditions (Continued).

Critical control	Description	Associated events
Design Features Critical to Event Evaluations		
DF	Loop 2 cools the PBW, TVP, MRA, reflector, and all Loop 2 water-cooled shielding.	AIC1-1; AIC3-3; AIC3-4; AIC3-5; AIC3-7; AIC3-10; AIC7-1; BG3-2; CW2-1a; CW3-1a; CW3-1b; CW3-1d; CW3-2a; CW3-2b; CW3-3a; CW3-3b; CW3-7b; CW3-10; CW4-1; CW4-2; HPV3-4b; HPV3-5b; TS3-8; TS3-13
DF	Proton beam window will not fail for nominally an hour without cooling so that it is not impacted by this event and does not provide a passive beam trip.	AIC1-1; AIC3-3; AIC3-5; AIC3-7; BG3-2; CW3-1b; CW3-1d; CW3-2a; CW3-2b; CW3-3b; CW3-7b; HPV3-4b; HPV3-5b; TS3-8; TS3-13
DF	Achieving a beam more focused than the design basis would require changes in magnet and operational configuration. The target and the proton beam window are designed to accept the design basis beam.	AIC3-1; TS3-9
DF	Core vessel ullage, burst disk designed with a rating of less than +7.35 PSIG and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures.	AIC3-3; AIC3-9; AIC3-10; BG7-8; BG7-9b; CW3-1d; TS3-2; TS3-3; TS3-4; TS3-5; TS3-6; TS3-7; TS3-12; TS3-13; TS3-15; TS3-16
DF	Redundant power supply busses for Loop 2 pumps.	AIC3-3
DF	Core vessel leak detection is located in the Core Vessel Drain	AIC3-3; AIC3-5
DF	A double walled heat exchanger is used between the tower water cooling loop and the Loop 1 cooling loop and between the tower water and the Loop 2 cooling loop	AIC3-4; BG7-9a; BG7-9b; CW3-2a; CW3-2b; CW3-4a; CW3-4b; CW3-5a; CW3-5b; CW3-9; TS3-5
DF	Loop 1 provides cooling water for the Target.	AIC3-4; AIC3-9; AIC3-10; BG3-2; CW2-1a; CW3-1a; CW3-1d; CW3-2b; CW3-3a; CW3-3b; CW3-7b; CW4-1; CW4-2; HPV3-5a; TS3-8; TS3-13
DF	Design of the current target module does not permit direct contact of the Tungsten and water. .	CW4-2
DF	Pulsed dipole magnet power supply will not allow all ring pulses into the RTST.	AIC3-5; AS4-14
DF	The earthquake causes loss of the accelerator proton beam	AIC7-1; BG7-11; CMS7-1; CMS7-3; CMS7-5; CMS7-6

Table 4.8. Critical Assumptions and Initial Conditions (Continued).

Critical control	Description	Associated events
DF	The RTST tunnel air normally operates as a closed system integral with the existing RTBT tunnel air though the existing RTBT/Ring/HEBT.	AS3-1; AS3-3; AS3-4
DF	The RTST HVAC recirculation system includes dust filtration (not HEPA) and humidity control.	AS3-1; AS3-3; AS3-4
DF	The HVAC system includes a grade mounted exhaust fan to permit manual exhaust of the tunnel ("smoke" exhaust).	AS3-1; AS3-3
DF	The RTST tunnel is connected to the RTBT and tunnel to the FTS with no air separation, but the RTST air activation control is maintained by the HVAC providing air flow from the RTST to the RTBT	AS3-1; AS3-3
DF	The PBW seals include multiple seals that would have to fail before core vessel atmosphere could go into the RTST.	AS3-2
DF	Turbo pump is installed downstream of the Fast-Acting Valve.	AS3-2
DF	The HVAC includes a control damper that can permit the HVAC to go to a 100% outside air supply operating mode.	AS3-3
DF	The RTST tunnel is connected to the RTBT and tunnel to the FTS with limited air separation, but the RTST is maintained at a slightly higher pressure than the RTBT	AS3-4
DF	Tunnel berm/shielding designed for normal operations.	AS4-5
DF	A single pulse to STS will not be capable of exceed approved power limit for target.	AS4-14
DF	After loss of cooling with beam trip decay heat cannot raise target temperature to 800 C threshold for tungsten/steam reaction.	BG3-2; BG6-1; BG7-1a; BG7-2; BG7-8; BG7-9a; BG7-11; BG7-12; CMS7-1; CMS7-3; CMS7-5; CMS7-6; CMS7-7; TS3-2; TS3-3; TS3-5; TS3-6; TS3-13; TS3-15; TS3-16
DF	A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values.	BG5-1; BG7-1a; BG7-11; BG7-12; CMS1-1; CMS1-2; CMS1-3; CMS1-4; CMS2-1; CMS2-2a; CMS2-2b; CMS2-2c; CMS2-3; CMS2-4; CMS2-5; CMS2-6; CMS3-1; CMS3-2; CMS3-4; CMS3-5; CMS3-6; CMS3-7; CMS4-1; CMS4-2; CMS4-3; CMS4-4; CMS5-1; CMS7-1; CMS7-3; CMS7-4; CMS7-5; CMS7-6; CMS7-7
DF	Cryogenic helium lines in areas outside the HUR and Helium Refrigerator Room are vacuum jacketed.	BG5-1; CMS2-4

Table 4.8. Critical Assumptions and Initial Conditions (Continued).

Critical control	Description	Associated events
DF	No Dewars are used in the CMS system.	BG5-1
DF	Target does not require electrical power for post shutdown cooling.	BG6-1
DF	Loss of power to accelerator facility upstream of target will result in loss of proton beam.	BG6-1
DF	Natural gas will not be piped into the second target building	BG6-5; BG6-6; HB1-1; HB1-2; HB2-1
DF	The layout of the second target building prevents a vehicle from being able to threaten the more significant amounts of radioactive material associated with the target itself, and cooling or waste processing equipment	BG6-10
DF	Location of the second target is away from all but the access driveway	BG6-10
DF	Reinforced concrete shielding and large amounts of steel shielding on the instrument floor and in the monolith would protect significant inventories of radioactive materials against damage associated with a gas-powered vehicle impact.	BG6-10
DF	Active cooling or electric power are not needed for target decay heat removal with the beam off.	BG7-1; BG7-2; BG7-4; BG7-8; BG7-9b; BG7-11; BG7-12; CMS7-1; CMS7-3; CMS7-7
DF	Target radionuclides are protected from possible effects of fire by massive steel and concrete shielding of the monolith structure.	BG7-1a; CMS7-3; CMS7-7
DF	Large components are structurally anchored and building structures seismically qualified to SDC-2 criteria to prevent collapse and protect evacuation paths. (SDC-2 and applicable Limit State B or C requirements)	BG7-1a; BG7-2; BG7-12
D	Building structures around the cryogenic hydrogen systems will have SDC-2 and Limit State B or C seismic qualification due to seismic interaction (2 over 1) considerations, as needed to prevent damage to or crimping of the H2 transfer line outside of the core vessel.	BG7-1a; BG7-12
DF	Monolith iron shielding and core vessel components position is retained by external concrete structure.	BG7-2; BG7-12; CMS7-1; CMS7-3; CMS7-7
DF	The hazardous radionuclides inside the SNS target are protected against possible tornado missiles by the multiple layers of shielding surrounding the e the core vessel protects the target itself.	BG7-4
DF	STS location precludes flooding from traditional sources (e.g., rivers or streams)	BG7-7
DF	The second target building will have a separate exhaust stack from the existing FTS stack.	BG7-10

Table 4.8. Critical Assumptions and Initial Conditions (Continued).

Critical control	Description	Associated events
DF	Target radionuclides are protected from possible effects of fire by massive steel and concrete shielding of the monolith structure	BG7-11
DF	Building structures seismically qualified to SDC-2 criteria to prevent collapse and protect evacuation paths (SDC-2 and applicable Limit State B or C requirements) (DF)	BG7-11
DF	Building structures around the cryogenic hydrogen systems will have SDC-2 and Limit State B or C seismic qualification due to seismic interaction (2 over 1) considerations, as needed to prevent damage to or crimping of the H2 transfer line outside of the core vessel	BG7-11
DF	Target Drive Room roof designed to passively vent to the high bay and prevent buildup of hydrogen in this space.	BG7-11
DF	Moderator and Hydrogen transfer line designed to meet SDC-2 loads	BG7-12
DF	Vacuum pump for core vessel would be pumping the core vessel contents (pump uses air in the system to pump the core vessel)	CMS1-1
DF	The CMS is an all-welded system	CMS1-1; CMS2-1
DF	Transfer lines are vacuum jacketed from the core vessel to the HUR.	CMS1-1; CMS-1-3; CMS1-4; CMS2-4; CMS2-5; CMS3-1; CMS3-6; CMS3-7
DF	The HUR will be designated as a Class 1, Division 2, Group B, hazardous location in accordance with NFPA 70	CMS1-1; CMS2-3; CMS3-2
DF	Gas cabinet purge and backfill system with no system “top off of hydrogen” during operation.	CMS1-2; CMS2-3; CMS2-6; CMS3-2
DF	Loss of vacuum will cause overpressure in hydrogen system and venting though hydrogen system hydrogen safe vents.	CMS1-4
DF	Inherent combustible inventory of core vessel is very low with the exception of the hydrogen in the CMS/MRA.	CMS2-2c; VS1-2; VS2-1a; VS2-1b
DF	HUR in STS located in a location away from radiological material and outside of high bay crane travel either in the Target Building or in an annex.	CMS3-1; HB2-1
DF	Released hydrogen is exhausted with the air in the HUR to atmosphere via the vent stack.	CMS2-6; CMS3-2
DF	Pressure rating of each system in the CMS makes this overpressure event BEU	MCS3-4

Table 4.8. Critical Assumptions and Initial Conditions (Continued).

Critical control	Description	Associated events
DF	A vacuum layer surrounds the hydrogen vessel and serves as insulation between the cold hydrogen (20 degrees K) and the pre-moderator/reflector (Loop 2) water.	CMS3-5; CW3-10
DF	Hydrogen vents through hydrogen safe vent if pressure in vacuum space exceeds 2 bar	CMS3-7
DF	Hydrogen vessels are buried in the reflector with two layers of aluminum and the beryllium reflector preventing any contact.	CMS4-2
DF	Hydrogen safe vent systems.	CMS4-4
DF	All Helium piping in the HUR is vacuum jacketed and requires failure of two layers to escape	CMS5-1
DF	Monolith stays intact after an SDC-2 level event and serves as target heat sink so decay heat cannot raise target temperature close to the 800 C threshold for a tungsten steam reaction.	CMS7-1
DF	Redundant power supply busses for Loop 2 pumps.	CW3-1b; CW3-2a; CW3-2b
DF	Ion exchange resin is not required to be maintained wet to prevent autoignition of the resin. The radionuclide inventory is not high enough for this to occur.	HPV1-3; RW2-2
DF	Leaks from primary piping in HPV or leaks from primary lines from the Target Drive Room to the HPV (which drain to HPV inside secondary piping).	HPV3-5a; HPV3-5b
DF/AC	Leaks from pipe pan between delay vault & vessel drains to a collection pipe in the HPV that can go to the core vessel drain tank pit, LLLW, or either cooling loop's drain tank, depending on which valve is open.	HPV3-6a
DF	Leaks from the GLS and Delay Tank locations in the HPV will drop to the HPV floor, and from there flow downslope to a tank pit, where the water will collect for disposal	HPV3-6a
DF	Leaks in HOG condensers drain to the HPV floor and from there to an HPV pit	HPV3-6a
DF	Leaks from bunker catch pans drain to a core vessel drain tank pit (with a valve to open the drain.	HPV3-6a
DF	No automatic Loop 1 or Loop 2 water makeup is provided.	HPV3-9
DF	Vacuum pumping system is located in the HPV	HPV3-10; SS3-4
DF	Flexible connections will be provided in the Service Cell to connect to the equipment for drying and hard piped connections to the hot offgas are provided in the HPV.	HPV3-10

Table 4.8. Critical Assumptions and Initial Conditions (Continued).

Critical control	Description	Associated events
DF	Electrical circuits are localized and serve relatively few items	ISB1-1; ISB1-2; ISC1-1
DF	Chopper aluminum disks have a low probability of failure due to low operating stress	ISB3-1; ISB3-2
DF	T0 chopper head has a low probability of failure due to low operating stress	ISB3-1; ISB3-2
DF	Chopper rotation is perpendicular to beam direction for all but Fermi choppers	ISB3-1; ISB3-2
	Monolith Insert design with inner and outer windows.	ISB3-2
	Failure causing a hydrogen release requires failure of 5 windows and the debris traveling down the beam insert. The open neutron flight path is 50mm x 50mm on the upstream end, 70mm x 70mm on the downstream end. Length of the insert is 4.5m, with the upstream end ~1m from the face of the moderator.	ISB3-2
D	LCS collects leaks and spills from the core vessel drain, GLS tanks, Delay tank, target drive room drain, bulk shielding drain, and area drains from the bunker	LCS1-1; LCS2-1; LCS3-1; LCS3-2; LCS3-3; LCS4-1
DF	Piping from the bulk shielding, pipe pans, and bunker are routed to the HPV and gravity drain but are instrumented and valved off (including a blind flange in some locations) and only opened when required to sample and drain the line	LCS1-1; LCS2-1; LCS4-1
DF	The core vessel drain is connected to the core vessel drain tank and is normally isolated, but during maintenance periods or during helium operation can drain the core vessel to permit continued operation.	LCS1-1; LCS2-1; LCS3-1; LCS3-2; LCS3-3; LCS4-1
DF	Leaks from the GLS and Delay Tank locations in the HPV will drop to the HPV floor, and from there flow downslope to a tank pit, where the water will collect for disposal.	LCS1-1; LCS2-1; LCS3-1; LCS3-2; LCS3-3; LCS4-1
DF	Leaks from the pump room go to the sloped floor, and from there to a tank pit.	LCS1-1; LCS2-1; LCS3-1; LCS3-2; LCS3-3; LCS4-1
DF	Piping from the bulk shielding, pipe pans, and bunker are routed to the HPV and gravity drain but are instrumented and valved off (including a blind flange in some locations) and only opened when required to sample and drain the line.	LCS3-1; LCS3-2; LCS3-3
DF	The LCS collection tank is located in a controlled and shielded locations the HPV. Access to the HPV requires PPS release for access.	LCS4-1
DF	The Drive Room roof plugs/hatches must be removed to allow overhead crane access to the core vessel.	RH3-1

Table 4.8. Critical Assumptions and Initial Conditions (Continued).

Critical control	Description	Associated events
DF	The integral shield door on the cask is open/closed manually. The Gamma Shield Door (that will reside at the high bay level) is motor driven.	RH3-9; RH3-10
DF	Core vessel exhaust is designed to handle maximum opening size.	RH3-11
DF	All casks to be mounted on the applicable plug/hatch opening lifted off of the Target Drive Room roof by an external attachment to the cask.	RH3-13
DF	The current target design eliminates the potential for Tungsten to come into contact with water caused from target clad breach or tungsten erosion	RH4-2
DF	Target drive is above the core vessel lid.	RH4-9
DF	Water released to LLLW tanks initially goes through the leak collection tanks or is pumped from the cooling loops, thus preventing short-cooled water from entering the LLLW system. (i.e., Nothing goes to the LLLW automatically.)	RW1-2; RW2-3; RW3-5; RW4-2;
DF	The HPV is on the Target Facility Secondary Confinement HVAC system.	RW3-8; RW3-9
DF	The service cell is on the Target Facility Secondary Confinement HVAC system but includes HEPA filtration in the Service Cell prior to connecting to the Secondary Confinement System	RW3-8; RW3-10
DF	Resin is transferred from the resin storage tank in a covered pit in the HPV to the Service Cell	RW3-13
DF	LLLW tanks, resin storage tank, and drain tanks are located in pits with covers in the HPV to prevent normal access and potential exposure.	RW4-2; RW4-3; VS2-2
DF	IX columns are in the HPV and shielded to minimize exposure	RW4-2; RW4-3; RW4-4
DF	Resign sampling will be performed from the Resin Storage Tank and not form the IX Columns	RW4-4
DF	Event assumes that the cooling channels for the target segments are on the outside of the target block and not in the immediate vicinity of the tungsten.	TS3-4; TS3-5; TS3-6; TS3-7
DF	With segmented target design, internal bypass flow within a segment is not credible. Plugging of several flow channels is assumed in this event.	TS3-6; TS3-12
DF	Pulsed Dipole magnet power supply will not allow all ring pulses into the RTST.	TS3-8
DF	With the hydrogen removed from the Core Vessel there is not a source of combustibles that reach LEL conditions.	VS2-1b
DF	Monolith Insert design with inner and outer windows	VS3-2

Table 4.8. Critical Assumptions and Initial Conditions (Continued).

Critical control	Description	Associated events
DF	Core Vessel vacuum System is intended to maintain core vessel at a slightly negative pressure from atmospheric during target removal.	VS3-3
DF	Target Drive Motor is not required to be removed for target segment replacement.	RH3-2
Administrative Controls Critical to Event Evaluations		
AC	Core vessel operating in inert helium near atmospheric pressure or in vacuum.	AIC3-3; BG7-8
AC	No personnel are permitted in the RTST tunnel during operation	AIC3-3; AIC4-1; AS3-1; AS3-3; AS3-4; AS4-4; AS4-7; AS4-12; AS4-14
AC	Water in the tunnel is operationally assumed to be contaminated and will be treated as such until determined that it is either not contaminated or that the contamination level is low enough to be removed.	AS4-2
AC	Beam commissioning will not occur before target or adequate shielded beam stop is ready to receive beam.	AS4-7; AS4-8
AC	Beam commissioning starts at low power and increase as appropriate	AS4-7; AS4-8
AC	Electric vehicles and hybrids that use lithium-ion batteries are not permitted next to the RTST tunnel.	AS6-2
AC	Electric cars or hybrids with lithium-ion batteries are excluded from entering or parking near the target building or instrument hall.	BG6-3
AC	Hydrogen is brought onto the site in approved compressed gas cylinders and in an ORNL approved transportation vehicle per SBMS requirements.	BG6-7
AC	Procedures in place to assure Gas cabinet purge and backfill system with no system “top off of hydrogen” during operation.	CMS1-2; CMS2-3; CMS2-6; CMS3-2
AC	Personnel are not permitted in the Target Drive Room during beam operation	CMS1-4; CMS2-5; CW4-1
AC	Core vessel drain is normally closed during beam operation.	CMS4-4
AC	Personnel are not permitted in the HPV during beam operation or when excessive radiation is present.	CW2-1b; CW4-1; HPV1-3; HPV3-3b; HP4-1; LCS4-1; RW1-4
AC	Spent target segments and other activated components out of the core vessel are not stored in the High Bay	HB2-1
AC	Workers are in the region of the target drive room, but not in the crane lift path	HB2-3
AC	Component drying is assumed to occur in the service cell	HB3-1; HB3-2; HB4-1

Table 4.8. Critical Assumptions and Initial Conditions (Continued).

Critical control	Description	Associated events
AC	Component initial dewatering is assumed to occur inside the core vessel.	HB3-1; HB3-2; HB4-1
AC	Personnel are permitted in the HPV during drying operations, but not with beam operations	HPV3-10
AC	No personnel are permitted in the Bunker during beam operation	ISB4-2
AC	Workers are not permitted along beam path during beam operation.	ISC4-5
AC	Personnel are not permitted in the target drive room during a lift of an activated component from the core vessel.	RH3-7; RH4-9
AC	Either a Ziplift or other attachment mechanism may be used to accomplish the lift	RH3-9
AC	Core vessel pressure is monitored to alarm operator	RH3-11
AC	The Core Vessel will be vented prior to any lifting operations of highly activated components from the Core Vessel.	RH3-11
AC	The Cask will be lowered to a minimum elevation of TBD immediately after lifting the cask off the Target Drive Room roof.	RH3-11; RH3-19; RH3-20; RH4-4; RH4-11
AC	Any water line is drained and partially blown down in-situ to establish a water level below the connection or cutting location before lifting into the cask	RH3-17; RH3-18; RH3-20; RH4-11
AC	No cask storage with highly activated replaceable components is permitted in the High Bay.	RH4-5
AC	Cooldown period established before access allowed after operation.	RH4-9; RH4-10
AC	No access to target drive region during the physical lift of the PBW or TVP.	RH4-10
AC	Solid CH waste stored and/or packaged according to ORNL waste management procedures contains bounding equilibrium nuclides from the material in the container (See Note 1)	RW2-1; RW4-1; TB3-1
AC	Decontamination activities are to be completed in the Service Cell or PIE Cell.	RW2-1
AC	Cleaning agents (e.g., strong oxidizer) are permitted in either the HPV or Service Cell only after evaluation of specific use and potential for interaction with resin	RW2-2
AC	Two IX Columns are used in operation and when one column is spent, it is allowed to decay for nominally 6 months prior to sluicing from that column to the resin storage tank where it is allowed to decay further.	RW2-2
AC	The spent IX Column is drained to the Resin Storage Tank in a Pit to allow further decay time before shipment.	RW2-2

Table 4.8. Critical Assumptions and Initial Conditions (Continued).

Critical control	Description	Associated events
AC	Personnel are permitted in the Service Cell for manual disconnect of resin transfer connection at one of the locations in the Service Cell from the High Integrity Container (HIC) (resin shipping container) or at the wall	RW3-7
AC	Other activated component handling operations in the Service Cell are not permitted at the same time personnel are performing resin sluicing operations.	RW3-7
ACAC	Two IX Columns are used in operation and when one column is spent, it is allowed to decay for nominally 6 months prior to sluicing from that column to the resin storage tank where it is allowed to decay further	RW3-13; RW4-4
AC/DF	All high-level activated waste is handled in the Service Cell. Only low-level contaminated waste would be stored in areas outside the Service Cell	RW4-1
AC	Component is transferred into and out of the pit via a cask.	SS3-2
AC	Personnel are permitted in the Service Cell during component drying operations.	SS3-4
AC	Connections in the Service Cell are all in vacuum during drying operation.	SS3-4
AC	No operations in the PIE Cell will create airborne particulate from grinding and cutting	SSP3-1
AC	Radioactive material in the truck bay is assumed to be limited to surface contamination or radioactive material in approved packaging	TB1-1
AC	TPS allows administrative bypass of stopped rotor and beam on permissive during commissioning activities	TS3-15

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APPENDIX A. ACCELERATOR INTERFACE COMPONENTS (AIC) HAZARD EVENT TABLES

Event Number
AIC1-1

Event Description:
A fire in the region of the Loop 2 cooling loop causes a release of activated water.

Assumptions and Initial Conditions:
1. Loop 2 cools the PBW, TVP, MRA, reflector, and all Loop 2 water-cooled shielding. (DF)
2. Workers are not permitted in the TDR. (IC)
3. Workers are permitted in the TVP Equipment Room. (IC)
4. The fire could occur during beam operation or when the beam is down. (IC)
5. Proton beam window will not fail for nominally an hour without cooling so that it is not impacted by this event and does not provide a passive beam trip. (DF)

Causes:
1. Overheating of Loop 2 pump motor.
2. TVP trimmer overheating.
3. Electrical fault.
4. Other undefined source of fire initiation.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Damage to cooling system components.
2. Possible damage to TVP equipment from lack of cooling or exposure to water.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent a fire from leading to a release of activated Loop 2 cooling water and limit radiological exposure to workers.

Method of Detection:	
PBW, TVP, reflector, or MRA cooling water diagnostics.	
Visual.	
Fire detection and alarm.	

Preventive Features – Attributes:	**Credited:**
Loop 2 Cooling water system design. (DF)	
Loop 2 cooling water system preventive maintenance and surveillance. (AC)	
Equipment designed to IEEE standards. (DF)	

Event Number
AIC1-1

Mitigative Features – Attributes:	Credited:
Fire detection and suppression system. (EC)	
EOPs. (AC)	
Worker training. (AC)	
MPS beam trip on loss of Loop 2 total flow (Supply or Return flow). (EC)	
MPS beam trip for abnormal Loop 2 return flow. (EC)	
Combustible Material Control Program Including: (AC) • Metallic covering of large quantities of hydrogenous shielding material to slow the ignition and propagation of a large hydrogenous shielding fire throughout the instrument hall. • Low combustibility hydraulic fluid.	
Building design (fire barriers and noncombustible construction) reduce the risk that fire could engulf the entire building. (DF)	
Fire Department response. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Determine the activation level of the water in Loop 2.
2. Perform a Project Fire Hazard Analysis (PFHA).
3. Assessment of fires per NFPA 801.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:

1. Neutron dose rate at the lower mirror is 5.18E+10 mrem/hr .
2. Photon dose rate at the lower mirror is 5.05E+8 mrem/hr .

Mitigated Frequency
A

Event Number
AIC3-1

Event Description:
Beam Misalignment (Focused Beam): Release of radioactive Loop 2 Cooling Water from Proton Beam Window due to overheating of the Proton Beam Window caused by a partially expanded beam or a focused beam. Release of cooling water into RTST Line and/or Core Vessel. (See Event TS3-9)

<table>
<tr><td>Assumptions and Initial Conditions:
1. Achieving a beam more focused than the design basis would require changes in magnet and operational configuration. The target and the proton beam window are designed to accept the design basis beam. (DF)</td><td colspan="2">Causes:
1. Malfunction in Beam Expander mechanism</td><td>Initiating Event Frequency
BEU</td></tr>
<tr><td rowspan="2">Unmitigated Impact on Systems:</td><td colspan="3">Unmitigated Consequences</td></tr>
<tr><td>Radiological
Public: N/A
WG1: N/A
WG2: N/A</td><td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
</table>

Safety Function:
Prevent a focused beam from causing a Proton Beam Window failure (breach leading to release of Loop 2 water).

Method of Detection:	

Preventive Features – Attributes:	**Credited:**

Mitigative Features – Attributes:	**Credited:**

Event Number AIC3-1			
Planned analysis, assumption validations, and Risk/Opportunities: 1. . .	**Mitigated Consequences:**		
	Radiological **Public**: N/A **WG1**: N/A **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Notes: **1.** See Event Evaluation in TS3-9.			**Mitigated Frequency** BEU

Event Number
AIC3-3

Event Description:
Loss of flow of cooling water Loop 2 causing a PBW, TVP, MRA, or reflector failure. Release of activated Cooling Water into Core Vessel caused by loss of flow. Release of activated water to the RTST due to overheating of Window caused by loss of flow. AIC3-3 evaluates PBW failure only. . Evaluation of other SSCs on Loop 2 are addressed in AIC3-9.

Assumptions and Initial Conditions:
1. Proton beam window will not fail (melt) for nominally an hour without cooling so that it is not immediately impacted by this event and does not provide a timely passive beam trip. (DF)
2. Core vessel ullage, burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. (DF)
3. Loop 2 cools the PBW, TVP, MRA, reflector, and all Loop 2 water-cooled shielding. (DF)
4. Core vessel operating in inert helium near atmospheric pressure or in vacuum. (AC/IC)
5. No personnel are permitted in the RTST tunnel during operation. (IC/AC)
6. Proton beam remains on. (IC)
7. Redundant power supply busses for Loop 2 pumps. (DF)
8. Core vessel leak detection is located in the Core Vessel Drain. (See Note 1) (DF)
9. Leak is on RTST side beam of the PBW will stop beam due to loss of vacuum (IC)

Causes:
1. Loss of Loop 2 Pumping power.
2. Locked Loop 2 Pump rotor.
3. Loop 2 Pump Seizes.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Bulk of water released from coolant system into the core vessel retained in ullage or core vessel drain.
2. Contamination of Core Vessel, Core Vessel Vacuum or He System, and RTST Line.
3. Proton beam window failure could leak to core vessel or RTST. (Note 4)
4. Leak could contaminate the PBW vacuum system.
5. Leak on the RTST side of the PBW could drain into the shielding outside of the core vessel. (Note 5)

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent loss of cooling water from causing a PBW, TVP, MRA, or reflector failure and release of Loop 2 cooling water.

Method of Detection:	
Loop 2 Pump status and/or low flow alarms indicates loss of flow condition.	
Loss of vacuum in the RTST.	
Loop 2 return flow, pressure, and temperature.	

Event Number AIC3-3	
Method of Detection (Continued):	
Ion vacuum pump failure in the RTST.	
RGA on vessel off-gas.	
Loop 2 GLS level indicator	
Core vessel pressure change or liquid detection probe.	
Ion vacuum pump failure in the RTST.	
Core Vessel Drain Line Liquid Detection.	
Preventive Features – Attributes:	**Credited:**
Redundant pump with automatic switching. (EC)	
Electrical and Mechanical codes and Standards. (DF)	
Specific valve positions interlocked in control circuitry with pump start/run condition. (EC/AC)	
Operating Procedures and Training (e.g., Valve line-up checklist). (AC)	
Preventive Surveillance and Maintenance. (AC)	
Mitigative Features – Attributes:	**Credited:**
MPS beam trip for abnormal Loop 2 return flow (EC)	
Core Vessel Drain Line Liquid Detection Probe. (EC) • Alarm in Control Room on detection of a leak. (EC) • MPS trip on High Level in the Core Vessel Drain Line. (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line. (EC)	
MPS beam trip upon detection of high Loop 2 return temperature. (EC)	
Inert core vessel atmosphere. (EC)	
EOPs. (AC)	
Worker training. (AC)	
Fast Acting Valves in RTST isolate RTST on window failure. (EC)	
Water containment in RTST between window and fast acting valves. (DF)	
Automatic beam loss by loss of vacuum in the RTST Line (for failure of Proton Beam Window). (EC)	
MPS beam trip on pump exit pressure. (EC) (See Note 2)	
MPS beam trip for water Loop 2 GLS tank low level (EC)	
MPS beam trip on high core vessel helium or vacuum pressure during operation. (EC)	
Fast acting valve in the RTST causes an MPS beam trip (EC)	
Collection of Water by the Core Vessel; Confinement by Core Vessel, Core Vessel Drain Line, RTST, and neutron beam windows (DF)	

Event Number
AIC3-3

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1 Evaluate onsite dose estimates. 2 Set point analysis for beam trip system. 3 Determine Loop 2 activation levels.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
1. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition. 2. Delay built into the MPS trip to provide recovery time prior to the required trip. Delay time TBD. 3. Failure within the Target and moderator addressed in CM and TS events. 4. A PBW failure allowing communication between the Core Vessel and the RTST line would require a complete failure of the PBW (both sides of the PBW). 5. The leak collection system provides a catch pan and drain to the capture leaks in this space.	**A**

Event Number
AIC3-4

Event Description:
Loss of Heat Sink: Release activated Cooling Water into the core vessel due to overheating of PBW, TVP, MRA, or reflector caused by loss of Loop 2 cooling due to failure in the Secondary Cooling Water system.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. Secondary Cooling Water System replaced by double walled HX. (DF) 2. Loop 1 provides cooling water for the Target. (DF) 3. Loop 2 provides cooling water for the PBW: TVP, CMS, and water-cooled shielding. (DF)	1. N/A	BEU

Unmitigated Impact on Systems:
1. Bulk of water released window and target retained in core vessel drain Line.
2. Failures within the Target and moderator addressed in CM and TS events.
3. Contamination of Core Vessel, Core Vessel Vacuum or He System, and RTST Line.
4. If leak is on RTST side beam will stop due to loss of vacuum.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent loss of heat sink from causing a PBW, TVP, MRA, or reflector failure and release of Loop 2 cooling water.

Method of Detection:	
Loop 2 cooling loop return flow and temperature.	
Loop 2 cooling loop gas liquid separator tank water level.	
Loss of vacuum in the RTST and Ion vacuum pump failure in the RTST.	
Core Vessel Drain Line Liquid Detection.	

Event Number
AIC3-4

Preventive Features – Attributes:	Credited:
Secondary Cooling Water System replaced by double walled HX. (DF)	

Mitigative Features – Attributes:	Credited:
MPS beam trip for abnormal Loop return flow. (EC)	
Core Vessel Drain Line Liquid Detection Probe. (EC) • Alarm in Control Room on detection of a leak. (EC) • MPS trip on High Level in the Core Vessel Drain Line. (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line. (EC)	
MPS beam trip upon detection of high Loop 2 return temperature. (EC)	
No access possible to the Proton Beam Window or Core Vessel when the release occurs. (EC)	
Inert core vessel atmosphere. (EC)	
Fast Acting Valves control leakage to the RTST. (EC)	
Worker training. (AC)	
MPS beam trip for water Loop 2 GLS tank low level. (EC)	
MPS beam trip on high core vessel helium or vacuum pressure during operation. (EC)	
Collection of Water by the Core Vessel; Confinement by Core Vessel, Core Vessel Drain Line, RTST, and neutron beam windows. (DF)	
Emergency Operating Procedures and Training. (AC)	
Fast acting valve in the RTST causes an MPS beam trip (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.	**BEU**

Event Number
AIC3-5

Event Description:
Accelerator switching system fails and delivers more than 15 pulses per second to STS resulting in damage to the Proton Beam Window.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1 Pulsed dipole magnet power supply will not allow all ring pulses into the RTST. (DF) 2 Loop 2 cools the PBW, TVP, MRA, reflector, and all Loop 2 water-cooled shielding. (DF) 3 Core vessel leak detection is located in the Core Vessel Drain line. (DF) 4 Proton beam window will not fail for nominally an hour without cooling so that it is not immediately impacted by this event and does not provide a timely passive beam trip. (DF) 5 Evaluation is of Proton Beam Window failure (the target and moderator failures are addressed in the CMS and TS event appendices; accelerator failures are addressed in the AS event appendix. (IC)	1 Accelerator Switching system failure	**EU**

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1 Possible Target damage before window failure (melt). 2 Proton Beam Window failure could cause cooling water to leak into the RTST and/or Core Vessel.	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent proton beam from reaching the proton beam window and target with substantially above the 15 pulses per second authorized design limit and prevent inadvertent personnel exposure to excessive radiation.

Method of Detection:	
MPS beam current monitors.	
Low Loop 2 return flow.	
Loss of vacuum in the RTST and Ion vacuum pump failure in the RTST.	

Preventive Features – Attributes:	**Credited:**
Design of switching system to limit the beam to not significantly exceed 15 pulses per second. (EC)	
PPS – Repetition Limiting System (RLS) Pulsed Dipole switching frequency. (EC)	
Configuration Management Program – assure proper beam is delivered to the RTST. (AC)	

Event Number
AIC3-5

Mitigative Features – Attributes:	Credited:
MPS beam trip for abnormal Loop 2 return flow. (EC)	
Design of switching system to limit the beam to not significantly exceed 15 pulses per second. (EC)	
Pulsed Dipole magnet power supply will not allow all ring pulses into the RTST. (DF)	
Core Vessel Drain Line Liquid Detection Probe. (EC) • Alarm in Control Room on detection of a leak. (EC) • MPS trip on High Level in the Core Vessel Drain Line. (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line. (EC)	
Core vessel burst disk rupture causes an alarm in the control room. (EC)	
Inert core vessel atmosphere. (EC)	
Core vessel pressure relief system – burst disk and hydrogen safe vent Core Vessel burst disk alarms in the control room (Note 3). (EC)	
No personnel access possible to the Proton Beam Window or Core Vessel when the release occurs. (EC)	
Collection of Water by the Core Vessel; Confinement by Core Vessel, Core Vessel Drain Line, RTST, and neutron beam windows. (DF)	
Worker training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:
1.

Mitigated Consequences:		
Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:
1. Delay built into the MPS trip to provide recovery time prior to the required trip. Delay time TBD.
2. A single pulse to STS will not be capable of exceed approved power limit for target.
3. The burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures.
4. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.

Mitigated Frequency
EU

Event Number AIC3-6 (Event Deleted as PBW moved to Loop 2)
Event Description: Tungsten-water reaction in target causing a loss of flow to cool the Proton Window.

Event Number AIC3-7		
Event Description: Target Building only loss of electric power leading to loss of cooling for PBW, TVP, MRA, reflector, and all Loop 2 water-cooled shielding, with the beam remaining on. Event only evaluates impact on Loop 2 cooled systems. Impact of this event on the Target Segments is addressed in the Appendix R TS events.		
Assumptions and Initial Conditions: 1. All power is lost in target building. (IC) 2. Accelerator operation continues. (IC) 3. Target rotation stops. (IC) 4. Window and Target cooling stops. (IC) 5. Proton beam window seal vacuum pumps stop. (IC) 6. Moderator cryogenic refrigerator compressor and circulators stop. (IC) 7. Workers are not permitted in the RTST tunnel with beam operation. (IC) 8. Loop 2 cools the PBW, TVP, MRA, reflector, and all Loop 2 water-cooled shielding. (DF) 9. Proton beam window will not fail (melt) for nominally an hour without cooling so that it is not immediately impacted by this event and does not provide a timely passive beam trip. (DF)	**Causes** 1. Fault in feeder substation. 2. Fault in power line to target building. 3. Switching error. 4. Software error. 5. Overload. 6. Other electrical outage.	**Initiating Event Frequency** **A**

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
1. Cooling water released to core vessel and RTST beam line. 2. Moderators vent from pressure rise due to loss of cooling then fail and residual vents though core vessel burst disk. 3. Loss of proton beam window vacuum seal causes leakage to high vacuum side and passive accelerator shutdown.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Assure loss of power to the Target Building does not cause a PBW, TVP, MRA, reflector, and all Loop 2 water-cooled shielding failure, with the beam remaining on (e.g.; required emergency power is available for this cooling system).

Method of Detection:	
Visual.	
UPS safety lighting.	

Preventive Features – Attributes:	**Credited:**
Electrical system design. (DF)	
Worker training and procedures. (AC)	

Event Number
AIC3-7

Mitigative Features – Attributes:	Credited:
No access possible to the Proton Beam Window or Core Vessel when the release occurs. (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of signal or loss of power to the MPS panel. (EC)	
Standby and UPS power for critical systems & CEC systems. (EC)	
EOPs. (AC)	
Worker training. (AC)	
Fast Acting Valves in RTST isolate RTST on window failure. (EC)	
Water containment in RTST between window and fast acting valves (will also cause an MPS beam trip on valve closure). (DF)	
Collection of Water by the Core Vessel; Confinement by Core Vessel, RTST, and neutron beam windows. (Note 2) (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Evaluate consequences of Loop 2 release.
2.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible **WG1**: Low **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:

1. This event addresses failure of the PBW, TVP, MRA, reflector, and all Loop 2 water-cooled shielding. Events impacting the Target is addressed in the TS and CM events.
2. The leak collection system provides a catch pan and drain to the capture leaks in this space

Mitigated Frequency
A

Event Number

AIC3-8 (Event Deleted as the Collimator has been removed from the design.

Event Description:

Misdirected beam strikes the collimator resulting in failure and cooling water spill.

Event Number
AIC3-9

Event Description:
Failure in the Loop 2 cooling water system results in a loss of cooling to the PBW, TVP, CMS, and water-cooled shielding.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Evaluation of PBW failure is addressed in AIC3-3. AIC3-9 addresses failures of other systems on Loop 2. (IC) 2. Loop 1 provides cooling water for the Target. (DF) 3. Loop 2 provides cooling water for the PBW: TVP, CMS, and water-cooled shielding. (DF) 4. Core vessel ullage, burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. (DF) 5. Core vessel operating in inert helium near atmospheric pressure or in vacuum. (IC) 6. Proton beam remains on. (IC)	1. Mechanical failure. 2. Corrosion. 3. Maintenance error. 4. Loss of Loop 2 Pumping power. 5. Locked Loop 2 Pump rotor. 6. Loop 2 Pump Seizes. 7. Failure to provide preventive maintenance and surveillances.	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Bulk of water released from coolant system into the core vessel retained in ullage or drain tank. 2. Failure within the moderator addressed in CMS events. 3. Contamination of Core Vessel, Core Vessel Vacuum or He System, and RTST Line. 4. Proton beam window failure could leak to core vessel or RTST. 5. If leak is on RTST side beam will stop due to loss of vacuum.	**Public**: Negligible **WG1**: Low **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Limit the impact (potential exposure to personnel) of a Loop 2 cooling water failure on CMS, TVP, and water cooled shielding.

Method of Detection:	
Loop 2 return temperature, pressure, and flow.	
TVP and CMS monitoring system.	

Preventive Features – Attributes:	**Credited:**
Mechanical design codes and standards. (DF)	
Preventive Maintenance. (AC)	

Event Number
AIC3-9

Mitigative Features – Attributes:	Credited:
MPS beam trip for abnormal Loop 2 return flow. (EC)	
Core Vessel Drain Line Liquid Detection Probe. (EC) • Alarm in Control Room on detection of a leak. (EC) • MPS trip on High Level in the Core Vessel Drain Line. (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line. (EC)	
Core vessel burst disk rupture will lead to an alarm in the control room. (EC)	
Inert core vessel atmosphere. (EC)	
Core vessel pressure relief system – burst disk and hydrogen safe vent (See Note 2). (EC)	
MPS beam trip on pump exit pressure. (EC) (See Note 1)	
MPS beam trip for water Loop 2 GLS tank low level. (EC)	
MPS trip on high core vessel helium or vacuum pressure during operation. (EC)	
Collection of Water by the Core Vessel; Confinement by Core Vessel, Core Vessel Drain Line, RTST, and neutron beam windows. (EC)	
Emergency Operating Procedures and Training. (AC)	
Location ensures significant shielding for personnel in the Target Building or outside the RTST tunnel. (DF)	
PPS interlocks on removable shielding ensures appropriate shielding for personnel in the Target Building or outside the RTST tunnel. (EC)	
Interlocked radiation monitors (IRM) tied to the PPS ensures appropriate protection from the shielding for personnel in the Target Building or outside the RTST tunnel. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:
1. Evaluate the consequences of Loop 2 release.
2. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible **WG1**: Low **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A

Notes:
1. Delay built into the MPS trip to provide recovery time prior to the required trip. Delay time TBD.
2. The burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures.
3. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.

Mitigated Frequency
A

Event Number AIC3-10					
Event Description: Failure in the Loop 2 cooling water system results in a loss of cooling to a single component in the AIC (PBW, TVP, CMS/MRA, PBW water cooled shield, or water-cooled shielding).					
Assumptions and Initial Conditions: 1. Loop 1 provides cooling water for the Target. (DF) 2. Loop 2 provides cooling water for the PBW, TVP, CMS/MRA, and water-cooled shielding. (DF) 3. Core vessel ullage, burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. (DF) 4. Core vessel operating in inert helium near atmospheric pressure or in vacuum. (IC) 5. Proton beam remains on. (IC)		**Causes**: 1. Valve misalignment. 2. Operator Error.			**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. Bulk of water released from coolant system into the core vessel retained in core vessel ullage and drain line. 2. Failure within the moderator addressed in CMS/MRA events. 3. Contamination of Core Vessel, Core Vessel Vacuum or He System, and RTST Line.		**Unmitigated Consequences**			
		Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible		**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Limit the impact (potential exposure to personnel) of a Loop 2 cooling water failure on a single component (PBW, CMS/MRA, TVP, and water-cooled shielding).					
Method of Detection:					
Loop 2 parameters out of bounds.					
TVP, PBW, and MRA monitoring systems.					
Core vessel leak detection systems					
Preventive Features – Attributes:					**Credited:**
Operator training and procedures. (AC)					
Valve alignment checklist. (AC)					

Event Number
AIC3-10

Mitigative Features – Attributes:	Credited:
MPS beam trip for abnormal Loop 2 return flow. (EC)	
Core Vessel Drain Line Liquid Detection Probe. (EC) • Alarm in Control Room on detection of a leak. (EC) • MPS trip on High Level in the Core Vessel Drain Line. (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line. (EC)	
Core vessel burst disk rupture causes an alarm in the control room. (EC)	
Inert core vessel atmosphere. (EC)	
Core vessel pressure relief system – burst disk and hydrogen safe vent (See Note 2). (EC)	
Collection of Water by the Core Vessel; Confinement by Core Vessel, Core Vessel Drain Line, RTST, and neutron beam windows. (DF/EC)	
Emergency Operating Procedures and Training. (AC)	
Location ensures significant shielding for personnel in the Target Building or outside the RTST tunnel. (DF)	
Collection of water by proton beam window assembly leak collection point. (DF/EC)	
MPS beam trip on pump exit pressure. (EC) (See Note 1)	
MPS beam trip for water Loop 2 GLS tank low level. (EC)	
PPS interlocks on removable shielding ensures appropriate shielding for personnel in the Target Building or outside the RTST tunnel. (EC)	
Interlocked radiation monitors (IRM) tied to the PPS ensures appropriate protection from the shielding for personnel in the Target Building or outside the RTST tunnel. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. Evaluate consequences of Loop 2 release. 2. Design team to determine how a fault in a single system can be detected and used to trip the beam. It does not appear that monitoring the bulk flow will be adequate. 3. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Event Number AIC3-10	
Notes: 1. Delay built into the MPS trip to provide recovery time prior to the required trip. Delay time TBD. 2. The burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. 3. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.	**Mitigated Frequency** **A**

Event Number
AIC3-11

Event Description:
Breach of the AIC vacuum system. Note: Other events leading to communication of the core vessel atmosphere and the outside environment are addressed in the VS events.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Core vessel operating in inert helium near atmospheric pressure or in vacuum. (IC) 2. Proton beam remains on. (IC) 3. Personnel could be in the TPV equipment room during beam operation (IC)	1. Mechanical failure of the vacuum seal. 2. Other event causing a pressure increase in the core vessel leading to AIC vacuum seal failure.	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Air is pulled into the core vessel in either vacuum mode or helium mode operation if the event is due to a rupture disk failure. 2. Contamination of the AIC vacuum system and TPV/TDR spaces.	**Public**: Negligible **WG1**: Low **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Limit the potential exposure of workers in the TPV equipment room from an AIC vacuum seal failure from over pressure in the core vessel.

Method of Detection:	
Core vessel rupture disk monitoring.	
TVP monitoring system.	
Detection of initiating event as addressed in other PHAR events.	
Preventive Features – Attributes:	**Credited:**
Mechanical design codes and standards. (DF)	

Event Number AIC3-11	
Mitigative Features – Attributes:	**Credited:**
MPS trip on high core vessel helium or vacuum pressure during operation. (EC)	
Core vessel burst disk rupture causes an alarm in the control room. (EC)	
Inert core vessel atmosphere. (EC)	
Core vessel pressure relief system – burst disk and hydrogen safe vent (See Note 2). (EC)	
Emergency Operating Procedures and Training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A

Notes:	**Mitigated Frequency**
1. There is no direct path with a single failure for gases from the core vessel reaching personnel. 2. The burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures.	**A**

Event Number
AIC4-1

Event Description:
Misdirected beam strikes the PBW shielding or Proton Beam Tube Assembly (PBTA) resulting in an increased dose to workers outside the tunnel, either in the Target Building or outside the Target Building.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Personnel are not permitted in the RTST tunnel with beam on. (IC/AC)	1. Partial magnet failure. 2. Operator Error. 3. Control System Malfunction.	**A**

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Potential damage to the Proton Beam Window from metal spattering or cooling water release. 2. Damage to the Proton Beam tube from metal spattering or cooling water release. 3. Potential damage to the TVP due to metal spattering or cooling water release.	**Public**: Negligible **WG1**: Low **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent a beam from impacting the PBW shielding or PBTA causing an increased dose to personnel outside the tunnel, either in the Target Building or outside the Target Building.

Method of Detection:	
Increased radiation in the Target Building.	
PPS Interlocked radiation monitor (IRM).	
HARP monitoring system and MPS beam trip	
HALO monitoring system and MPS beam trip.	

Preventive Features – Attributes:	**Credited:**
Beam controls (instruments and diagnostics). (AC/EC)	

Event Number
AIC4-1

Mitigative Features – Attributes:	Credited:
PPS interlocks on removable shielding ensures appropriate shielding for personnel in the Target Building or outside the RTST tunnel. (EC)	
Interlocked radiation monitors (IRM) tied to the PPS ensures appropriate protection from the shielding for personnel in the Target Building or outside the RTST tunnel. (EC)	
HALO thermocouples will cause an MPS trip (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Determine Loop 2 cooling water activation.
2. Verify potential dose from spilled beam in the TVP equipment room and outside controlled spaces (target building and outside the target building.
3. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:

1. Inherent shielding during operation limits potential dose to workers.
2. There is currently one HARP in the design in the AS scope on the RTST side of the PBW. A second HARP has been approved on the target side and the design is ongoing. This HARP is on the PBW shielding and is in TS (AIC) scope. Both would drive an MPS trip. There are three HALOs in the design and all three are in the TS (AIC) scope. One on the PBW shielding on the RTST side, one on the PBW itself, and one on the PBW shielding on the target side. MPS trips are only on the PBW HALO.

Mitigated Frequency
A

Event Number
AIC4-2

Event Description:
Failure to install doghouse shielding after maintenance on the TVP resulting in excessive exposure to workers.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Beam on at design conditions. (IC) 2. WG1 is in the vicinity of the TVP equipment room or outside the target drive room (TDR). (IC)	1. Maintenance error. 2. Failure to follow procedures.	A

Unmitigated Impact on Systems:
1. None.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: High	**WG1**: N/A	**WG1**: N/A
WG2: Low	**WG2**: N/A	**WG2**: N/A

Safety Function:
Assure adequate shielding for normal operations is in place for the TVP.

Method of Detection:	
PPS interlocked radiation monitors. (IRM)	
Personal dosimetry.	
Visual.	

Preventive Features – Attributes:	**Credited:**
Maintenance procedures. (AC)	
Configuration Control Program. (AC)	

Event Number AIC4-2	
Mitigative Features – Attributes:	**Credited:**
Personnel training. (AC)	
PPS interlocked radiation monitors (IRM). (EC)	X
Personal dosimetry. (AC)	
TPPS Sweep and Evict Procedure - Proper procedures and training for the sweep and evict protocols prior to securing the TDR before beam operations. (AC)	X
PPS Access Control to the Target Drive Room (EC)	X

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. Neutron dose rate at the upper mirror of the TVP is 1.23E+06 mrem/hr. 2. Photon dose rate at the upper mirror of the TVP is 1.08E+04 mrem/hr.	A

Event Number
AIC7-1

Event Description:
A seismic event leads to a failure of the proton beam window and the cooling system. Consequences from releases from the cryogenic moderator, target system, and core vessel and the potential for a hydrogen detonation are addressed the applicable BG, CM, and TS events.

Assumptions and Initial Conditions:
1. The seismic event causes both a failure of the window (vacuum failure) and cooling system breach. (IC)
2. Loop 2 cools the PBW, TVP, MRA, reflector, and all Loop 2 water-cooled shielding. (DF)
3. WG1 is assumed to not be in the RTST tunnel when the event occurs. (IC)
4. The earthquake causes loss of the accelerator proton beam. (See Note 4) (DF)

Causes:
1. Seismic Event

Initiating Event Frequency
U

Unmitigated Impact on Systems:
1. Credited Controls, Impact, and Consequences for the full facility are the same as for BG7-1a.
2. Loss of vacuum in the core vessel and RTST with associated contamination of these systems.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
The full safety function for this event is addressed in the applicable BG, CM, and TS events. There is no specific safety function associated with a seismic event for the Proton Beam window.

Method of Detection:	
Audible.	
Visual.	
Tactile.	

Preventive Features – Attributes:	**Credited:**
None	

Event Number
AIC7-1

Mitigative Features – Attributes:	Credited:
Monolith external structure designed to maintain monolith iron shielding in place. (DF)	
Emergency response procedures and Worker training to respond to a seismic event. (AC)	
Tunnel design will limit impact outside the tunnel. (DF)	
TPS beam trip due to TPS fail safe design providing a trip on loss of signal or loss of power to the TPS panel. (EC)	
Core vessel burst disk rupture causes an alarm in the Control Room. (EC)	
MPS beam trip on Loop 2 pump exit pressure. (EC) (See Note 2)	
MPS beam trip for water Loop 2 GLS tank low level. (EC)	
Core Vessel Drain Line Liquid Detection Probe. (EC) • Alarm in Control Room on detection of a leak. (EC) • MPS trip on High Level in the Core Vessel Drain Line. (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. Evaluate the consequences of Loop 1 release	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Event Number AIC7-1	
Notes: 1. This event is applied to the failure of the Proton Window and is associated with CM, BG, and TS events for a seismic event with and without a follow-on detonation and or fire. 2. Delay built into the MPS trip to provide recovery time prior to the required trip. Delay time TBD. 3. Credited Controls to address building NPH design, TPS trips on the beam, and inherent safety design of the TPS beam trip function are the same as BG7-1a. 4. SNS FSAD-NF assumes that an NPH event of PC-2 or higher would cause a beam trip. Since the same linac supplying the FTS as supplies the STS, this beam trip is assumed. (102030102-ES0016-R03, “Spallation Neutron Source Final Safety Assessment Document for Neutron Facilities”, September 2011). Further evaluation beyond the SNS study supports any felt motion that is strong enough to damage equipment would also shut down the beam. Operator action is required to restart the beam, so the beam would remain off. 5. The burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. 6. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.	**Mitigated Frequency** **U**

APPENDIX B. ACCELERATOR SYSTEMS (AS) HAZARD EVENT TABLES

APPENDIX B. ACCELERATOR SYSTEMS (AS) HAZARD EVENT TABLES

Event Number
AS1-1

Event Description:
A fire in a cable tray or electrical component in the tunnel is initiated by an inadvertent ignition source (electrical short, electrical overload, overheat, etc.).

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. Activated material in the tunnel is generally fixed and would not be released in a fire. (IC) 2. Event can occur either during beam operation or during maintenance operations (WG-1 is assessed based on maintenance operations). (IC) 3. If the fire is near cooling water piping this fire results in a loss of confinement event for the cooling water the tunnel. (IC)	1. Electrical short. 2. Electrical overload/overheat. 3. Maintenance failure.	A

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. Loss of electrical equipment powered by affected cable trays, including magnet operation leads to loss of ability of beam operation. 2. Fire could lead to potential equipment damage. 3. Equipment damage from fire water and recovery from the water release would lead to an extended outage.	**Public:** Negligible **WG1:** Negligible **WG2:** Negligible	**Public:** N/A **WG1:** N/A **WG2:** N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
To control the consequences of a fire in the RTST Tunnel and limit radiological exposure to workers. .

Method of Detection:	
ICS/MPS – Recognition of off normal conditions, control room notification, and actions.	
Smoke	
Fire Detection and alarm.	
Temperature switches hardware to magnet power supplies.	
Beam loss monitors detect a beam spill.	

Preventive Features - Attributes:	Credited:
IEEE Standards used in design. (EC)	
NPFA Design and requirements. (EC)	

Event Number AS1-1				
Mitigative Features - Attributes:				**Credited:**
Fire Detection and Notification – alarms and monitors. (EC)				
Fire Detection and Suppression System – Wet pipe system. (EC)				
ICS/MPS – Recognition of off normal conditions, control room notification, and actions tied to the Fire Detection System to monitor and support evacuation. (EC)				
Design to IEEE standards. (AC)				
Beam Loss monitors (EC)				
Design to NFPA standards and requirements. (DF)				
Each magnet coil has a temperature switch interlocked to the magnets' power supply. (See Note 3) (EC)				
Operator Training and Procedures – to respond to fire alarms and evacuate. (AC)				
Planned analysis, assumption validations, and Risk/Opportunities: 1. Project Fire Hazard Analysis (PFHA). 2. Assessment of fires per NFPA 801.	**Mitigated Consequences:**			
	Radiological **Public:** Negligible **WG1:** Negligible **WG2:** Negligible	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Notes: 1. Activated material is releasable in a fire. 2. Fire could cause loss of beam operation. 3. Each magnet will have a thermo switch attached to each of its coils. The switches will be wired in series and interlocked into the power supply of the magnet. This is part of the magnet design.				**Mitigated Frequency** A

Event Number
AS1-2

Event Description:
Due to a localized fire, there is a loss of cooling water to the magnets in the RTST Tunnel causing damage to the magnets.

Assumptions and Initial Conditions:
1. Event applicable during beam operation or magnet operation without beam operation. (IC)
2. No personnel are permitted in the tunnel during beam operation. (IC)
3. Design of the magnets does not preclude overheating from causing a fire. (IC)

Causes:
1. Operator error.
2. Maintenance failure (no flow/pressure, low flow/ pressure).
3. Loss or reduction of cooling water.

Initiating Event Frequency
U

Unmitigated Impact on Systems:
1. The unmitigated impact on systems is the direct impact of the fire and contamination from the cooling water radiological material.
2. This event leads to a loss of ability of beam operation, loss of production, and potential equipment damage.
3. Magnet overheating and damage to affected magnets

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1:** N/A	**WG1**: N/A
WG2: Negligible	**WG2:** N/A	**WG2**: N/A

Safety Function:
To prevent and control the radiological consequences to workers of a localized fire to prevent a loss of cooling water to the magnets in the RTST Tunnel.

Method of Detection:	
Fire Detection and alarm.	
Pressure and flow sensors on the cooling loop.	
Smoke	
Temperature switches hardwired to magnet power supplies.	

Preventive Features - Attributes:	**Credited:**
IEEE Standards used in design. (DF)	
NPFA Design and requirements. (DF/EC)	

Event Number AS1-2				
Mitigative Features – Attributes:				**Credited:**
Fire Detection and Notification – alarms and monitors. (EC)				
Fire Detection and Suppression System – Wet pipe system. (EC)				
Each magnet coil has a temperature switch interlocked to the magnets' power supply. (See Note 3) (EC)				
MPS monitors the "ON" status of the magnets. (EC)				
Emergency response procedures. (AC)				
Personnel have limited access to the tunnel with the magnets energized. (AC)				
Operator Training and Procedures – to respond to alarms, sensors, and evacuate. (AC)				
Planned analysis, assumption validations, and Risk/Opportunities: 1. Project Fire Hazard Analysis (PFHA). 2. Assessment of fires per NFPA 801.	**Mitigated Consequences:**			
	Radiological **Public:** Negligible **WG1:** Negligible **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Notes: 1. A fire in the RTST tunnel could cause a loss of cooling water and if left operating without cooling it could lead to a fire in the magnets and associated consequences in the tunnel. 2. Loss of cooling water to magnet while personnel are in the tunnel (i.e., magnet is not energized, but beam could be on or off) is assumed to not be a credible initator for a fire event. 3. Each magnet will have a thermo switch attached to each of its coils. The switches will be wired in series and interlocked into the power supply of the magnet. This is part of the magnet design.				**Mitigated Frequency** U

Event Number
AS3-1

Event Description:
Air in the RTST Tunnel is inadvertently released to the environment due to realignment of HVAC to allow unfiltered tunnel air exhaust directly to the environment.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1) Air in the RTBT tunnel potentially becomes activated during operation, however, under current SNS operations, air activation is not measurable in the RTBT (See Note 3). (IC) 2) The RTST tunnel air normally operates as a closed system integral with the existing RTBT tunnel air though the existing RTBT/Ring/HEBT. (DF) 3) The RTST HVAC recirculation system includes dust filtration (not HEPA) and humidity control. (DF) 4) The HVAC system includes a grade mounted exhaust fan to permit manual exhaust of the tunnel (“smoke” exhaust). (DF) 5) The HVAC includes a control damper that can permit the HVAC to go to a 100% outside air supply operating mode. (DF) 6) The RTST tunnel is connected to the RTBT and tunnel to the FTS with no air separation, but the RTST air activation control is maintained by the HVAC providing air flow from the RTST to the RTBT. (See Note 4) (DF) 7) Based on SNS Proton operations, the activated air is anticipated to be well below 10 CFR Part 20 limits for release to the environment and the limits for worker and public exposure requiring Safety Related Credited Controls. (IC) 8) Workers are not permitted in the tunnel during beam operation. (AC/IC)	1. Operator or procedural error or ventilation system failure allows air to be exhausted to the environment through the smoke exhaust system. 2. Ventilation control system error sends signal to change damper configuration to open 100% outside air supply mode. 3. Operator or procedural error from entering the tunnel before short lived radionuclides adequately decay causes worker to attempt to enter the tunnel. 4. External event that causes loss of confinement of the tunnel entry/exit locations.	A

Unmitigated Impact on Systems:	Unmitigated Consequences: Radiological	Chemical	ODH
1. The unmitigated impact on systems loss of production time due to associated investigations. 2. The tunnel air would bring in outside air at the associated humidity and temperature impacting accelerator controls and equipment. 3. No hardware/system impacts other systems beyond the initial failure.	**Public:** Negligible **WG1:** Negligible **WG2:** Negligible	**Public:** N/A **WG1:** N/A **WG2:** N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
None based on the RTST tunnel air activation level.

Method of Detection:	
PPS – to detect and alarm (interlock controlling access to the tunnel, as well as increased radiation in occupied areas outside the tunnel).	
PPS – Interlocked Radiation Monitors (IRM) – detection and alarm for increased radiation in occupied areas outside the tunnel.	
Monitoring and control room notification of HVAC 100% outside air supply operating mode.	
Monitoring and control room notification of activation of smoke exhaust system.	
Pressure instrumentation – differential pressure from tunnel to surroundings (or alternate control used to maintain pressure differential requirements).	

Event Number
AS3-1

Preventive Features - Attributes:	Credited:
Fire Barriers - Ventilation system damper design (“fail as is” and monitoring of damper position) and interlock. (EC)	
Ventilation System Damper Position - administrative controls to verify position prior to operation. (AC)	
PPS – Permissive tied to RSO confinement mode change and damper realignment. (EC)	
RTST Tunnel HVAC – HVAC alignment for confinement operation. (EC)	

Mitigative Features - Attributes:	Credited:
RTST Tunnel HVAC – • Tunnel air handling system would include appropriate humidity control which will limit tritium activity and filtration (Dust and not HEPA). (EC) • Air flow is maintained from the RTST tunnel to the RTBT by the HVAC system. (EC) • HVAC alignment for confinement operation (Interlock to prevent inadvertent activation of smoke exhaust system or 100% outside air supply. (EC)	
RTST Tunnel Design – • All penetrations will be sealed to the maximum extent possible within allowed confinement/release limits. (EC)	
Monitoring and control room notification of HVAC 100% outside air supply operating mode. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Calculate potential air activation levels in the tunnel at the 1 w/m design limit for the RTST and RTBT to determine if the unmitigated consequences are Low or Negligible.
2. Monitor the penetration design in the tunnel to assure that the tunnel’s confinement is as tight as reasonably achievable. Based on SNS experience, this monitoring will extend into operation to assure that leaks are sealed to the maximum extent practicable.
3. After the power upgrade, verify that there is not an increased radiation level.
4. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:

1. Revisit event with Conventional Facilities.
2. Except for smoke exhaust for the RTST, RTST tunnel air is exhausted through the existing tunnel air handling systems in the SNS.
3. With current SNS operations, measurable air activation has only been found in the Ring Injection area where beam losses are highest. If air activation at measurable levels is produced in the RTBT or RTST areas, it will be at levels creating a Negligible hazard to workers. Following installation, verify that penetrations are adequately sealed.
4. Activated air from the RTBT into the RTST tunnel is anticipated to produce a Negligible hazard at most. STS intends to run the RTST tunnel at a positive pressure compared to the RTBT.

Mitigated Frequency
A

Event Number
AS3-2

Event Description:
A small leak develops in the PBW assembly, allowing core vessel atmosphere upstream into the RTST.

Assumptions and Initial Conditions:	**Causes:**	**Initiating Event Frequency**
1. The PBW seals include multiple seals that would have to fail before core vessel atmosphere could go into the RTST. (DF) 2. Turbo pump is installed downstream of the Fast-Acting Valve. (DF) 3. There is a potential for core vessel atmosphere to be activated. (IC) 4. The leak is assumed to be small enough to not result in an inherent beam trip due to loss of vacuum. (IC) 5. The core vessel is maintained at a pressure less than the RTST tunnel, but above the beam tube vacuum. (IC)	1. PBW leak due to: a. Corrosion. b. Mechanical failure. c. Manufacturing defect. d. Installation error.	BEU (See Notes)

Unmitigated Impact on Systems:	**Unmitigated Consequences:**		
1.	**Radiological** **Public**: N/A **WG1**: N/A **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
To prevent core vessel atmosphere from being leaked into worker locations above 10 CFR Part 20 limits for release to the environment.

Method of Detection:	
None unless pressure goes above fast-acting valve setpoint	

Preventive Features - Attributes:	**Credited:**
None	

Event Number AS3-2	
Mitigative Features - Attributes:	**Credited:**
Fast-acting valve closing will cause and MPS beam trip (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1.	**Radiological** **Public**: N/A **WG1**: N/A **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. The design of the PBW seals requires two failures to have core vessel atmosphere reach the RTST. Individual failures of the PBW seals are addressed in AIC3-3. 2. Even with a loss of the vacuum supporting the PBW seals, the mechanical seal prevents no more than negligible leakage that does not create a safety concern. 3. Leak must be on RTST side of PBW to allow gas into the RTST. A small leak may not be sufficient to trip the fast valve. 4. If the leak is on the RTST side of PBW, then the gas entering the RTST will be air from the monolith shield block region, 5. A second leak is required at Target side of PBW to allow core vessel atmosphere into RTST. Even then, most of the leaking gas will be lost through the monolith shielding.	BEU

Event Number
AS3-3

Event Description:
Activated air in the RTST Tunnel is inadvertently released to the environment during commissioning.

Assumptions and Initial Conditions:

1) Not all penetrations between the RTST tunnel and the service building or target building are sealed. (IC)
2) Air in the RTST tunnel potentially becomes activated during operation, but based on SNS Proton operations and commissioning operations, the activated air is anticipated during both normal operation and commissioning to be well below 10 CFR Part 20 limits for release to the environment. (See Note 5) (IC)
3) Personnel are not permitted in the tunnel during beam operation. (AC/IC)
4) RTST operations are in accordance with the commissioning plan and Operational Safety Envelope. (IC)
5) The tunnel air normally operates as a closed system integral with the existing linac tunnel. RTST air activation control is maintained by the HVAC providing air flow from the RTBT to the RTST. (See Note 6)
6) The HVAC recirculation system includes dust filtration (not HEPA) and humidity control with pressure control provided by the HVAC air flow from the RTST to the RTBT. (DF)
7) The HVAC system includes a grade mounted exhaust fan to permit manual exhaust of the tunnel ("smoke" exhaust). (DF)
8) The HVAC includes a control damper that can permit the HVAC to go to a 100% outside air supply operating mode. (DF)
9) The RTST tunnel is connected to the RTBT and tunnel to the FTS with no air separation, but the RTST air activation control is maintained by the HVAC providing air flow from the RTBT to the RTST. (See Note 6). (DF)

Causes:

1. Operator or procedural error from entering the tunnel before short lived radionuclides adequately decay causes worker to attempt to enter the tunnel.
2. Operator or procedural error or ventilation system failure allows air to be exhausted to the environment through the smoke exhaust system.
3. Ventilation control system error sends signal to change damper configuration to open 100% outside air supply mode.
4. External event that cause loss of confinement of the tunnel entry/exit locations.

Initiating Event Frequency
A

Unmitigated Impact on Systems:

1. None.
2. No hardware/system impacts other systems beyond the initial failure (if applicable).

Unmitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1:** N/A	**WG1**: N/A
WG2: Negligible	**WG2:** N/A	**WG2**: N/A

Safety Function:
To prevent the uncontrolled release of activated air in the tunnel above 10 CFR Part 20 limits for release to the environment.

Event Number AS3-3	
Method of Detection:	
PPS – to detect and alarm (including interlock controlling access to the tunnel, as well as increased radiation in occupied areas outside the tunnel).	
Monitoring and control room notification of HVAC 100% outside air supply operating mode.	
Monitoring and control room notification of activation of smoke exhaust system.	
Visual for external events.	
Pressure instrumentation – differential pressure from tunnel to surroundings (or alternate control used to maintain pressure differential requirements).	
Preventive Features – Attributes:	**Credited:**
Fire Barriers – Ventilation system damper design ("fail as is" and monitoring of damper position) and interlock. (EC)	
Ventilation System Damper Position – administrative controls to verify position prior to operation. (AC)	
PPS – Permissive tied to RSO confinement mode change and damper realignment. (EC)	
RTST Entry Program -Delay required to obtain the trapped key and enter the RTST tunnel under RCT control. (AC)	
Mitigative Features – Attributes:	**Credited:**
Air Activation Monitoring – monitors and alarm for increased radiation in circulating air in RTST tunnel. (AC)	
ASE Limits – Commissioning Procedures. (AC)	
RTST Tunnel HVAC – • Tunnel air handling system would include appropriate humidity control which will limit tritium activity and filtration (Dust and not HEPA). (EC) • Air flow is maintained from the RTST tunnel to the RTBT by the HVAC system. (EC) • HVAC alignment for confinement operation (Interlock to prevent inadvertent activation of smoke exhaust system or 100% outside air supply. (EC)	
RTST Tunnel Design – • Normal entry/egress points include locked doors with PPS controlled trap keys to provide confinement function in the tunnel during operation and prior to authorization for personnel to enter the tunnel. (EC) • All penetrations will be sealed to the extent possible within normal releases. (EC)	
Installation Procedures – assuring temporary penetration seals are in place to limit open air paths from the tunnel to the environment. (AC)	
PPS – Alarm if door opened or radiation levels increase outside the tunnel (including interlock controlling access to the tunnel, as well as increased radiation in occupied areas outside the tunnel). (EC)	
Monitoring and control room notification of HVAC 100% outside air supply operating mode. (EC)	

Event Number
AS3-3

Planned analysis, assumption validations, and Risk/Opportunities:

1. Monitor the penetration design in the tunnel to assure that the tunnel's confinement is as tight as reasonably achievable. Based on SNS experience, this monitoring will extend into operation to assure that leaks are sealed to the maximum extent practicable.
2. After the power upgrade, verify that there is not an increased radiation level.
3. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1:** N/A	**WG1**: N/A
WG2: Negligible	**WG2:** N/A	**WG2**: N/A

Notes:

1. OSE and ASE limits for commissioning must be defined before the ARR.
2. Operations following the commissioning plan will assure that air activation is not significant.
3. Review event and controls with Conventional Facilities
4. Except for smoke exhaust for the RTST, RTST tunnel air is exhausted through the existing tunnel air handling systems in the SNS.
5. Under current SNS RTBT operations air activation is not measurable in the RTBT.
6. With current SNS operations, measurable air activation has only been found in the Ring Injection area where beam losses are highest. If air activation at measurable levels is produced in the RTBT or RTST areas, it will be at levels creating a Negligible hazard to workers.
7. STS will run the RTST tunnel at a positive pressure compared to the RTBT, with the positive pressure condition produced by providing makeup air in the RTST and operating the existing exhaust fans (EF-PE-01 and EF-PE-02) in CEF-1 to control ventilation and contamination control between the RTST and RTBT.

Mitigated Frequency
A

Event Number
AS3-4

Event Description:
Air from the RTBT Tunnel inadvertently enters the RTST during beam operation to the FTS, when personnel are in the RTST for commissioning, maintenance, or other conditions where beam is not intended to go to the RTST or STS.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1) Air in the RTBT tunnel potentially becomes activated during operation, however, under current SNS operations, air activation is not measurable in the RTBT (See Note 2). (IC) 2) The RTST tunnel air normally operates as a mostly closed system integral with the existing linac tunnel. RTST air activation control is maintained by the HVAC providing air flow from the RTBT to the RTST. (See Note 4 and 5) (AC/IC) 3) The HVAC recirculation system includes dust filtration (not HEPA) and humidity control, but the RTST is maintained at a slightly higher pressure than the RTBT. (DF) 4) The RTST tunnel is connected to the RTBT and tunnel to the FTS with limited air separation. (DF) 5) Based on SNS Proton planed operations at increased beam power, the activated air not expected to be above limits for worker exposure requiring Safety Related Credited Controls. (IC) 6) Workers are permitted in the RTST tunnel during beam operation to the FTS. (AC/IC)	1. Operator or procedural error or ventilation system failure allows air from the RTBT to enter the RTST. 2. Inadvertent activation of the RTST smoke exhaust system.	A

Unmitigated Impact on Systems:
1. The unmitigated impact on systems loss of production time due to associated investigations.
2. No hardware/system impacts other systems beyond the initial failure.

Unmitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public:** N/A	**Public**: N/A
WG1: Negligible	**WG1:** N/A	**WG1**: N/A
WG2: Negligible	**WG2:** N/A	**WG2**: N/A

Safety Function:
Assure that air from the RTBT does not enter the RTST if the air in the RTBT is above allowable limits for personnel exposure when personnel are allowed to be in the RTST tunnel. .

Method of Detection:	
Monitoring and control room notification of HVAC 100% outside air supply operating mode.	
Monitoring and control room notification of activation of smoke exhaust system.	

Preventive Features - Attributes:	Credited:
Ventilation System to maintain a positive air flow between the RTST and RTBT. (EC)	
RTST Tunnel HVAC – HVAC alignment for personnel access to the RTST. (EC)	

Event Number
AS3-4

Mitigative Features - Attributes:	Credited:
RTST Tunnel HVAC – • Air flow is maintained from the RTST tunnel to the RTBT by the HVAC system. (EC) • HVAC alignment for confinement operation (PPS controls to prevent inadvertent activation of smoke exhaust system - See Note 6). (EC)	
Monitoring and control room notification of HVAC parameters. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Calculate potential air activation levels in the tunnel at the 1 w/m design limit for the RTST and RTBT to determine if the unmitigated consequences are Low or Negligible.
2. After the power upgrade, verify that there is not an increased radiation level.
3. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:

1. Except for smoke exhaust for the RTST, RTST tunnel air is exhausted through the existing tunnel air handling systems in the SNS.
2. With current SNS operations, measurable air activation has only been found in the Ring Injection area where beam losses are highest. If air activation at measurable levels is produced in the RTBT or RTST areas, it will be at levels creating a Negligible hazard to workers.
3. With current SNS operations, measurable air activation has only been found in the Ring Injection area where beam losses are highest. If air activation at measurable levels is produced in the RTBT or RTST areas, it will be at levels creating a Negligible hazard to workers.
4. STS will run the RTST tunnel at a positive pressure compared to the RTBT, with the positive pressure condition produced by providing makeup air in the RTST and operating the existing exhaust fans (EF-PE-01 and EF-PE-02) in CEF-1 to control ventilation and contamination control between the RTST and RTBT.
5. The PPS follows a beam on vs beam off condition to assure that PPS controlled items are in the appropriate condition. PPS monitors the smoke exhaust damper condition. The Fire Department is the governing organization that determines if the smoke exhaust needs to b activated.

Mitigated Frequency
A

Event Number
AS4-1

Event Description:
Free water from multiple sources becomes activated and pools in the RTST tunnel posing a potential contamination concern for workers. Sources of water include condensation, leaks, groundwater infiltration, previous spills that were not cleaned prior to operation.

Assumptions and Initial Conditions:	**Causes:**	**Initiating Event Frequency**
1. Small amounts of water are assumed to not be noticed and may remain in the tunnel during operation. (IC) 2. Depending on the source water in the tunnel is assumed to be contaminated and will be treated as such until determined that it is either not contaminated or that the contamination level is low enough to be removed. (IC) 3. This event is likely to only impact worker entering the tunnel. (IC)	1. Leakage of ground water into the tunnel. 2. Humidity in the air condenses on tunnel walls. 3. Leaks from process equipment. (See Note 1) 4. Spilled water from maintenance activities.	A

Unmitigated Impact on Systems:	**Unmitigated Consequences:**		
	Radiological	**Chemical**	**ODH**
1. Excess water would increase the duty of the HVAC. 2. Activated water (primarily tritium) is discharged to sanitary sewer.	**Public:** Negligible **WG1:** Negligible **WG2**: Negligible	**Public**: N/A **WG1:** N/A **WG2:** N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Limit/control the quantity of free water in the tunnel.

Method of Detection:	
Visual of pooled water.	
Increased HVAC condensate generation.	
HP detection during pre-entry survey (air and water).	

Preventive Features - Attributes:	**Credited:**
RTST Tunnel Design - Tunnel sealed from groundwater infiltration. (DF)	
RTST HVAC humidity control reduces tunnel wall condensation. (DF	
Conduct of Maintenance to prevent spills or clean up after spills. (AC)	

Event Number
AS4-1

Mitigative Features - Attributes:	Credited:
RTST Tunnel Design - sealed tunnel (including monitoring and patching of leaks as they are identified). (DF/EC)	
RTST Tunnel HVAC - system design captures condensate for processing as contaminated waste depending on monitoring of the condensate. (EC)	
Water System Confinement -Design of water-cooling systems in the RTST tunnel as a closed loop with appropriate design to minimize the potential for leaks. (DF)	
Environmental Safety and Health Management System Program (ESHMS) – assesses the need for specific requirements for defined activity. (AC)	
Radiation Safety Program • Health Physics Survey - RCT entry sweep to assure free water is not visible. (AC)	
Operator Training and Procedures will provide for appropriate response to potentially activated water (avoidance, identify, and cleaning pooled water). (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1.	**Radiological** **Public:** Negligible **WG1**: Negligible **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
1. Leaks from process equipment in the tunnel are addressed in event AS4-9. 2. Review event and controls with Conventional Facilities. 3. HVAC condensate is piped to a collection vessel and monitored before releasing to the sanitary sewer. 4. All free water in the RTST is assumed contaminated until determined otherwise. Free water would only potentially provide a contamination issue and not a risk to workers warranting further controls.	A

Event Number
AS4-2

Event Description:
An inadvertent actuation of the fire suppression system or failure leads to a potential spread of contamination in the RTST Tunnel.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. The fire suppression system is a wet-pipe system. (IC) 2. Water in the tunnel is operationally assumed to be contaminated and will be treated as such until determined that it is either not contaminated or that the contamination level is low enough to be removed. (AC/IC)	1. Mechanical failure due to maintenance error or unidentified equipment malfunction 2. Worker failure to follow procedures or training	A

Unmitigated Impact on Systems:	Unmitigated Consequences:		
	Radiological	**Chemical**	**ODH**
1. Unmitigated impact on systems is water damage to process equipment in the tunnel.	**Public:** Negligible **WG1:** Negligible **WG2:** Negligible	**Public**: N/A **WG1:** N/A **WG2:** N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Limit the potential for inadvertent water release from the fire suppression system.

Method of Detection:	
Fire System Instrumentation.	
Visual	

Preventive Features - Attributes:	**Credited:**
Fire Detection and Suppression System -is designed consistent with the existing fire detection and suppression system in the SNS Tunnel. (DF/EC)	

Event Number AS4-2				
Mitigative Features - Attributes:				**Credited:**
Operator Training and Procedures – to evacuate in the event of an inadvertent release of the Fire Detection and Suppression System. (AC)				
Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**			
	Radiological **Public:** Negligible **WG1:** Negligible **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Notes: 1. Based on testing water in the existing linac tunnel sprinkler system, no activation has been detected in this system. Water in the fire suppression system in the RTST tunnel is not anticipated to become activated. 2. Review event and controls with Conventional Facilities.				**Mitigated Frequency** A

Event Number
AS4-3

Event Description:
A worker inadvertently remains in the RTST tunnel when the beam becomes operational receives a significant exposure from normal beam operations.

Assumptions and Initial Conditions:
1. Inherent operation of the beam due to losses generates a significant field in the RTST tunnel during operation. (IC)
2. The number of procedures and systems involved in this operation and for this event to occur reduces the likelihood of this event. (IC)
3. Only WG1 is impacted by this event. (IC)

Causes:
1. Failure of the PPS.
2. Failure to follow RTST startup procedures and tunnel search and evict protocols prior to starting the beam to the RTST.
3. Search and evict system failures.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. No unmitigated impact on systems.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: N/A	**Public**: N/A	**Public**: N/A
WG1: High	**WG1:** N/A	**WG1**: N/A
WG2: N/A	**WG2:** N/A	**WG2**: N/A

Safety Function:
To assure that no personnel are in the tunnel during beam operation.

Method of Detection:	
PPS E-Stop Button.	

Preventive Features - Attributes:	**Credited:**
Personnel Protection System (PPS)	
• Audible and visible alarm of impending beam operation. (EC)	X
• E-Stop Buttons. (EC)	X
Tunnel access training including how to use the E-stop buttons & what is the meaning of the audible and visual alarms for impending beam. (AC)	X
Sweep and Evict Procedure - Proper procedures and training for the sweep and evict protocols prior to closing the tunnel before beam operations. (AC)	X
Verbal in-tunnel announcement of beginning sweep and evict prior to beam operation. (AC)	

<table>
<tr><td colspan="4">Event Number
AS4-3</td></tr>
<tr><td colspan="3">Mitigative Features - Attributes:</td><td>Credited:</td></tr>
<tr><td colspan="3">E-Stop Buttons. (EC</td><td></td></tr>
<tr><td rowspan="2">Planned analysis, assumption validations, and Risk/Opportunities:</td><td colspan="3">Mitigated Consequences:</td></tr>
<tr><td>Radiological
Public: N/A
WG1: N/A
WG2: N/A</td><td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
<tr><td colspan="3">Notes:</td><td>Mitigated Frequency
Prevented</td></tr>
</table>

Event Number AS4-4				
Event Description: Failure to install local shielding as required for local high loss areas of the RTST resulting in exposure to workers outside the tunnel.				
Assumptions and Initial Conditions: 1. Passive installed shielding is adequate to meet the 1 W/meter design losses for the RTST. (IC) 2. Personnel are not permitted in the tunnel with the beam operational. (AC/IC)	**Causes:** 1. Operator Error. 2. Beam losses higher than anticipated. 3. Failure to reinstall shielding following maintenance operations.			**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. Increased activation of tunnel hardware and services.	**Unmitigated Consequences:**			
	Radiological **Public:** Negligible **WG1:** Low **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A		**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Assure that adequate shielding is in place for normal operations based on design losses from the RTST and equipment and verify shielding adequacy by RCT surveys during operation.				
Method of Detection:				
PPS Interlocked Radiation Monitors (IRM) and alarms in occupied areas.				
Preventive Features - Attributes:				**Credited:**
Configuration Management Program – assure shielding is in place prior to beam operation. (AC)				
PPS interlocked shield blocks (e.g., using passive trapped keys or other positive means of assuring that the shielding blocks are in place). (EC)				
Radiation Safety Program – • RCT Surveys. (AC) • Shielding analysis and implementation. (AC/EC)				

Event Number
AS4-4

Mitigative Features - Attributes:	**Credited:**
PPS – trip beam on high radiation readings in occupied areas. (EC)	
PPS - Interlocked Radiation Monitors (IRM) and alarms. (EC)	
Operator training and procedures to respond to Area Radiation Alarms. (AC)	

<table>
<tr><th rowspan="2">Planned analysis, assumption validations, and Risk/Opportunities:</th><th colspan="3">Mitigated Consequences:</th></tr>
<tr><th>Radiological</th><th>Chemical</th><th>ODH</th></tr>
<tr><td>1. Shielding design and analysis to assure that dose at the tunnel wall for high loss regions is no more than the 1 W/meter design basis for the RTST.
2. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.</td><td>Public: Negligible
WG1: Low
WG2: Negligible</td><td>Public: N/A
WG1: N/A
WG2: N/A</td><td>Public: N/A
WG1: N/A
WG2: N/A</td></tr>
</table>

Notes:	**Mitigated Frequency**
	A

Event Number
AS4-5

Event Description:
The beam becomes misdirected to an unintended location, impacting the beam pipe wall or RTST components, resulting in direct exposure to a person outside the tunnel.

<table>
<tr>
<td>Assumptions and Initial Conditions:
1. During beam operation. (IC)
2. No personnel are permitted in tunnel during beam operation. (IC)
3. Tunnel berm/shielding designed for normal operations. (DF)</td>
<td>Causes:
1. Mechanical failure – component failure.
2. Resistive magnet(s) in the tunnel fail.
3. Maintenance failure.
4. Local power loss.
5. Controls failure.
6. Operator error.</td>
<td>Initiating Event Frequency
A</td>
</tr>
</table>

<table>
<tr>
<td rowspan="2">Unmitigated Impact on Systems:
1. The unmitigated impact on systems results in damage to accelerator components not designed to absorb this beam and loss of STS operation.
2. Potential loss of vacuum depending on the component hit by the beam.</td>
<td colspan="3">Unmitigated Consequences:</td>
</tr>
<tr>
<td>Radiological
Public: Negligible
WG1: High
WG2: Negligible</td>
<td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td>
<td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td>
</tr>
</table>

Safety Function:
To prevent a loss of beam (beam spill) from causing an exposure to workers or the public above allowable limits.

Method of Detection:	
Beam Loss Monitoring System – provides input the MPS and Global Control System.	
PPS – to detect high losses. • Interlocked Radiation Monitoring (IRM) – detection and alarm for increased radiation in occupied areas outside the tunnel.	
Beam Instrumentation and Diagnostics.	

Preventive Features - Attributes:	**Credited:**
Beam controls (Instrument and Diagnostics). (EC)	

Event Number AS4-5	
Mitigative Features - Attributes:	**Credited:**
Beam Loss Monitoring System – provides input the MPS and Global Control System. (EC)	
MPS – to detect the fault and terminate beam operation on beam misdirection. (EC)	
PPS – to detect the fault and terminate beam operation on high radiation alarm. (EC) • Interlocked Radiation Monitoring (IRM) – detection and alarm for increased radiation in occupied areas outside the tunnel. (EC)	X X
Beam instrumentation and diagnostics – to notify operators of loss of beam (due to misdirection, component failure, etc.). (EC)	
RTST Tunnel Design – provides shielding to the personnel outside RTST tunnel based on normal operational losses. (DF)	X
Operator training and procedures – to respond to beam diagnostics. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Final configuration of tunnel and equipment needs to be analyzed against potential losses and doses to workers and the public to set the PPS maximum trip times. 2. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.	**Radiological** **Public:** Negligible **WG1:** Low **WG2:** Negligible	**Chemical** **Public:** **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A
Notes: 1.			**Mitigated Frequency** A

Event Number AS4-6					
Event Description: Worker inadvertently enters the RTST Tunnel prior to required RCT controls.					
Assumptions and Initial Conditions: 1. During beam operation or following beam shut down, but prior to required RCT entry protocols. (IC)		**Causes:** 1. Operator error. 2. Failure to follow procedures.			**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. None.		**Unmitigated Consequences:**			
		Radiological **Public:** Negligible **WG1:** Moderate **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A		**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: To prevent a direct exposure of WG1 to higher than allowed sources in the RTST tunnel by entering the RTST tunnel prior to RCT permitting entry					
Method of Detection:					
Personal radiation monitors.					
Visual in control room or RCT entry.					
Preventive Features - Attributes:					**Credited:**
Radiation Safety Program – • Radiological Work Permit (RWP). (AC) • Health Physics Survey - Post entry sweep to allow trained personnel access. (AC) • RTST Entry Program – requires controls to prevent workers from entering the tunnel prior to activated components cool down. (AC)					
PPS prevention of RTST access when in power permit or in a higher mode. (EC)					

Event Number AS4-6	
Mitigative Features - Attributes:	**Credited:**
PPS – • To detect the error, terminate beam operation (if warranted), and alarm on entry. (EC) • Provide a lock on the access door preventing entry until authorized by mode change from the control room. (EC) • Limits access to authorized personnel during controlled access mode. (EC)	X
RTST Tunnel Design – provides shielding based on normal operation to the personnel outside the tunnel. (EC)	
Operator training and procedures – to respond to PPS. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public:** Negligible **WG1:** Low **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. PPS beam status has visible beam status light and display with mode indicated in each access door. 2. Access to the facility could be from any of the tunnel entry and egress locations (Access Tunnel Labyrinth, Egress Stair Labyrinth, or RTBT).	A

<table>
<tr><td colspan="4">Event Number
AS4-7</td></tr>
<tr><td colspan="4">Event Description:
Worker inadvertently enters the RTST Tunnel during commissioning prior to determining it is safe to enter.</td></tr>
<tr><td>Assumptions and Initial Conditions:
1. During commissioning beam operation or following beam shut down, but prior to required RCT entry protocols. (IC)
2. RTST operations are in accordance with the commissioning plan, Accelerator Safety Envelope, and Operational Envelope. (IC)
3. Personnel are not permitted in the tunnel during commissioning. (IC/AC)
4. Beam commissioning will not occur before target is ready to receive beam. (AC/IC)
5. Beam commissioning starts at low power and increase as appropriate. (IC/AC)</td><td colspan="2">Causes:
1. Operator error.
2. Failure to follow procedures.</td><td>Initiating Event Frequency
A</td></tr>
<tr><td rowspan="2">Unmitigated Impact on Systems:
1. None.</td><td colspan="3">Unmitigated Consequences:</td></tr>
<tr><td>Radiological
Public: Negligible
WG1: Moderate
WG2: Negligible</td><td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
<tr><td colspan="4">Safety Function:
To prevent a direct exposure of WG1 to higher than allowed sources in the tunnel during commissioning by entering the RTST tunnel prior to RCT permitting entry .</td></tr>
<tr><td colspan="3">Method of Detection:</td><td></td></tr>
<tr><td colspan="3">PPS – access control breach to not allow doors to be opened prior to activated component cooldown and terminate beam operation if door is opened.</td><td></td></tr>
<tr><td colspan="3">Visual</td><td></td></tr>
<tr><td colspan="3">Preventive Features - Attributes:</td><td>Credited:</td></tr>
<tr><td colspan="3">Environmental Safety and Health Management System Program (ESHMS) – assesses the need for specific requirements or training to perform this operation. (AC)</td><td></td></tr>
<tr><td colspan="3">Radiation Safety Program –
• Radiological Work Permit (RWP). (AC)
• Health Physics Survey - Post entry sweep to allow trained personnel access. (AC)
• RTST Entry Program – requires controls to prevent workers from entering the tunnel prior to activated components cool down. (AC)</td><td></td></tr>
</table>

Event Number
AS4-7

Mitigative Features - Attributes:	Credited:
ASE Limits - Commissioning Procedures. (AC)	
Installation Procedures – assuring temporary penetration seals are in place to limit open air paths from the tunnel to the environment. (AC)	
PPS – • To detect the error, terminate beam operation (if warranted), and alarm on entry. (EC) • Provide a lock on the access door preventing entry until authorized by mode change from the control room. (EC)	X
RTST Tunnel Design – provides shielding to the Public and WG 2. (EC)	
Operator training and procedures – to respond to PPS. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public:** Negligible **WG1:** Negligible **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
1. Operation per the commissioning plan and ASE prevents activation levels of either airborne contaminants or activated components following beam shutdown to be significant, either in the air or from components. **2.** Access to the facility could be from any of the tunnel entry and egress locations (Access Tunnel Labyrinth, Egress Stair Labyrinth, or RTBT)	A

Event Number
AS4-8

Event Description:
The beam becomes misdirected, impacting the beam pipe wall or RTST components during commissioning, resulting in direct exposure.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. During beam commissioning. (IC) 2. No personnel are permitted in tunnel during beam commissioning operations. (IC) 3. Beam commissioning will not occur before target or adequate shielded beam stop is ready to receive beam. (IC/AC) 4. Beam commissioning starts at low power and increase as appropriate. (IC/AC)	1. Mechanical failure – component failure. 2. Resistive magnet(s) in the tunnel fail. 3. Maintenance failure. 4. Local power loss.	U

Unmitigated Impact on Systems:	Unmitigated Consequences:		
	Radiological	**Chemical**	**ODH**
1. The unmitigated impact on systems results in loss of equipment and loss of ability of beam operation.	**Public:** Negligible **WG1:** Moderate **WG2:** Negligible	**Public**: N/A **WG1:** N/A **WG2:** N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
To prevent a loss of beam (beam spill) from causing an exposure to workers outside the tunnel or the public above allowable limits.

Method of Detection:	
MPS – to detect high losses and terminate beam operation.	
PPS – to detect increased radiation and terminate beam operation. • Interlocked Radiation Monitoring (IRM) – detection and alarm for increased radiation in occupied areas outside the tunnel.	
Beam Instrumentation and Diagnostics	

Preventive Features - Attributes:	Credited:
Beam controls for normal operations (Instrument and Diagnostics). (EC)	
MPS – detect fault from Pulsed Dipole Waveform Monitor and terminate beam operation. (EC)	

Event Number
AS4-8

Mitigative Features - Attributes:	Credited:
MPS – to detect the fault and terminate beam operation on beam misdirection. (EC)	
PPS – to detect increased radiation and terminate beam operation on beam misdirection. (EC) • Interlocked Radiation Monitoring (IRM) – detection and alarm for increased radiation in occupied areas outside the tunnel. (EC)	X X
ASE Limits - Commissioning Procedures. (AC)	
Beam Loss Monitoring System – provides in put the MPS and Global Control System. (EC)	
Beam instrumentation and diagnostics – to notify operators of loss of beam (due to misdirection, component failure, etc.). (EC)	
RTST Tunnel Design – provides shielding personnel outside RTST tunnel based on normal operational losses.. (DF)	X
Shielding – If a beam stop is used, adequate shielding is provided (AC/DF)	X
Configuration Management Program – • to assure that the RTST equipment is as assumed in the commissioning plan. (AC)	
Operator training and procedures – to respond to beam diagnostics. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval. 2. Initial configuration of tunnel and equipment has been analyzed against potential losses and doses to workers and the public to set the PPS maximum trip times.	**Radiological** **Public:** Negligible **WG1:** Low **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
1.	U

<table>
<tr><td colspan="4">Event Number
AS4-9</td></tr>
<tr><td colspan="4">Event Description:
Potentially activated water in the magnet cooling system is leaked into the tunnel.</td></tr>
<tr><td>Assumptions and Initial Conditions:
1. Water in the cooling system can become activated and leaked into the tunnel either during beam operation or when the beam is off. (IC)
2. WG1 is evaluated both for the leak occurring while a worker is in the tunnel with the beam off or on initial entry into the tunnel following a leak during beam operation. (IC)</td><td colspan="2">Causes:
1. Maintenance error.
2. Worker error.
3. Equipment failure.</td><td>Initiating Event Frequency
A</td></tr>
<tr><td rowspan="2">Unmitigated Impact on Systems:
1. Potential water impact on process electrical equipment.
2. Operations delay permitting repair and cleanup.</td><td colspan="3">Unmitigated Consequences:</td></tr>
<tr><td>Radiological
Public: Negligible
WG1: Low
WG2: Negligible</td><td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
<tr><td colspan="4">Safety Function:
Detect a leak of activated cooling water and avoid worker exposure above allowable limits.</td></tr>
<tr><td colspan="3">Method of Detection:</td><td></td></tr>
<tr><td colspan="3">Visual on tunnel entry.</td><td></td></tr>
<tr><td colspan="3">Magnet cooling system instrumentation (pressure and makeup water monitoring).</td><td></td></tr>
<tr><td colspan="3">Preventive Features - Attributes:</td><td>Credited:</td></tr>
<tr><td colspan="3">Magnet cooling system design. (DF)</td><td></td></tr>
<tr><td colspan="3">Preventive maintenance on the magnet cooling system. (AC)</td><td></td></tr>
<tr><td colspan="3"></td><td></td></tr>
<tr><td colspan="3"></td><td></td></tr>
</table>

Event Number				
AS4-9				
Mitigative Features - Attributes:				**Credited:**
Radiation Safety Program • RCT Survey – Initial RTST tunnel entry sweep to assure free water is not visible. (AC)				
Planned analysis, assumption validations, and Risk/Opportunities: 1. Verify potential water activation levels.	**Mitigated Consequences:**			
	Radiological **Public:** Negligible **WG1:** Low **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Notes: 1.				**Mitigated Frequency** A

Event Number AS4-10					
Event Description: Higher than anticipated dose in the RTST from Target System components.					
Assumptions and Initial Conditions: 1. Facility is down for maintenance or other activities in the RTST. (IC) 2. Beam has been operational at design levels prior to shutdown. (IC)		**Causes:** 1. Failure of RCT survey to detect the condition. 2. Worker enters a region of the tunnel that is not permitted.			**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. None.			**Unmitigated Consequences:**		
			Radiological **Public:** Negligible **WG1:** Moderate **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Maintain worker exposures ALARA during maintenance or other activities in the RTST from Target System components.					
Method of Detection:					
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC) • Personal radiation monitors.					
Preventive Features - Attributes:					**Credited:**
Radiation Safety Program: Radiological Work Permit (RWP). (AC) Health Physics Survey – Post entry sweep to allow trained personnel access. (AC)					
RTST Entry Program – requires controls to prevent workers from entering the tunnel prior to defining access limitations. (AC)					X

Event Number
AS4-10

Mitigative Features - Attributes:	Credited:
Operator training and procedures to understand access controls for the RTST. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC) • Personal radiation monitors.	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. Determine the need for a RTST Gamma Blocker in the RTST Beam Line.	**Radiological** **Public**: N/A **WG1:** N/A **WG2:** N/A	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
1.	Prevented

Event Number				
AS4-11				
Event Description: The RTST Gamma Blocker drops into the RTST beam line during baseline beam operation resulting in direct exposure to a person outside the tunnel.				
Assumptions and Initial Conditions: 1. During beam operation. (IC) 2. No personnel are permitted in tunnel during beam operation. (IC)	**Causes:** 1. Mechanical failure – component failure. 2. Maintenance failure. 3. Operator error in securing RTST Gamma Blocker.			**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. Damage to the RTST gamma blocker.	**Unmitigated Consequences:**			
	Radiological **Public:** Negligible **WG1:** Moderate **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A		**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: To prevent an RTST gamma blocker fault from causing an exposure to workers allowable limits.				
Method of Detection:				
Beam Loss Monitoring System – provides input the MPS and Global Control System.				
PPS – to detect high losses • Interlocked Radiation Monitoring (IRM) – detection and alarm for increased radiation in occupied areas outside the tunnel.				
Beam Instrumentation and Diagnostics.				
Preventive Features - Attributes:				**Credited:**
Procedures to assure that the gamma blocker is appropriately secured. (AC)				
RTST Gamma Blocker securing system. (EC)				

Event Number
AS4-11

Mitigative Features - Attributes:	Credited:
Beam Loss Monitoring System – provides input the MPS and Global Control System. (EC)	
MPS – to detect the fault and terminate beam operation on beam misdirection. (EC)	
PPS – to detect the fault and terminate beam operation on high radiation alarm. (EC)	X
• Interlocked Radiation Monitoring (IRM) – detection and alarm for increased radiation in occupied areas outside the tunnel. (EC)	X
• PPS to detect the RTST Gamma Blocker position and terminate beam operation if the RTST Gamma Blocker is out of position. (EC)	X
Beam instrumentation and diagnostics – to notify operators of loss of beam (due to misdirection, component failure, etc.). (EC)	
RTST Tunnel Design – provides shielding to the personnel outside RTST tunnel. (DF)	
Operator training and procedures – to respond to beam diagnostics. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. Final configuration of tunnel and equipment needs to be analyzed against potential doses to workers to set the PPS maximum trip times. 2. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.	**Radiological** **Public:** Negligible **WG1:** Low **WG2:** Negligible	**Chemical** **Public:** **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:	Mitigated Frequency
1.	A

<table>
<tr><td colspan="5">Event Number
AS4-12</td></tr>
<tr><td colspan="5">Event Description:
A magnet support fails allowing the beam to strike the face of the magnet, resulting in direct exposure to a person outside the tunnel.</td></tr>
<tr><td>Assumptions and Initial Conditions:
1. During beam operation. (IC)
2. No personnel are permitted in tunnel during beam operation. (IC/AC).</td><td colspan="3">Causes:
1. Mechanical failure – component support failure.
2. Maintenance failure.</td><td>Initiating Event Frequency
A</td></tr>
<tr><td rowspan="2">Unmitigated Impact on Systems:
1. The unmitigated impact on systems results in damage to magnet.
2. Potential loss of vacuum.</td><td colspan="4">Unmitigated Consequences:</td></tr>
<tr><td colspan="2">Radiological
Public: Negligible
WG1: Moderate
WG2: Negligible</td><td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
<tr><td colspan="5">Safety Function:
To prevent a magnet support fault from causing an exposure to workers above allowable limits.</td></tr>
<tr><td colspan="4">Method of Detection:</td><td></td></tr>
<tr><td colspan="4">Beam Loss Monitoring System – provides input the MPS and Global Control System.</td><td></td></tr>
<tr><td colspan="4">PPS – to detect high losses.
• Interlocked Radiation Monitoring (IRM) – detection and alarm for increased radiation in occupied areas outside the tunnel.</td><td></td></tr>
<tr><td colspan="4">Beam Instrumentation and Diagnostics.</td><td></td></tr>
<tr><td colspan="4">Preventive Features - Attributes:</td><td>Credited:</td></tr>
<tr><td colspan="4">Magnet and support design. (DF)</td><td></td></tr>
</table>

Event Number
AS4-12

Mitigative Features - Attributes:	Credited:
Beam Loss Monitoring System – provides input the MPS and Global Control System. (EC)	
MPS – to detect the fault and terminate beam operation on beam misdirection. (EC)	
PPS – to detect the fault and terminate beam operation on high radiation alarm. (EC) • Interlocked Radiation Monitoring (IRM) – detection and alarm for increased radiation in occupied areas outside the tunnel. (EC)	X X
Beam instrumentation and diagnostics – to notify operators of component failure. (EC)	
RTST Tunnel Design – provides shielding to the personnel outside RTST tunnel. (DF)	X
Operator training and procedures – to respond to beam diagnostics. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. Final configuration of tunnel and equipment needs to be analyzed against potential losses when beam strikes the magnet face and doses to workers to set the PPS maximum trip times. 2. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.	**Radiological** **Public:** Negligible **WG1:** Low **WG2:** Negligible	**Chemical** **Public:** **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:	Mitigated Frequency
1.	A

Event Number
AS4-13

Event Description:
The beam becomes misdirected in the RTBT, impacting the beam pipe wall or RTBT components during beam operation to the FTS when personnel are permitted in the RTST during STS or RTST construction, commissioning, or testing resulting in direct exposure.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. During beam operation in the RTBT to the FTS and personnel are permitted in the RTST. (IC) 2. Design shielding is in place between the RTBT and RTST tunnel for normal operation of the beam to the RTBT with personnel in the RTBT. (EC)	1. Mechanical failure – component failure. 2. Resistive magnet(s) in the tunnel fail. 3. Maintenance failure. 4. Local power loss.	U

Unmitigated Impact on Systems:	Unmitigated Consequences:		
	Radiological	**Chemical**	**ODH**
1. The unmitigated impact on systems results in RTBT equipment damage, but no damage to equipment in the RTST.	**Public:** Negligible **WG1:** High **WG2:** Negligible	**Public**: N/A **WG1:** N/A **WG2:** N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
To prevent an RTBT loss of beam (beam spill) from causing an exposure to workers in the RTST tunnel above allowable limits when personnel are permitted in the RTST during STS or RTST construction, commissioning, or testing resulting in direct exposure.

Method of Detection:	
MPS – to detect high losses and terminate beam operation.	
PPS – to detect increased radiation in the RTST and terminate beam operation. • Interlocked Radiation Monitoring (IRM) – detection and alarm for increased radiation in occupied in the RTST tunnel.	
RTBT Beam Instrumentation and Diagnostics	

Preventive Features - Attributes:	Credited:
RTBT Beam controls (Instrument and Diagnostics). (EC)	

Event Number
AS4-13

Mitigative Features - Attributes:	Credited:
SNS MPS – to detect the fault and terminate beam operation on beam misdirection. (EC)	
STS PPS – to detect increased radiation and terminate beam operation on beam misdirection. (EC) • Interlocked Radiation Monitoring (IRM) – detection and alarm for increased radiation in occupied areas of the RTST tunnel. (EC)	X X
PPS prevents workers from entering the labyrinth from the RTST permitted location. (EC)	X
RTBT Beam Loss Monitoring System – provides in put the MPS and Global Control System. (EC)	
RTBT Beam instrumentation and diagnostics – to notify operators of loss of beam (due to misdirection, component failure, etc.). (EC)	
RTBT to RTST Tunnel Design – • Provides shielding adequate for normal operation of the RTBT with personnel in the RTST. (DF) • Labyrinth shields worker permitted areas when beam is only going to the FTS. (DF)	X
Operator training and procedures – to respond to beam diagnostics. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. Final configuration of tunnel and equipment needs to be analyzed against potential losses and doses to workers to set the PPS maximum trip times. 2. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.	**Radiological** **Public:** Negligible **WG1:** Low **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
1.	U

<table>
<tr><td colspan="6">Event Number
AS4-14</td></tr>
<tr><td colspan="6">Event Description:
Excessive beam power (beyond the approved beam power) is supplied to the RTST leading to excessive losses and higher doses to occupied areas.</td></tr>
<tr><td colspan="2">Assumptions and Initial Conditions:
1. Authorized beam duty cycle is established prior to startup. (IC)
2. Personnel are not permitted in the tunnel during beam operation. (AC/IC)
3. Pulsed Dipole magnet power supply will not allow all ring pulses into the RTST. (DF)
4. A single pulse to STS will not be capable of exceed approved power limit for target. (IC/DF)</td><td colspan="3">Causes:
1. Equipment (control) failure.
2. Operator Error (setting up beam conditions).
3. Control error.</td><td>Initiating Event Frequency
EU</td></tr>
<tr><td rowspan="2" colspan="2">Unmitigated Impact on Systems:
1. None.</td><td colspan="4">Unmitigated Consequences:</td></tr>
<tr><td colspan="2">Radiological
Public: Negligible
WG1: Low
WG2: Negligible</td><td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
<tr><td colspan="6">Safety Function:
Assure that the RTST operating conditions are not exceeded.</td></tr>
<tr><td colspan="5">Method of Detection:</td><td></td></tr>
<tr><td colspan="5">MPS beam current monitors.</td><td></td></tr>
<tr><td colspan="5">PPS - RLS (repetition limiting System).</td><td></td></tr>
<tr><td colspan="5">Preventive Features - Attributes:</td><td>Credited:</td></tr>
<tr><td colspan="5">Operating procedures (OSE). (AC)</td><td></td></tr>
<tr><td colspan="5">PPS – Limits beam to 15 pulses per second. (EC)</td><td></td></tr>
<tr><td colspan="5">PPS – Repetition Limiting System (RLS) on Pulsed Dipole switching frequency. (EC)</td><td></td></tr>
</table>

Event Number
AS4-14

Mitigative Features - Attributes:	Credited:
Personnel Protection System (PPS). • Interlocked Radiation Monitors (IRM) to terminate beam by detecting increased radiation levels. (EC) • Alarm and trip on high radiation alarm. (EC)	
Pulsed Dipole magnet power supply will not allow all ring pulses into the RTST. (DF)	
Design of switching system limits the beam to not significantly exceed 15 pulses per second. (EC)	
RTST Tunnel design providing Shielding for a 1MW beam. (DF)	
Operator training and procedures to respond to Interlocked Radiation Monitor (IRM) Alarms. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. Radiation consequence analysis required for configuration to determine if a beam trip is warranted, or beam trip time required for this condition. 2. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.	**Radiological** **Public:** Negligible **WG1:** Low **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
1.	EU

Event Number AS4-16				
Event Description: The beam is steered into the RTST when the area not prepared to receive beam. The event results in direct exposure to workers.				
Assumptions and Initial Conditions: 1. Construction workers or STS staff are in the RTST tunnel. (IC) 2. RTST shielding is in place. (IC) 3. Could occur during ring tuning or during full FTS beam operation. (IC) 4. Transport lattice magnets powered. (IC)	**Causes:** 1. Equipment failure. 2. Operator Error. 3. Control error. 4. Pulsed and transport dipole magnet power supplies turned on inadvertently.			**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. Damage to equipment not ready to receive beam.	**Unmitigated Consequences:**			
	Radiological **Public:** Negligible **WG1:** High **WG2:** Moderate	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Safety Function: Assure that the beam is not directed into the RTST when personnel are in the RTST tunnel or the area is not approved for receiving beam.				
Method of Detection:				
Beam instrumentation and diagnostics.				
Preventive Features - Attributes:				**Credited:**
PPS prevents Pulsed dipoles (25D50) from turning ON to allow beam to enter the RTST. (EC)				X
PPS prevents the first transport dipoles (17D120) from turning ON to allow beam to enter the RTST. (EC)				X
RS holds are applied the magnet cables to prevent polarity reversal during maintenance or STS activities in the RTBT/RTST. (AC)				
Configuration Management Program – assure power disconnect is in place prior to beam operation. (AC)				

Event Number AS4-16			
Mitigative Features - Attributes:			**Credited:**
Radiation survey is conducted before allowing workers to occupy the RTST tunnel. (AC)			
STS Installation and Construction Procedures. (AC)			
PPS Trip on high radiation in the RTST - Interlocked Radiation Monitor (IRM) in the RTST tunnel. (EC)			X
Planned analysis, assumption validations, and Risk/Opportunities: 1. Evaluation shows that either locking out the pulsed dipoles or the first transfer dipoles is sufficient to prevent beam to the RTST tunnel. 2. Optics analysis to show that locking out the Pulsed Dipole system is sufficient to prevent beam to the RTST tunnel. 3. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.	**Mitigated Consequences:** **Radiological** **Public:** N/A **WG1:** N/A **WG2:** N/A	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Notes: 1.			**Mitigated Frequency** **Prevented**

Event Number
AS4-18

Event Description:
Proton Beam is not adequately focused (diffused) causing increased losses in the RTST and both direct radiation exposure and air activation.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. 700 kW beam power. (IC) 2. No personnel in the RTST tunnel. (IC) 3. No personnel in the Target PPS controlled areas. (IC)	1. Beam control field incorrectly set. 2. Quadrupole magnet failure. 3. Operator error.	A

Unmitigated Impact on Systems:
1. Additional activation of RTST Line and the air outside of the RTST Line or the air in the RTST Tunnel.
2. This event could also cause higher activation of Target components that may increase direct exposure during maintenance activities.
3. No release unless beam is strong enough to penetrate the RTST Line.
4. Damage on the RTST Line.
5. Potential for the proton beam to be over-expanded (with the potential to activate the surrounding air in the tunnel).

Unmitigated Consequences

Radiological	**Chemical**	**ODH**
Public: Negligible **WG1**: Low **WG2:** Negligible	**Public**: N/A **WG1**: N/A **WG2:** N/A	**Public:** N/A **WG1:** N/A **WG2:** N/A

Safety Function:
Prevent an over-expanded beam from causing excessive exposure to workers from direct shine or air activation.

Method of Detection:	
Beam Diagnostic (HARP).	
PPS Interlocked Radiation Monitors (IRM).	
Beam loss monitors.	
Beam collimator monitors (in AIC)	

Preventive Features – Attributes:	**Credited:**
Operating Procedures and Training. (AC)	
Surveillance & Maintenance. (AC)	

Event Number
AS4-18

Mitigative Features – Attributes:	Credited:
HARP monitoring by Operators. (AC)	
Earth berm covering RTST Line. (DF)	
Worker training. (AC)	
PPS Interlocked Radiation Monitors (IRM). (EC)	
EOPs. (AC)	
No access is allowed in the RTST Tunnel. (AC)	
MPS Beam Trip on beam loss monitors in Run Permit mode. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Credible diffused beam parameters.
2. Determine Dose rates above berm for an unfocused beam.
3. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public:** N/A
WG1: Low	**WG1**: N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Notes:

Mitigated Event Frequency
A

Event Number
AS4-19

Event Description:
Worker receives a higher than expected dose from an activated component when entering the RTST Tunnel.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. Following beam shut down. (IC)	1. Operator error 2. Failure to follow procedures	A

Unmitigated Impact on Systems:	Unmitigated Consequences:		
	Radiological	**Chemical**	**ODH**
1. None.	**Public:** Negligible **WG1:** Moderate **WG2:** Negligible	**Public**: N/A **WG1:** N/A **WG2:** N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
To prevent a direct exposure of WG1 to higher than allowed sources in the RTST tunnel.

Method of Detection:	
Personal radiation monitors.	

Preventive Features - Attributes:	Credited:
Radiation Safety Program – • Radiological Work Permit (RWP). (AC) • RTST Entry Program – requires controls to prevent workers from entering the tunnel prior to activated components cool down or proper controls (e.g., local shielding) are in place. (AC) • Installed shielding and RWP postings	X
PPS prevention of RTST access when in power permit or higher operational mode. (EC)	

Event Number
AS4-19

Mitigative Features - Attributes:	Credited:
PPS – • Provide a lock on the access door preventing entry until authorized by mode change from the control room. (EC) • Limits access to authorized personnel during controlled access mode. (EC)	X
Radiation Safety Program – • Radiological Work Permit (RWP) requiring operators to wear Electronic Personal Detectors (EPDs). (AC) • Installed shielding and RWP postings	
Installed local shielding or temporary shielding as determined by RCT entry survey. (DF/AC)	X
Operator training and procedures. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public:** Negligible **WG1:** Low **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
.	Prevented

Event Number
AS6-1

Event Description:
A vehicle impact above the RTST tunnel causes fuel to leak through penetrations in the RTST Tunnel potentially being ignited by equipment in the tunnel initiating a fire.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. Air in the RTST tunnel becomes slightly activated during operation. Based on the existing Linac, unmitigated, the activated air is anticipated to be below regulatory limits for release to the environment. (IC) 2. WG1 is included because personnel may or may not be in the tunnel at the time of the event. WG1 is included to assure completeness in the evaluation. (IC)	1. Human error or health condition driving the vehicle. 2. Mechanical failure.	BEU

Unmitigated Impact on Systems:	Unmitigated Consequences:		
	Radiological	**Chemical**	**ODH**
1. The unmitigated impact on systems is damage to the facility caused by the vehicle impact and potential contamination. 2. This event would also cause equipment damage, and loss of production time.	**Public:** Negligible **WG1:** Negligible **WG2:** Negligible	**Public:** N/A **WG1:** N/A **WG2:** N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
To prevent the seepage of fuel reaching the RTST tunnel and being a fuel source in the tunnel.

Method of Detection:	
Visual.	
Fire detection and alarm.	

Preventive Features - Attributes:	Credited:
RTST Tunnel Design – limits the number of external events because it is underground. (DF)	
Building design and location relative to traffic location – minimizes the potential for vehicles to directly impact the building. (DF)	
Traffic Control Program – limits speed of vehicles on main road. (AC)	

<table>
<tr><td colspan="4">Event Number
AS6-1</td></tr>
<tr><td colspan="3">Mitigative Features - Attributes:</td><td>Credited:</td></tr>
<tr><td colspan="3">RTST Tunnel Design - All penetrations will be sealed to the maximum extent possible to control normal releases. (DF)</td><td></td></tr>
<tr><td colspan="3">Operating Training and Procedures – trained to respond as defined in the ORNL Emergency Response Program. (AC)</td><td></td></tr>
<tr><td colspan="3">Emergency Response Program – evacuation of personnel. (AC)</td><td></td></tr>
<tr><td rowspan="2">Planned analysis, assumption validations, and Risk/Opportunities:
1. Monitor the penetration design in the tunnel to assure that the tunnel’s confinement is as tight as reasonably achievable</td><td colspan="3">Mitigated Consequences:</td></tr>
<tr><td>Radiological
Public: Negligible
WG1: Negligible
WG2: Negligible</td><td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
<tr><td colspan="3">Notes:
1. Vehicle impact and possible fire is anticipated to cause no more than superficial damage to the building exterior.
2. Discuss with conventional facilities.
3. EVs and Hybrid vehicles are addressed in AS6-2.</td><td>Mitigated Frequency
BEU</td></tr>
</table>

Event Number
AS6-2

Event Description:
An EV or hybrid vehicle that use lithium-ion batteries impact above the RTST tunnel or parked near the RTST tunnel causes an intense fire from the lithium battery that penetrates in the RTST Tunnel.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. Air in the RTST tunnel has the potential to become slightly activated during operation. Based on the existing Linac, unmitigated, the activated air is anticipated to be well below regulatory limits for release to the environment. (IC) 2. WG1 is included because personnel may or may not be in the tunnel at the time of the event. WG1 is included to assure completeness in the evaluation. (IC) 3. Electric vehicles and hybrids that use lithium-ion batteries are not permitted next to the RTST tunnel. (AC/IC)	1. Human error or health condition driving the vehicle. 2. Mechanical failure.	BEU

Unmitigated Impact on Systems:	Unmitigated Consequences:		
	Radiological	**Chemical**	**ODH**
1. The unmitigated impact on systems is damage to the facility caused by the vehicle impact and potential contamination. 2. This event would also cause equipment damage, and loss of production time.	**Public:** Negligible **WG1:** Negligible **WG2:** Negligible	**Public:** N/A **WG1:** N/A **WG2:** N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
To prevent an EV or hybrid vehicle with a lithium-ion battery fire impacting the RTST tunnel.

Method of Detection:	
Visual.	
Fire detection and alarm.	

Preventive Features - Attributes:	Credited:
RTST Tunnel Design – limits the number of external events because it is underground. (DF)	
Building design and location relative to traffic location – minimizes the potential for vehicles to directly impact the building. (DF)	
Electric vehicles and hybrids with lithium-ion batteries are not permitted next to the RTST tunnel. (AC/IC)	
Traffic Control Program – limits speed of vehicles on main road. (AC)	

Event Number AS6-2				
Mitigative Features - Attributes:				**Credited:**
RTST Tunnel Design - All penetrations will be sealed to the maximum extent possible to control normal releases. (DF)				
Operating Training and Procedures – trained to respond as defined in the ORNL Emergency Response Program. (AC)				
Emergency Response Program – evacuation of personnel. (AC)				
Planned analysis, assumption validations, and Risk/Opportunities: 1. Monitor the penetration design in the tunnel to assure that the tunnel's confinement is as tight as reasonably achievable	**Mitigated Consequences:**			
	Radiological **Public:** Negligible **WG1:** Negligible **WG2:** Negligible	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Notes: 1. Vehicle impact and possible fire is anticipated to cause no more than superficial damage to the building exterior. 2. Discuss with conventional facilities.				**Mitigated Frequency** BEU

APPENDIX C. BUILDING GENERAL (BG) HAZARD EVENT TABLES

APPENDIX C. BUILDING GENERAL (BG) HAZARD EVENT TABLES

Event Number
BG1-1

Event Description:
Facility wide fire with release of Hazardous material.

Assumptions and Initial Conditions:

1. Fire spreads throughout facility where flammable material is located. Large amounts of flammable material located in instrument halls in the form of hydrogenous neutron shielding provides the primary fuel for a large fire. (IC)
2. Fire suppression system and fire-fighting efforts are assumed ineffective. (IC)
3. Building structures may collapse. Cold source hydrogen may escape and cause a deflagration in high bay. (IC)
4. Structural collapses may crush cold source transfer line and allow air leaks into core vessel. (IC)
5. Structural collapse may impact the target drive room and the target drive systems or systems located on the core vessel lid. (IC)
6. Moderator or transfer line fails inside core vessel from failed structures impact. (IC)
7. Detonation occurs adjacent to target, significant release of airborne radioactivity. (IC)
8. Excessive heating of the target by facility fire is prevented by mass of surrounding core vessel and monolith shielding. (IC)
9. Accelerator beam stops due to operator action, TPS trip due to loss of cooling or loss of rotation, or loss of high vacuum PBW seals from failure of vacuum systems or impacts. (See Note 1) (IC)

Causes:

1. Electrical short.
2. Thermal energy from electrical equipment.
3. Friction from bearings, gears, motors, and power tools.
4. Sparks from welding.
5. Hydraulic fluid leaks from forklift and is ignited.
6. Human error.
7. Combustibles in facility.
8. Other unidentified ignition source.
9. Cleaning or decontamination agents contact other materials and produce flammable fumes.
10. Vehicle fire (including electric vehicles with lithium-ion batteries).

Initiating Event Frequency:
U

Unmitigated Impact on Systems:

1. Complete and permanent loss of the facility.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Low	**Public:** N/A	**Public:** N/A
WG1: Moderate	**WG1:** N/A	**WG1:** N/A
WG2: Low	**WG2:** N/A	**WG2:** N/A

Safety Function:
Implement structures and/or programs that minimize the likelihood of fires to engulf the whole facility or result in a significant release of radiological material due to a large fire.

Method of Detection:	
Visual or nasal (odor) detection by employee.	
Fire detection and alarm system.	
Fire suppression system water flow alarm.	

Event Number BG1-1	
Preventive Features – Attributes:	**Credited**:
Electrical equipment design codes and standards, including NEC and NTRL approved equipment. (DF)	
Prohibition for electric cars/trucks or hybrids with lithium-ion batteries from entering or having access near the target building. (DF/AC)	X
NFPA standards. (AC)	
Hot Works Program. (AC)	
Applicable DOE standards used for building design. (EC)	
Mitigative Features – Attributes:	**Credited:**
Combustible Material Control Program Including: (AC) • Metallic covering of large quantities of hydrogenous shielding material to slow the ignition and propagation of a large hydrogenous shielding fire throughout the instrument hall. • Low combustibility hydraulic fluid.	X
Fire Detection and Suppression System. (EC)	
Building design (fire barriers and noncombustible construction) reduce the risk that fire could engulf the entire building. (DF)	
TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel. (See Note 3) (EC)	X
TPS beam trip due to TPS fail safe design providing a trip on loss of power to the TPS panel. (See Note 3) (EC)	X
TPS beam trip for abnormal Loop 1 return flow. (See Note 3) (EC)	
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip on Loop 1 or Loop 2 pump exit pressure. (See Note 2 and 3) (EC)	
MPS beam trip for abnormal water Loop 1 or Loop 2 return flow. (See Note 3) (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of monitored signal to the MPS panel. (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of power to the MPS panel. (EC)	
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
Preventive Maintenance Programs. (AC)	
Radiation and contamination control procedures. (AC)	
Emergency response procedures. (AC)	
Trained personnel. (AC)	
Fire Department response. (AC)	
Operating Procedures and Training. (AC)	

Event Number BG1-1			
Planned analysis, assumption validations, and Risk/Opportunities: 1. Following building layout determination, identify where hazardous material could be located and the associated quantities that could be released. 2. A Project Fire Hazard Analysis will be performed in support of CD-2 and inform the fire events in the PHAR. 3. Assessment of fires per NFPA 801.	**Mitigated Consequences:** **Radiological** **Public:** Negligible **WG1:** Low **WG2:** Negligible	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A
Notes 1. TS and CMS/MRA events without operator action to trip the beam address target system trips to protect the target. 2. Driven by other events there is a delay built into the MPS beam trip on Loop 1 pump exit pressure. 3. Fail safe design for the TPS and MPS. Either an MPS or TPS beam trip is based on credit in the Item 9 of the Inputs and Assumptions section. 4. Proton beam window will not fail for nominally an hour so that it is not impacted by this event and does not provide a passive beam trip. However, the seals could be affected and on failure of the accelerator side of the PBW seals this would spoil the vacuum and stop the beam. 5. Mitigated frequency is reduced from U to EU based on the credited prohibition of letting EVs or Hybrid vehicles with lithium-ion batteries in the Target Building or having access near the target buidling.			**Mitigated Frequency** **EU**

Event Number
BG3-2

Event Description:
Target Building only loss of electric power.

Assumptions and Initial Conditions:
1. All power is lost in target building. (IC)
2. Accelerator operation continues. (IC)
3. Target rotation stops within 1 second. (IC)
4. Target cooling stops. (IC)
5. Proton beam window seal vacuum pumps stop. (IC)
6. Moderator cryogenic refrigerator compressor and circulators stop. (IC)
7. After loss of cooling with beam trip decay heat cannot raise target temperature to 800 C threshold for tungsten/steam reaction. (DF)
8. Proton beam window will not fail for nominally an hour without cooling so that it is not impacted by this event and does not provide a passive beam trip. (DF)
9. Inert core vessel atmosphere with helium or vacuum mode of core vessel operation. (IC)
10. Loop 1 provides cooling water for the Target. (DF)
11. Loop 2 provides cooling water for the Proton Beam Window, TVP, CMS/MRA, and water-cooled shielding. (DF)

Causes
1. Fault in feeder substation.
2. Fault in power line to target building.
3. Switching error; software error.
4. Overload.
5. Other electrical outage**.**

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Target shell/cooling lines fails from overheating.
2. Cooling water released to core vessel.
3. Moderators vent from pressure rise due to loss of cooling.
4. Up to 2 segments of target vaporized.
5. Loss of proton beam window vacuum seal causes leakage to high vacuum side and eventual passive accelerator shutdown.
6. Significant target damage and release of radioactivity.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Low	**Public:** N/A	**Public:** N/A
WG1: Moderate	**WG1:** N/A	**WG1:** N/A
WG2: Moderate	**WG2:** N/A	**WG2:** N/A

Safety Function:
Mitigate the radiological consequences of a loss of power to the Target Building without an inherent Proton Beam Trip caused by the event.

Method of Detection:

Visual.

Operators would know that there had been a loss of power to various equipment and normal lighting.

Event Number BG3-2	
Preventive Features – Attributes:	**Credited:**
Electrical system design. (DF)	
Worker training and procedures (AC)	
Mitigative Features – Attributes:	**Credited:**
TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel. (See Note 4) (EC)	X
TPS beam trip due to TPS fail safe design providing a trip on loss of power to the TPS panel. (See Note 4) (EC)	X
TPS beam trip for abnormal Loop 1 return flow. (See Note 4) (EC)	X
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip on Loop 1 pump exit pressure. (See Note 2) (EC)	
MPS beam trip for abnormal water Loop 1 return flow. (See Note 4) (EC)	
EOPs and Worker training. (AC)	
Loss of proton beam due to loss of proton beam line vacuum caused by failure of proton beam window sealing function. (DF)	
MPS beam trip on abnormal Loop 1 operating parameters in the target and window. (See Note 4) (EC)	
MPS beam trip on abnormal operating parameters in Loop 2 systems. (See Note 4) (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of monitored signal to the MPS panel. (See Note 4) (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of power to the MPS panel. (See Note 4) (EC)	
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
Emergency lighting will be provided throughout the area in accordance with applicable codes	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Accident Analysis of impact on loss of power to various systems (Including TPS)	**Radiological** **Public:** Negligible **WG1:** Low **WG2:** Negligible	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A

Event Number BG3-2	
Notes: 1. Power also lost to the Target Protection System which would trip the proton beam due to its fail-safe design characteristic. 2. Driven by other events there is a delay built into the MPS beam trip on Loop 1 pump exit pressure. 3. The time to target failure without rotation has been initially determined to be less than 4 seconds. 4. Fail safe design for the TPS and MPS. Either an MPS or TPS beam trip is based on credit in the Inputs and Assumptions section.	**Mitigated Frequency** **A**

Event Number
BG5-1

Event Description:
Inert Gas Release: Leak of in helium supply piping results in release of a large quantity of asphyxiant into an area with limited volume.

Assumptions and Initial Conditions:	**Causes:**	**Initiating Event Frequency**
1. Cryogenic moderator hydrogen is an asphyxiant, but the combustible hazard outweighs the oxygen deficiency hazard and is addressed separately. (IC) 2. This event only applies if the magnitude or complexity of the use of inert gas is significantly beyond the miscellaneous and incidental uses of inert gas typical of industrial or research enterprises. (IC) 3. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF) 4. Cryogenic helium lines in areas outside the HUR and Helium Refrigerator Room are jacketed. (DF) 5. No Dewars are used in the CMS system. (DF) 6. There are no ODH hazards in the target building that would warrant safety credited controls. ORNL SBMS and design codes provide adequate protection for these hazards. (IC)	1. Failure of the piping due to corrosion. 2. Piping damaged during installation or maintenance. 3. Cracking at welds as the result of metal fatigue (e.g., from vibration).	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. A loss of inert gas supply would likely disrupt one or more functions within the facility.	**Public:** Negligible **WG1:** Negligible **WG2:** Negligible	**Public:** N/A **WG1:** N/A **WG2:** N/A	**Public:** Negligible **WG1:** SIH **WG2:** Negligible

Safety Function:
Prevent a failure of the helium systems from causing an immediate ODH hazard consistent with SIH requirements.

Method of Detection:	
For release of cryogenic liquids: visual detection of fog due to condensation of atmospheric moisture.	
Audible detection by worker of escaping gas.	
Alarm based on low helium pressure.	

Preventive Features – Attributes:	**Credited:**
Piping design (including material selection, bracing, vibration isolators, venting relief valves at safe location. (DF)	
Preventive maintenance and surveillances for active components as needed for normal operations: Inspection before use and periodic inspection during service. (AC)	
Jacketing of cryogenic lines. (DF)	

Event Number
BG5-1

Mitigative Features – Attributes:	Credited:
Building HVAC system dilutes asphyxiant or routes to outdoors. (EC)	
Automatic oxygen monitoring with alarm in locations with limited volume as required by ORNL SBMS and national consensus codes and standards. (EC)	
Worker training. (AC)	
Supply for they Hydrogen system is provided in bottles that are either not connected to the CMS or valved out during operation. (DF/AC)	
Helium buffer tank is located outside the Target Building. (DF)	
Exclusion of natural gas in the target building. (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Typical laboratory usages of inert gas are covered under the ORNL SBMS and will not be analyzed in detail in the HA or Safety Assessment Document since the safety measures are prescribed by the SBMS. If a use of inert gas exceeds the size or complexity envisioned by the ORNL SBMS, then a hazard analysis will be documented to determine the need for credited control.
2. Need to determine which rooms this event would drive special SBMS actions for (see Note 1 below on likely candidates).

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public:** N/A	**Public:** N/A
WG1: Negligible	**WG1:** N/A	**WG1:** Negligible
WG2: Negligible	**WG2:** N/A	**WG2:** Negligible

Notes:

1. SBMS special considerations are potentially needed in the HUR, compressor room, and Helium Refrigerator Room. It is clear that no ODH hazard would exist in the High Bay general space due to the size of the area and normal ventilation.
2. There are plans to have 2 helium bottles in the HUR for filling the hydrogen accumulator. All bottles are SIH and adequately addressed by the ORNL SBMS design and handling requirements.

Mitigated Frequency
A

Event Number
BG6-1

Event Description:
Release of radioactive material due to loss of Facility power, or loss of power to all or part of the target facility.

Assumptions and Initial Conditions:
1. Target does not require electrical power for post shutdown cooling. (DF)
2. Loss of power to accelerator facility upstream of target will result in loss of proton beam. (DF)
3. Loss of power to TPS results in loss of proton beam by virtue of the permissive (fail-safe) design characteristic of the TPS. (IC)
4. Loss of confinement systems (e.g., secondary confinement system and HOG). (IC)
5. After loss of cooling with beam trip decay heat cannot raise target temperature to 800 C threshold for tungsten/steam reaction. (DF)

Causes:
1. Human error.
2. Impact by vehicle.
3. Adverse weather conditions or another natural phenomenon.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Operations will be shut down as the result of the power loss.
2. Recovery time required for decontamination efforts. Moderator cryogenic hydrogen would be released through system hydrogen safe vent(s) due to loss of refrigeration.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public:** N/A	**Public:** N/A
WG1: Moderate	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Safety Function:
Mitigate the radiological consequences of a loss of site power including loss of building ventilation/confinement.

Method of Detection:	
Visual.	
Non-essential equipment shutdown.	
Beam shutdown.	
Standby power source starts.	

Preventive Features – Attributes:	**Credited:**
Electrical design codes and standards. (DF)	

Event Number
BG6-1

Mitigative Features – Attributes:	Credited:
Dampers, pumps, valves, etc. designed to fail to safe position upon power loss. (DF)	
Standby power source (e.g., diesel generator). (EC)	
Operator rounds that include requirement for verification of ready status of backup power source. (AC)	
TPS beam trip for abnormal Loop 1 return flow (See Note 5). (EC)	
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip on Loop 1 pump exit pressure (See Note 3 and 5). (EC)	
MPS beam trip for abnormal water Loop 1 return flow (See Note 5). (EC)	
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
Procedure for emergency actions following a total power outage. (AC)	
Periodic load tests on standby and backup power source. (AC)	
In general, for all systems, consideration of safe failure mode for loss of power can be a preventive feature. (EC)	
Alarm response procedures for HVAC failure. (AC)	
Worker training. (AC)	
Preventive maintenance program for backup and standby power source. (AC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel (See Note 5). (EC)	X
TPS beam trip due to TPS fail safe design providing a trip on loss of power to the TPS panel (See Note 5). (EC)	X
MPS beam trip due to MPS fail safe design providing a trip on loss of monitored signal to the MPS panel (See Note 5). (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of power to the MPS panel (See Note 5). (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Evaluation of the need for UPS and sequence of systems to be restored and safety impact.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public:** N/A	**Public:** N/A
WG1: Low	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Notes:

1. Worst case of this event, total loss of power to target-building-only is identical to BG3-2, Loss of power to part of target building would be initiator for other sequences, e, g., loss of cooling, loss of rotation, etc.
2. See TS and CW events for local loss of electrical power consequences with beam operation continuing.
3. There is a delay built into the MPS beam trip on Loop 1 pump exit pressure.
4. BG3-2 covers the consequences from loss of power to just the target building.
5. Fail safe design for the TPS and MPS or either an MPS or TPS beam trips are based on credit in the inputs and assumptions section.

Mitigated Frequency
A

Event Number BG6-2					
Event Description: Small fire in 40m or 50 m building outside the Instrument Cave.					
Assumptions and Initial Conditions: 1. Electrical circuitry of experiment equipment is subject to SNS review and approval. (IC) 2. The consequences of this event assume that the fire is confined to the instrument building outside the Instrument Cave (Instrument Cave fires are addressed in the IS events). (IC) 3. The radiological material located in an Instrument Cave cannot release enough material to workers in the instrument hall to raise the consequences to Low. (IC)		Causes: 1. Vehicle fire in Instrument building. 2. Hydraulic fluid on forklift; hydraulic fluid on forklift leaks. ignition source on forklift. 3. Electrical short. 4. Other unidentified ignition source. 5. Combustibles in Instrument building. 6. Worker error.			**Initiating Event Frequency** **A**
Unmitigated Impact on Systems: 1. This event would be expected to cause significant disruption of operations in the experiment area.		**Unmitigated Consequences**			
		Radiological **Public:** Negligible **WG1:** Negligible **WG2:** Negligible	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A		**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A
Safety Function: Prevent a small fire in an instrument building from propagating and causing a release of radiological material above allowable limits.					
Method of Detection:					
Visual or nasal (odor) detection by worker.					
Fire sprinkler system waterflow alarm.					
Fire detection system in instrument building general areas.					
Preventive Features – Attributes:					Credited:
Electrical equipment design codes and standards, including NEC and NTRL approved equipment. (DF)					
Low combustibility hydraulic fluid. (AC)					
NFPA standards. (DF)					
Applicable DOE standards used for building design. (DF)					
Preventive Maintenance Programs. (AC)					
Operating Procedures and Training (e.g., Hot Works Program). (AC)					

Event Number BG6-2	
Mitigative Features – Attributes:	**Credited:**
Building and instrument design (noncombustible construction) reduce the risk that fire could grow beyond a small fire. (DF)	
Fire Detection and Suppression System. (EC)	
Emergency response procedures. (AC)	
Combustible material control program. (AC)	
Worker training. (AC)	
Fire Department response. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public:** Negligible **WG1:** Negligible **WG2:** Negligible	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A
Notes: Event BG6-3 describes a more severe external fire that propagates to the processing areas of target building.			**Mitigated Frequency** **A**

Event Number
BG6-3

Event Description:
Damage to target building and subsequent release of radiological material due to external event (fire).

Assumptions and Initial Conditions:
1. Fire is external to the target building or instrument building. (IC)
2. The consequences of this event assume that the fire impinges on, and penetrates, the target building but does not propagate to become a full facility fire. (IC)
3. Radiological release is limited to fixed contamination or waste containers. (IC)
4. Consequences for a full facility fire are given in Event BG1-1. (IC)
5. Electric cars or hybrids with lithium-ion batteries are excluded from entering or parking near the target building or instrument hall. (DF/AC)

Causes:
1. Instrument building fire or external fire.
2. Grass fire.
3. Forest fire.
4. Truck at truck bay entrance catches fire.
5. Chemicals or gas bottles on delivery vehicle leak and are ignited.
6. Ignition sources could include spark generated by lightning, electrical short or other unidentified ignition source.
7. Vehicle (including an electric vehicle with a lithium-ion battery) fire.

Initiating Event Frequency
U

Unmitigated Impact on Systems:
1. Depending on the combustibles available, the fire could spread to other areas of the facility that contain significant quantities of radiological material.
2. Event BG1-1 describes the effects of a full facility fire.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public:** N/A	**Public:** N/A
WG1: Negligible	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Safety Function:
Prevent an external fire from leading to a release of significant quantities of radiological material.

Method of Detection:	
Visual or nasal (odor) detection by worker.	
Fire detection system in building general areas.	
Fire sprinkler system waterflow alarm.	

Preventive Features – Attributes:	**Credited:**
Wildfire prevention practices. (AC)	
SBMS practices for chemicals and chemical transport. (AC)	

Event Number BG6-3	
Mitigative Features – Attributes:	**Credited:**
Building fire resistant design. (DF)	
Exclusion of electric cars or hybrids with lithium-ion batteries from entering or parking near the target building or instrument hall. (AC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel. (EC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of power to the TPS panel. (EC)	
TPS beam trip for abnormal Loop 1 return flow. (EC)	
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of monitored signal to the MPS panel. (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of power to the MPS panel. (EC)	
MPS beam trip on Loop 1 pump exit pressure (See Note 1). (EC)	
MPS beam trip for abnormal water Loop 1 return flow. (EC)	
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
Building fire barriers. (DF)	
NFPA standards. (DF)	
Building fire detection and suppression systems. (EC)	
Combustible material control program. (AC)	
Trained personnel. (AC)	
Emergency response procedures. (AC)	
Fire Department response. (AC)	
Lightning protection system. (EC)	
Applicable DOE standards used for building design including spatial separation. (DF)	
Building HVAC system. (EC)	
Operating Procedures and Training. (AC)	
Preventive Maintenance Programs. (AC)	
Hot Works Program. (AC)	

Event Number BG6-3			
Planned analysis, assumption validations, and Risk/Opportunities: 1. Determine if ORNL or STS has limitations on electric cars or hybrids with lithium-ion batteries (including personal vehicles) near facilities.	**Mitigated Consequences:** **Radiological** **Public:** Negligible **WG1:** Negligible **WG2:** Negligible	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A
Notes: 1. There is a delay built into the MPS beam trip on Loop 1 pump exit pressure.			**Mitigated Frequency** **U**

Event Number BG6-4				
Event Description: Explosion in the laboratory area from chemical interactions impacts target support areas.				
Assumptions and Initial Conditions: 1. Only laboratory quantities of chemicals available, therefore it is unlikely that a major explosion could occur resulting in a release of significant radiological material or chemicals. (IC) 2. The impact to the target building would be to be minimal. (IC)	**Causes**: 1. Inadvertent mixing of incompatible chemicals in laboratory. 2. Explosive fumes combined with an ignition source. 3. Flammable gases used in lab area.			**Initiating Event Frequency** **A**
Unmitigated Impact on Systems: 1. This event would be expected to cause significant disruption of operations in the laboratory area. 2. Potential for disruption of operations in other areas.	**Unmitigated Consequences**			
	Radiological **Public:** Negligible **WG1:** Negligible **WG2:** Negligible	**Chemical** **Public:** N/A **WG1:** Low **WG2:** Low		**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A
Safety Function: Control chemical use to prevent an explosion in the laboratory.				
Method of Detection:				
Visual.				
Building smoke and fire detection system.				
Audible.				
Preventive Features – Attributes:				**Credited:**
Ventilation hoods and HVAC system remove or dilute gases. (EC)				
Chemical storage container design (non-glass). (AC)				
Storage locations designed specifically for handling chemicals (to prevent spills). (DF)				
Containers used for storing liquid propane are certified for use. (AC)				
Chemical control program could minimize potential for use of reactive or incompatible chemicals. (AC)				
Chemical handling procedures. (AC)				
Operating Procedures and Training for use of propane or other flammable gases in the laboratory. (AC)				

Event Number
BG6-4

Mitigative Features – Attributes:	Credited:
Building design (physical location of the laboratory) would likely minimize the potential for impact to other target systems in the event of an explosion) (DF)	
Target building structure (DF)	
Lab building structure (DF)	
Emergency response procedures (AC)	
SBMS requirements for handling and using chemicals (AC)	
Worker training (AC)	
Laboratory ventilation for handling chemicals (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. Establish program to monitor and control chemical that could lead to an expolosion.	**Radiological** **Public:** Negligible **WG1:** Negligible **WG2:** Negligible	**Chemical** **Public:** N/A **WG1:** Low **WG2:** Low	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A

Notes:	Mitigated Frequency
	A

Event Number BG6-5					
Event Description: Natural gas explosion in furnace or from breached natural gas piping in the furnace room within the target building.					
Assumptions and Initial Conditions: 1. Natural gas will not be piped into the second target building, so this event if not evaluated further. (DF)	**Causes:** 1. Gas piping damaged as the result of corrosion 2. Impact on piping 3. Maintenance error allowing release of natural gas to the atmosphere				Initiating Event Frequency BEU
Unmitigated Impact on Systems: 1. Damage to external STS support buildings such as the CUBII or CLOII		**Unmitigated Consequences**			
		Radiological **Public:** N/A **WG1:** N/A **WG2:** N/A	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A	
Safety Function: Prevent a natural gas leak/explosion from causing a release of radiological material in the STS.					
Method of Detection:					
Preventive Features – Attributes:					**Credited:**

Event Number BG6-5				
Mitigative Features – Attributes:				**Credited:**
Planned analysis, assumption validations, and Risk/Opportunities: 1. Verify location of natural gas lines on the SNS site.	**Mitigated Consequences:**			
	Radiological **Public:** N/A **WG1:** N/A **WG2:** N/A	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A	
Notes: This event is not applicable to the second target because, like the first target, natural gas is not piped into the second target facility.				**Mitigated Frequency** BEU

Event Number
BG6-6

Event Description:
Facility damage as the result of a natural gas explosion from closest natural gas supply line

Assumptions and Initial Conditions:
1. A projectile from the explosion could strike the target building and the impact would cause structural damage. (IC)
2. Significant inventories of radioactive material are inherently protected by heavy shielding structures and by location in the building. (IC)
3. The likelihood of adversely impacting an individual critical system (e.g., equipment in the Hydrogen Utility Room) outside the massive shielding is remote. (IC)
4. It is assumed that the building could suffer minor damage as the result of the shock wave. (IC)
5. Natural gas is not permitted in the STS Target Building (DF)

Causes:
1. Gas piping damaged as the result of corrosion.
2. Impact on piping.
3. Maintenance error allowing release of natural gas to the atmosphere.
4. Gas could be ignited by passing vehicle.

Initiating Event Frequency
U

Unmitigated Impact on Systems:
1. Damage to external STS support buildings such as the CUBII or CLOII

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public:** N/A	**Public:** N/A
WG1: Negligible	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Safety Function:
Prevent a natural gas leak/explosion from causing a release of radiological material from the STS.

Method of Detection:	
Visible	
Audible	

Preventive Features – Attributes:	**Credited**:
Piping design to applicable standards including NFPA and ANSI/ASME B31.8 Gas Transmission and Distribution Piping (DF)	
Impact barriers at natural gas piping protecting the piping from impacts (DF)	
Maintenance program for gas piping (AC)	

Event Number BG6-6	
Mitigative Features – Attributes:	**Credited:**
Target building design; e.g.; building structure and location (DF)	
Emergency response procedures (AC)	
Location of piping (to minimize potential for inadvertent impact) (DF)	
TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel (See Note 2) (EC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of power to the TPS panel (See Note 2) (EC)	
TPS beam trip for abnormal Loop 1 return flow (See Note 2) (EC)	
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip on Loop 1 pump exit pressure (See Note 1 and 2) (EC)	
MPS beam trip for abnormal water Loop 1 return flow (See Note 2) (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of monitored signal to the MPS panel (See Note 2) (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of power to the MPS panel (See Note 2) (EC)	
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Verify location of natural gas piping.	**Radiological** **Public:** Negligible **WG1:** Negligible **WG2:** Negligible	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A

Notes:	**Mitigated Frequency**
1. There is a delay built into the MPS beam trip on Loop 1 pump exit pressure 2. Fail safe design for the TPS and MPS or either an MPS or TPS beam trips are based on credit in the inputs and assumptions section.	**U**

Event Number
BG6-7

Event Description:
Vehicle transporting hazardous materials including chemicals has an accident outside the target building.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. Hydrogen is brought onto the site in approved compressed gas cylinders and in an ORNL approved transportation vehicle per SBMS requirements. (AC) 2. Bulk chemicals required on site are not brought into the facility and are of low toxicity required to treat the tower cooling water in the Central Utilities Building (CUBII). (IC) 3. Support systems may be breached, and loose surface contamination in various areas within the facility may be released as the result of the explosion. (IC) 4. Location of significant inventory of target radionuclides is protected from external explosions by massive shielding. (IC) 5. Risk from lithium fires generated by an electric car/truck or hybrids with lithium-ion batteries are not included in this event evaluation. (IC)	1. Breach of container carrying the hazardous material results from corrosion, impact, improper loading of material on vehicle. 2. Breach caused by wear on container.	**A**

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. Potential for damage to target building	**Public:** Negligible **WG1**: Negligible **WG2:** Negligible	**Public:** N/A **WG1:** Low **WG2:** Negligible	**Public:** N/A **WG1:** N/A **WG2:** N/A

Safety Function:
Prevent transport of hazardous material on site from resulting in release of hazardous material in the STS.

Method of Detection:	
Audible	
Visible	

Preventive Features – Attributes:	**Credited:**
Truck and containers certified for transporting hazardous materials (AC)	
Restrictions on materials transported in vicinity of target building (AC)	
Prohibition for electric cars/trucks or hybrids with lithium-ion batteries from entering or having access near the target building (DF/AC)	
Trained personnel (AC)	
ORNL SBMS handling and transportation requirements. (AC)	

Event Number
BG6-7

Mitigative Features – Attributes:	Credited:
Target building design; e.g., building structure. (DF)	
Emergency response procedures (AC)	
Worker training. (AC)	
Limited quantities of hazardous materials handled at a time (AC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel (See Note 2) (EC)	
TPS beam trip due to TPS fail safe design providing a trip on loss power to the TPS panel (See Note 2) (EC)	
TPS beam trip for abnormal Loop 1 return flow (See Note 2) (EC)	
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip on Loop 1 pump exit pressure (See Note 1 and 2) (EC)	
MPS beam trip for abnormal water Loop 1 return flow (See Note 2) (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of monitored signal to the MPS panel (See Note 2) (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of power to the MPS panel (See Note 2) (EC)	
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public:** Negligible **WG1**: Negligible **WG2:** Negligible	**Chemical** **Public:** N/A **WG1:** Low **WG2:** Negligible	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A

Notes:	Mitigated Frequency
1. There is a delay built into the MPS beam trip on Loop 1 pump exit pressure. 2. Fail safe design for the TPS and MPS or either an MPS or TPS beam trips are based on credit in the inputs and assumptions section.	A

Event Number BG6-8					
Event Description: Damage to target building and radiological release due to impact from large aircraft.					
Assumptions and Initial Conditions: This event was evaluated for the first target and it was decided as a result of analysis that this is not a credible event (*Aircraft Impact Risk for the Spallation Neutron Source Target Facility*, WSMS-OR-00-0015, August 2000). **Therefore, this event is not analyzed further for the second target.** Note: this event includes all aircraft categories except general aviation which is addressed by event BG6-9.		**Causes:** 1. Large aircraft pilot error. 2. Large aircraft mechanical failure.			**Initiating Event Frequency** BEU
Unmitigated Impact on Systems: .		**Unmitigated Consequences**			
		Radiological **Public:** N/A **WG1:** N/A **WG2:** N/A	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A		**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A
Safety Function:					
Method of Detection:					
Preventive Features – Attributes:					**Credited:**

Event Number BG6-8				
Mitigative Features – Attributes:				**Credited:**
Planned analysis, assumption validations, and Risk/Opportunities: 1. Verify that the analysis performed for the FTS at SNS is still applicable for STS.	**Mitigated Consequences:**			
	Radiological **Public:** N/A **WG1:** N/A **WG2:** N/A	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A	
Notes:				**Mitigated Frequency** **BEU**

Event Number
BG6-9

Event Description:
Damage to target building and radiological release due to impact from small aircraft. This event includes all aircraft that come under the category General Aviation.

Assumptions and Initial Conditions:
1. Reinforced concrete shielding and large amounts of steel shielding on the instrument floor and in the monolith would protect significant inventories of radioactive materials against damage associated with aircraft impact. These were taken into account in the SNS aircraft impact risk study (*Aircraft Impact Risk for the Spallation Neutron Source Target Facilit*y, WSMS-OR-00-0015, August 2000) and found to reduce the risk of general aviation damage to an actual target to less than 10^{-6}/year. (IC)
2. Similarly, fire temperatures are not high enough to cause significant releases from the tantalum clad tungsten target because it is located within the massive steel and concrete monolith structure. (IC)

Causes:
1. Small aircraft or helicopter impacts target building through pilot error or mechanical failure of aircraft.

Initiating Event Frequency
U

Unmitigated Impact on Systems:
1. Significant damage to the target building and support systems would be expected.
2. A fire resulting from the impact could occur in the upper regions of the target building.
3. Some potential for explosions related to release of aircraft fuel or release of hydrogen as the result of the impact with cryogenic moderator system components.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public:** N/A	**Public:** N/A
WG1: Moderate	**WG1:** N/A	**WG1:** N/A
WG2: Low	**WG2:** N/A	**WG2:** N/A

Safety Function:
Limit the radiological consequences from a postulated small aircraft crash into the STS.

Method of Detection:	
Visual	
Audible	
Potential for fire detection system to be functional	

Preventive Features – Attributes:	**Credited:**
None	

Event Number BG6-9	
Mitigative Features – Attributes:	**Credited:**
The target building outer structure provides protection against an impact by a small aircraft. These features would prevent release of target radionuclides. (DF)	
The neutron beamline bunkers in target building and neutron beamlines radiating outward in the instrument hall provide significant protection against impact reaching the monolith (DF)	X
The monolith shielding protects the core vessel and the shielding inside the core vessel, in turn, protects the target (DF)	X
Emergency Response procedures (AC)	
Storage/transport casks with waste within the high bay limit release following and impact. (EC)	
Worker training (AC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel (See Note 2) (EC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of power to the TPS panel (See Note 2) (EC)	
TPS beam trip for abnormal Loop 1 return flow (See Note 2) (EC)	
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip on Loop 1 pump exit pressure (See Note 1 and 2) (EC)	
MPS beam trip for abnormal water Loop 1 return flow (See Note 2) (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of monitored signal to the MPS panel (See Note 2) (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of power to the MPS panel (See Note 2) (EC)	
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Applicability of the SNS first target aircraft impact risk assessment to the second target will need to be confirmed since the results are dependent on specific parameters of the target building. The first and second target buildings are similar but not identical. 2. Based on FTS analysis, determine if STS needs to update the DOE-STD-3014-96 analysis based on STS risk.	**Radiological** **Public:** Negligible **WG1:** Negligible **WG2**: Negligible	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A

Notes:	**Mitigated Frequency**
1. There is a delay built into the MPS beam trip on Loop 1 pump exit pressure. 2. Fail safe design for the TPS and MPS or either an MPS or TPS beam trips are based on credit in the inputs and assumptions section.	**U**

Event Number
BG6-10

Event Description:
Release of radiological material as the result of a vehicle crashing into the facility.

Assumptions and Initial Conditions:
1. The layout of the second target building prevents a vehicle from being able to threaten the more significant amounts of radioactive material associated with the target itself, and cooling or waste processing equipment. (DF)
2. Location of the second target is away from all but the access driveway. (DF)
3. Reinforced concrete shielding and large amounts of steel shielding on the instrument floor and in the monolith would protect significant inventories of radioactive materials against damage associated with a gas-powered vehicle impact. (DF)

Causes:
1. Improper driving or impaired driver.
2. Malfunction of vehicle.

Initiating Event Frequency
U

Unmitigated Impact on Systems:
1. Potential for significant damage to target building, including fire caused by the impact.
2. Temporary shutdown of the affected area.
3. Vehicle could impact ancillary target support systems, electrical cabling or components, etc.
4. The impact could result in a fire which, depending on the quantity of combustibles in available (including vehicle fuel), could spread throughout the facility.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public:** N/A	**Public:** N/A
WG1: Moderate	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Safety Function:
Prevent a vehicle impact on the STS which could lead to a radiological release.

Method of Detection:	
Visual	
Audible	
Possibly by smoke detectors	

Preventive Features – Attributes:	**Credited:**
Site layout, particularly the roads (DF)	
Speed limits for vehicles (AC)	
Prohibition for electric cars/trucks or hybrids with lithium-ion batteries from entering or having access near the target building (DF/AC)	X

Event Number BG6-10			
Mitigative Features – Attributes:			**Credited:**
Building structural design (DF)			
Emergency training and procedures (AC)			
Fire suppression system will respond to fire (EC)			
TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel (See Note 2) (EC)			
TPS beam trip due to TPS fail safe design providing a trip on loss of power to the TPS panel (See Note 2) (EC)			
TPS beam trip for abnormal Loop 1 return flow (See Note 2) (EC)			
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)			
MPS beam trip on Loop 1 pump exit pressure (See Note 1 and 2) (EC)			
MPS beam trip for abnormal water Loop 1 return flow (See Note 2) (EC)			
MPS beam trip due to MPS fail safe design providing a trip on loss of monitored signal to the MPS panel (See Note 2) (EC)			
MPS beam trip due to MPS fail safe design providing a trip on loss of power to the MPS panel (See Note 2) (EC)			
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)			
Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public:** Negligible **WG1:** Low **WG2**: Negligible	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A
Notes: 1. There is a delay built into the MPS beam trip on Loop 1 pump exit pressure. 2. Fail safe design for the TPS and MPS or either an MPS or TPS beam trips are based on credit in the inputs and assumptions section.			**Mitigated Frequency** **U**

Event Number
BG7-1 **(Event Deleted – see event CMS7-3)**

Event Number
BG7-1a

Event Description:
An SDC-2 level seismic event results in structural damage to target building and subsequent release of hazardous material followed by an explosion and follow-on fire outside the core vessel.

Assumptions and Initial Conditions:

1. The facility damage from an earthquake may cause a fire. (IC)
2. The facility damage from an earthquake may cause a release of hydrogen outside the core vessel contributing to either a fire and/or hydrogen explosion. (See Note 1) (IC)
3. Active cooling or electric power are not needed for target decay heat removal with the beam off. (DF)
4. The earthquake causes loss of the accelerator proton beam. (IC)
5. Target radionuclides are protected from possible effects of fire by massive steel and concrete shielding of the monolith structure. (DF)
6. Hydrogen is released outside the core vessel and detonates in the high bay. (See Note 1) (IC)
7. Workers are assumed to evacuate buildings instinctively during earthquakes. (IC)
8. Large components are structurally anchored and building structures seismically qualified to SDC-2 criteria to prevent collapse and protect evacuation paths. (SDC-2 and applicable Limit State B or C requirements) (DF)
9. Building structures around the cryogenic hydrogen systems will have SDC-2 and Limit State B or C seismic qualification due to seismic interaction (2 over 1) considerations, as needed to prevent damage to or crimping of the H2 transfer line outside of the core vessel. (DF)
10. After loss of cooling with beam trip decay heat cannot raise target temperature to 800 C threshold for tungsten/steam reaction. (DF)
11. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF)
12. The impact of a stack collapse is evaluated in BG7-10 (IC)

Causes:

1. SDC-2 level Seismic event

Initiating Event Frequency
U

Unmitigated Impact on Systems:

1. Potential for significant damage to the target building
2. Building damage could lead to a Roof collapse which could impact hydrogen utility room releasing H2.
3. Building damage could lead to a Roof collapse which could impact equipment stored in the high bay.
4. Building damage could lead to a Roof collapse which could damage the target systems above the core vessel.
5. Building damage could lead to a Roof collapse which could damage waste stored in casks in the high bay.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public:** N/A	**Public:** N/A
WG1: Moderate	**WG1:** N/A	**WG1:** N/A
WG2: Low	**WG2:** N/A	**WG2:** N/A

Event Number BG7-1a	
Safety Function: Prevent an SDC-2 level seismic event from resulting in a release of significant radiological material following the event and a subsequent fire and or hydrogen detonation in the target building. Release of radiological material must be prevented (by preventing a detonation and providing confinement) until Worker Group 1 can be evacuated to at least the 100-meter location. Additionally assure that an egress path remains for Worker Group 1.	
Method of Detection:	
Audible	
Visual	
Tactile	
Preventive Features – Attributes:	Credited:
None	
Mitigative Features – Attributes:	**Credited:**
Large components are structurally anchored and building structures seismically qualified to prevent collapse, protect evacuation paths, and protect applicable confinement of hazardous material (applicable SSCs meet SDC-2 and applicable Limit State B or C requirements) (DF)	X
Building design to meet SDC-2 level seismic event and applicable DOE standards (DF)	X
Target segment attachment points designed to withstand an SDC-2 seismic event with a design margin of TBD.	
Combustible materials control program reduces the probability of a large fire (AC)	
Exclusion of natural gas service in the target and instrument buildings. (DF)	
Monolith concrete shielding and building steel structures seismically qualified to prevent gross displacement (SDC-2 and applicable Limit State B or C requirements) (DF)	
Fire barriers minimize consequences of large fire. (DF)	
Emergency procedures and training, including specific guidance on response to a seismic event (AC)	X
Fire department response (AC)	
Foundation design such as Micro-piles or drilled piers with pier caps under STS mitigate seismic building response (DF)	
TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel. (See Note 5) (EC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of power to the TPS panel. (See Note 5) (EC)	
TPS beam trip for abnormal Loop 1 return flow. (See Note 5) (EC)	
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of monitored signal to the MPS panel. (See Note 5) (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of power to the MPS panel. (See Note 5) (EC)	
MPS beam trip on Loop 1 pump exit pressure (See Note 3 and 5) (EC)	

Event Number
BG7-1a

Planned analysis, assumption validations, and Risk/Opportunities:

1. Seismic qualification parameters of SSCs with SDC-2 and Limit States of B or C based on safety functions need to be defined.
2. Determine if a hydrogen explosion outside the core vessel is credible.
3. Evaluate potential storage locations for activated material in the High Bay. Location of highly activated/contaminated material/components is addressed in the RH and RW event tables.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public:** N/A	**Public:** N/A
WG1: Low	**WG1:** N/A	**WG1:** N/A
WG2: Low	**WG2:** N/A	**WG2:** N/A

Notes:

1. Hydrogen release outside the core vessel and inside the Target Drive Room is addressed in Event BG7-11.
2. CMS7-2 and CMS7-3 evaluate a seismic event causing target damage along with a hydrogen explosion inside the core vessel.
3. There is a delay built into the MPS beam trip on Loop 1 pump exit pressure.
4. Credited items are included to protect the Inputs and Assumptions for this event.
5. Fail safe design for the TPS and MPS or either an MPS or TPS beam trips are based on credit in the inputs and assumptions section.
6. SNS FSAD-NF assumes that an NPH event of PC-2 or higher would cause a beam trip. Since the same linac supplying the FTS as supplies the STS, this beam trip is assumed. (102030102-ES0016-R03, "Spallation Neutron Source Final Safety Assessment Document for Neutron Facilities", September 2011). Later evaluations determined that any felt motion (i.e., that which could cause equipment damage) would also lead to a loss of beam to the target.
7. Event BG7-10 evaluates the impact of a stack collapse.
8. HUR is covered by level 3.5 providing a measure of protection from roof failure.
9. Target Station Shielding shall not permit motion of the shielding to cause the cryogenic transfer lines to release Hydrogen under SDC2 seismic conditions.

Mitigated Frequency
U

Event Number
BG7-2

Event Description:
A seismic event results in structural damage to target building and subsequent release of radiological material (with no explosions or fires).

Assumptions and Initial Conditions:

1. After loss of cooling with beam trip decay heat cannot raise target temperature to 800 C threshold for tungsten/steam reaction (DF)
2. Active cooling or electric power are not needed for target decay heat removal with the beam off. (DF)
3. The earthquake causes loss of the accelerator proton beam. (DF)
4. Monolith iron shielding and core vessel components position is retained by external concrete structure. (DF)
5. Core vessel boundary seals fail and inert atmosphere is lost. (IC)
6. Workers are assumed to evacuate buildings instinctively during earthquakes. (IC)
7. Large components are structurally anchored and building structures seismically qualified to prevent collapse and protect evacuation paths (applicable SDC and Limit State requirements) (DF)
8. The impact of a stack collapse is evaluated in BG7-10 (IC)

Causes:

1. SDC-2 level Seismic event

Initiating Event Frequency
U

Unmitigated Impact on Systems:

1. Potential for significant damage to the target building
2. Building damage could lead to a Roof collapse which could impact equipment stored in the high bay.
3. Building damage could lead to a Roof collapse which could damage the target systems above the core vessel.
4. Building damage could lead to a Roof collapse which could damage waste stored in casks in the high bay

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public:** N/A	**Public:** N/A
WG1: Moderate	**WG1:** N/A	**WG1:** N/A
WG2: Low	**WG2:** N/A	**WG2:** N/A

Safety Function:
Prevent an SDC-2 level seismic event from resulting in a release of significant radiological material following the event Release of radiological material must be prevented until Worker Group 1 can be evacuated to at least the 100-meter location. Additionally assure that an egress path remains for Worker Group 1

Method of Detection:	
Audible	
Visual	
Tactile	

Preventive Features – Attributes:	**Credited:**
None	

Event Number BG7-2	
Mitigative Features – Attributes:	**Credited:**
Large components are structurally anchored and building structures seismically qualified to prevent collapse, protect evacuation paths, and protect applicable confinement of hazardous material (applicable SSCs meet SDC-2 and applicable Limit State B or C requirements) (DF)	X
Building design to meet SDC-2 level seismic event and applicable DOE standards (DF)	X
Monolith concrete shielding and building steel structures seismically qualified to prevent gross displacement. (SDC-2 and applicable Limit State B or C requirements) (DF)	
Emergency procedures and training, including specific guidance on response to a seismic event. (AC)	X
Foundation design such as Micro-piles or drilled piers with pier caps under STS mitigate seismic building response. (DF)	
TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel. (See Note 3) (EC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of power to the TPS panel (See Note 3) (EC)	
TPS beam trip for abnormal Loop 1 return flow (See Note 3) (EC)	
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip on Loop 1 pump exit pressure (See Note 1 and 3) (EC)	
MPS beam trip for abnormal water Loop 1 return flow (See Note 3) (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of monitored signal to the MPS panel (See Note 3) (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of power to the MPS panel (See Note 3) (EC)	
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
Target segment attachment points designed to withstand an SDC-2 seismic event with a design margin of TBD.	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Passive decay heat removal characteristic of target is subject to confirmation. 2. Seismic qualification parameters of SSCs with SDC-2 and Limit States of B or C based on safety functions need to be defined. 3. Evaluate potential storage locations for activated material in the High Bay. Location of highly activated/contaminated material/components is addressed in the RH and RW event tables.	**Radiological** **Public:** Negligible **WG1:** Low **WG2**: Low	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A

Event Number BG7-2	
Notes: 1. There is a delay built into the MPS beam trip on Loop 1 pump exit pressure. 2. SNS FSAD-NF assumes that an NPH event of PC-2 or higher would cause a beam trip. Since the same linac supplying the FTS as supplies the STS, this beam trip is assumed. (102030102-ES0016-R03, “Spallation Neutron Source Final Safety Assessment Document for Neutron Facilities”, September 2011). Later evaluations determined that any felt motion (i.e., that which could cause equipment damage) would also lead to a loss of beam to the target. 3. Fail safe design for the TPS and MPS or either an MPS or TPS beam trips are based on credit in the inputs and assumptions section. 4. Event BG7-10 evaluates the impact of a stack collapse. 5. Target Station Shielding shall not permit motion of the shielding to cause the cryogenic transfer lines to release Hydrogen under SDC2 seismic conditions.	**Mitigated Frequency** **U**

Event Number
BG7-3 (EVENT DELETED)

Event Number
BG7-4

Event Description:
A WDC-2 level Tornado, high winds, or microburst damage target building with subsequent release of radiological material

Assumptions and Initial Conditions:	**Causes**:	Initiating Event Frequency
1. The hazardous radionuclides inside the SNS target are protected against possible tornado missiles by the multiple layers of shielding surrounding the target. The heavily shielded beam lines of the instrument hall protect the monolith and the monolith protects the core vessel and shielding inside the core vessel protects the target itself. (DF) 2. Tornado damage to the roof of the Target Building could be similar to a roof collapse from snow or ice buildup and damage target systems within the facility. There is the potential for an extreme storm causing a building collapse. (IC) 3. This event assumes that a tornado, high straight winds, or missiles generated by either could severely damage the High Bay shell. (IC) 4. No spent core vessel components (e.g., target segment or MRA vessel is storge in the High Bay. All similarly activated components with the potential for release are housed in the Service Cell. The transfer times for moving these components from the core vessel to the Service Cell is short enough so that assuming a WDC-2 level wind event during transfer from the core vessel is BEU. (IC) 5. Power to the SNS complex is lost for an extreme storm when the 13.8 kV above ground line is damaged and thus the beam is inherently lost. (IC) 6. Active cooling or electric power are not needed for decay heat removal with the beam off. (DF) 7. The event could cause a stack collapse (a stack collapse is evaluated in BG7-5) (IC)	1. WDC-2 level Tornado or high straight winds. 2. Missiles generated by tornados or high straight winds. 3. Microburst (a sudden, powerful, localized air current, especially a downdraft.)	U

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
1. Potential for significant damage to the target building 2. Building damage could lead to a Roof collapse which could impact hydrogen utility room releasing H2. 3. Building damage could lead to a Roof collapse which could impact equipment stored in the high bay. 4. Building damage could lead to a Roof collapse which could damage the target systems above the core vessel. 5. Building damage could lead to a Roof collapse which could damage waste stored in casks in the high bay.	**Radiological** **Public:** Negligible **WG1:** Moderate **WG2**: Negligible	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A

Safety Function:
Prevent building damage from an WDC-2 level tornado or high wind from causing a significant release of radiological material.

Method of Detection:	
Visual and audible	
Severe weather warnings	

Event Number BG7-4	
Preventive Features – Attributes:	Credited:
None	
Mitigative Features – Attributes:	**Credited:**
Target building design to meet SDC-2 criteria provides inherent protection from collapse during this WDC-2 level event (DF)	X
Emergency response procedures (AC)	
Designed location of core vessel containing high-hazard radiological material within the building would limit the likelihood of impact by a missile generated by high winds or a tornado (DF)	
Robust concrete walls, and/or shielding protecting core vessel, target service cell, and Hot Process Vault (DF)	
Personnel training (AC)	
Spent target transfer cask and highly activated disposable components will be in a local confinement (service cell). The components are located in Service Cell pits during component drying operation and in a sealed container. The service cell is located in a place where the cask and components are protected from tornado generated loads. (AC/DF)	X
ORNL Planning Facility Protection for Severe Conditions Program requirements within SBMS for operational practices for severe weather (AC)	
Operational shutdown in the event of severe weather (terminate beam for tornado warning and shelter in place announcement) (AC)	
EOPs (AC)	
Should a shelter order be issued for the SNS site and the operators are required to leave the control room, their ACs require them to trip the beam before exiting. (AC)	
Transfer/storage cask design (EC) (DF)	
TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel. (See Note 2) (EC)	X
TPS beam trip due to TPS fail safe design providing a trip on loss of power to the TPS panel. (See Note 2) (EC)	X
TPS beam trip for abnormal Loop 1 return flow. (See Note 2) (EC)	
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of monitored signal to the MPS panel. (See Note 2) (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of power to the MPS panel. (See Note 2) (EC)	
MPS beam trip on Loop 1 pump exit pressure. (See Note 2 and 3) (EC)	
MPS beam trip for abnormal water Loop 1 return flow. (See Note 2) (EC)	

Event Number BG7-4			
Planned analysis, assumption validations, and Risk/Opportunities: 1. Specific procedures must be developed to address all severe weather conditions and include applicable ones in the SAD to comply with the SBMS requirements. This event needs to be reviewed with a multi-disciplinary group to determine if there are any highly **radioactive** materials that might also be vulnerable to high wind or tornado caused missiles.	**Mitigated Consequences:** **Radiological** **Public:** Negligible **WG1:** Negligible **WG2**: Negligible	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A
Notes: 1. The Planning Facility Protection for Severe Conditions Program description within SBMS identifies existing proactive maintenance management measures that are necessary in order to continue safe facility operations during severe environmental conditions, such as severe weather or wildfires. 2. Fail safe design for the TPS and MPS or either an MPS or TPS beam trips are based on credit in the inputs and assumptions section. 3. There is a delay built into the MPS beam trip on Loop 1 pump exit pressure 4. HUR is covered by level 3.5 providing a measure of protection from roof failure.			**Mitigated Frequency** **U**

Event Number
BG7-5

Event Description:
A WDC-2 level Tornado or high winds cause exhaust stack to collapse

Assumptions and Initial Conditions:
1. The second target building will have a separate exhaust stack from the existing FTS stack. (IC)
2. The STS exhaust stack is a prefabricated double walled steel assembly braced off the T&I building structure and is assumed to cause catastrophic damage if it fell over onto the target building. (IC)

Causes:
1. WDC-2 level NPH event—high wind, etc.

Initiating Event Frequency
U

Unmitigated Impact on Systems:
1. Loss of exhaust stack would result in loss of dispersion of gases exhausted from the STS and require that target operations be halted until the stack is repaired.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public:** N/A	**Public:** N/A
WG1: Moderate	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Safety Function:
Prevent a stack collapse from causing a significant release of radiological material as a result of a WDC-2 level event.

Method of Detection:
- Visual
- Severe storm alerts

Preventive Features – Attributes:	Credited:
None	

Event Number
BG7-5

Mitigative Features – Attributes:	Credited:
Worker training (AC)	
The stack is constructed with features that meet WDC-2 level conditions preventing collapse in high winds short of a tornado (DF)	X
Target building design to meet SDC-2 criteria provides inherent protection from collapse during this WDC-2 level event (DF)	X
Emergency response procedures (AC)	
Spent target transfer cask and highly activated disposable components will be in a local confinement (service cell). The components are located in Service Cell pits during component drying operation and in a sealed container. The service cell is located in a place where the cask and components are protected from tornado generated loads, (AC/DF)	X
ORNL Planning Facility Protection for Severe Conditions Program requirements within SBMS for operational practices for severe weather (AC)	
Operational shutdown in the event of severe weather (terminate beam for tornado warning and shelter in place announcement) (AC)	
EOPs (AC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel. (See Note 3) (EC)	X
TPS beam trip due to TPS fail safe design providing a trip on loss of power to the TPS panel. (See Note 3) (EC)	X
TPS beam trip for abnormal Loop 1 return flow. (See Note 3) (EC)	
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip on Loop 1 pump exit pressure. (See Note 2 and 3) (EC)	
MPS beam trip for abnormal water Loop 1 return flow. (See Note 3) (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of monitored signal to the MPS panel. (See Note 3) (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of power to the MPS panel. (See Note 3) (EC)	
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Specific procedures must be developed to address all severe weather conditions and include applicable ones in the SAD to comply with the SBMS requirements.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public:** N/A	**Public:** N/A
WG1: Low	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Notes:

1. The Planning Facility Protection for Severe Conditions Program description within SBMS identifies existing proactive maintenance management measures that are necessary in order to continue safe facility operations during severe environmental conditions, such as severe weather or wildfires.
2. There is a delay built into the MPS beam trip on Loop 1 pump exit pressure.
3. Fail safe design for the TPS and MPS or either an MPS or TPS beam trips are based on credit in the inputs and assumptions section.
4. The stack is a Van-Pacer Model: D2A; Liner: 18 GA Type 304 SS; Shell: 20 GA ALZD Steel; Insulation thickness 2" Air Space.

Mitigated Frequency
U

Event Number
BG7-6

Event Description:
A lightning strike to the target building impacts components and systems resulting in a radiological release.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
Radiological release due to damage to target building from a lightning strike (IC)	1. Direct lightning strike to target building. 2. Lightning strike to other adjacent building or equipment that affects equipment or controls in the STS.	**A**

Unmitigated Impact on Systems:
1. A direct lightning strike to the target building could result in a loss of electrical power to the building, fires, explosions (if hydrogen is released).
2. A direct lightning strike to the target building could result in Spalling of concrete, significant damage to electrical and/or electronic equipment; failure of cooling systems and/or active safety systems that depend on electronics.
3. A steam explosion is possible if water systems become a conductive path.
4. Potential for major disruption of operations.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public:** N/A	**Public:** N/A
WG1: Negligible	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Safety Function:
Prevent a lightning strike from causing a release of radiological material.

Method of Detection:	
Visual	
Audible	

Preventive Features – Attributes:	**Credited:**
None	

Event Number BG7-6	
Mitigative Features – Attributes:	**Credited:**
Safety systems such as the target protection system have design features that prevent loss of capability in the event of lightning related power surges: two channel architecture, power surge protectors, fail-safe design features. (See Note 4) (DF)	
Emergency response procedures. (AC)	
ORNL Planning Facility Protection for Severe Conditions Program requirements within SBMS for operational practices for severe weather. (AC)	
Operational shutdown in the event of severe weather (terminate beam). (AC)	
Worker training. (AC)	
Building lightning protection system to minimize the potential damage from a full lightning strike. (See Note 4) (EC)	
Inspection and monitoring of building lightning protection system. (AC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel. (See Note 3) (EC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of power to the TPS panel. (See Note 3) (EC)	
TPS beam trip for abnormal Loop 1 return flow. (See Note 3) (EC)	
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip on Loop 1 pump exit pressure. (See Note 2 and 3) (EC)	
MPS beam trip for abnormal water Loop 1 return flow. (See Note 3) (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of monitored signal to the MPS panel. (See Note 3) (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of power to the MPS panel. (See Note 3) (EC)	
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Evaluate the possibility of lightning-caused voltage surges running through the building power and/or electronic circuits is troublesome. This event needs to be reviewed to determine possible need to credit the target protection system design features that prevent lightning/surge from causing failure of target protection system function. 2. Specific procedures must be developed to address all severe weather conditions and include applicable ones in the SAD to comply with the SBMS requirements.	**Radiological** **Public:** Negligible **WG1:** Negligible **WG2**: Negligible	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A

Notes:	**Mitigated Frequency**
1. The Planning Facility Protection for Severe Conditions Program description within SBMS identifies existing proactive maintenance management measures that are necessary in order to continue safe facility operations during severe environmental conditions, such as severe weather or wildfires. 2. There is a delay built into the MPS beam trip on Loop 1 pump exit pressure. 3. Fail safe design for the TPS and MPS or either an MPS or TPS beam trips are based on credit in the inputs and assumptions section. 4. DOE-STD-2010-2016 requires that applicable SSCs be either (a) designed to withstand the effects of lightning strikes or (b) protected from strikes in accordance with the criteria of NFPA-780-2020 (Rev. 11).	A

Event Number BG7-7					
Event Description: Flooding of the STS target building vaults as a result of extreme rain, fire water supply, or domestic water main rupture causing a release of radiological material.					
Assumptions and Initial Conditions: 1. Release of radiological material as the result of partial flooding of target building vaults. (IC) 2. Facility is configured for beam operation. (IC) 3. Beam is on the target (IC) 4. STS location precludes flooding from traditional sources (e.g., rivers or streams) (DF)	**Causes**: 1. Prolonged heavy rain. 2. Break of domestic water supply line. 3. Unexpected Groundwater intrusion.				**Initiating Event Frequency** **A**
Unmitigated Impact on Systems: 1. Partial flooding of building locations could result in release and transport of surface contamination to non-contaminated areas within the building or in extreme events, could result in flooding run-off outside the building to the environment. 2. Damage to equipment in the vaults. 3. Electrical system shorting due to water.		**Unmitigated Consequences**			
		Radiological **Public:** Negligible **WG1:** Low **WG2**: Negligible	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A		**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A
Safety Function: Prevent excessive water from outside the facility from causing a flooding condition in the target building.					
Method of Detection:					
Visual					
Sump probes					
Preventive Features – Attributes:					Credited:
Building siting (DF)					
Target building and adjacent parking lot storm water drainage system (DF)					
The design provides for positive drainage away from the truck entrance to prevent flooding.. (DF)					
Periodic storm water drainage system cleanout servicing (AC)					

Event Number
BG7-7

Mitigative Features – Attributes:	Credited:
Procedures to pump sumps on receipt of a sump alarm. (AC)	
Capability to pump to process waste tanks, LLLW tanks, and sanitary sewer (DF/EC)	
Pits in several locations within the target building collect water from leakage (e.g., HPV). (DF)	
Worker training (AC)	
EOPs (AC)	
ORNL Planning Facility Protection for Severe Conditions Program requirements within SBMS for operational practices for severe weather. (AC)	
Operational shutdown in the event of severe weather (terminate beam). (AC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel. (See Note 4) (EC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of power to the TPS panel. (See Note 4) (EC)	
TPS beam trip for abnormal Loop 1 return flow (EC) . (See Note 4)	
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip on Loop 1 pump exit pressure (See Note 3 and 4) (EC)	
MPS beam trip for abnormal water Loop 1 return flow. (See Note 4) (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of monitored signal to the MPS panel. (See Note 4) (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of power to the MPS panel. (See Note 4) (EC)	
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
Building structures designed for the 200 year return period weather event for the STS site. (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Specific procedures must be developed to address all severe weather conditions and include applicable ones in the SAD to comply with the SBMS requirements.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public:** N/A	**Public:** N/A
WG1: Negligible	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Notes:

1. Flooding due to a process water leak is addressed in the applicable process system events.
2. The Planning Facility Protection for Severe Conditions Program description within SBMS identifies existing proactive maintenance management measures that are necessary in order to continue safe facility operations during severe environmental conditions, such as severe weather or wildfires.
3. There is a delay built into the MPS beam trip on Loop 1 pump exit pressure.
4. Fail safe design for the TPS and MPS or either an MPS or TPS beam trips are based on credit in the inputs and assumptions section.

Mitigated Frequency
A

Event Number
BG7-8

Event Description:
Buildup of snow and/or ice leads to collapse of the target building roof and result in damage to target building interior with release of radiological material.

Assumptions and Initial Conditions:
1. Collapse target building roof could result in damage to target building interior with release of radiological material. (IC)
2. The only chemicals potentially released are considered standard industrial hazards based on chemicals and quantity available for release. (IC)
3. Under such extreme conditions it is possible that the beam will inherently be shut down on target building collapse, but this has not been included in this event scenario. (IC)
4. Roof collapse is not expected to cause damage to the target in the core vessel monolith. (IC)
5. Active cooling or electric power are not needed for decay heat removal with the beam off. (DF)
6. Target rotation stops within 1 second on loss of power to the target drive motor or with room collapse onto the target drive motor (IC)
7. Beam stays on (IC)
8. Core vessel operating in inert helium near atmospheric pressure or in vacuum (DF/IC)
9. After loss of cooling with beam trip decay heat cannot raise target temperature to 800 C threshold for tungsten/steam reaction (DF)
10. Core vessel ullage, burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. (DF)
11. Neutron beam windows remain intact throughout event although active pumping to maintain the seal is not assumed. (IC)
12. Two segments of tungsten assumed vaporized. (IC)
13. Proton Beam Window will remain undamaged for nominally an hour without cooling and continued beam operation. (IC)

Causes:
1. Snow and ice collect on roof over extensive period of below freezing weather with precipitation.
2. Snow/ice buildup followed by heavy rain.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Roof collapse could impact hydrogen utility room releasing H2.
2. Roof collapse could impact equipment stored in the high bay.
3. Roof collapse could damage the target systems above the core vessel.
4. Roof collapse could damage waste stored in casks in the high bay.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public:** N/A	**Public:** N/A
WG1: Moderate	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	

Safety Function:
Prevent roof collapse from a buildup of snow, ice, and water on the STS roof.

Event Number BG7-8	
Method of Detection:	
Visual	
Audible	
Preventive Features – Attributes:	Credited:
Mitigative Features – Attributes:	**Credited:**
Building roof designed to meet NDC-2 criteria (200-year return period) provides structural loads for protection from collapse during this event consistent with the climate in Tennessee (DOE-STD-1020-2016) and to support heavy snow and ice loads, consistent with best practices for climate in Tennessee and code requirements. (DF)	X
Emergency response procedures (AC)	
Trained workers (AC)	
ORNL Planning Facility Protection for Severe Conditions Program requirements within SBMS for operational practices for severe weather. (AC)	
Operational shutdown in the event of severe weather (terminate beam). (AC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel. (See Note 8) (EC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of power to the TPS panel. (See Note 8) (EC)	
TPS beam trip for abnormal Loop 1 return flow. (See Note 8) (EC)	
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip on Loop 1 pump exit pressure (See Note 3 and 8) (EC)	
MPS beam trip for abnormal water Loop 1 return flow. (See Note 8) (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of monitored signal to the MPS panel. (See Note 8) (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of power to the MPS panel. (See Note 8) (EC)	
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
Core Vessel Drain Line Liquid Detection Probe (EC) • Alarm in Control Room on detection of a leak. (EC) • MPS trip on High Level in the Core Vessel Drain Line (EC). (See Note 8) • TPS beam trip on high-high level in the Core Vessel Drain Line. (See Note 8) (EC)	
Passive decay heat removal to fixed monolith shielding in mitigated case after beam trip (DF)	
Burst disk in CMS (reduces hydrogen inventory) (EC)	
Moderator Reflector Assembly design (Hydrogen moderator is insulated by a vacuum layer and there is also a water layer between the hydrogen vessel and target wheel) (DF)	

Event Number
BG7-8

Planned analysis, assumption validations, and Risk/Opportunities:

1. Specific procedures must be developed to address all severe weather conditions and include applicable ones in the SAD to comply with the SBMS requirements.
2. Accident (consequence) analysis for stationary target for unmitigated case with beam causing a loss of cooling event.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public:** N/A	**Public:** N/A
WG1: Low	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Notes:

1. The Planning Facility Protection for Severe Conditions Program description within SBMS identifies existing proactive maintenance management measures that are necessary in order to continue safe facility operations during severe environmental conditions, such as severe weather or wildfires.
2. Damage to storage/transfer casks in the High Bay would be the same as event HB3-2.
3. There is a delay built into the MPS beam trip on Loop 1 pump exit pressure,
4. This event is similar to Event TS3-2 for a locked rotor. The event will also have a loss of cooling, but the locked rotor bounds the loss of cooling.
5. The time to target failure without rotation has been initially determined to be less than 4 seconds.
6. Consequences for this event have not been calculated for the collocated worker. However, since the core vessel in inerted and the release is only through the vents, the releases should be no more than moderate. Since the core vessel leak detection is defined as a credited control for other events, it has also been identified here as a second level of control per the Control Selection Policy.
7. Proton beam window will not fail for nominally an hour so that it is not impacted by this event and does not provide a passive beam trip. However, the seals could be affected by loss of PBW seal vacuum. However, the seals could be affected and on failure of the accelerator side of the PBW seals this would spoil the vacuum and stop the beam.
8. Fail safe design for the TPS and MPS or either an MPS or TPS beam trips are based on credit in the inputs and assumptions section.
9. HUR is covered by level 3.5 providing a measure of protection from roof failure.
10. The burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures.
11. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.

Mitigated Frequency
A

Event Number
BG7-9a

Event Description:
Cold weather results in tower water freezing, leading to a loss of heat sink for target systems.

Assumptions and Initial Conditions:

1. Loss of heat sink causes primary loop temperatures to increase until boiling and loss of target cooling occurs resulting in shell over temperature and structural failure of shell. (IC)
2. Loop 1 cooling water leaks into the core vessel. (IC)
3. Core vessel operating in inert helium near atmospheric pressure or in vacuum (IC)
4. After loss of cooling with beam trip decay heat cannot raise target temperature to 800 C threshold for tungsten/steam reaction (DF)
5. Core vessel ullage, burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. (DF)
6. Neutron beam windows remain intact throughout event (IC) (Note 3)
7. Target rotation continues so whole target heats from beam until loss of shell strength at elevated temperatures causes disk to collapse onto steel shielding and stops rotation. (IC)
8. A double walled heat exchanger is used between the tower water cooling loop and the Loop 1 cooling loop and between the tower water and the Loop 2 cooling loop. (DF)

Causes:

1. Extreme cold weather
2. Failure of tower control system
3. Operator fails to respond to heat sink conditions.

Initiating Event Frequency
U

Unmitigated Impact on Systems:

1. Possible moderator vessel failure and hydrogen release after target shroud collapses.
2. Half of tungsten assumed vaporized.
3. Hydrogen and water vapor vents through core vessel burst disk and hydrogen safe vent.
4. Bulk of water released from target retained in ullage or drain tank.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Low	**Public:** N/A	**Public:** N/A
WG1: Moderate	**WG1:** N/A	**WG1:** N/A
WG2: Low	**WG2:** N/A	**WG2:** N/A

Safety Function:
Prevent a cold weather induced loss of heat sink from causing a loss of cooling to the target systems.

Method of Detection:	
Cooling tower instrumentation	
Target cooling loop return flow and temperature	
Core Vessel leak detection probe	

Event Number BG7-9a	
Preventive Features – Attributes:	**Credited:**
None	
Mitigative Features – Attributes:	**Credited:**
Core Vessel Drain Liquid Detection Probe (EC) • Alarm in Control Room on detection of a leak (EC) • MPS trip on High Level in the Core Vessel Drain. (See Note 5) (EC) • TPS beam trip on high-high level in the Core Vessel Drain. (See Note 5) (EC	
Cooling Tower control to prevent freezing (EC/AC)	
Double walled heat exchanger eliminates freezing of intermediate loop. (DF)	X
Core vessel burst disk rupture alarm in the control room (EC)	
Inert core vessel atmosphere (AC)	
Core vessel pressure relief system – burst disk and hydrogen safe vent (See Note 6) (EC)	
MPS trip on Tower water flow. (See Note 5) (EC)	
MPS trip on Target cooling loop level in the GLS tank, flow, temperature and pressure monitors out of limits. (See Note 5) (EC)	
MPS trip on high core vessel helium or vacuum pressure during operation. (See Note 5) (EC)	
Passive decay heat removal to fixed monolith shielding in mitigated case after beam trip (DF)	
Confinement of Water by the Core Vessel; proton beam window, fast acting valves, and neutron beam windows (EC)	
Fast acting valve closure will cause and MPS beam trip (EC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel. (See Note 5) (EC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of power to the TPS panel. (See Note 5) (EC)	
TPS beam trip for abnormal Loop 1 return temperature. (See Note 5) (EC)	X
TPS beam trip for abnormal Loop 1 return flow. (See Note 5) (EC)	
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of monitored signal to the MPS panel. (See Note 5) (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of power to the MPS panel. (See Note 5) (EC)	
MPS beam trip on Loop 1 pump exit pressure (See Note 1 and 5) (EC)	
MPS beam trip for abnormal water Loop 1 return flow. (See Note 5) (EC)	

Event Number
BG7-9a

Planned analysis, assumption validations, and Risk/Opportunities:
1. Analysis of target system loss of cooling event to address this cause of a loss of cooling event.
2. Set point for TPS and MPS for loss of cooling.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public:** N/A	**Public:** N/A
WG1: Low	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Notes:
1. There is a delay built into the MPS beam trip on Loop 1 pump exit pressure.
2. This event has the same consequences as TS3-4.
3. Proton beam window will not fail for nominally an hour so that it is not impacted by this event and does not provide a passive beam trip.
4. Continued target rotation with beam on extends the heatup time to over 5 minutes.
5. Fail safe design for the TPS and MPS or either an MPS or TPS beam trips are based on credit in the inputs and assumptions section.
6. The burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures.
7. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.

Mitigated Frequency
U

Event Number
BG7-9b

Event Description:
Cold weather results in secondary DI water freezing, leading to a loss of heat sink for target systems.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. Loss of heat sink causes primary loop temperatures to increase until boiling and loss of target cooling occurs resulting in shell over temperature and structural failure of shell. (IC) 2. Loop 1 cooling water leaks into the core vessel. (IC) 3. Core vessel operating in inert helium near atmospheric pressure or in vacuum (IC) 4. After loss of cooling with beam trip decay heat cannot raise target temperature to 800 C threshold for tungsten/steam reaction (DF) 5. Core vessel ullage, burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. (DF) 6. Neutron beam windows remain intact throughout event (IC) 7. Target rotation continues so whole target heats from beam until loss of shell strength at elevated temperatures causes disk to collapse onto steel shielding and stops rotation. (IC) 8. A double walled heat exchanger is used between the tower water cooling loop and the Loop 1 cooling loop and between the tower water and the Loop 2 cooling loop. (DF)	1. Extreme cold weather 2. Failure of tower control system 3. Operator fails to respond to heat sink conditions.	BEU

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. None as event is not credible with double walled heat exchanger.	**Public:** N/A **WG1:** N/A **WG2:** N/A	**Public:** N/A **WG1:** N/A **WG2:** N/A	**Public:** N/A **WG1:** N/A **WG2:** N/A

Safety Function:
Prevent a loss of heat sink from causing a loss of cooling to the target systems by using a double walled heat exchanger..

Method of Detection:	
N/A	

Preventive Features – Attributes:	Credited:
A double walled heat exchanger is used between the tower water cooling loop and the Loop 1 cooling loop and between the tower water and the Loop 2 cooling loop. (DF)	X

Event Number BG7-9b				
Mitigative Features – Attributes:				**Credited:**
Event not credible due to use of double walled heat exchanger (DF)				
Planned analysis, assumption validations, and Risk/Opportunities: 1.	**Mitigated Consequences:**			
	Radiological **Public:** N/A **WG1:** N/A **WG2:** N/A	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A	
Notes: 1.				**Mitigated Frequency** Prevented

Event Number
BG7-10

Event Description:
An SDC-2 level earthquake causes the exhaust stack to collapse

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. The second target building will have a separate exhaust stack from the existing FTS stack. (DF) 2. The STS exhaust stack is a prefabricated double walled steel assembly braced off the T&I building structure and is assumed to cause catastrophic damage if it fell over onto the target building. (IC) 3. See BG7-1a and BG7-2 for additional assumptions and initial conditions associated with e building and this event. (IC/DF)	1. SDC-2 level NPH event	**U**

Unmitigated Impact on Systems:
1. Loss of exhaust stack would result in loss of dispersion of gases exhausted from the STS and require that target operations be halted until the stack is repaired.
2. Catastrophic damage to the target building and surrounding structures if the stack falls on them.

Unmitigated Consequences

Radiological	**Chemical**	**ODH**
Public: Negligible	**Public:** N/A	**Public:** N/A
WG1: Moderate	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Safety Function:
Prevent an SDC-2 level seismic event from resulting in a stack collapse causing damage to the target building or surrounding buildings and a significant release of radiological material. Release of radiological material must be prevented until Worker Group 1 can be evacuated to at least the 100-meter location. Additionally assure that an egress path remains for Worker Group 1.

Method of Detection:	
Visual	

Preventive Features – Attributes:	Credited:
None	

Event Number
BG7-10

Mitigative Features – Attributes:	Credited:
Worker training. (AC)	
The stack is constructed with features that prevent collapse during an SDC-2 level seismic event. (DF)	X
Periodic inspection of stack. (AC)	
EOPs (AC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel. (See Note 3) (EC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of power to the TPS panel. (See Note 3) (EC)	
TPS beam trip for abnormal Loop 1 return flow. (See Note 3) (EC)	
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip on Loop 1 pump exit pressure (See Note 1 and 3) (EC)	
MPS beam trip for abnormal water Loop 1 return flow. (See Note 3) (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of monitored signal to the MPS panel. (See Note 3) (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of power to the MPS panel. (See Note 3) (EC)	
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
Large components are structurally anchored and building structures seismically qualified to prevent collapse, protect evacuation paths, and protect applicable confinement of hazardous material (applicable SSCs meet SDC-2 and applicable Limit State B or C requirements) (DF)	X
Emergency procedures and training, including specific guidance on response to a seismic event (AC)	X
Building design to meet SDC-2 level seismic event and applicable DOE standards. (DF)	X

Planned analysis, assumption validations, and Risk/Opportunities:

1. Structural analysis of the impact of an SDC-2 level seismic event on the stack .

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public:** N/A	**Public:** N/A
WG1: Negligible	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Notes:

1. There is a delay built into the MPS beam trip on Loop 1 pump exit pressure.
2. SNS FSAD-NF assumes that an NPH event of PC-2 or higher would cause a beam trip. Since the same linac supplying the FTS as supplies the STS, this beam trip is assumed. (102030102-ES0016-R03, “Spallation Neutron Source Final Safety Assessment Document for Neutron Facilities”, September 2011). Later evaluations determined that any felt motion (i.e., that which could cause equipment damage) would also lead to a loss of beam to the target.
3. Fail safe design for the TPS and MPS or either an MPS or TPS beam trips are based on credit in the inputs and assumptions section.
4. See BG7-1a and BG7-2 for mitigative features and controls associated with a SDC-2 level event without a stack failure.
5. The stack is a Van-Pacer Model: D2A; Liner: 18 GA Type 304 SS; Shell: 20 GA ALZD Steel; Insulation thickness 2” Air Space.

Mitigated Frequency
U

Event Number
BG7-11

Event Description:
An SDC-2 level seismic event results in structural damage to target building and subsequent release of hazardous material followed by an explosion and follow-on fire or detonation outside the core vessel and in the Target Drive Room. (This even is similar to BG7-1a with the focus on the follow-on fire or detonation in the Target Drive Room.)

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. The facility damage from an earthquake may cause a fire (IC) 2. The facility damage from an earthquake may cause a release of hydrogen outside the core vessel contributing to either a fire and/or hydrogen explosion. (See Note 1 and 3) (IC) 3. Active cooling or electric power are not needed for decay heat removal with the beam off. (DF) 4. The earthquake causes loss of the accelerator proton beam (DF) 5. Target radionuclides are protected from possible effects of fire by massive steel and concrete shielding of the monolith structure. (DF) 6. Hydrogen is released outside the core vessel and detonates within the Target Drive Room. (See Note 1) (IC) 7. Workers are assumed to evacuate buildings instinctively during earthquakes. (IC) 8. Building structures seismically qualified to SDC-2 criteria to prevent collapse and protect evacuation paths (SDC-2 and applicable Limit State B or C requirements) (DF) 9. Building structures around the cryogenic hydrogen systems will have SDC-2 and Limit State B or C seismic qualification due to seismic interaction (2 over 1) considerations, as needed to prevent damage to or crimping of the H2 transfer line outside of the core vessel (DF) 10. Target Drive Room roof designed to passively vent to the high bay and prevent buildup of hydrogen in this space. (DF) 11. Core vessel operating in inert helium near atmospheric pressure or in vacuum (IC) 12. After loss of cooling with beam trip decay heat cannot raise target temperature to 800 C threshold for tungsten/steam reaction (DF) 13. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF)	1. SDC-2 level Seismic event	U

Unmitigated Impact on Systems:
1. Potential for significant damage to the target building
2. Building damage could lead to a Roof collapse which could impact hydrogen utility room releasing H2.
3. Building damage could lead to a Roof collapse which could impact equipment stored in the high bay.
4. Building damage from seismic event and hydrogen explosion in the Target Drive Room could lead to damage to the target systems above the core vessel. .
5. Seismic Event and explosion in the Target Drive Room could lead to a Target Drive Room T-Beams falling damaging the target drive, core vessel lid, and lines leading to the target and moderator cooling systems.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible **WG1:** Low **WG2**: Low	**Public:** N/A **WG1:** N/A **WG2:** N/A	**Public:** N/A **WG1:** N/A **WG2:** N/A

Event Number
BG7-11

Safety Function:
Prevent an SDC-2 level seismic event from resulting in a release of significant radiological material following the event and a subsequent fire and or hydrogen detonation in the target drive room. Release of radiological material must be prevented (by preventing a detonation and providing confinement) until worker group 1 can be evacuated to at least the 100-meter location. Additionally assure that an egress path remains for Worker Group 1.

Method of Detection:	
Audible	
Visual	
Tactile	
Preventive Features – Attributes:	Credited:
None	

Mitigative Features – Attributes:	**Credited:**
Large components are structurally anchored and building structures seismically qualified to prevent collapse, protect evacuation paths, and protect applicable confinement of hazardous material (applicable SSCs meet SDC-2 and applicable Limit State B or C requirements). (DF)	X
Core vessel operating in inert helium near atmospheric pressure or in vacuum.	
Target segment attachment points designed to withstand an SDC-2 seismic event with a design margin of TBD.	X
Building design to meet SDC-2 level seismic event and applicable DOE standards. (DF)	
Combustible materials control program reduces the probability of a large fire. (AC)	.
Exclusion of natural gas service in the target and instrument buildings. (DF)	
Monolith concrete shielding and building steel structures seismically qualified to prevent gross displacement (SDC-2 and applicable Limit State B or C requirements. (DF)	
Fire barriers minimize consequences of large fire. (DF)	
Emergency procedures and training, including specific guidance on response to a seismic event. (AC)	X
TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel. (See Note 6) (EC)	X
TPS beam trip due to TPS fail safe design providing a trip on loss of power to the TPS panel. (See Note 6) (EC)	X
TPS beam trip for abnormal Loop 1 return flow. (See Note 6) (EC)	X
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of monitored signal to the MPS panel. (See Note 6) (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of power to the MPS panel. (See Note 6) (EC)	
MPS beam trip on Loop 1 pump exit pressure (See Note 4 and 6) (EC)	
MPS beam trip for abnormal water Loop 1 return flow. (See Note 6) (EC)	
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
Target Drive Room design for passive venting to prevent hydrogen build up in this space. (DF)	X
Foundation design such as Micro-piles or drilled piers with pier caps under STS mitigate seismic building response (DF)	

Event Number
BG7-11

Planned analysis, assumption validations, and Risk/Opportunities:

1. Seismic qualification parameters of SSCs with SDC and Limit States base on safety functions need to be defined
2.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public:** N/A	**Public:** N/A
WG1: Low	**WG1:** N/A	**WG1:** N/A
WG2: Low	**WG2:** N/A	**WG2:** N/A

Notes:

1. Release of hydrogen outside the Target Drive Room and Core Vessel, but in the high bay is evaluated in BG7-1a.
2. Passive venting of the Target Drive Room prevents a detonation in this space.
3. Credited items in this event are included to protect the critical assumptions in the event.
4. There is a delay built into the MPS beam trip on Loop 1 pump exit pressure.
5. SNS FSAD-NF assumes that an NPH event of PC-2 or higher would cause a beam trip. Since the same linac supplying the FTS as supplies the STS, this beam trip is assumed. (102030102-ES0016-R03, “Spallation Neutron Source Final Safety Assessment Document for Neutron Facilities”, September 2011). Later evaluations determined that any felt motion (i.e., that which could cause equipment damage) would also lead to a loss of beam to the target.
6. Fail safe design for the TPS and MPS or either an MPS or TPS beam trips are based on credit in the inputs and assumptions section.
7. HUR is covered by level 3.5 providing a measure of protection from roof failure.
8. Target Station Shielding shall not permit motion of the shielding to cause the cryogenic transfer lines to release Hydrogen under SDC2 seismic conditions.

Mitigated Frequency
<u>U</u>

Event Number
BG7-12

Event Description:
A seismic event below the SDC-2 level causes the potential loss of multiple facility systems not designed to meet the seismic conditions. (See Note 8)

Assumptions and Initial Conditions:

1. Workers are assumed to evacuate buildings instinctively during earthquakes however, until they reach 100 m from the building, they are considered WG1 (IC)
2. Core vessel boundary seals fail and inert atmosphere is lost. (IC)
3. Monolith iron shielding and core vessel components position is retained by external concrete structure (DF)
4. No follow-on fire results from this event. (IC)
5. Most hydrogen vents through moderator transfer line due to loss of electric power. (IC)
6. Monolith stays intact and serves as target heat sink. (IC)
7. Moderator and Hydrogen transfer line designed to meet SDC-2 loads. (Note 5) (DF)
8. Active cooling or electric power are not needed for decay heat removal with the beam off. (DF)
9. The earthquake causes loss of the accelerator proton beam (DF)
10. Core vessel operating in inert helium near atmospheric pressure or in vacuum (IC)
11. After loss of cooling with beam trip decay heat cannot raise target temperature to 800 C threshold for tungsten/steam reaction. (DF)
12. Large components are structurally anchored and building structures seismically qualified to SDC-2 criteria to prevent collapse and protect evacuation paths. (SDC-2 and applicable Limit State B or C requirements) (DF)
13. Building structures around the cryogenic hydrogen systems will have SDC-2 and Limit State B or C seismic qualification due to seismic interaction (2 over 1) considerations, as needed to prevent damage to or crimping of the H2 transfer line outside of the core vessel. (DF)
14. Potential for release of trace quantities of tritium or activated particulates contained in the hydrogen; pre-moderator/reflector (Loop 2) and reflector water could be heavily tritiated. (IC)
15. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF)

Causes:

1. Seismic Event less than SDC-2

Initiating Event Frequency
U

Unmitigated Impact on Systems:

1. Seismic event of significant magnitude could inherently cause a beam trip, however, the trip is not considered inherent for this event scenario.
2. Potential for damage to the target building and systems.
3. Seismic event could damage electrical systems, control systems, system process monitors, protection systems, etc.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: Negligible	**Public**: N/A
WG1: Moderate	**WG1**: Negligible	**WG1**: N/A
WG2: Low	**WG2**: Negligible	**WG2**: N/A

Event Number BG7-12	
Safety Function: Prevent a significant release of radiological material caused by a seismic event less than SDC-2. Release of radiological material must be prevented (by preventing a detonation and providing confinement) until worker group 1 can be evacuated to at least the 100-meter location. Additionally assure that an egress path remains for Worker Group 1.	
Method of Detection:	
Felt motion of seismic event.	
Pressure monitoring in core vessel environment	
Various system instrumentation, such as process monitors, MPS, and TPS fault detection.	
Preventive Features – Attributes:	**Credited:**
None	
Mitigative Features – Attributes:	**Credited:**
Monolith concrete shielding and building steel structures seismically qualified to prevent gross displacement (SDC-2 and applicable Limit State B or C requirements) (See Note 7) (DF)	
Core vessel liquid detection probe (EC)	
Foundation design such as Micro-piles or drilled piers with pier caps under STS mitigate seismic building response (DF)	
Monolith external structure designed to maintain monolith iron shielding in place (DF)	
Target building ventilation system (EC)	
Moderator and Hydrogen transfer line designed to meet SDC-2 loads. (Note 5) (DF)	X
Alarm response procedures (AC)	
Hydrogen and vacuum piping designed and built to the applicable portions of AMSE B31.12 and ASME B31.3 (DF)	
Building design to meet SDC-2 level seismic event and applicable DOE standards	X
Large components are structurally anchored and building structures seismically qualified to prevent collapse, protect evacuation paths, and protect applicable confinement of hazardous material (applicable SSCs meet SDC-2 and applicable Limit State B or C requirements). (DF)	X
Emergency procedures and training, including specific guidance on response to a seismic event (AC)	X
MPS beam trip system response to abnormal hydrogen parameters (e.g., pressure and flow) to mitigate consequences. (See Note 7) (EC)	
TPS beam trip for abnormal Loop 1 return flow	X
TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel. (See Note 7) (EC)	X
TPS beam trip due to TPS fail safe design providing a trip on loss of power to the TPS panel. (See Note 7) (EC)	X
MPS beam trip due to MPS fail safe design providing a trip on loss of monitored signal to the MPS panel. (See Note 7) (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of power to the MPS panel. (See Note 7) (EC)	
Seismic event will inherently cause a beam trip. (See Note 6) (DF)	X
Core vessel operating in inert helium near atmospheric pressure or in vacuum. (DF/AC)	
Target segment attachment points designed to withstand an SDC-2 seismic event with a design margin of TBD.	X

Event Number
BG7-12

Planned analysis, assumption validations, and Risk/Opportunities:

1. Structural and thermal analysis of the moderators
2. Seismic analysis of transfer lines including seismic interaction considerations.
3. Evaluate all release paths from the core vessel.
4. Venting analysis
5. Evaluate the potential use of seismic motion detectors.
6. Evaluate integrated dose for WG-1 during evacuation and while located as WG-2 at 100-meters.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:

1. Instruments that could be used to assess the consequences of a seismic event are assumed to be available although they are not designed to be seismically qualified. They are identified for detection of the leak only.
2. The portion of the TPS at the front end that provides the beam trip on loss of signal must be designed to work through and after an SDC-2 event.
3. Consequences for a detonation are based on the assumed inventory. When the target design is finalized, the MAR needs to be verified as consistent with the analysis.
4. Note deleted.
5. The hydrogen transfer lines and moderators are designed to withstand an SDC-2 event. Therefore, a lesser seismic event will not cause failure of these system boundaries. The hydrogen process equipment and helium refrigerator include sensitive equipment (circulators, turbine, etc.) that may not continue to function through a seismic event. However, this loss of function would lead to a passive release of hydrogen through the rupture discs and into the inert vent stack without possibility for a detonation. (DF)
6. SNS FSAD-NF assumes that an NPH event of PC-2 or higher would cause a beam trip. Since the same linac supplying the FTS as supplies the STS, this beam trip is assumed. (102030102-ES0016-R03, "Spallation Neutron Source Final Safety Assessment Document for Neutron Facilities", September 2011). Later evaluations determined that any felt motion (i.e., that which could cause equipment damage) would also lead to a loss of beam to the target.
7. Fail safe design for the TPS and MPS or either an MPS or TPS beam trips are based on credit in the inputs and assumptions section.
8. This event was included to address events seismic events that are below the NPH design basis of an SDC-2 level event. As noted in Note 6 above any seismic event that is strong enough to cause damage to equipment will also lead to a beam trip. The credited controls in this case don't rely on the expected beam trip due to the seismic motion but assure that the beam is tripped based on loss of function for any of the systems relied on for safe beam and target operation. No specific SSC fault is assumed to result from the seismic event, but any fault that could result in target damage and release of radiological material is addressed.
9. Limit State C is required to provide confinement of hazardous material and hydrogen. Limit State B is required to Seismic Interaction (II over I) protection for both SSCs that could release hazardous material or hydrogen as well as assuring that workers can evacuate to the 100-meter location.
10. Target Station Shielding shall not permit motion of the shielding to cause the cryogenic transfer lines to release Hydrogen under SDC2 seismic conditions.

Mitigated Frequency
EU

APPENDIX D. CRYOGENIC MODERATOR SYSTEM AND MODERATOR REFLECTOR (CMS) ASSEMBLY HAZARD EVENT TABLES

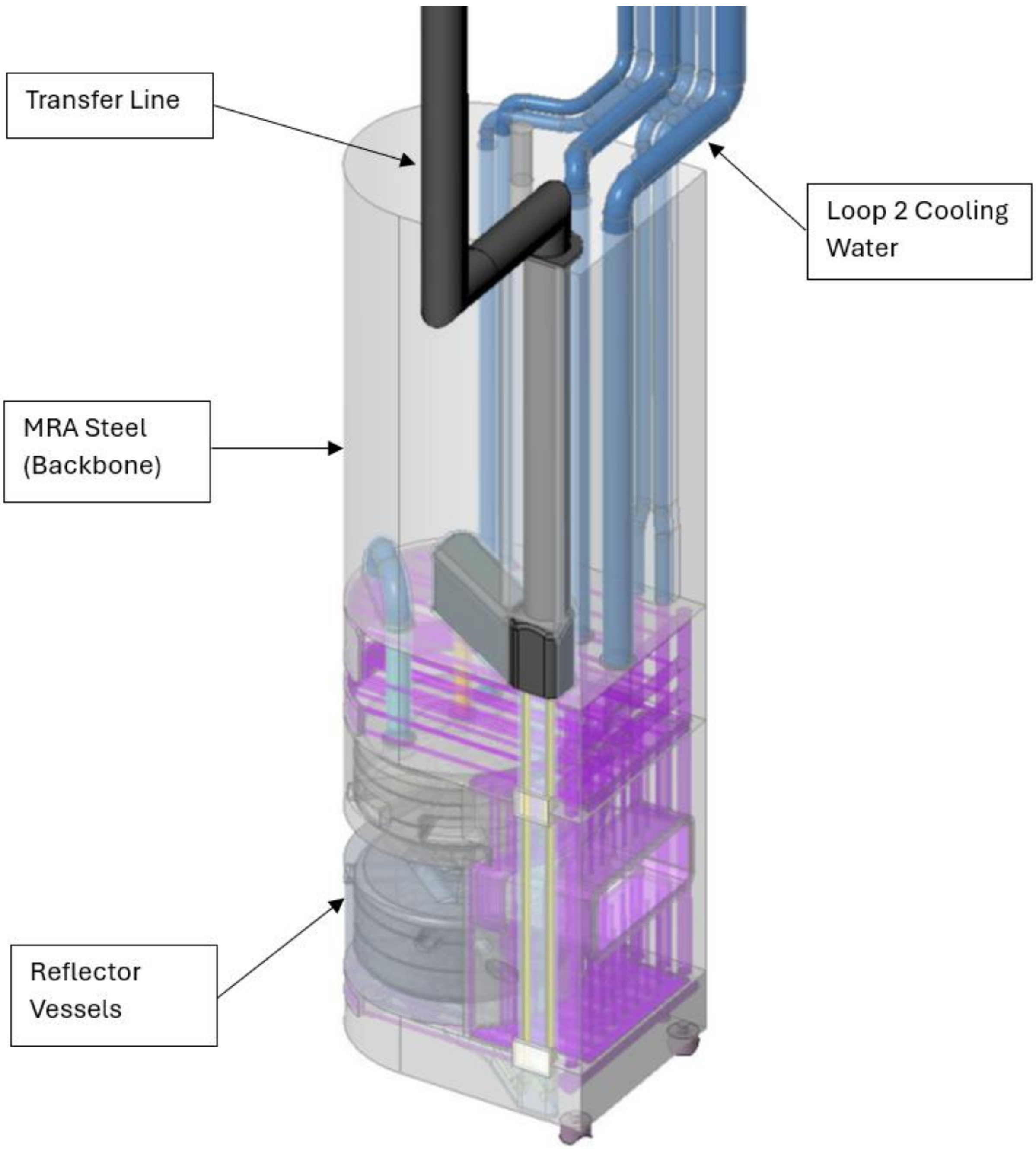

Figure D-1. MRA Configuration.

APPENDIX D. CRYOGENIC MODERATOR SYSTEM AND MODERATOR REFLECTOR (CMS) ASSEMBLY HAZARD EVENT TABLES

<table>
<tr><td colspan="5">Event Number
CMS1-1</td></tr>
<tr><td colspan="5">Event Description:
Breach of cryogenic moderator vessel or piping in Core Vessel allows hydrogen to escape to the core vessel with a possible deflagration in the vacuum system exhaust at the vacuum pump location in the high bay. (See Note 3)</td></tr>
<tr><td colspan="2">Assumptions and Initial Conditions:
1. Initial breach is of both the hydrogen and vacuum boundary. (IC)
2. Vacuum pump for core vessel would be pumping the core vessel contents (pump uses air in the system to pump the core vessel). (DF)
3. Inert core vessel atmosphere with helium or vacuum mode of core vessel operation. IC)
4. Hydrogen leak accompanied would lead to a loss of vacuum around moderator and transfer line. (IC)
5. All welded system. (DF)
6. Transfer lines are vacuum jacketed from the core vessel to the HUR. (DF)
7. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF)</td><td colspan="2">Causes:
1. Failure of the moderator assembly or the hydrogen piping due to material fatigue (e.g., vibration).
2. Damage to the moderator vessel during construction.
3. Installation error (e.g., weld) during MRA replacement.
4. Design or fabrication errors.
5. Radiation damage.
6. Full crimping of the transfer line outside the target drive room. (See Event CMS2-2b)</td><td>Initiating Event Frequency
U</td></tr>
<tr><td rowspan="2">Unmitigated Impact on Systems:
1. Loss of vacuum causes pressure rise above 19 bar and hydrogen release through hydrogen and moderator vacuum hydrogen safe vent.
2. Leakage of hydrogen and possibly pre-moderator/reflector (Loop 2) water to core vessel.
3. If core vessel pressure exceeds 1.5 bar, hydrogen will vent through core vessel hydrogen safe vent.</td><td colspan="4">Unmitigated Consequences</td></tr>
<tr><td colspan="2">Radiological
Public: Negligible
WG1: Low
WG2: Negligible</td><td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
<tr><td colspan="5">Safety Function:
Prevent a fire in the vacuum system exhaust at the vacuum pump from a hydrogen release in the Core Vessel from resulting in a significant release of radiological material.</td></tr>
<tr><td colspan="4">Method of Detection:</td><td></td></tr>
<tr><td colspan="4">Loss of hydrogen pressure in cryogenic moderator system detected by monitoring instrumentation in hydrogen handling system or accumulator bellows motion.</td><td></td></tr>
<tr><td colspan="4">Pressure monitoring in core vessel environment.</td><td></td></tr>
<tr><td colspan="4">Core vessel burst disk rupture alarm in the control room.</td><td></td></tr>
<tr><td colspan="4">Core vessel exhaust system vent system monitoring.</td><td></td></tr>
<tr><td colspan="4">Breach of moderator vessel could be indicated by monitors in CMS transfer line monitoring for loss of vacuum.</td><td></td></tr>
<tr><td colspan="4">MPS Monitoring of the hydrogen system parameters (e.g., pressure and flow).</td><td></td></tr>
<tr><td colspan="4">Core vessel liquid detection probe if premoderator also fails.</td><td></td></tr>
</table>

Event Number
CMS1-1

Preventive Features – Attributes	Credited:
CMS/MRA Vessel and piping design. (DF)	
Installation procedures and welding practices on MRA replacement. (AC)	
Preventive features for a crimped transfer line are listed in CMS2-5a&b	
Mitigative Features – Attributes:	**Credited:**
Core vessel pressure relief burst disk and hydrogen safe vent (See Note 4). (EC)	
RGA monitoring of core vessel gas composition. (EC)	
Core vessel liquid detection probe and alarm on detection. (EC)	
MPS beam trip system response to abnormal hydrogen parameters (e.g., pressure and flow). (EC)	
Pressure monitoring system to detect a leak of hydrogen into vacuum space. (EC)	
Ullage and Confinement capability of the core vessel for liquids. (DF)	
Hydrogen and Vacuum jacket lines designed for venting. (DF)	
Vent path for hydrogen is protected. (DF)	
Vent path for Core Vessel is protected. (DF)	
Deflagration or Detonation prevented by inert core vessel. (EC)	
Alarm response procedures. (AC)	
Combustible Material Control Program. (AC)	
Emergency response procedures. (AC)	
Mitigative features for a crimped transfer line are listed in CMS2-5a&b	
Operating Procedures and Training. (AC)	

Event Number
CMS1-1

Planned analysis, assumption validations, and Risk/Opportunities:

1. Hydrogen venting analysis.
2. Determine exhaust flow path for helium core vessel operations.
3. Perform a Project Fire Hazard Analysis (PFHA).
4. Assessment of fires per NFPA 801.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Notes:

1. The impact to the facility worker (Onsite 1 receptor) is from radiological consequences only as the deflagration is a SIH.
2. A breach of the vacuum boundary for the MRA/CMS will lead to hydrogen venting out the hydrogen safe vent.
3. Should the vacuum pump not be located in the high bay, this event will require reevaluation.
4. The burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures.

Mitigated Frequency
U

Event Number
CMS1-2

Event Description:
Breach of hydrogen piping in Hydrogen Utility Room (HUR) allows hydrogen to escape to the room; hydrogen accumulates in concentrations greater than the LFL in air resulting in a rapid deflagration releasing trace quantities of tritium or activated particulates contained in the hydrogen.

Assumptions and Initial Conditions:
1. HUR in STS located in a location away from radiological material and outside of high bay crane travel either in the Target Building or in an annex. (IC)
2. This event is assumed to be limited to a rapid deflagration. (IC)
3. The HUR will be designated as a Class 1, Division 2, Group B, hazardous location in accordance with NFPA 70. (See Note 2) (DF)
4. Gas cabinet purge and backfill system with no system "top off of hydrogen" during operation. (DF/AC)
5. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF)

Causes:
1. Failure of the hydrogen piping due to corrosion.
2. Piping damaged during installation or maintenance.
3. Cracking at welds as the result of long-term vibration.
4. Release of hydrogen accompanied by spark generated by instrumentation, electrical equipment, static charge; friction or unknown ignition source; excessive heat caused by circulator heater malfunction.
5. Maintenance operations or Maintenance worker error.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. A fire in the Hydrogen Utility Room could result in significant damage to the cryogenic moderator system.
2. A fire of this nature could result in the release of contamination and could ultimately lead to release of additional hydrogen sufficient to produce a deflagration or detonation.
3. Significant delay in STS operations until repairs are completed.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent a fire from hydrogen release in the HUR from resulting in a significant release of radiological material.

Method of Detection:	
Loss of hydrogen pressure in cryogenic moderator system detected by monitoring instrumentation in hydrogen handling system.	
MPS Monitoring of the hydrogen system parameters (e.g., pressure and flow).	
Fire detection system.	
Hydrogen sensor and alarm in the HUR.	

Preventive Features – Attributes:	Credited:
Electronic or instrumentation systems designed to minimize the potential for ignition sources. (DF)	
Maintenance procedures. (AC)	
Operating Procedures and Training. (AC)	
Gas cabinet purge and backfill system with no system "top off of hydrogen" during operation. (DF/AC)	

Event Number
CMS1-2

Mitigative Features – Attributes:	Credited:
Pressure monitoring system to detect a leak of hydrogen. (EC)	
ODH sensor to detect low O_2 levels and alarms for evacuation or to prevent entry. (EC)	
Hydrogen Utility Room atmosphere hydrogen sensor detects low concentrations of hydrogen (below LFL). (EC)	
Forced ventilation dilutes and removes hydrogen. (EC)	
Combustible material control program. (AC)	
Controlled access to Hydrogen Utility Room. (AC)	
Emergency response procedures. (AC)	
Worker training. (AC)	
Hydrogen Utility Room will be designed to meet Class 1, Division 2, Group B, hazardous location in accordance with NFPA 70. (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Ventilation analysis for HUR.
2. Analysis to determine O_2 levels in the area after Hydrogen release and the potential for deflagration.
3. Based on final location of the HUR determine if equipment above the HUR could exacerbate the event.
4. Perform a Project Fire Hazard Analysis (PFHA).
5. Assessment of fires per NFPA 801.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Notes:

1. The impact to the facility worker (Onsite 1 receptor) is from radiological consequences only as the deflagration is a SIH.
2. The approach for STS will be similar to FTS. From FTS, this utility room is designated as a Class 1, Division 2, Group B, hazardous location in accordance with NFPA 70. The NFPA 70 basis for this designation is a location "in which volatile flammable liquids or flammable gases are handled, processed, or used, but in which the liquids, vapors, or gases will normally be confined within closed containers or closed systems from which they can escape only in case of accidental rupture or breakdown of such containers or systems, or in case of abnormal operation of equipment." Instrument and electrical connections inside the control room next to the HUR are of a hydrogen-safe design per NFPA 70. Valve operators are pneumatic and employ non-incentive controls.
   A pump, which is not listed for use in Class 1, Division 2, Group B, classified locations, in accordance with NFPA 70, is being utilized in the utility room. To offset the lack of classification both the 269cfm mechanical ventilation system and one of the 8,000 cfm rooftop ventilators operate continuously, which essentially allows the area to be considered an electrically Unclassified area in accordance with NFPA 497, Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Area. The continuous operation of these two fans provides adequate explosion prevention by combustible concentration reduction.
   However, for STS the potential for hydrogen accumulation should be limited to the HUR. The control room should not have any requirements for hydrogen safe design.
3. Evaluate need for blow out panel on an external wall.
4. This event may have to be reevaluated based on the final location of the HUR.

Mitigated Frequency
A

Event Number
CMS1-3

Event Description:
Breach of hydrogen piping in High Bay allows hydrogen to escape to the High Bay area; hydrogen accumulates in concentrations greater than the LFL in air resulting in a rapid deflagration releasing trace quantities of tritium or activated particulates contained in the hydrogen. (See Planned Analysis Item 4)

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. HUR in STS located in a location away from radiological material and outside of high bay crane travel either in the Target Building or in an annex. (IC) 2. This event is assumed to be limited to a rapid deflagration. (IC) 3. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF) 4. Transfer lines are vacuum jacketed from the core vessel to the HUR. (DF)	1. Failure of the hydrogen piping due to corrosion. 2. Piping damaged during installation or maintenance. 3. Cracking at welds as the result of long-term vibration. 4. Release of hydrogen accompanied by spark from electrical equipment, friction, or unknown ignition source. 5. Crane drop on piping. 6. Maintenance operations or Maintenance worker error.	**A**

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Damage to target support systems. 2. Damage to equipment in the High Bay.	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent a hydrogen release in the High Bay from causing a fire and resulting in a significant release of radiological material.

Method of Detection:	
Hydrogen system monitoring instrumentation.	
MPS Monitoring of the hydrogen system parameters (e.g., pressure and flow).	
Fire detection system.	
Visual and Audible.	
CMS transfer line monitoring for loss of vacuum.	

Preventive Features – Attributes:	**Credited:**
Piping designed to ASME B31.3/B31.12. (DF)	
Transfer line cover plates or physical protection. (Note 4) (DF)	
Hydrogen pipe routing minimizing potential impact from a crane load drop, direct crane impact, or forklift.(Note 4) (DF)	
Pipes carrying hydrogen are jacketed with vacuum. (DF)	
Crane inspection and certification program. (AC)	

Event Number CMS1-3	
Hoisting and rigging program. (AC)	
Restrictions on crane travel and equipment/material lifted in the vicinity of hydrogen piping. (See Note 3) (AC)	
Operating Procedures and Training. (AC)	
Maintenance procedures and Training. (AC)	
Mitigative Features – Attributes:	**Credited:**
Building fire detection and suppression system. (EC)	
Forced ventilation dilutes and removes hydrogen. (EC)	
High Bay volume and building ventilation system limit potential for accumulation of hydrogen in concentrations exceeding LFL. (DF)	
All welded system. (DF)	
Emergency response procedures. (AC)	
Combustible material control program. (AC)	
Worker training. (AC)	
Gas cabinet purge and backfill system with no system "top off of hydrogen" during operation. (DF/AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Evaluate potential hydrogen release quantities and high bay concentrations. 2. Evaluate hydrogen transfer lines cover plates/physical protection and routing against crane drop. 3. Evaluate hydrogen transfer lines to B31.3/B31.12. 4. Determine which areas in the STS will need to be designed to meet the criteria listed in CMS1-2 or portions thereof. 5. Perform a Project Fire Hazard Analysis (PFHA). 6. Assessment of fires per NFPA 801.	**Radiological** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:	**Mitigated Frequency**
1. The impact to the facility worker (Onsite 1 receptor) is from radiological consequences only as the deflagration is a SIH. 2. Should the vacuum piping routing not be located in the high bay, this event will require reevaluation. 3. The load permitted will be limited by the protection for the transfer line routing and cover plates/physical protection. 4. Hydrogen transfer lines between the Core Vessel and the HUR are located in trenches/recesses/protected with cover plates to prevent impact from operations or falling objects from damage to the transfer line leading to a release of hydrogen.	**A**

Event Number
CMS1-4

Event Description:
Breach of hydrogen piping in the target drive room above the core vessel and inside shielding blocks allows hydrogen to escape. Hydrogen accumulates in concentrations greater than the LFL in air resulting in a rapid deflagration and follow-on fire releasing trace quantities of tritium or activated particulates contained in the hydrogen and activated cooling water.

Assumptions and Initial Conditions:
1. This event is assumed to be limited to a rapid deflagration. An LEL is evaluated in Event CMS2-5. (IC)
2. Pockets of hydrogen could accumulate under shield blocks which are located above the core vessel. (IC)
3. This event could release activated cooling water as the result of damage to water lines in the area. (IC)
4. Loss of vacuum will cause overpressure in hydrogen system and venting though hydrogen system hydrogen safe vents. (DF)
5. Personnel are not permitted in the Target Drive Room during beam operation (AC/EC)
6. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF)
7. Transfer lines are vacuum jacketed from the core vessel to the HUR. (DF)

Causes:
1. Failure of the hydrogen piping due to corrosion.
2. Piping damage during installation or maintenance.
3. Cracking at welds as the result of long-term vibration.
4. Release of hydrogen accompanied by spark from electrical equipment, friction, or unknown ignition source.

Initiating Event Frequency
U

Unmitigated Impact on Systems:
1. A fire of this nature could result in the release of contamination.
2. Potential for significant damage to equipment located in space above core vessel (e.g., target drive motor and water lines). If the drive motor and stops rotation of the target, the consequences are covered in the TS events.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
System design such that a hydrogen release would not lead to a fire which could result in a release of radiological material. Note: Activated material in the hydrogen line would result in negligible consequences.

Method of Detection:	
Hydrogen system monitoring instrumentation.	
CMS transfer line monitoring for loss of vacuum.	
Loop 1 or Loop 2 abnormal condition monitoring.	
MPS Monitoring of the hydrogen system parameters (e.g., pressure and flow).	
Fire detection system.	

Event Number
CMS1-4

Preventive Features – Attributes:	Credited:
Pipes carrying hydrogen are jacketed with vacuum. (DF)	
Transfer line routing and cover plates/physical protection. (Note 3) (DF)	
Hydrogen transfer lines designed to B31.12 or B31.3. (DF)	
Preventive maintenance program. (AC)	

Mitigative Features – Attributes:	Credited:
Building fire detection and suppression system. (EC)	
Bulk shield liner designed to collect spilled liquid water. (DF)	
Combustible material control program. (AC)	
PPS secures the Target Drive Room during beam operation. (EC)	
Fire detection and Alarm response procedures. (EC/AC)	
Emergency response procedures. (AC)	
Worker training. (AC)	
Target Drive Room T-Beams permits ventilation of the space (passive). (DF)	
Active ventilation of the Target Drive Room prevents a buildup of hydrogen in this space. (EC)	
Monitoring of the active ventilation of the Target Drive Room during operation and alarm in the control room. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Hydrogen transfer line analysis to B31.3 or B31.12.
2. Verify that the consequences for a ground level release for this unmitigated event are low or moderate.
3. Evaluate routing of hydrogen and water lines for protection from external impacts.
4. Evaluate water getting out of the space under the Target Drive Room and into the High Bay.
5. Perform a Project Fire Hazard Analysis (PFHA).
6. Assessment of fires per NFPA 801.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: N/A	**Public**: N/A	**Public**: N/A
WG1: N/A	**WG1:** N/A	**WG1:** N/A
WG2: N/A	**WG2:** N/A	**WG2:** N/A

Notes:

1. The impact to the facility worker (Onsite 1 receptor) is from radiological consequences only as the deflagration is a SIH.
2. The initial condition (design feature) that the transfer lines are vacuum jacketed from the core vessel to the HUR makes this event BEU, as it takes a double failure to release hydrogen in this space.
3. Hydrogen transfer lines between the Core Vessel and the HUR are located in trenches/recesses/protected with cover plates to prevent impact from operations or falling objects from damage to the transfer line leading to a release of hydrogen.

Mitigated Frequency
BEU

Event Number
CMS2-1

Event Description:
Breach of Cryogenic Moderator vessel allows hydrogen to escape from the moderator vessel into the surrounding area within the core vessel leading to a detonation in the vacuum system exhaust at the vacuum pump location in the high bay. (See Note 2)

Assumptions and Initial Conditions:

1. Initial breach is of both the hydrogen and vacuum boundary. (IC)
2. Vacuum pump for core vessel would be pumping the core vessel contents (air could be in the system exhaust). (IC)
3. Inert core vessel atmosphere with helium or vacuum mode of core vessel operation. (IC)
4. Hydrogen leak accompanied by a loss of vacuum around moderator. (IC)
5. All welded system. (DF)
6. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF)

Causes:

1. Failure of the moderator assembly or the hydrogen piping due to material fatigue (e.g., vibration).
2. Damage to the moderator vessel during construction.
3. Installation error (e.g., weld) during MRA replacement.
4. Design or fabrication errors.
5. Radiation damage.
6. Full crimping of the transfer line outside the target drive room. (See Event CMS2-2b)

Initiating Event Frequency
U

Unmitigated Impact on Systems:

1. Loss of vacuum causes pressure rise above 19 bar and hydrogen release through hydrogen and moderator vacuum hydrogen safe vent.
2. If core vessel pressure exceeds 1.5 bar, hydrogen will vent through core vessel hydrogen safe vent.
3. Leakage of hydrogen and possibly pre-moderator/reflector (Loop 2) water to core vessel.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent a release of hydrogen in the Core Vessel from resulting in a detonation in the vacuum system exhaust and causing a significant release of radiological material.

Method of Detection:	
Loss of hydrogen pressure in cryogenic moderator system detected by monitoring instrumentation in hydrogen handling system.	
Pressure monitoring in core vessel environment.	
Core vessel burst disk rupture alarm in the control room.	
Core vessel exhaust system vent system monitoring.	
CMS transfer line vacuum monitoring for loss of vacuum.	
MPS monitoring hydrogen parameters (e.g.) pressure and flow).	
Core vessel liquid detection probe if premoderator also fails.	

Event Number
CMS2-1

Preventive Features – Attributes:	Credited:
CMS Piping designed to B31.3/B31.12. (DF)	
MRA Vessel design (DF)	
Preventive features for a crimped transfer line are listed in CMS2-5a&b	
Hydrogen Vessel and piping design. (DF)	
Installation procedures and welding practices on MRA replacement. (AC)	
Mitigative Features – Attributes:	**Credited:**
Pressure monitoring system to detect a leak of hydrogen into vacuum space. (EC)	
RGA monitoring of core vessel gas composition. (EC)	
Core vessel liquid detection probe and alarm on detection. (EC)	
Ullage and Confinement capability of the core vessel for liquids. (DF)	
Core vessel pressure relief burst disk and hydrogen safe vent (See Note 4). (DF)	
Vacuum jacket designed for venting. (DF)	
Deflagration or Detonation prevented by inert core vessel. (DF)	
Alarm response procedures. (AC)	
Operating Procedures and Training. (AC)	
Emergency response procedures. (AC)	
Worker training. (AC)	
CMS Vacuum jacket designed for venting hydrogen. (DF)	
Vent path for hydrogen is protected. (DF)	
Vent path for Core Vessel is protected. (DF)	
CMS Piping designed to B31.3/B31.12. (DF)	
Combustible Material Control Program. (AC)	

Event Number CMS2-1			
Planned analysis, assumption validations, and Risk/Opportunities: 1. Core vessel vacuum and helium systems potential for hydrogen deflagration/detonation. 2. Transient thermal and structural venting analysis. 3. Moderator thermal and structural analysis. 4. Evaluate hydrogen transfer lines to B31.3/B31.12.	**Mitigated Consequences:** **Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A
Notes: 1. The impact to the facility worker (Onsite 1 receptor) is from radiological consequences only as the deflagration is a SIH. 2. Should the vacuum pump not be located in the high bay, this event will require reevaluation. 3. A breach of the vacuum boundary for the MRA/CMS will lead to hydrogen venting out the hydrogen safe vent. 4. The burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures.			**Mitigated Frequency** **U**

Event Number
CMS2-2a

Event Description:
Breach of Cryogenic Moderator vessel allows hydrogen to escape from the moderator vessel into the surrounding area within the core vessel. Hydrogen accumulates in concentrations greater than the LEL in air resulting in a detonation releasing a fraction of the activated target mass and activated cooling water. No follow-on fire results.

Assumptions and Initial Conditions:
1. Initial breach is of both the hydrogen and vacuum boundary. (IC)
2. Inert core vessel atmosphere with helium or vacuum mode of core vessel operation (IC)
3. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF)

Causes:
1. Failure of the moderator assembly or the hydrogen piping due to material fatigue (e.g., vibration).
2. Damage to the moderator vessel during construction.
3. Installation error (e.g., weld) during MRA replacement.
4. Design or fabrication errors.
5. Radiation damage.
6. Full crimping of the transfer line outside the target drive room. (See Event CMS2-2b)

Initiating Event Frequency
BEU

Unmitigated Impact on Systems:
1. Loss of vacuum causes pressure rise above 19 bar and hydrogen release through hydrogen and moderator vacuum hydrogen safe vent.
2. If core vessel pressure exceeds core vessel burst disk pressure, hydrogen will vent through core vessel hydrogen safe vent.
3. Leakage of hydrogen and possibly pre-moderator/reflector (Loop 2) water to core vessel.

Unmitigated Consequences

Radiological	**Chemical Public**:	**ODH**
Public: Negligible **WG1**: Low **WG2**: Negligible	N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Inert Core Vessel required to prevent the deflagration or detonation in the Core Vessel

Method of Detection:	
Loss of hydrogen pressure in cryogenic moderator system detected by monitoring instrumentation in hydrogen handling system.	
Pressure monitoring in core vessel environment.	
Core vessel burst disk rupture alarm in the control room.	
Core vessel exhaust system vent system monitoring.	
CMS transfer line vacuum monitoring for loss of vacuum. (EC)	
MPS monitoring hydrogen parameters (e.g.) pressure and flow). (EC)	
Core vessel liquid detection probe if premoderator also fails.	

Event Number
CMS2-2a

Preventive Features – Attributes:	Credited:
Inert core vessel atmosphere with helium or vacuum mode of core vessel operation. (DF)	

Mitigative Features – Attributes:	Credited:

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: N/A **WG1**: N/A **WG2:** N/A	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:	Mitigated Frequency
Event is BEU based on IC of inerted Core Vessel either with vacuum or helium.	BEU

Event Number CMS2-2b					
Event Description: Breach of Cryogenic Moderator vessel allows hydrogen to escape from the moderator vessel into the surrounding area within the core vessel. Hydrogen accumulates in concentrations greater than the LEL in air resulting in a detonation releasing a fraction of the activated target mass and activated cooling water. No follow-on fire results.					
Assumptions and Initial Conditions: 1. Inert core vessel atmosphere with helium or vacuum mode of core vessel operation (IC) 2. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF)		**Causes**: 1. Crane drop or other impact on CMS transfer line outside the target drive room resulting in a full crimping of the hydrogen supply and return line as well as the vacuum jacked. 2. Events other than full crimping of the transfer line outside the target drive room. (See Event CMS2-2a)			**Initiating Event Frequency** U
Unmitigated Impact on Systems: 1. Loss of vacuum causes pressure rise above 19 bar and hydrogen release through hydrogen and moderator vacuum hydrogen safe vent. 2. If core vessel pressure exceeds core vessel burst disk pressure, hydrogen will vent through core vessel hydrogen safe vent. 3. Leakage of hydrogen and possibly pre-moderator/reflector (Loop 2) water to core vessel.			**Unmitigated Consequences** **Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Inert Core Vessel required to prevent the deflagration or detonation in the Core Vessel.					
Method of Detection:					
Loss of hydrogen pressure in cryogenic moderator system detected by monitoring instrumentation in hydrogen handling system.					
Pressure monitoring in core vessel environment.					
Core vessel burst disk rupture alarm in the control room.					
Core vessel exhaust system vent system monitoring.					
CMS transfer line vacuum monitoring for loss of vacuum. (EC)					
MPS monitoring hydrogen parameters (e.g.) pressure and flow). (EC)					
Core vessel liquid detection probe if premoderator also fails. (EC)					

Event Number
CMS2-2b

Preventive Features – Attributes:	Credited:
Transfer line cover plates or physical protection. (Note 2) (DF)	
Hydrogen pipe routing minimizing potential impact from a crane load drop, direct crane impact, or forklift. (DF)	
Hoisting and rigging program. (AC)	
Restrictions on crane travel and equipment/material lifted in the vicinity of hydrogen piping. (AC)	
Operating Procedures and Training. (AC)	
Maintenance procedures and Training. (AC)	
Crane inspection and certification program. (AC)	

Mitigative Features – Attributes:	Credited:
Inert core vessel atmosphere with helium or vacuum mode of core vessel operation. (DF)	X
Transfer line routing and cover plates/physical protection. (DF)	
MRA design (See Note 1)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:

1. The design of the MRA required to provide the neutrons for operation makes the neutron windows are the most likely failure point. The vacuum vessel will fail before the transfer lines vacuum layer fails based on the operational functional requirements of the components. Thus, with a full crimp of the CMS line, heating will cause the pressure on the MRA to increase until it fails and releases hydrogen into the core vessel. The consequences are mitigated by the inert core vessel atmosphere and this event is a unique cause for this release into the core vessel.
2. Hydrogen transfer lines between the Core Vessel and the HUR are located in trenches/recesses/protected with cover plates to prevent impact from operations or falling objects from damage to the transfer line leading to a release of hydrogen.

Mitigated Frequency
U

Event Number
CMS2-2c

Event Description:
Breach of Cryogenic Moderator vessel allows hydrogen to escape from the moderator vessel into the surrounding area within the core vessel during remote handling operations when the Core Vessel is not inerted. Hydrogen accumulates in concentrations greater than the LEL in air resulting in a detonation releasing a fraction of the activated target mass and activated cooling water. No follow-on fire results.

Assumptions and Initial Conditions:
1. Core vessel atmosphere is not inerted with the core vessel opened for remote handling operations. (IC)
2. Event occurs during operations with the core vessel open to the atmosphere. (IC)
3. Inherent combustible inventory of core vessel is very low. (See Note 1) (DF)
4. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF)

Causes:
1. Crane drop or other impact on CMS inside the core vessel breaching the hydrogen supply and return line as well as the vacuum jack.
2. Maintenance or operator error.
3. Flammable/combustible liquid inadvertently drained into vessel during maintenance.
4. Welding during maintenance.
5. Hydrogen gas accumulation.

Initiating Event Frequency
U

Unmitigated Impact on Systems:
1. Core vessel damage and damage to components in the core vessel.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Moderate	**WG1**: N/A	**WG1**: N/A
WG2: Low	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent or mitigate release of radiological material from a detonation in the Core Vessel when the core vessel is open for remote handling operations and hydrogen is in the CMS/MRA.

Method of Detection:	
Loss of hydrogen pressure in cryogenic moderator system detected by monitoring instrumentation in hydrogen handling system.	
Core vessel instrumentation (pressure/temperature).	
Core vessel exhaust system vent system monitoring.	
MPS monitoring hydrogen parameters (e.g.) pressure and flow). (EC)	
Fire detection in the High Bay.	

Event Number
CMS2-2c

Preventive Features – Attributes:	**Credited:**
Hoisting and rigging program. (AC)	
Restrictions on crane travel and equipment/material lifted in the vicinity of hydrogen piping. (AC)	
Operating Procedures and Training. (AC)	
Maintenance procedures and Training. (AC)	
Crane inspection and certification program. (AC)	

Mitigative Features – Attributes:	**Credited:**
CMS Transfer line routing. (DF)	X
MRA design. (DF)	
Combustible inventory of core vessel is very low. (DF)	
EOPs. (AC)	
Active venting of the core vessel atmosphere to maintain a slightly negative pressure in the core vessel. (See Note 3) (AC/EC)	X

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:	**Mitigated Frequency**
1. Detonation events with hydrogen removed from the CMS/MRA are addressed in the VS event scenarios. 2. The lower frequency for this event is associated with the limited time that the core vessel is open to the atmosphere and hydrogen is in the CMS/MRA. 3. The core vessel will be continually vented to maintain air flow into the core vessel from the core vessel lid and out the vessel exhaust to control contamination spread during these operations.	U

Event Number
CMS2-3

Event Description:
Breach of hydrogen piping in the Hydrogen Utility Room (HUR) allows hydrogen to escape to the room. Hydrogen accumulates in concentrations greater than the LEL in air resulting in a detonation releasing trace quantities of tritium or activated particulates contained in the hydrogen.

Assumptions and Initial Conditions:
1. HUR in STS located in a location away from radiological material and outside of high bay crane travel either in the Target Building or in an annex. (IC)
2. The HUR will be designated as a Class 1, Division 2, Group B, hazardous location in accordance with NFPA 70 (See Note 2) (DF)
3. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF)
4. Gas cabinet purge and backfill system with no system "top off of hydrogen" during operation. (DF/AC)

Causes:
1. Failure of the hydrogen piping due to corrosion.
2. Piping damaged during installation or maintenance.
3. Cracking at welds as the result of long-term vibration.
4. Release of hydrogen accompanied by spark generated by instrumentation, electrical equipment, static charge; friction or unknown ignition source; excessive heat caused by circulator heater malfunction; maintenance operations.
5. Maintenance operations or worker error.

Initiating Event Frequency
U

Unmitigated Impact on Systems:
1. An explosion in the Hydrogen Utility Room (HUR) would likely result in major damage to the cryogenic moderator system and could have an adverse impact on equipment in the vicinity of the utility room.
2. There may be some potential for damage to the He refrigeration system, and to the helium storage tank (depending on location of these systems).
3. Loss of cooling for moderators.
4. Possible moderator failure from overheating if beam not cut-off.
5. Significant delay in STS operations until repairs are completed.

Unmitigated Consequences

Radiological	Chemical	ODH (Note 3)
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent a breach of hydrogen piping in the Hydrogen Utility Room (HUR) from leading to a detonation and release of radiological material.

Method of Detection:	
Loss of hydrogen pressure in cryogenic moderator system detected by monitoring instrumentation in hydrogen handling system.	
MPS Monitoring of the hydrogen system parameters (e.g., pressure and flow).	
HUR hydrogen concentration sensor and alarm.	

Event Number CMS2-3	
Preventive Features – Attributes:	**Credited:**
Electronic or instrumentation systems designed to minimize the potential for ignition sources. (DF)	
Gas cabinet purge and backfill system with no system “top off of hydrogen” during operation. (DF/AC)	
Hydrogen piping design to ASMS B31.3/B31.12. (DF)	
Maintenance procedures. (AC)	
Operating Procedures and Training. (AC)	
Mitigative Features – Attributes:	**Credited:**
IF required by SMBM and National Consensus Codes and Standards, ODH sensor to detect low O_2 levels and alarms for evacuation or to prevent entry.	
Pressure monitoring system to detect a leak of hydrogen. (EC)	
Forced ventilation dilutes and removes hydrogen. (EC)	
Controlled access to Hydrogen Utility Room. (EC)	
Emergency response procedures. (AC)	
Worker training. (AC)	
Combustible material control program. (AC)	
Hydrogen Utility Room will be designed to meet Class 1, Division 2, Group B, hazardous location in accordance with NFPA 70. (DF)	
Hydrogen Utility Room atmosphere hydrogen sensor detects low concentrations of hydrogen (below LFL). (EC)	

Event Number
CMS2-3

Planned analysis, assumption validations, and Risk/Opportunities:

1. HUR ventilation analysis
2. Verify activity level of the hydrogen in the HUR.
3. Evaluate need for blow out panel on an external wall.

Mitigated Consequences:

Radiological	Chemical	ODH (Note 3)
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:

1. The impact to the facility worker (Onsite 1 receptor) is from radiological consequences only as the deflagration is a SIH.
2. The approach for STS will be similar to FTS. From FTS, this utility room is designated as a Class 1, Division 2, Group B, hazardous location in accordance with NFPA 70. The NFPA 70 basis for this designation is a location "in which volatile flammable liquids or flammable gases are handled, processed, or used, but in which the liquids, vapors, or gases will normally be confined within closed containers or closed systems from which they can escape only in case of accidental rupture or breakdown of such containers or systems, or in case of abnormal operation of equipment." Instrument and electrical connections inside the control room next to the HUR are of a hydrogen-safe design per NFPA 70. Valve operators are pneumatic and employ non-incentive controls.
   A pump, which is not listed for use in Class 1, Division 2, Group B, classified locations, in accordance with NFPA 70, is being utilized in the utility room. To offset the lack of classification both the 269cfm mechanical ventilation system and one of the 8,000 cfm rooftop ventilators operate continuously, which essentially allows the area to be considered an electrically Unclassified area in accordance with NFPA 497, Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Area. The continuous operation of these two fans provides adequate explosion prevention by combustible concentration reduction.
   However, for STS the potential for hydrogen accumulation should be limited to the HUR. The control room should not have any requirements for hydrogen safe design.
3. ODH consequences are considered a SIH.
4. This event may have to be reevaluated based on the final location of the HUR.

Mitigated Frequency
<u>U</u>

Event Number
CMS2-4

Event Description:
Breach of hydrogen piping to the cryogenic moderator system allows hydrogen to escape to the High Bay area. Hydrogen accumulates in concentrations greater than the LEL in air resulting in a detonation releasing trace quantities of tritium or activated particulates contained in the hydrogen. (See Note 2 and Planned Analysis Item 4)

Assumptions and Initial Conditions:
1. This event is assumed to be limited to a detonation. (IC)
2. Detonation could impact transient waste in the High Bay. (IC)
3. Detonation could impact process systems routed through the High Bay. (IC)
4. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF)
5. Transfer lines are vacuum jacketed from the core vessel to the HUR. (DF)

Causes:
1. Failure of the hydrogen piping due to corrosion.
2. Piping damaged during installation or maintenance.
3. Cracking at welds as the result of long-term vibration.
4. Release of hydrogen accompanied by spark from electrical equipment, friction, or unknown ignition source.
5. Crane drop on piping.
6. Maintenance operations or Maintenance worker error.

Initiating Event Frequency
U

Unmitigated Impact on Systems:
1. A hydrogen explosion in the High Bay could result in severe damage to equipment in the High Bay and surrounding areas.
2. It is unlikely that there would be a catastrophic impact on the core vessel.

Unmitigated Consequences

Radiological	**Chemical**	**ODH**
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent a hydrogen in the High Bay from resulting in a detonation and a significant release of radiological material.

Method of Detection:	
Hydrogen system monitoring instrumentation.	
Visual and Audible.	
Fire detection system.	
MPS Monitoring of the hydrogen system parameters (e.g., pressure and flow).	

Preventive Features – Attributes:	**Credited:**
Pipes carrying hydrogen are jacketed with vacuum. (DF)	
Hydrogen transfer lines designed to B31.3/B31.12. (DF)	
Transfer line routing and cover plates/physical protection. (Note 3) (DF)	
All welded transfer lines. (DF)	
Crane inspection and certification program. (AC)	

Event Number
CMS2-4

Mitigative Features – Attributes:	Credited:
High Bay volume and building ventilation system limit potential for accumulation of hydrogen in concentrations exceeding LEL. (DF)	
Target building structure minimizes the impact of the explosion on other areas of the facility. (DF)	
Emergency response procedures. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Evaluate potential hydrogen release quantities and high bay concentrations.
2. Evaluate hydrogen transfer lines to B31.3/B31.12.
3. Evaluate transfer line cover plates/physical protection and routing against crane drops or other impacts.
4. Determine which areas in the STS will need to be designed to meet the criteria listed in CMS2-4 or portions thereof.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Notes:

1. The impact to the facility worker (Onsite 1 receptor) is from radiological consequences only as the deflagration is a SIH.
2. Should the vacuum piping routing not be located in the high bay, this event will require reevaluation.
3. Hydrogen transfer lines between the Core Vessel and the HUR are located in trenches/recesses/protected with cover plates to prevent impact from operations or falling objects from damage to the transfer line leading to a release of hydrogen.

Mitigated Frequency
U

Event Number
CMS2-5a **(Event Deleted as the vacuum jacked makes the event BEU and no need to have 2 events)**

Event Description:
Breach of hydrogen piping in the target drive space above the core vessel and inside Target Drive Room allows hydrogen to escape. Hydrogen accumulates in concentrations greater than the LEL in air resulting in a detonation releasing trace quantities of tritium or activated particulates contained in the hydrogen, release of activated cooling water. A Target Drive Room roof failure onto the top of the core vessel and target drive motor is evaluated in CMS2-5b.

Assumptions and Initial Conditions:
1. Pockets of hydrogen could accumulate under shield blocks which are located above the core vessel. (IC)
2. This event could release activated cooling water as the result of damage to water lines in the area. (IC)
3. Loss of vacuum will cause overpressure in hydrogen system and venting though hydrogen system hydrogen safe vents. (IC)
4. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF)
5. Personnel are not permitted in the Target Drive Room during beam operation (AC/DF)
6. Transfer lines are vacuum jacketed from the core vessel to the HUR. (DF)

Causes:
1. Failure of the hydrogen piping due to corrosion.
2. Piping damaged weakening the piping during installation or maintenance.
3. Cracking at welds as the result of long-term vibration.
4. Release of hydrogen accompanied by spark from electrical equipment, friction, or unknown ignition source.

Initiating Event Frequency
U

Unmitigated Impact on Systems:
1. Potential for significant damage to equipment located in space above core vessel (e.g., target drive motor, water lines).
2. The energy associated with the detonation could cause a loss of core vessel integrity/atmosphere.
3. The energy associated with the detonation could cause a loss of target cooling and loss of target rotation (target impacts are covered in TS events, except core vessel Inerting cannot be assumed).

Unmitigated Consequences

Radiological	**Chemical**	**ODH**
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent a detonation in the target drive room from causing a significant release of radiological material.

Method of Detection:	
Hydrogen system monitoring instrumentation.	
CMS transfer line vacuum monitoring of loss of vacuum.	
MPS monitoring of the hydrogen system parameters (e.g., pressure and flow).	

Event Number CMS2-5a **(Event Deleted as the vacuum jacked makes the event BEU and no need to have 2 events)**	
Preventive Features – Attributes:	**Credited:**
Pipes carrying hydrogen are jacketed with vacuum (DF)	
Transfer line routing and cover plates/physical protection. (DF)	
Transfer lines are vacuum jacketed from the core vessel to the HUR. (DF)	
Hydrogen transfer lines designed to B31.3 or B31.12. (DF)	
Preventive maintenance program. (AC)	
Mitigative Features – Attributes:	**Credited:**
TPS Beam Trip on Loop 1 return flow. (EC)	
MPS Beam Trip on Loop 2 return flow. (EC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel. (EC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of power to the TPS panel. (EC)	
Target Drive Room T-Beams permits ventilation of the space (passive). (DF)	
Active ventilation of the Target Drive Room prevents a buildup of hydrogen in this space. (EC)	
Monitoring of the active ventilation for the Target Drive Room during operation and alarm in the Control Room. (EC)	
Shielding blocks and target building structure minimize the impact of the explosion on other areas of the facility (DF)	
Bulk shield liner designed to collect spilled liquid water. (DF)	
Combustible material control program. (AC)	
Alarm response procedures. (AC)	
Emergency response procedures. (AC)	
Worker training. (AC)	
Workers are not permitted in the Target Drive Room during beam operation. (AC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of monitored signal to the MPS panel. (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of power to the MPS panel. (EC)	
MPS beam trip system response to abnormal hydrogen parameters (e.g. pressure and flow) to mitigate consequences. (EC)	

<table>
<tr><td colspan="4">Event Number
CMS2-5a (Event Deleted as the vacuum jacked makes the event BEU and no need to have 2 events)</td></tr>
<tr><td rowspan="2">Planned analysis, assumption validations, and Risk/Opportunities:
1. Evaluate routing of hydrogen and water lines for protection from external impacts.
2. Evaluate hydrogen transfer lines to B31.3 or B31.12.
3. Analysis to determine the potential for cooling water getting out of the space under the Target Drive Room and into the high bay and verify consequences if released.</td><td colspan="3">Mitigated Consequences:</td></tr>
<tr><td>Radiological
Public: N/A
WG1: N/A
WG2: N/A</td><td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
<tr><td colspan="3">Notes:
1. The impact to the facility worker (Onsite 1 receptor) is from radiological consequences only.
2. The initial condition (design feature) that the transfer lines are vacuum jacketed from the core vessel to the HUR makes this event BEU, as it takes a double failure to release hydrogen in this space.</td><td>Mitigated Frequency
BEU</td></tr>
</table>

Event Number
CMS2-5

Event Description:
Breach of hydrogen piping in the target drive space above the core vessel and inside Target Drive Room allows hydrogen to escape. Hydrogen accumulates in concentrations greater than the LEL in air resulting in a detonation releasing trace quantities of tritium or activated particulates contained in the hydrogen, release of activated cooling water, and Target Drive Room roof to fall onto the top of the core vessel and target drive motor.

Assumptions and Initial Conditions:

1. Pockets of hydrogen could accumulate under shield blocks which are located above the core vessel. (IC)
2. This event could release activated cooling water as the result of damage to water lines in the area. (IC)
3. Loss of vacuum will cause overpressure in hydrogen system and venting though hydrogen system hydrogen safe vents. (IC)
4. Target Drive Room roof failure results in an immediate stoppage of target rotation and a breach of the core vessel boundary (at the lid). (IC)
5. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF)
6. Transfer lines are vacuum jacketed from the core vessel to the HUR. (DF)
7. Personnel are not permitted in the Target Drive Room during beam operation (AC/EC)

Causes:

1. Failure of the hydrogen piping due to corrosion.
2. Piping damaged weakening the piping during installation or maintenance.
3. Cracking at welds as the result of long-term vibration.
4. Release of hydrogen accompanied by spark from electrical equipment, friction, or unknown ignition source.

Initiating Event Frequency
U

Unmitigated Impact on Systems:

1. Potential for significant damage to equipment located in space above core vessel (e.g., target drive motor, water lines).
2. The energy associated with the detonation could cause a loss of core vessel integrity/atmosphere.
3. The energy associated with the detonation could cause a loss of target cooling and loss of target rotation (target impacts are covered in TS events, except core vessel Inerting cannot be assumed).
4. Damage to the target drive and target segments.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Moderate	**WG1**: N/A	**WG1**: N/A
WG2: Low	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent a detonation in the target drive room from causing a significant release of radiological material.

Method of Detection:	
Hydrogen system monitoring instrumentation.	
CMS transfer line vacuum monitoring of loss of vacuum.	
MPS monitoring of the hydrogen system parameters (e.g., pressure and flow).	

Event Number
CMS2-5

Preventive Features – Attributes:	Credited:
Pipes carrying hydrogen are jacketed with vacuum. (DF)	
Transfer line routing and cover plates/physical protection. (Note 3) (DF)	
Transfer lines are vacuum jacketed from the core vessel to the HUR. (DF)	X
Hydrogen transfer lines designed to B31.3 or B31.12. (DF)	
Preventive maintenance program. (AC)	

Mitigative Features – Attributes:	Credited:
TPS Beam Trip on Loop 1 return flow. (EC)	
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS Beam Trip on Loop 2 return flow. (EC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel. (EC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of power to the TPS panel. (EC)	
Target Drive Room T-Beams permits ventilation of the space (passive). (DF)	
Active ventilation of the Target Drive Room prevents a buildup of hydrogen in this space. (EC)	
Monitoring of the active ventilation for the Target Drive Room during operation and alarm in the Control Room. (EC)	
Shielding blocks and target building structure minimize the impact of the explosion on other areas of the facility. (DF)	
Bulk shield liner designed to collect spilled liquid water. (DF)	
Combustible material control program. (AC)	
Alarm response procedures. (AC)	
Emergency response procedures. (AC)	
Worker training. (AC)	
Workers are not permitted in the Target Drive Room during beam operation. (AC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of monitored signal to the MPS panel. (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of power to the MPS panel. (EC)	
MPS beam trip system response to abnormal hydrogen parameters (e.g. pressure and flow) to mitigate consequences. (EC)	

Event Number
CMS2-5

Planned analysis, assumption validations, and Risk/Opportunities:

1. Evaluate routing of hydrogen and water lines for protection from external impacts.
2. Evaluate hydrogen transfer lines to B31.3 or B31.12.
3. Analysis to determine the potential for cooling water getting out of the space under the Target Drive Room and into the high bay and verify consequences if released.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1:** N/A **WG2:** N/A	**Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:

1. The impact to the facility worker (Onsite 1 receptor) is from radiological consequences only.
2. The initial condition (design feature) that the transfer lines are vacuum jacketed from the core vessel to the HUR makes this event BEU, as it takes a double failure to release hydrogen in this space.
3. Hydrogen transfer lines between the Core Vessel and the HUR are located in trenches/recesses/protected with cover plates to prevent impact from operations or falling objects from damage to the transfer line leading to a release of hydrogen.

Mitigated Frequency Prevented

Event Number CMS2-6					
Event Description: Compressed hydrogen bottle leaks or ruptures allowing hydrogen to accumulate in the hydrogen utility room (HUR) in concentrations greater than the LEL in air, is inadvertently ignited and explodes.					
Assumptions and Initial Conditions: 1. This event assumes that the hydrogen bottles are located in the Hydrogen Utility Room. (HUR). (IC) 2. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF) 3. HUR in STS located in a location away from radiological material and outside of high bay crane travel either in the Target Building or in an annex. (IC) 4. Gas cabinet purge and backfill system with no system “top off of hydrogen” during operation. (DF/AC) 5. Released hydrogen is exhausted with the air in the HUR to atmosphere via the vent stack. (DF)		**Causes**: 1. Gas bottle valve failure. 2. Operator error.			**Initiating Event Frequency** **A**
Unmitigated Impact on Systems:		**Unmitigated Consequences**			
		Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A		**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Prevent a release of hydrogen from hydrogen supply bottles in the hydrogen utility room (HUR) in concentrations greater than the LEL in air.					
Method of Detection:					
Preventive Features – Attributes:					**Credited:**
Hydrogen bottles are located outside the building. (DF)					

Event Number
CMS2-6

Mitigative Features – Attributes:	Credited:
The number of hydrogen bottles permitted in the HUR are limited to required for operation with no additional bottles stored in the HUR. (AC)	
Hydrogen gas bottles are handled in accordance with ORNL procedures and practices. (AC)	
Operating Procedures and Training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
	A

Event Number CMS2-7 (**Event deleted as redundant with CMS 2-1)**
Event Description: Breach of Cryogenic Moderator vessel or associated piping in the core vessel allows hydrogen to escape into the surrounding area within the core vessel. The core vessel vacuum vent system draws hydrogen from the core vessel into vacuum vent system to the roughing pump in concentrations greater than the LEL leading to a detonation at the roughing pump releasing trace quantities of tritium or activated particulates contained in the hydrogen.

Event Number
CMS3-1

Event Description:
Breach of hydrogen piping to cryogenic moderator system allows hydrogen to escape to the High Bay area releasing trace quantities of tritium and activated particulates contained in the hydrogen. (See Note 1)

Assumptions and Initial Conditions:
1. HUR in STS located in a location away from radiological material and outside of high bay crane travel either in the Target Building or in an annex. (DF)
2. There is no deflagration or explosion that follows the hydrogen piping breach. (IC)
3. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF)
4. Transfer lines are vacuum jacketed from the core vessel to the HUR. (DF)

Causes:
1. Failure of the hydrogen piping due to corrosion.
2. Piping damage during installation or maintenance.
3. Cracking at welds as the result of long-term vibration.
4. Crane drop.
5. Piping impacted by crane or crane load.
6. Maintenance operation or error while working on other equipment in the high bay.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Damage to cryogenic moderator system piping could be major.
2. Core vessel Vacuum and helium supply systems could be adversely impacted.
3. Damage to target support systems
4. Decontamination may be needed in the High Bay Area.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
None as there is negligible release of hazardous material.

Method of Detection:	
Hydrogen system monitoring instrumentation.	
CMS transfer line vacuum monitoring for loss of vacuum.	
MPS Monitoring of the hydrogen system parameters (e.g., pressure and flow).	
Loss of hydrogen system pressure detected by instrumentation.	

Preventive Features – Attributes:	**Credited:**
Pipes carrying hydrogen are jacketed with vacuum. (DF)	
Hydrogen transfer lines designed to ASME B31.3.B31/12. (DF)	
Transfer line routing and cover plates/physical protection. (Note 3) (DF)	
Crane inspection and certification program. (AC)	
Hoisting and rigging program. (AC)	
Restrictions on crane travel and heavy equipment/material lifted in the vicinity of hydrogen piping. (See Note 2) (AC)	

Event Number
CMS3-1

Preventive Features (Continued) – Attributes:	Credited:
Operating Procedures and Training. (AC)	
Maintenance procedures and Training. (AC)	

Mitigative Features – Attributes:	Credited:
Transfer line design with vacuum jacket and design to ASME B31-3. (DF)	
High Bay volume and building ventilation system limit potential for accumulation of hydrogen in concentrations exceeding LFL. (DF/EC)	
Emergency response procedures. (AC)	
Worker training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:
1. Evaluate potential hydrogen release quantities and high bay concentrations.
2. Evaluate hydrogen transfer lines cover plates/physical protection and routing against crane drop.
3. Evaluate hydrogen transfer lines to B31.3/B31.12.
4. Determine which areas in the STS will need to be designed to meet the criteria listed in CMS1-2 or portions thereof.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:
1. Should the vacuum piping routing not be located in the high bay, this event will require reevaluation.
2. The load permitted will be limited by the protection for the transfer line routing and cover plates/physical protection.
3. Hydrogen transfer lines between the Core Vessel and the HUR are located in trenches/recesses/protected with cover plates to prevent impact from operations or falling objects from damage to the transfer line leading to a release of hydrogen.

Mitigated Frequency
A

Event Number
CMS3-2

Event Description:
Breach of hydrogen piping in Hydrogen Utility Room (HUR) allows hydrogen to escape to the room releasing trace quantities of tritium and activated particulates contained in the hydrogen to the room which stays below LFL and LEL in air.

Assumptions and Initial Conditions	Causes	Initiating Event Frequency
1. HUR in STS located in a location away from radiological material and outside of high bay crane travel either in the Target Building or in an annex. (IC) 2. Gas cabinet purge and backfill system with no system “top off of hydrogen” during operation. (DF/AC) 3. There is no significant accumulation of hydrogen. (IC) 4. There is no deflagration or detonation that follows the hydrogen piping breach. (IC) 5. Released hydrogen is exhausted with the air in the HUR to atmosphere via the vent stack. (DF) 6. Transfer lines are vacuum jacketed.. (IC) 7. Hydrogen is vented prior to maintenance operations in this space. (IC) 8. The HUR will be designated as a Class 1, Division 2, Group B, hazardous location in accordance with NFPA 70. (See Note 2) (DF) 9. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF)	1. Failure of the hydrogen piping due to corrosion. 2. Piping damaged during installation or maintenance. 3. Cracking at welds as the result of long-term vibration.	**U**

Unmitigated Impact on Systems	Unmitigated Consequences: Radiological	Chemical	ODH
1. Loss of cryogenic moderator	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
None as there is negligible release of hazardous material.

Method of Detection:	
Loss of hydrogen pressure in cryogenic moderator system detected by monitoring instrumentation in hydrogen handling system.	
CMS transfer line vacuum monitoring for loss of vacuum.	
MPS Monitoring of the hydrogen system parameters (e.g., pressure and flow).	

Preventive Features – Attributes:	Credited:
System and piping design; Certain lines carrying hydrogen are jacketed with vacuum. (DF)	
Maintenance procedures. (AC)	
Operating Procedures and Training. (AC)	
Hydrogen piping designed to B31.3/B31.12. (DF)	

Event Number
CMS3-2

Mitigative Features – Attributes:	Credited:
Hydrogen Utility Room atmosphere hydrogen sensor detects low concentrations of hydrogen (below LFL). (EC)	
Hydrogen system piping in HUR designed to B31.3/B31.12. (DF)	
Forced ventilation dilutes and removes hydrogen. (EC)	
Pressure monitoring system to detect a leak of hydrogen. (EC)	
Controlled access to Hydrogen Utility Room. (EC)	
Emergency response procedures. (AC)	
Worker training. (AC)	
Hydrogen Utility Room will be designed to meet Class 1, Division 2, Group B, hazardous location in accordance with NFPA 70. (See Note 2) (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:
1. Ventilation analysis for HUR.
2. Analysis to determine O_2 levels in the area after Hydrogen release. ODH concern is considered a SIH.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:
1. The impact to the facility worker (Onsite 1 receptor) is from radiological consequences only as the deflagration is a SIH.
2. The approach for STS will be similar to FTS. From FTS, this utility room is designated as a Class 1, Division 2, Group B, hazardous location in accordance with NFPA 70. The NFPA 70 basis for this designation is a location "in which volatile flammable liquids or flammable gases are handled, processed, or used, but in which the liquids, vapors, or gases will normally be confined within closed containers or closed systems from which they can escape only in case of accidental rupture or breakdown of such containers or systems, or in case of abnormal operation of equipment." Instrument and electrical connections inside the control room next to the HUR are of a hydrogen-safe design per NFPA 70. Valve operators are pneumatic and employ non-incentive controls.
   A pump which is not listed for use in Class 1, Division 2, Group B, classified locations, in accordance with NFPA 70, is being utilized in the utility room. To offset the lack of classification both the 269cfm mechanical ventilation system and one of the 8,000 cfm rooftop ventilators operate continuously, which essentially allows the area to be considered an electrically Unclassified area in accordance with NFPA 497, Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Area. The continuous operation of these two fans provides adequate explosion prevention by combustible concentration reduction.
   However, for STS the potential for hydrogen accumulation should be limited to the HUR. The control room should not have any requirements for hydrogen safe design.

Mitigated Frequency
A

Event Number CMS3-4					
Event Description: Breach in cryogenic moderator system due to over-pressurization or high temperature condition. Release of hydrogen containing trace quantities of tritium and activated particulates into the Core Vessel. The gaseous material is pulled out of the core vessel through the core vessel exhaust system and the activated water drains into the core vessel drain system.					
Assumptions and Initial Conditions: 1. Breach caused by overpressure condition or melting of moderator vessel due to over-temperature condition. (IC) 2. Inert Core Vessel with either vacuum or helium. (IC) 3. No deflagration or detonation in the core vessel or in the vent lines. (IC) 4. Pressure rating of each system makes this event BEU. (DF) 5. Beam is on for this event. (IC) 6. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF)		**Causes**: 1. Loss of hydrogen flow in cryogenic moderator results in stagnant hydrogen in moderator vessel (due to loss of power or failure of hydrogen circulators). 2. Loss of Helium refrigerator in cryogenic moderator system (due to loss of power, motor seizing, or leak in helium refrigeration system).			**Initiating Event Frequency** **BEU**
Unmitigated Impact on Systems: 1. Moderator Reflector Assembly replacement needed. 2. Recovery time (including operational verification that the system is safe to operate) to restore normal operation. 3. Removing water from the bottom of the Core Vessel and vessel drain system. 4. Loss of cryogenic moderator.			**Unmitigated Consequences**		
			Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Prevent a loss of cooling or circulation of hydrogen moderator from leading to a release of significant quantities of radiological material.					
Method of Detection:					
Hydrogen pressure indication.					
CMS transfer line vacuum monitoring for loss of vacuum.					
Core Vessel Pressure monitoring.					
MPS Monitoring of the hydrogen system parameters (e.g., pressure and flow).					
Reflector water (Loop 2) flow, pressure, or temperature instrumentation.					
Preventive Features – Attributes:					**Credited:**
MPS beam trip on loss of power or refrigeration system out of limits prevents overheating (trip on turbine running signal). (EC)					
Rupture disk and relief valve to relieve Hydrogen to hydrogen safe vent. (EC)					
Rupture disk to relieve vacuum space to hydrogen safe vent. (DF/EC)					
Hydrogen vessel design. (DF)					
Hydrogen transfer line design to B31.3/B31.12. (DF)					

Event Number CMS3-4	
Mitigative Features – Attributes:	**Credited:**
Core Vessel Liquid Detection Probe. (EC)	
Hydrogen burst disk and venting via hydrogen safe vent. (EC)	
Vacuum system burst disk and venting. (EC)	
Vacuum jacket and transfer line design for venting. (DF)	
Core vessel vent to stack. (DF)	
Cryogenic Moderator system venting design. (DF)	
Cryogenic system operating procedures. (AC)	
Emergency response procedures. (AC)	
Trained operators. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Determine activation level of the Loop 2 water. 2. Determine activation level of the hydrogen (activation products in hydrogen). 3. Hydrogen venting analysis.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency BEU**
1. The burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. 2. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.	

Event Number
CMS3-5

Event Description:
Loss of or reduction of Loop 2 pre-moderator/reflector water flow results in overheating and boiling of pre-moderator/reflector water and breach of reflector vessel releasing water to core vessel. Inner wall may also fail resulting in loss of insulating vacuum for moderator and transfer line.

Assumptions and Initial Conditions:
1. A vacuum layer surrounds the hydrogen vessel and serves as insulation between the cold hydrogen (20 degrees K) and the pre-moderator/reflector (Loop 2) water. (DF)
2. The proton beam remains on, heating the pre-moderator/reflector. (IC)
3. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF)

Causes:
1. Local loss of power results in pre-moderator/reflector (Loop 2) water circulation pump being de-energized.
2. Circulation pump failure.
3. Valve error.
4. Plugged water piping.
5. Plugged water outlet results in lowered flow.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Reflector vessel leaks into the core vessel.
2. Hydrogen vents due to heat load from loss of vacuum if inner wall fails.
3. Moderator Reflector Assembly replacement needed.
4. Recovery time (including operational verification that the system is safe to operate) to restore normal operation.
5. Removing water from the bottom of the Core Vessel.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent a loss of pre-moderator/reflector cooling water from leading to a moderator failure with release of radiological material.

Method of Detection:	
CMS transfer line vacuum monitoring loss of vacuum.	
Core Vessel liquid detection probe.	
Vacuum pump status.	
Reflector water (Loop 2) flow, pressure, and temperatures.	
Loop 2 System indicators and alarms.	

Preventive Features – Attributes:	**Credited:**
System valve alignment procedures (AC)	
Redundant Loop 2 circulation pumps (DF)	

Event Number
CMS3-5

Mitigative Features – Attributes:	Credited:
Core vessel leak collection system. (DF)	
Transfer line and vacuum jacket designed for venting after moderator failure. (DF)	
Core vessel vent. (DF)	
Loop 2 condition monitoring (flow, temperature, pressure). (AC)	
Emergency response procedures. (AC)	
Worker training. (AC)	
Core Vessel Liquid Detection Probe. (EC)	
MPS Beam trip for abnormal Loop 2 flow. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Determine activation level of the Loop 2 water.
2. Determine activation level of the hydrogen.
3. Hydrogen venting analysis.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:

Mitigated Frequency
A

Event Number CMS3-6				
Event Description: Refrigeration heaters in the cryogenic moderator system fail to energize when the proton beam shuts down, or refrigeration heaters fail with proton beam shut down. H2 freezes in cryogenic moderator system heat exchanger blocking H2 flow; beam power is restored. Without H2 flow, moderator vessel ruptures due to pressure. Hydrogen is vented through the hydrogen safe vent system.				
Assumptions and Initial Conditions: 1. Inert core vessel atmosphere with helium or vacuum mode of core vessel operation. (IC) 2. No detonation or deflagration is assumed in the core vessel or vents. (IC) 3. Vacuum vessel is designed to contain a moderator vessel failure and hydrogen release. (DF) 4. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF) 5. Transfer lines are vacuum jacketed from the core vessel to the HUR. (DF)	**Causes**: 1. Local loss of power. 2. Mechanical or electrical failure of circulator. 3. Proton beam to refrigeration heater interlock failure.			**Initiating Event Frequency** **U**
Unmitigated Impact on Systems: 1. Major damage to cryogenic moderator. 2. Loss of hydrogen flow causes pressure rise above 19 bar and hydrogen release through hydrogen and moderator vacuum hydrogen safe vent. 3. If core vessel pressure exceeds 1.5 bar, hydrogen will vent through core vessel hydrogen safe vent. 4. Leakage of hydrogen into the vacuum space and bursts the rupture disk. 5. Moderator Reflector Assembly must be replaced. 6. Recovery time required to remove damaged components, replace MRA and hydrogen, and to restore normal operating conditions.	**Unmitigated Consequences** **Radiological** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A		**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Prevent a refrigeration system failure from leading to a release of radiological material.				
Method of Detection:				
CMS transfer line vacuum monitoring loss of vacuum.				
Refrigeration heater status indicators and alarms.				
Hydrogen system instrumentation.				
Helium refrigeration system instrumentation.				
Preventive Features – Attributes:				**Credited:**
Hydrogen system control system. (EC)				
Helium refrigeration heaters. (DF)				
Preventive maintenance program for the refrigeration controls. (AC)				
Helium system control system. (EC)				

Event Number
CMS3-6

Mitigative Features – Attributes:	Credited:
Hydrogen system control system. (EC)	
Vacuum system vent system. (DF)	
Hydrogen safe vent system (rupture disk and relief valves). (DF)	
Emergency response procedures. (AC)	
Worker training. (AC)	
MPS beam trip system response to abnormal hydrogen parameters (e.g., pressure and flow) to mitigate consequences. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
1.	**U**

Event Number
CMS3-7

Event Description:
Failure of cryogenic moderator hydrogen circulators with the proton beam on over pressurizes the hydrogen and the hydrogen relieve valves and rupture disk fail causing the hydrogen vessel to fail. Hydrogen gas enters the vacuum insulating space and pressure builds up causing hydrogen to vent through the vacuum space rupture disk.

Assumptions and Initial Conditions: 1. Inert core vessel atmosphere with helium or vacuum mode of core vessel operation. (IC) 2. No detonation or deflagration is assumed in the core vessel or vents. (IC) 3. Hydrogen vents through hydrogen safe vent if pressure in vacuum space exceeds 2 bar. (DF) 4. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF) 5. Transfer lines are vacuum jacketed from the core vessel to the HUR. (DF)	**Causes**: 1. Local loss of power 2. Mechanical or electrical failure of circulator.		**Initiating Event Frequency** **EU**
Unmitigated Impact on Systems: 1. Major damage to cryogenic moderator. 2. Loss of hydrogen flow causes pressure rise above 19 bar and hydrogen release through hydrogen and moderator vacuum hydrogen safe vent. 3. Moderator Reflector Assembly plug must be replaced. 4. Recovery time required to remove damaged components, replace MRA and hydrogen, and to restore normal operating conditions.	**Unmitigated Consequences** **Radiological** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent a failure of cryogenic moderator hydrogen circulators from leading to a release of radiological material.

Method of Detection:	
Circulator status indicators and alarms	
Hydrogen temperature and pressure	
CMS transfer line vacuum monitoring loss of vacuum	
Refrigeration system instrumentation	
MPS Monitoring of the hydrogen system parameters (e.g. pressure and flow)	
Preventive Features – Attributes:	**Credited:**
Hydrogen rupture disks. (DF/EC)	
Hydrogen relief valves. (DF/EC)	
Preventive maintenance program for the circulators to support normal operation. (AC)	

Event Number
CMS3-7

Mitigative Features – Attributes:	**Credited:**
Hydrogen relief valves. (DF/EC)	
Hydrogen rupture disks. (DF/EC)	
Emergency response procedures. (AC)	
Worker training. (AC)	
MPS beam trip system response to abnormal hydrogen parameters (e.g., pressure and flow) to mitigate consequences. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1.	**Radiological** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. Failure of the circulator along with a relief valve failure is a double failure. Because the relief valve failure could exist prior to the circulator failure, this event is only EU and not BEU. 2. Replacement of the MRA requires removal of three target segments, as well as the shield blocks over both the target segments and the MRA.	**EU**

Event Number
CMS4-1

Event Description:
Water leak from premoderator freezes on moderator and builds up causing moderator failure and release of activated water and hydrogen into core vessel with trace quantities of tritium or activated particulates contained in the hydrogen.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. Inert core vessel in helium or vacuum mode. (IC) 2. Hydrogen safe vent systems. (DF/IC) 3. No deflagration or detonation of the hydrogen in the Core Vessel or in the Vessel Vent system. (IC) 4. Pre-moderator/reflector (Loop 2) water could be heavily tritiated. (IC) 5. Hydrogen and gaseous material is vented from the Core Vessel via the Core Vessel vacuum system. (IC) 6. Released water is captured in the bottom of the Core Vessel and flows into the STS Core Vessel leak handling system. (IC) 7. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF) 8. Core vessel drain is normally closed during beam operation. (IC)	1. Failure of the premoderator due to corrosion. 2. Premoderator damaged during installation or maintenance. 3. Cracking at welds as the result of long-term vibration.	**A**

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. Moderator Reflector Assembly replacement needed. 2. Recovery time (including operational verification that the system is safe to operate) to restore normal operation. 3. Removing water from the bottom of the Core Vessel.	**Public**: Negligible **WG1**: Low **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent workers from receiving a significant dose from being in the region of the core vessel drain system during operation or during a drain.

Method of Detection:	
Loss of hydrogen pressure in cryogenic moderator system detected by monitoring instrumentation in hydrogen handling system/ accumulator bellows motion.	
Pressure and concentration (RGA) monitoring in core vessel environment.	
CMS transfer line vacuum monitoring loss of vacuum.	
Core vessel liquid detection probe.	
MPS Monitoring of the hydrogen system parameters (e.g., pressure and flow).	

Event Number
CMS4-1

Preventive Features – Attributes:	**Credited:**
Hydrogen transfer lines designed to ASME B31.3/B31.12. (DF)	
Moderator Reflector Assembly Design. (DF)	
Maintenance procedures and Training. (AC)	

Mitigative Features – Attributes:	**Credited:**
Confinement capability of the core vessel at pressures less than 1.5 atmosphere (gage pressure). (DF)	
Core vessel liquid detection probe. (EC)	
MPS beam trip system response to abnormal hydrogen parameters (e.g., pressure and flow) to mitigate consequences. (EC)	
Collection of Water by the Core Vessel and Core Vessel Drain (DF)	
Core Vessel Drain Line Liquid Detection Probe (EC) • Alarm in Control Room on detection of a leak in the Core Vessel Drain line (EC) • MPS trip on High Level in the Core Vessel Drain line (EC) • TPS beam trip on high-high level in the Core Vessel Drain line r (EC)	
Pressure monitoring system to detect a leak of hydrogen. (EC)	
PPS secures the rooms near the core vessel in the region of the core vessel drain system. (EC)	
Moderator design. (DF)	
Emergency response procedures. (AC)	
Preventive maintenance program. (AC)	
Alarm response procedures. (AC)	
Operating Procedures and Training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:
1. Determine activation level of water in Loop 2.
2. Verify core vessel water response actions.

Mitigated Consequences:

Radiological	**Chemical**	**ODH**
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:
1. Consequences of gaseous releases are covered by event CMS3-1.
2. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.

Mitigated Frequency
A

Event Number
CMS4-2

Event Description:
Rotating target strikes reflector and causes moderator vessel failure with release of hydrogen and activated water into core vessel with trace quantities of tritium or activated particulates contained in the hydrogen leading to a potential direct exposure to a worker from higher than anticipated water activation in the drain line.

Assumptions and Initial Conditions	Causes	Initiating Event Frequency
1. Inert core vessel in helium or vacuum mode. (IC) 2. Hydrogen safe vent systems. (IC) 3. No deflagration or detonation of the hydrogen in the Core Vessel or in the Vessel Vent system. (IC) 4. Pre-moderator/reflector (Loop 2) water could be heavily tritiated. (IC) 5. Hydrogen and gaseous material is vented from the Core Vessel via the Core Vessel vacuum system. (IC) 6. Released water is captured in the bottom of the Core Vessel and flows into the STS Core Vessel leak handling system. (IC) 7. Hydrogen vessels are buried in the reflector with two layers of aluminum and the beryllium reflector preventing any contact. (DF) 8. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF) 9. Core vessel drain is normally closed during beam operation. (IC)	1. Mechanical failure of the target rotating system due to vibration or fabrication error. 2. Installation error. 3. Maintenance operations. 4. Maintenance worker error.	U

Unmitigated Impact on Systems	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. Hydrogen leak. 2. Impacts common with CM2-1a.	**Public**: Negligible **WG1**: Low **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent workers from receiving a significant dose from being in the region of the core vessel drain system during operation or during a drain.

Method of Detection:	
Loss of hydrogen pressure in cryogenic moderator system detected by monitoring instrumentation in hydrogen handling system/ accumulator bellows motion.	
Pressure monitoring in core vessel environment.	
CMS transfer line vacuum monitoring loss of vacuum.	
Core vessel liquid detection probe.	
Target rotation measurement.	
MPS Monitoring of the hydrogen system parameters (e.g., pressure and flow).	
Beam on Target Imaging System.	

Event Number CMS4-2	
Preventive Features – Attributes:	**Credited:**
Reflector and shielding design with adequate clearance. (DF)	
Mitigative Features – Attributes:	**Credited:**
Pressure monitoring system to detect a leak of hydrogen. (EC)	
MPS beam trip system response to abnormal hydrogen parameters (e.g., pressure and flow) to mitigate consequences. (EC)	
Core vessel liquid detection probe. (EC)	
PPS secures the rooms near the core vessel and in the region of the core vessel drain system. (EC)	
Collection of Water by the Core Vessel and Core Vessel Drain Line (DF)	
Core Vessel Drain LIne Liquid Detection Probe (EC) • Alarm in Control Room on detection of a leak in the Core Vessel Drain Line (EC) • MPS trip on High Level in the Core Vessel Drain Line r (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line (EC)	
Confinement capability of the core vessel at pressures less than the Core Vessel Burst Disk design pressure. (DF)	
Reflector and shielding design with adequate clearance. (DF)	
Moderator Reflector Assembly design. (DF)	
Emergency response procedures. (AC)	
Preventive maintenance program. (AC)	
Alarm response procedures. (AC)	
Operating Procedures and Training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Determine activation level of water in Loop 2. 2. Verify core vessel water response actions. 3. Tolerance stack-up analysis for target and Moderator Reflector Assembly. 4. Evaluate if shielding and reflector design protects moderators so any contact would be expected to be on the shielding and not the moderators.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Event Number CMS4-2	
Notes: 1. Consequences of gaseous releases are covered by event CMS3-1. 2. Consequences of a Hydrogen leak with detonation have consequences and Impacts common with CMS2-1. 3. Consequences of a Hydrogen leak with deflagration have consequences and Impacts common with CMS1-1. 4. The burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. 5. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.	**Mitigated Frequency** U

Event Number
CMS4-3

Event Description:
The ortho-para converter screen/filter fails and allows the Fe_2O_3 catalyst powder to escape into the circulating hydrogen.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Fe_2O_3 powder can be transported into the moderator vessel, become activated by neutrons, and then flow back out to an unshielded area. (IC) 2. Accumulation of activated iron in unshielded location could lead to high radiation levels in area occupied by workers. If not detected promptly, a worker could receive >25 rem external radiation dose in less than 8 hours. (IC) 3. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF)	1. Improper installation or manufacture of the screen/filter components. 2. Screen and/or filter fails in service.	**A**

Unmitigated Impact on Systems:
1. The moderator loop could require clean-out or replacement.
2. Radiation levels in unshielded area could increase.
3. Accumulation of Fe_2O_3 could change flow resistance or functioning of flow control elements.

Unmitigated Consequences

Radiological	**Chemical**	**ODH**
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Moderate	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent Fe_2O_3 from escaping from the ortho-para converter.

Method of Detection:	
Radiation surveys may detect increased radiation levels in unshielded places.	
CMS process signals indicate abnormal flow or pressure.	
MPS Monitoring of the hydrogen system parameters (e.g., pressure and flow).	

Preventive Features – Attributes:	**Credited:**
Robust design of ortho-para converter with screen and filter to retain the Fe_2O_3 powder. (DF)	X
Ortho-para converter screen and filter installation surveillance procedures. (AC)	X

Event Number CMS4-3	
Mitigative Features – Attributes:	**Credited:**
Periodic RCT area radiation surveys. (AC)	
Radiological control procedures. (AC)	
Moderator design. (DF)	
Hydrogen loop design. (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Determine the physically plausible extent of Fe_2O_3 transport around the CMS loop. 2. Evaluate, informed by results of Item 1, whether Fe_2O_3 powder accumulations could interfere with functioning of flow control elements in the CMS loop (pumps, valves, etc.). 3. Determine expected levels of activation if Fe_2O_3 was transported around the loop and determine if it can be transported to the MRA..	**Radiological** **Public**: N/A **WG1**: N/A **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency Prevented**
1. Pending the outcome of planned analyses, the ability of this hypothetical event to cause the harms listed above could be shown to be BDB in which case it would not be necessary to credit the robust filter screen design. 2. Neutronics needs to be consulted to determine if the Fe_2O_3 activation during transport around the loop can be effectively calculated. If it is not feasible to calculate the activation level, then the conservative assumption will stand. 3. If planned analysis 3 above determines that the consequences could be higher than assumed, then if a method of detection is needed.	

Event Number CMS4-4				
Event Description: Inadequate purging of the cryogenic moderator system leaves oxygen/nitrogen in the system. Following the hydrogen fill, the oxygen/nitrogen freezes and "acts like grains of sand" settling in the lowest point of the CMS (i.e., Moderator Vessel) leading to vessel failure.				
Assumptions and Initial Conditions: 1. Inert core vessel in helium or vacuum mode. (IC) 2. Hydrogen safe vent systems. (DF/IC) 3. No deflagration or detonation of the hydrogen in the Core Vessel or in the Vessel Vent system. (IC) 4. Pre-moderator/reflector (Loop 2) water could be heavily tritiated. (IC) 5. Hydrogen and gaseous material is vented from the Core Vessel via the Core Vessel vacuum system. (IC) 6. Released water is captured in the bottom of the Core Vessel and flows into the STS Core Vessel leak handling system. (IC) 7. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF) 8. Core vessel drain is normally closed during beam operation. (AC/IC)	**Causes**: 1. Failure of the premoderator due to corrosion. 2. Premoderator damaged during installation or maintenance. 3. Cracking at welds as the result of long-term vibration.			**Initiating Event Frequency** **A**
Unmitigated Impact on Systems: 1. Moderator Reflector Assembly replacement needed. 2. Recovery time (including operational verification that the system is safe to operate) to restore normal operation. 3. Removing water from the bottom of the Core Vessel.	**Unmitigated Consequences**			
	Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible		**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Prevent workers from receiving a significant dose from being in the region of the core vessel drain system during operation or during a drain.				
Method of Detection:				
Loss of hydrogen pressure in cryogenic moderator system detected by monitoring instrumentation in hydrogen handling system/ accumulator bellows motion.				
Pressure and concentration (RGA) monitoring in core vessel environment.				
CMS transfer line vacuum monitoring loss of vacuum.				
Core vessel liquid detection probe.				
MPS Monitoring of the hydrogen system parameters (e.g., pressure and flow).				

Event Number
CMS4-4

Preventive Features – Attributes:	Credited:
Hydrogen transfer lines designed to ASME B31.3/B31.12. (DF)	
Moderator Reflector Assembly Design. (DF)	
CMS purge and fill procedures. (AC)	
Maintenance procedures and Training. (AC)	

Mitigative Features – Attributes:	Credited:
Confinement capability of the core vessel at pressures less than the Core Vessel Burst Disk design pressure. (DF)	
Core vessel liquid detection probe. (EC)	
MPS beam trip system response to abnormal hydrogen parameters (e.g., pressure and flow) to mitigate consequences. (EC)	
Collection of Water by the Core Vessel and Core Vessel Drain LIne(DF)	
Core Vessel Drain Line Liquid Detection Probe (EC) • Alarm in Control Room on detection of a leak in the Core Vessel Drain Line (EC) • MPS trip on High Level in the Core Vessel Drain Line (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line (EC)	
Pressure monitoring system to detect a leak of hydrogen. (EC)	
PPS secures the rooms near the core vessel and in the region of the core vessel drain system. (EC)	
Moderator design. (DF)	
Emergency response procedures. (AC)	
Preventive maintenance program. (AC)	
Alarm response procedures. (AC)	
Operating Procedures and Training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:
1. Determine activation level of water in Loop 2.
2. Verify core vessel water response actions.

Mitigated Consequences:		
Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Event Number CMS4-4	
Notes: 1. Consequences of gaseous releases are covered by event CMS3-1. 2. The burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. 3. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.	**Mitigated Frequency** **A**

Event Number
CMS5-1

Event Description:
Breach of either the helium or hydrogen in piping in Hydrogen Utility Room (HUR) allows cryogenic material to escape to the room creating a rapid ODH concern without a fire or detonation.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. HUR in STS located in a location away from radiological material and outside of high bay crane travel either in the Target Building or in an annex. (IC) 2. This event is assumed to not result in a deflagration. (IC) 3. All Helium piping in the HUR is vacuum jacketed and requires failure of two layers to escape. (DF) 4. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF)	1. Failure of the hydrogen or helium piping due to corrosion. 2. Piping damaged during installation or maintenance. 3. Cracking at welds as the result of long-term vibration. 4. Maintenance operations or Maintenance worker error.	EU

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH (Note 1)**
None	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: SIH **WG2**: SIH

Safety Function:
Prevent a release of cryogenic material from causing a rapid ODH hazard.

Method of Detection:	
CMS Monitoring of the hydrogen system parameters (e.g., pressure and flow).	
Increase in ventilation flow in the HUR on hydrogen detection.	
ODH sensor and alarm in the HUR. if required by ORNL SBMS and national consensus codes and standards.	
Hydrogen sensor and alarm in the HUR.	

Preventive Features – Attributes:	Credited:
Piping designed and built to ASME B31.3/B31.12. (DF)	
Maintenance procedures. (AC)	
Operating Procedures and Training. (AC)	

Event Number
CMS5-1

Mitigative Features – Attributes:	Credited:
ODH sensor to detect low O_2 levels and alarms for evacuation if required by ORNL SBMS and national consensus codes and standards. (EC)	
Hydrogen Utility Room atmosphere hydrogen sensor detects low concentrations of hydrogen (below LFL). (EC)	
Forced ventilation dilutes and removes hydrogen or helium. (EC)	
Pressure monitoring system to detect a leak of hydrogen or helium. (EC)	
Hydrogen Utility Room ventilation system. (DF)	
Controlled access to Hydrogen Utility Room. (AC)	
Emergency response procedures. (AC)	
Worker training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Determine the potential oxygen deficiency in this space and verify if credited controls are needed for the ventilation.
2. Ventilation analysis for HUR.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1:** N/A	**WG1:** SIH
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Notes:

1. ODH consequences are considered a SIH.

Mitigated Frequency
EU

Event Number
CMS7-1

Event Description:
Breach of Cryogenic Moderator vessel after an SDC-2 level seismic event which allows hydrogen to escape from the moderator vessel into the surrounding area within the core vessel. The Core vessel boundary fails and air at 1 bar enters the core vessel. Hydrogen accumulates in core vessel in concentrations greater than the LEL in air resulting in a detonation releasing a fraction of the activated target mass, reflector beryllium, and activated cooling water. The seismic event is assumed to cause a beam trip. (See Note 6)

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. Workers are assumed to evacuate buildings instinctively during earthquakes however, until they reach 100 m from the building, they are considered WG1 however, the egress path must be protected to permit evacuation. (IC) 2. Core vessel boundary seals fail and inert atmosphere is lost. (IC) 3. Monolith iron shielding and core vessel components position is retained by external concrete structure. (DF) 4. Most hydrogen vents through moderator transfer line due to loss of vacuum, but enough is released into the core vessel to detonate and cause target damage. (IC) 5. No follow-on fire results from this event. (IC) 6. The earthquake causes loss of the accelerator proton beam. (See Note 6) (DF) 7. Monolith stays intact and serves as target heat sink so decay heat cannot raise target temperature close to the 800 C threshold for a tungsten steam reaction. (IC/DF) 8. Potential for release of trace quantities of tritium or activated particulates contained in the hydrogen; pre-moderator/reflector (Loop 2) and reflector water could be heavily tritiated. (IC) 9. Active cooling or electric power are not needed for decay heat removal with the beam off. (DF/IC) 10. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF) 11. After loss of cooling with beam trip decay heat cannot raise target temperature to 800 C threshold for tungsten/steam reaction. (DF) 12. No spent core vessel components (e.g., target segment or MRA vessel) are storge in the High Bay. All similarly activated components with the potential for release are housed in the Service Cell Pits. The transfer times for moving these components from the core vessel to the Service Cell Pits is short enough so that assuming a SDC-2 level event is during transfer from the core vessel is BEU. (IC)	1. SDC-2 level Seismic Event. 2. SDC-2 level causes failure of the moderator assembly or the hydrogen piping due to displacements within the core vessel. 3. Ignition could be provided by friction from rotating target contacting shielding, thermal build-up.	U

Event Number CMS7-1			
Unmitigated Impact on Systems: 1. A detonation involving hydrogen and air in the core vessel would result in damage to the moderator system, target, proton beam window, shielding, neutron beam windows, etc. 2. Hydrogen detonation results in target material and reflector beryllium release. 3. Potential for significant damage to the target building. 4. Seismic event building damage could lead to a Roof collapse which could impact hydrogen utility room releasing H2, equipment stored in the high bay, target systems above the core vessel, damage the core vessel lid (including the target drive motor, target drive, process lines in this area, target segments), and transient waste in the high bay and add additional sources for this scenario.	**Unmitigated Consequences** **Radiological** **Public**: Negligible **WG1**: Moderate **WG2**: Negligible	**Chemical** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent an SDC-2 level seismic event from causing a breach of the Cryogenic Moderator vessel and significant release of radiological material. Release of radiological material must be prevented (by preventing a detonation and providing confinement) until Worker Group 1 can be evacuated to at least the 100-meter location.

Preventive Features – Attributes:	**Credited:**
None.	
Method of Detection:	
Felt motion of seismic event.	
MPS Monitoring of the hydrogen system parameters (e.g., pressure and flow).	
Pressure monitoring in core vessel environment.	
CMS transfer line vacuum monitoring loss of vacuum.	
Core vessel liquid detection probe.	
Preventive Features – Attributes:	**Credited:**
None	
Mitigative Features – Attributes:	**Credited:**
Monolith concrete shielding and building steel structures seismically qualified to prevent gross displacement (SDC-2 and applicable Limit State B or C requirements) (See Note 7). (DF)	
Core vessel liquid detection probe. (EC)	
Foundation design such as Micro-piles or drilled piers with pier caps under STS mitigate seismic building response. (DF)	
Monolith external structure designed to maintain monolith iron shielding in place. (DF)	
Target building ventilation system. (EC)	
Moderator Reflector Assembly design. (DF)	

Event Number CMS7-1	
Mitigative Features – Attributes: (Continued)	**Credited:**
Alarm response procedures. (AC)	
Hydrogen transfer lines designed and built to the applicable portions of AMSE B31.12 and ASME B31.3 and provide Limit State C protection during an SDC-2 event (See Note 7). (DF)	
Building structures seismically qualified to prevent collapse, protect evacuation paths, and protect applicable confinement of hazardous material (applicable SSCs meet SDC-2 and applicable Limit State B or C requirements) (See Note 7). (DF)	X
Seismic event will inherently cause a beam trip. (See Note 6) (DF)	
Core vessel operating in inert helium near atmospheric pressure or in vacuum. (DF/AC)	
Emergency procedures and training, including specific guidance on response to a seismic event. (AC)	X
MPS beam trip system response to abnormal hydrogen parameters (e.g., pressure and flow) to mitigate consequences. (EC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel during and following an SDC-2 event. (EC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of power to the TPS panel during and following an SDC-2 event. (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of monitored signal to the MPS panel. (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of power to the MPS panel. (EC)	

Event Number
CMS7-1

Planned analysis, assumption validations, and Risk/Opportunities:

1. Consequence analysis.
2. Evaluate potential chemical hazard from Beryllium released during accident.
3. Structural and thermal analysis of the moderators.
4. Seismic analysis of transfer lines.
5. Evaluate all release paths from the core vessel.
6. Venting analysis.
7. Results of target source term analysis to determine fraction included in the consequences.
8. Evaluate integrated dose for WG-1 during evacuation and while located as WG-2 at 100-meters.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: Negligible	**Public**: N/A
WG1: Negligible	**WG1**: Negligible	**WG1**: N/A
WG2: Negligible	**WG2**: Negligible	**WG2**: N/A

Notes:

1. Instruments that could be used to assess the consequences of a seismic event are assumed to be available although they are not designed to be seismically qualified. They are identified for detection of the leak only.
2. CMS7-3 evaluates an additional detonation in the core vessel and a follow-on fire.
3. Moderator and core vessel vent lines may be blocked by debris allowing hydrogen to leak directly into the core vessel. Vent line blocking does not change the event consequences.
4. Consequences for a detonation are based on the assumed inventory. When the target design is finalized, the MAR needs to be verified as consistent with the analysis.
5. Note deleted.
6. SNS FSAD-NF assumes that an NPH event of PC-2 or higher would cause a beam trip. Since the same linac supplying the FTS as supplies the STS, this beam trip is assumed. (102030102-ES0016-R03, "Spallation Neutron Source Final Safety Assessment Document for Neutron Facilities", September 2011). Further evaluation beyond the SNS study supports any felt motion that is strong enough to damage equipment would also shut down the beam. Operator action is required to restart the beam, so the beam would remain off.
7. Limit State C is required to provide confinement of hazardous material and hydrogen. Limit State B is required to Seismic Interaction (II over I) protection for both SSCs that could release hazardous material or hydrogen as well as assuring that workers can evacuate to the 100-meter location.

Mitigated Frequency
U

Event Number CMS7-2 **(Event Deleted as a seismic event always causes a beam trip)**		
Event Description: Breach of Cryogenic Moderator vessel after an SDC-2 level seismic event which allows hydrogen to escape from the moderator vessel into the surrounding area within the core vessel. The Core vessel boundary fails and air at 1 bar enters the core vessel. Hydrogen accumulates in core vessel in concentrations greater than the LEL in air resulting in a detonation releasing a fraction of the activated target mass, reflector beryllium, and activated cooling water. The seismic event is assumed to result in an inherent beam trip. (See Note 6).		
Assumptions and Initial Conditions: 1. Workers are assumed to evacuate buildings instinctively during earthquakes however, until they reach 100-m from the building they are considered WG1 however, the egress path must be protected to permit evacuation. (IC) 2. The earthquake causes loss of the accelerator proton beam. (See Note 6) (DF) 3. Core vessel boundary seals fail and inert atmosphere is lost. (IC) 4. Monolith iron shielding and core vessel components position is retained by external concrete structure. (DF) 5. No follow-on fire results from this event. (IC) 6. Most hydrogen vents through moderator transfer line due to loss of vacuum, but enough is released into the core vessel to detonate and cause target damage should air enter the core vessel. (IC) 7. Monolith stays intact and serves as target heat sink so decay heat cannot raise target temperature close to the 800 C threshold for a tungsten steam reaction. (IC/DF) 8. Potential for release of trace quantities of tritium or activated particulates contained in the hydrogen; pre-moderator/reflector (Loop 2) and reflector water could be heavily tritiated. (IC) 9. Active cooling or electric power are not needed for decay heat removal with the beam off. (DF) 10. The TPS inherent trip capability at the front end is designed to SDC-2 requirements and would provide a beam trip on either a system fault signal or loss of system monitoring signal. (DF) 11. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF) 12. Active cooling or electric power are not needed for decay heat removal with the beam off. (DF/IC)	**Causes**: 1. SDC-2 level Seismic Event. 2. SDC-2 level causes failure of the moderator assembly or the hydrogen piping due to displacements within the core vessel. 3. Ignition could be provided by friction from rotating target contacting shielding, thermal build-up.	**Initiating Event Frequency** **EU**

Event Number
CMS7-2 **(Event Deleted as a seismic event always causes a beam trip)**

Unmitigated Impact on Systems:

1. A detonation involving hydrogen and air in the core vessel would result in damage to the Moderator Reflector assembly, target, proton beam window, shielding, neutron beam windows, etc.
2. Hydrogen detonation could result in-target material and reflector beryllium released.
3. Potential for significant damage to the target building.
4. Seismic event building damage could lead to a Roof collapse which could impact hydrogen utility room releasing H2, equipment stored in the high bay, target systems above the core vessel, damage the core vessel lid (including the target drive motor, target drive, process lines in this area, target segments), and transient waste in the high bay and add additional sources for this scenario.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: Negligible	**Public**: N/A
WG1: Moderate	**WG1**: Negligible	**WG1**: N/A
WG2: Low	**WG2**: Negligible	**WG2**: N/A

Safety Function:
Prevent a breach of the Cryogenic Moderator vessel from leading to release of radiological material. Release of radiological material must be prevented (by preventing a detonation and providing confinement) until Worker Group 1 can be evacuated to at least the 100-meter location.

Method of Detection:	
Felt motion of seismic event.	
MPS Monitoring of the hydrogen system parameters (e.g., pressure and flow).	
Pressure monitoring in core vessel environment.	
CMS transfer line vacuum monitoring for loss of vacuum.	
Core vessel liquid detection probe.	

Preventive Features – Attributes:	**Credited:**
None	

Event Number
CMS7-2 **(Event Deleted as a seismic event always causes a beam trip)**

Mitigative Features – Attributes:	**Credited:**
Monolith concrete shielding and building steel structures seismically qualified to prevent gross displacement (SDC-2 and applicable Limit State B or C requirements). (DF)	
Core vessel liquid detection probe (EC)	
Foundation design such as Micro-piles or drilled piers with pier caps under STS mitigate seismic building response. (DF)	
Monolith external structure designed to maintain monolith iron shielding in place. (DF)	
Target building confinement ventilation system. (EC) (See Note 5)	X
Moderator Reflector Assembly Design. (DF)	
Alarm response procedures. (AC)	
Hydrogen transfer lines designed and built to the applicable portions of AMSE B31.12 and ASME B31.3. (DF)	
Building structures seismically qualified to prevent collapse, protect evacuation paths, and protect applicable confinement of hazardous material (applicable SSCs meet SDC-2 and applicable Limit State B or C requirements) (See Note 7). (DF)	X
Emergency procedures and training, including specific guidance on response to a seismic event (AC)	X
MPS beam trip system response to abnormal hydrogen parameters (e.g., pressure and flow) to mitigate consequences (EC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel during and following an SDC-2 event (EC)	X
TPS beam trip due to TPS fail safe design providing a trip on loss of power to the TPS panel during and following an SDC-2 event (EC)	X
MPS beam trip due to MPS fail safe design providing a trip on loss of monitored signal to the MPS panel (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of power to the MPS panel (EC)	

Event Number
CMS7-2 **(Event Deleted as a seismic event always causes a beam trip)**

Planned analysis, assumption validations, and Risk/Opportunities:

1. Accident consequence analysis.
2. Structural and thermal analysis of the moderators.
3. Seismic evaluation of transfer lines.
4. Seismic evaluation of core vessel seals.
5. Evaluate all release paths from the core vessel.
6. Venting analysis.
7. Results of target source term analysis to determine fraction included in the consequences.
8. Determine where core vessel systems exhaust and if crediting the building confinement system up stream of the HEPA filters is adequate. Does this protect core vessel vacuum system and other systems? Note that if these exhaust paths are separate, additional confinement may warrant protection.
9. Evaluate integrated dose for WG-1 during evacuation and while located as WG-2 at 100-meters.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:

1. Instruments that could be used to assess the consequences of a seismic event are assumed to be available although they are not designed to be seismically qualified. They are identified for detection of the leak only.
2. CMS7-3 evaluates an additional detonation in the core vessel and a follow-on fire.
3. Moderator and core vessel vent lines may be blocked by debris allowing hydrogen to leak directly into the core vessel. Vent line blocking does not change the event consequences.
4. Consequences for a detonation are based on the assumed inventory. When the target design is finalized, the MAR needs to be verified as consistent with the analysis.
5. The passive boundary portion of the building confinement system that is credited is on the suction side (upstream) of the HEPA filters (including the filters). The remainder of the system provides defense in depth.
6. SNS FSAD-NF assumes that an NPH event of PC-2 or higher would cause a beam trip. Since the same linac supplying the FTS as supplies the STS, this beam trip is assumed. (102030102-ES0016-R03, "Spallation Neutron Source Final Safety Assessment Document for Neutron Facilities", September 2011). Further evaluation beyond the SNS study supports any felt motion that is strong enough to damage equipment would also shut down the beam. Operator action is required to restart the beam, so the beam would remain off.
7. Limit State C is required to provide confinement of hazardous material and hydrogen. Limit State B is required for Seismic Interaction (II over I) protection for both SSCs that could release hazardous material or hydrogen as well as assuring that workers can evacuate to the 100-meter location.

Mitigated Frequency
EU

Event Number
CMS7-3

Event Description:
An SDC-2 level seismic event results in structural damage to target building resulting in a breach of Cryogenic Moderator vessel and core vessel with moderator and core vessel vent lines blocked by debris. The event allows hydrogen to escape from the moderator vessel into the surrounding area within the core vessel. The Core vessel boundary fails and air at 1 bar infiltrates the vessel. Hydrogen accumulates in concentrations greater than the LEL in air resulting in a detonation releasing a fraction of the activated target mass and activated cooling water. A secondary detonation within core vessel after the initial detonation is assumed when LEL is reached from the remaining hydrogen release into the vessel. A follow-on facility fire is assumed outside the core vessel.

Assumptions and Initial Conditions:
1. The earthquake causes loss of the accelerator proton beam. (See Note 6) (DF)
2. Workers are assumed to evacuate buildings instinctively during earthquakes however, until they reach 100-m from the building they are considered WG1 however, the egress path must be protected to permit evacuation. (IC)
3. Core vessel boundary seals fail, and inert atmosphere is lost. (IC)
4. Monolith iron shielding and core vessel components position is retained by external concrete structure. (DF)
5. Most hydrogen vents through moderator transfer line due to loss of vacuum, but enough is released into the core vessel to detonate next to the target and cause target damage. (IC)
6. Monolith stays intact and serves as target heat sink so decay heat cannot raise target temperature close to the 800 C threshold for a tungsten steam reaction. (IC)
7. Potential for release of trace quantities of tritium or activated particulates contained in the hydrogen; pre-moderator/reflector (Loop 2) water could be heavily tritiated; moderator hydrogen could be released directly to the hydrogen safe vent stack. (IC)
8. After loss of cooling with beam trip decay heat cannot raise target temperature to 800 C threshold for tungsten/steam reaction. (DF)
9. No spent core vessel components (e.g., target segment or MRA vessel) are storge in the High Bay. All similarly activated components with the potential for release are housed in the Service Cell Pits. The transfer times for moving these components from the core vessel to the Service Cell Pits is short enough so that assuming a SDC-2 level event is during transfer from the core vessel is BEU. (IC)
10. Target radionuclides are protected from possible effects of fire by massive steel and concrete shielding of the monolith structure and limited potential for an external fire causing a chimney effect in the core vessel. (DF)
11. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF)
12. Active cooling or electric power are not needed for decay heat removal with the beam off. (DF/IC)

Causes:
1. SDC-2 level Seismic event.
2. SDC-2 event causes failure of the moderator assembly or the hydrogen piping due to displacements within the core vessel.
3. Ignition could be provided by friction from rotating target contacting shielding, thermal build-up or sparks from any electrical equipment such as controls and monitoring devices (e.g., thermocouples).

Initiating Event Frequency
U

Event Number CMS7-3			
Unmitigated Impact on Systems: 1. A detonation involving hydrogen and air in the core vessel would result in damage to the moderator system, target, proton beam window, shielding, etc. 2. Seismic event of this magnitude would inherently cause a beam trip. 3. Potential for significant damage to the target building 4. Seismic event building damage could lead to a Roof collapse which could impact hydrogen utility room releasing H2, equipment stored in the high bay, target systems above the core vessel, damage the core vessel lid (including the target drive motor, target drive, process lines in this area, target segments), and transient waste in the high bay and add additional sources for this scenario.	**Unmitigated Consequences** **Radiological** **Public**: Negligible **WG1**: Moderate **WG2**: Low	**Chemical** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent a release of hydrogen causing a detonation and follow-on fire leading to a significant release of radiological material following an SDC-2 level seismic event. Release of radiological material must be prevented (by preventing a detonation and providing confinement) until worker group 1 can be evacuated to at least the 100-meter location.

Method of Detection:	
Felt motion of seismic event.	
MPS Monitoring of the hydrogen system parameters (e.g., pressure and flow)	
Pressure monitoring in core vessel environment;	
CMS transfer line vacuum monitoring for loss of vacuum	
Core vessel liquid detection probe	
Preventive Features – Attributes:	**Credited:**
None	
Mitigative Features – Attributes:	**Credited:**
Moderator Reflector Assembly Design. (DF)	
Hydrogen Transfer Line design to B31.3/B31.12 and provide Limit State C protection during an SDC-2 event. (DF)	
TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel during and following an SDC-2 event. (See Note 7) (EC)	X
TPS beam trip due to TPS fail safe design providing a trip on loss of power to the TPS panel during and following an SDC-2 event. (See Note 7) (EC)	X
MPS beam trip due to MPS fail safe design providing a trip on loss of monitored signal to the MPS panel. (See Note 7) (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of power to the MPS panel. (See Note 7)` (EC)	
MPS beam trip system response to abnormal hydrogen parameters (e.g., pressure and flow) to mitigate consequences. (See Note 7) (EC)	
Target segment attachment points designed to withstand an SDC-2 seismic event with a design margin of TBD.	X

Event Number
CMS7-3

Mitigative Features – Attributes (Continued):	Credited:
Core vessel liquid detection probe. (EC)	
Target building ventilation system. (EF)	
Foundation design such as Micro-piles or drilled piers with pier caps under STS mitigate seismic building response. (DF)	
Monolith concrete shielding and building steel structures seismically qualified to prevent gross displacement (SDC-2 and applicable Limit State B or C requirements). Enough iron shielding is in place to provide a heat sink and keep the target below 800 C in all configurations. (DF)	X
Massive monolith shielding assembly outside the core vessel with positive retention protects the target from the facility fire. (DF)	X
Emergency response procedures and training including specific guidance on response to a seismic event. (AC)	X
Building structures around the cryogenic hydrogen systems will have seismic qualification due to seismic interaction requirements (2-over-1), as needed to prevent crimping of the H2 transfer line outside of the core vessel or rupture of line or moderator vessel itself inside the core vessel (applicable SSCs meet SDC-2 and applicable Limit State B or C requirements). (See Note 8) (DF)	
Building structures seismically qualified to prevent collapse, protect evacuation paths, and protect applicable confinement of hazardous material (applicable SSCs meet SDC-2 and applicable Limit State B or C requirements) (See Note 8). (DF)	X
Combustible material control program reduces the probability of a large fire. (AC)	
Fire barriers minimize consequences of large fire. (DF)	
Fire department response. (AC)	
Exclusion of natural gas service in the target and instrument buildings. (DF)	
Seismic event will inherently cause a beam trip. (See Note 6) (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Accident consequence analysis.
2. Seismic qualification parameters of SSCs with SDC-2 and Limit States of B or C based on safety functions need to be defined.
3. Evaluate integrated dose for WG-1 during evacuation and while located as WG-2 at 100-meters.
4. Detailed accident analysis to be, including potential for hydrogen explosion.
5. Structural and thermal analysis of the moderators.
6. Seismic analysis of transfer lines.
7. Evaluate all release paths from the core vessel.
8. Venting analysis
9. Results of target source term analysis to determine fraction included in the consequences

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A

Event Number CMS7-3	
Notes: 1. Instruments that could be used to assess the consequences of a seismic event are assumed to be available although they are not designed to be seismically qualified. They are identified for detection of the leak only. 2. CMS7-1 evaluates a single detonation in the core vessel and a follow-on fire. 3. Moderator and core vessel vent lines may be blocked by debris allowing hydrogen to leak directly into the core vessel. Vent line blocking does not change the event consequences. 4. Consequences for a detonation are based on the assumed inventory. When the target design is finalized, the MAR needs to be verified as consistent with the analysis. 5. Note deleted. 6. SNS FSAD-NF assumes that an NPH event of PC-2 or higher would cause a beam trip. Since the same linac supplying the FTS as supplies the STS, this beam trip is assumed. (102030102-ES0016-R03, "Spallation Neutron Source Final Safety Assessment Document for Neutron Facilities", September 2011). Further evaluation beyond the SNS study supports any felt motion that is strong enough to damage equipment would also shut down the beam. Operator action is required to restart the beam, so the beam would remain off. 7. Fail safe design for the TPS and MPS or either an MPS or TPS beam trips are based on credit in the inputs and assumptions section. 8. Limit State C is required to provide confinement of hazardous material and hydrogen. Limit State B is required to Seismic Interaction (II over I) protection for both SSCs that could release hazardous material or hydrogen as well as assuring that workers can evacuate to the 100-meter location.	**Mitigated Frequency** **U**

Event Number
CMS7-4

Event Description:
Breach of Cryogenic Moderator vessel and core vessel after an SDC-2 level seismic event with moderator and core vessel vent lines blocked by debris allows hydrogen to escape from the moderator vessel into the surrounding area within the core vessel; Core vessel boundary fails and air at 1 bar is in vessel. Hydrogen accumulates in concentrations greater than the LEL in air leading to a detonation releasing a fraction of the activated target mass and activated cooling water. Multiple detonations within core vessel after initial detonation due to mixing of trapped hydrogen with air in the vessel.

Assumptions and Initial Conditions:

1. Multiple detonations beyond the 2 assumed for CMS7-3 are not considered credible because of the rapid venting that would occur after the first detonation and loss of cryogenic insulating vacuum around the moderators and transfer lines. (IC)
2. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF)

Causes:

1. SDC-2 level Seismic event.
2. SDC-2 level causes failure of the moderator assembly or the hydrogen piping due to displacements within the core vessel.
3. Ignition could be provided by friction from rotating target contacting shielding, thermal build-up or sparks from any electrical equipment such as controls and monitoring devices (e.g., thermocouples).

Initiating Event Frequency
BEU

Unmitigated Impact on Systems:

Unmitigated Consequences

Radiological	Chemical	ODH
Public: N/A	**Public**: N/A	**Public**: N/A
WG1: N/A	**WG1**: N/A	**WG1**: N/A
WG2: N/A	**WG2**: N/A	**WG2**: N/A

Safety Function:
N/A

Method of Detection:

Preventive Features – Attributes:

Credited:

Event Number
CMS7-4

Mitigative Features – Attributes:	Credited:

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. Accident analysis for hydrogen detonation with loss of vacuum within core vessel will be done to validate the assumption that more than 2 detonations are not credible.	**Radiological** **Public**: N/A **WG1**: N/A **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency BEU

Event Number
CMS7-5

Event Description:
SDC-2 level Seismic event with Breach of Cryogenic Moderator vessel and core vessel. Moderator and core vessel vent lines blocked by debris or are fully crimped allowing trapped hydrogen to escape from the moderator vessel into the surrounding area within the core vessel. Hydrogen accumulates in concentrations greater than the LFL in air, is ignited and deflagrates heating the target mass. Reaction gases or powders released through core vessel boundary breaches.

Assumptions and Initial Conditions:
1. Workers are assumed to evacuate buildings instinctively during earthquakes however, until they reach 100-m from the building they are considered WG1 however, the egress path must be protected to permit evacuation. (IC)
2. Core vessel boundary seals fail and inert atmosphere is lost. (IC)
3. Hydrogen is released in the core vessel and burns adjacent to target. (IC)
4. Monolith stays intact and serves as target heat sink so decay heat cannot raise target temperature close to the 800 C threshold for a tungsten steam reaction. (IC)
5. Potential for release of trace quantities of tritium or activated particulates contained in the hydrogen; pre-moderator/reflector (Loop 2) water could be heavily tritiated. (IC)
6. After loss of cooling with beam trip decay heat cannot raise target temperature to 800 C threshold for tungsten/steam reaction. (DF)
7. No spent core vessel components (e.g., target segment or MRA vessel) are storge in the High Bay. All similarly activated components with the potential for release are housed in the Service Cell Pits. The transfer times for moving these components from the core vessel to the Service Cell Pits is short enough so that assuming a SDC 2 level event is during transfer from the core vessel is BEU. (IC)A single cryogenic moderator loop. (DF)
8. The earthquake causes loss of the accelerator proton beam. (See Note 6) (DF)
9. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF)
10. Active cooling or electric power are not needed for decay heat removal with the beam off. (DF/IC)

Causes:
1. SDC-2 level Seismic Event
2. SDC-2 level causes failure of the moderator assembly or the hydrogen piping due to displacements within the core vessel.
3. Ignition could be provided by friction from rotating target contacting shielding, thermal build-up

Initiating Event Frequency
U

Unmitigated Impact on Systems:
1. A rapid deflagration involving hydrogen in the core vessel could result in damage to the moderator reflector assembly, target, proton beam window, shielding, etc.
2. Water could be released from the premoderator, and the deflagration could heat the target mass.
3. Seismic event of this magnitude would inherently cause a beam trip.
4. Potential for significant damage to the target building
5. Seismic event building damage could lead to a Roof collapse which could impact hydrogen utility room releasing H2, equipment stored in the high bay, target systems above the core vessel, damage the core vessel lid (including the target drive motor, target drive, process lines in this area, target segments), and transient waste in the high bay and add additional sources for this scenario.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: Negligible	**Public**: N/A
WG1: Moderate	**WG1**: Negligible	**WG1**: N/A
WG2: Negligible	**WG2**: Negligible	**WG2**: N/A

Event Number CMS7-5	
Safety Function: Prevent an SDC-2 level seismic event from causing a blockage of the hydrogen vent lines and leading to release of radiological material. Release of radiological material must be prevented (by preventing a detonation and providing confinement) until worker group 1 can be evacuated to at least the 100-meter location.	
Method of Detection:	
Felt motion of seismic event	
MPS Monitoring of the hydrogen system parameters (e.g. pressure and flow)	
Pressure monitoring in core vessel environment;	
CMS transfer line vacuum monitoring for loss of vacuum	
Core vessel liquid detection probe	
Preventive Features – Attributes:	**Credited:**
None	
Mitigative Features – Attributes:	**Credited:**
Moderator Reflector Assembly Design (DF)	
TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel during and following an SDC-2 event (EC)	X
TPS beam trip due to TPS fail safe design providing a trip on loss of power to the TPS panel during and following an SDC-2 event (EC)	X
MPS beam trip due to MPS fail safe design providing a trip on loss of monitored signal to the MPS panel (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of power to the MPS panel (EC)	
MPS beam trip system response to abnormal hydrogen parameters (e.g., pressure and flow) to mitigate consequences (EC)	
Seismic event will inherently cause a beam trip. (See Note 6) (DF)	X
Core vessel liquid detection probe (EC)	
Foundation design such as Micro-piles or drilled piers with pier caps under STS mitigate seismic building response (DF)	
Target building ventilation system (EC)	
Emergency response procedures and training including specific guidance on response to a seismic event (AC)	
Combustible material control program (AC)	
Hydrogen transfer lines designed and built to applicable portions of AMSE B31.12 and ASME B31.3 and provide Limit State C protection during an SDC-2 event. (DF)	X
Building structures seismically qualified to prevent collapse, protect evacuation paths, and protect applicable confinement of hazardous material (applicable SSCs meet SDC-2 and applicable Limit State B or C requirements) (See Note 8). (DF)	X
The entire pathway of the CMS cryogenic transfer line from the core vessel to the relief valves must be protected from being crushed or crimped by failing or falling structures or installed components	

Event Number CMS7-5			
Mitigative Features – Attributes: (Continued)			**Credited:**
Monolith concrete shielding and building steel structures seismically qualified to prevent gross displacement (SDC-2 and applicable Limit State B or C requirements) (See Note 8). Enough iron shielding is in place to provide a heat sink and keep the target below 800 C in all configurations. (DF)			X
Massive monolith shielding assembly outside the core vessel with positive retention protects the target from a facility fire. (DF)			
Fire barriers minimize consequences of large fire. (DF)			
Fire department response (AC)			
Exclusion of natural gas service in the target and instrument buildings. (DF)			

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Accident analysis of hydrogen deflagration will be done to estimate the temperatures and time at temperature for the target to evaluate the potential for a tungsten steam reaction. 2. Structural and thermal analysis of moderator 3. Seismic analysis of Hydrogen transfer lines 4. Evaluate all release paths from the core vessel. 5. Venting analysis 6. Results of target source term analysis to determine fraction included in the consequences. 7. Seismic qualification parameters of SSCs with SDC-2 and Limit States of B or C based on safety functions need to be defined. 8. Evaluate integrated dose for WG-1 during evacuation and while located as WG-2 at 100-meters.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Event Number CMS7-5	
Notes: 1. Instruments that could be used to assess the consequences of a seismic event are assumed to be available although they are not designed to be seismically qualified. They are identified for detection of the leak only. 2. CMS7-1 and CMS7-3 evaluate detonations in the core vessel and a follow-on fire. 3. Moderator and core vessel vent lines may be blocked by debris allowing hydrogen to leak directly into the core vessel. Vent line blocking does not change the event consequences. 4. Building structure is credited to maintain the assumption/initial condition that the building is designed to provide an evacuation path for workers in the building. 5. Note deleted. 6. SNS FSAD-NF assumes that an NPH event of PC-2 or higher would cause a beam trip. Since the same linac supplying the FTS as supplies the STS, this beam trip is assumed. (102030102-ES0016-R03, “Spallation Neutron Source Final Safety Assessment Document for Neutron Facilities”, September 2011). Further evaluation beyond the SNS study supports any felt motion that is strong enough to damage equipment would also shut down the beam. Operator action is required to restart the beam, so the beam would remain off. 7. Fail safe design for the TPS and MPS or either an MPS or TPS beam trips are based on credit in the inputs and assumptions section. 8. Limit State C is required to provide confinement of hazardous material and hydrogen. Limit State B is required to Seismic Interaction (II over I) protection for both SSCs that could release hazardous material or hydrogen as well as assuring that workers can evacuate to the 100-meter location.	**Mitigated Frequency** **U**

Event Number
CMS7-6

Event Description:
Hydrogen release from core vessel after an SDC-2 level seismic event mixes with air in neutron beam bunkers and accumulates in concentrations greater than the LEL, leading to a detonation.

Assumptions and Initial Conditions	Causes	Initiating Event Frequency
1. No follow-on fire results from this event. (IC) 2. Workers are assumed to evacuate buildings instinctively during earthquakes however, until they reach 100-m from the building they are considered WG1 however, the egress path must be protected to permit evacuation. (IC) 3. Most hydrogen vents through moderator transfer line due to loss of vacuum. (IC) 4. Monolith stays intact and serves as target heat sink so decay heat cannot raise target temperature close to the 800 C threshold for a tungsten steam reaction. (IC) 5. Potential for release of trace quantities of tritium or activated particulates contained in the hydrogen; pre-moderator/reflector (Loop 2) water could be heavily tritiated. (IC) 6. Neutron shutters do not close, and hydrogen is released into the instrument bunkers. (IC) 7. No detonation or deflagration in the Core Vessel. (IC) 8. Neutron Beam bunkers configured for operation. (IC) 9. Active cooling or electric power are not needed for decay heat removal with the beam off. (DF/IC) 10. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF) 11. The earthquake causes loss of the accelerator proton beam. (See Note 2) (DF) 12. After loss of cooling with beam trip decay heat cannot raise target temperature to 800 C threshold for tungsten/steam reaction. (DF) 13. No spent core vessel components (e.g., target segment or MRA vessel) are storge in the High Bay. All similarly activated components with the potential for release are housed in the Service Cell Pits. The transfer times for moving these components from the core vessel to the Service Cell Pits is short enough so that assuming a SDC-2 level event is during transfer from the core vessel is BEU. (IC)	1. SDC-2 Seismic Event fails hydrogen and vacuum boundary and at least on neutron optics insert core vessel seal. 2. SDC-2 seismic event causes failure of the moderator assembly or the hydrogen piping due to displacements within the core vessel. 3. Ignition could be provided by friction from rotating target contacting shielding, thermal build-up	U

Unmitigated Impact on Systems:
1. Extensive damage to the neutron beam optics and instrumentation within the bunker region could occur.
2. The bunker region could also be contaminated.
3. The beam optical equipment may have already been damaged by the seismic event assuming they are not designed for the seismic event.
4. Seismic event building damage could lead to a Roof collapse which could impact hydrogen utility room releasing H2, equipment stored in the high bay, target systems above the core vessel, damage the core vessel lid (including the target drive motor, target drive, process lines in this area, target segments), and transient waste in the high bay and add additional sources for this scenario.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible **WG1**: Low **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Event Number CMS7-6	
Safety Function: Prevent a Hydrogen release from core vessel after an SDC-2 level seismic event from resulting hydrogen accumulates in concentrations greater than the LEL, leading to a detonation and a significant release of radiological material.	
Method of Detection:	
Felt motion of seismic event.	
MPS Monitoring of the hydrogen system parameters (e.g., pressure and flow).	
Pressure monitoring in core vessel environment.	
CMS transfer line vacuum monitoring for loss of vacuum.	
Core vessel liquid detection probe.	
Preventive Features – Attributes:	**Credited:**
None	
Mitigative Features – Attributes:	**Credited:**
Moderator Reflector Assembly Design. (DF)	
Building structures seismically qualified to prevent collapse, protect evacuation paths, and protect applicable confinement of hazardous material (applicable SSCs meet SDC-2 and applicable Limit State B or C requirements) (See Note 3). (DF)	X
Core vessel liquid detection probe. (EC)	
Pressure monitoring system to detect a leak of hydrogen. (EC)	
Foundation design such as Micro-piles or drilled piers with pier caps under STS mitigate seismic building response. (DF)	
Confinement capability of the core vessel at pressures less than one atmosphere (gage pressure). (DF)	
Target building ventilation system. (DF)	
Neutron beam window design. (DF)	
Combustible material control program reduces the probability of a large fire. (AC)	
Emergency response procedures and training including specific guidance on response to a seismic event. (AC)	
Fire barriers minimize consequences of large fire. (DF)	
Fire department response. (AC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel during and following an SDC-2 event. (EC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of power to the TPS panel during and following an SDC-2 event. (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of power to the MPS panel (EC)	

Event Number CMS7-6	
Mitigative Features – Attributes: (Continued)	**Credited:**
Hydrogen transfer lines designed and built to the applicable portions of ASME B31.3 and AMSE B31.12 and provide Limit State C protection during an SDC-2 event. (DF)	
MPS beam trip system response to abnormal hydrogen parameters (e.g., pressure and flow) to mitigate consequences (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of monitored signal to the MPS panel (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Neutron beam window analysis 2. Structural and thermal analysis of moderators 3. Seismic analysis of transfer lines 4. Consequences for a detonation are based on the assumed inventory. When the target design is finalized, the MAR needs to be verified as consistent with the analysis.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. Note deleted. 2. SNS FSAD-NF assumes that an NPH event of PC-2 or higher would cause a beam trip. Since the same linac supplying the FTS as supplies the STS, this beam trip is assumed. (102030102-ES0016-R03, “Spallation Neutron Source Final Safety Assessment Document for Neutron Facilities”, September 2011). Further evaluation beyond the SNS study supports any felt motion that is strong enough to damage equipment would also shut down the beam. Operator action is required to restart the beam, so the beam would remain off. 3. Limit State C is required to provide confinement of hazardous material and hydrogen. Limit State B is required to Seismic Interaction (II over I) protection for both SSCs that could release hazardous material or hydrogen as well as assuring that workers can evacuate to the 100-meter location.	**U**

Event Number
CMS7-7

Event Description:
An SDC-2 level seismic event during a system outage results in structural damage to target building resulting in a breach of Cryogenic Moderator vessel and core vessel with moderator and core vessel vent lines blocked by debris or pinched transfer line. The event allows hydrogen to escape from the moderator vessel into the surrounding area within the core vessel. The Core vessel boundary fails and air at 1 bar infiltrates the vessel. Hydrogen accumulates in concentrations greater than the LEL in air resulting in a detonation releasing a fraction of the activated target mass and activated cooling water. A secondary detonation within core vessel after the initial detonation is assumed when LEL is reached from the remaining hydrogen release into the vessel. A follow-on facility fire is assumed outside the core vessel.

Assumptions and Initial Conditions:
1. The accelerator proton beam is off during an outage. (IC)
2. Hydrogen is assumed to remain in the CMS unless the core vessel is opened to atmosphere and the inert atmosphere is not in place. (AC)
3. Workers are assumed to evacuate buildings instinctively during earthquakes however, until they reach 100-m from the building they are considered WG1 however, the egress path must be protected to permit evacuation. (IC)
4. Core vessel boundary seals fail, and inert atmosphere is lost. (IC)
5. Monolith iron shielding and core vessel components position is retained by external concrete structure. (DF)
6. Hydrogen is released in the core vessel and detonates adjacent to target. (IC)
7. Monolith stays intact and serves as target heat sink so decay heat cannot raise target temperature close to the 800 C threshold for a tungsten steam reaction. (IC)
8. Potential for release of trace quantities of tritium or activated particulates contained in the hydrogen; pre-moderator/reflector (Loop 2) water could be heavily tritiated; moderator hydrogen could be released directly to the hydrogen safe vent stack. (IC)
9. After loss of cooling with beam off decay heat cannot raise target temperature to 800 C threshold for tungsten/steam reaction. (DF)
10. Target radionuclides are protected from possible effects of fire by massive steel and concrete shielding of the monolith structure and limited potential for an external fire causing a chimney effect in the core vessel. (DF)
11. A single cryogenic moderator loop that has a quantity of hydrogen below the NFPA2 MAQ values. (DF)
12. Active cooling or electric power are not needed for decay heat removal with the beam off. (DF/IC)
13. The core vessel may not be initially inerted during maintenance operations. (IC)

Causes:
1. SDC-2 level Seismic event.
2. SDC-2 event causes failure of the moderator assembly or the hydrogen piping due to displacements within the core vessel.
3. Ignition could be provided by friction from rotating target contacting shielding, thermal build-up or sparks from any electrical equipment such as controls and monitoring devices (e.g., thermocouples).

Initiating Event Frequency
U

Event Number
CMS7-7

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
1. A detonation involving hydrogen and air in the core vessel could result in damage to the moderator system, target, proton beam window, shielding, etc. 2. Potential for significant damage to the target building. 3. Seismic event building damage could lead to a Roof collapse which could impact hydrogen utility room releasing H2, equipment stored in the high bay, target systems above the core vessel, damage the core vessel lid (including the target drive motor, target drive, process lines in this area, target segments), and transient waste in the high bay and add additional sources for this scenario.	**Radiological** **Public**: Negligible **WG1**: Moderate **WG2**: Low	**Chemical** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent a release of hydrogen causing a detonation and follow-on fire leading to a significant release of radiological material following an SDC-2 level event during a facility outage. Release of radiological material must be prevented (by preventing a detonation and providing confinement) until Worker Group 1 can be evacuated to at least the 100-meter location.

Method of Detection:	
Felt motion of seismic event.	
Pressure monitoring in core vessel environment.	
CMS transfer line vacuum monitoring for loss of vacuum.	
Core vessel liquid detection probe.	
Preventive Features – Attributes:	**Credited:**
None	
Mitigative Features – Attributes:	**Credited:**
Moderator Reflector Assembly Design. (DF)	
Hydrogen Transfer Line design to B31.3/B31.12 and provide Limit State C protection during an SDC-2 event. (DF)	
Combustible material control program reduces the probability of a large fire. (AC)	
Fire barriers minimize consequences of large fire. (DF)	
Fire department response. (AC)	
Exclusion of natural gas service in the target and instrument buildings. (DF)	

Event Number
CMS7-7

Mitigative Features – Attributes (Continued):	Credited:
Core vessel liquid detection probe. (EC)	
Foundation design such as Micro-piles or drilled piers with pier caps under STS mitigate seismic building response. (DF)	
Monolith concrete shielding and building steel structures seismically qualified to prevent gross displacement (SDC-2 and applicable Limit State B or C requirements) (See Note 3). Enough iron shielding is in place to provide a heat sink and keep the target below 800 C in all configurations. (DF)	X
Massive monolith shielding assembly outside the core vessel with positive retention protects the target from the facility fire. (DF)	X
Emergency response procedures and training including specific guidance on response to a seismic event. (AC)	X
Building structures around the cryogenic hydrogen systems will have seismic qualification due to seismic interaction requirements (2-over-1), as needed to prevent crimping of the H2 transfer line outside of the core vessel or rupture of line or moderator vessel itself inside the core vessel (applicable SSCs meet SDC-2 and applicable Limit State B or C requirements) (See Note 3). (DF)	
Building structures seismically qualified to prevent collapse, protect evacuation paths, and protect applicable confinement of hazardous material (applicable SSCs meet SDC-2 and applicable Limit State B or C requirements) (See Note 3). (DF)	X

Planned analysis, assumption validations, and Risk/Opportunities:

1. Accident consequence analysis.
2. Seismic qualification parameters of SSCs with SDC-2 and Limit States of B or C based on safety functions need to be defined.
3. Evaluate integrated dose for WG-1 during evacuation and while located as WG-2 at 100-meters.
4. Detailed accident analysis to be, including potential for hydrogen explosion.
5. Seismic analysis of transfer lines.
6. Evaluate all release paths from the core vessel.
7. Venting analysis
8. Results of target source term analysis to determine fraction included in the consequences.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:

1. Moderator and core vessel vent lines may be blocked by debris allowing hydrogen to leak directly into the core vessel. Vent line blocking does not change the event consequences.
2. Consequences for a detonation are based on the assumed inventory. When the target design is finalized, the MAR needs to be verified as consistent with the analysis.
3. Limit State C is required to provide confinement of hazardous material and hydrogen. Limit State B is required to Seismic Interaction (II over I) protection for both SSCs that could release hazardous material or hydrogen as well as assuring that workers can evacuate to the 100-meter location.

Mitigated Frequency
U

APPENDIX E. COOLING WATER (CW) HAZARD EVENT TABLES

APPENDIX E. COOLING WATER (CW) HAZARD EVENT TABLES

<table>
<tr><td colspan="5">Event Number
CW2-1a</td></tr>
<tr><td colspan="5">Event Description:
Explosion in Loop 1 GLS tank in the HPV.</td></tr>
<tr><td>Assumptions and Initial Conditions:
1. Explosion is assumed to not involve target failure and core vessel water release. (IC)
2. Could occur during venting or evacuation of system high point gases from the system (radiolysis gases: H_2 and O_2). (IC)
3. Personnel access is restricted when the beam is on and before required dose level decay has occurred. (IC)
4. Beam is terminated preventing target loss (target events with beam continuing to operate are addressed in TS event tables). (IC)
5. Loop 1 provides cooling water for the Target. (DF)
6. Loop 2 provides cooling water for the Proton Beam Window, TVP, MRA, and water-cooled shielding. (DF)</td><td colspan="3">Causes:
1. Improper venting procedures.
2. Ignition caused by static charge buildup.
3. Failure to use non-sparking tools or equipment.
4. Other unidentified ignition source.</td><td>Initiating Event Frequency
U</td></tr>
<tr><td colspan="2" rowspan="2">Unmitigated Impact on Systems:
1. Loss of containment in the Loop 1 cooling system.
2. Explosion in one gas/liquid separation tank could damage the other components in the e HPV (including Loop 2 components) causing a release of their inventory as well.
3. Water hammer effect from explosion could damage the target.
4. Contamination in the HPV delaying operations.</td><td colspan="3">Unmitigated Consequences</td></tr>
<tr><td>Radiological
Public: Negligible
WG1: Low
WG2: Negligible</td><td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
<tr><td colspan="5">Safety Function:
Reduce potential for an explosion in the GLS tank from resulting in release of significant amount of radioactive coolant impacting WG1.</td></tr>
<tr><td colspan="4">Method of Detection:</td><td></td></tr>
<tr><td colspan="4">Visual</td><td></td></tr>
<tr><td colspan="4">Audible</td><td></td></tr>
<tr><td colspan="4">Abnormal system indications for affected cooling system</td><td></td></tr>
</table>

Event Number
CW2-1a

Preventive Features – Attributes:	Credited:
Instrument selection on all gas /liquid separation tanks minimize the possibility of sparks contacting hydrogen gas during venting operations. (DF)	
All gas /liquid separation tanks are continuously purged with nitrogen to reduce oxygen levels and control hydrogen concentration at half LFL limit by controlling purge rate. (EC)	
Operating Procedures. (AC)	
Trained operators. (AC)	

Mitigative Features – Attributes:	Credited:
TPS beam trip following loss of flow in Loop 1. (EC)	
HPV Area Radiation Monitors (ARM) alarming on high radiation levels. (EC)	
TPPS controlled access for workers to the HPV. (EC)	
HPV concrete construction provides containment and shielding from small explosion. (DF)	
HEPA filtered SCE system will filter released particulate radionuclides and discharge to the CEF. (DF)	
RCT procedure controlling access to HPV. (AC)	
Emergency response procedures. (AC)	
Worker training. (AC)	
MPS beam trip on Loop 1 pump exit pressure. (EC) (See Note 1)	
MPS beam trip for Loop 1 GLS level. (EC)	
Arrangement of components in the HPV minimizes impact of other components in the HPV from a small explosion. (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:
1. Delay built into the MPS trip to provide recovery time prior to the required trip. Delay time TBD.
2. The GLS tanks will be installed on a platform in the HPV.

Mitigated Frequency
U

Event Number
CW2-1b

Event Description:
Explosion in Loop 2 GLS tank in the HPV .

Assumptions and Initial Conditions:
1. Explosion is assumed to not involve target failure and core vessel water release. (IC)
2. Could occur during venting or evacuation of system high point gases from the system (radiolysis gases: H_2 and O_2). (IC)
3. Beam is terminated preventing Loop 2 cooled component damage (See CW loss of cooling events for impact). (IC)
4. Personnel are not permitted in the HPV during beam operation. (AC/EC/IC)

Causes:
1. Improper venting procedures.
2. Ignition caused by static charge buildup.
3. Failure to use non-sparking tools or equipment.

Initiating Event Frequency
U

Unmitigated Impact on Systems:
1. Loss of individual containments in the Loop 2 cooling system.
2. Explosion in one gas/liquid separation tank could damage the other components in the e HPV (including Loop 1 components) causing a release of their inventory as well.
3. Water hammer effect from explosion could damage Loop 2 cooling system components including the proton beam window.
4. Cleanup and decontamination required.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible **WG1**: Low **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Reduce potential for an explosion in the Loop 2 GLS tank from resulting in release of significant amount of radioactive coolant impacting WG1.

Method of Detection:	
Visual	
Audible	
Abnormal system indications for affected cooling system	

Preventive Features – Attributes:	**Credited:**
Permanent offgas connections to all gas /liquid separation tanks minimize the possibility of sparks contacting hydrogen gas during venting Operations. (DF)	
All gas /liquid separation tanks are continuously purged with nitrogen to reduce oxygen levels and control hydrogen concentration. (DF)	
Operating Procedures. (AC)	
Trained operators. (AC)	

Event Number CW2-1b	
Mitigative Features – Attributes:	**Credited:**
MPS beam trip on loss of pressure or flow in Loop 2. (EC)	
HEPA filtered SCE system will filter released particulate radionuclides and discharge to the CEF. (DF)	
HPV concrete construction provides containment and shielding from small explosion. (DF)	
Emergency response procedures. (AC)	
Worker training. (AC)	
Personnel access restrictions to the HPV. (AC)	
MPS beam trip on Loop 2 pump exit pressure. (EC) (See Note 1)	
MPS beam trip on Loop 2 GLS level. (EC)	
Arrangement of components in the HPV minimizes impact of other components in the HPV from a small explosion. (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Low **WG2**: Low	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. Delay built into the MPS trip to provide recovery time prior to the required trip. Delay time TBD. 2. The GLS tanks will be installed on a platform in the HPV.	**U**

Event Number
CW3-1a

Event Description:
Loss of Loop 1 cooling water flow (See Note 2).

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Loop 1 provides cooling water for the Target. (DF) 2. Loop 2 provides cooling water for the Proton Beam Window, TVP, MRA, and water-cooled shielding. (DF) 3. Proton Beam Window and other Loop 2 components are unaffected by this event. (IC) 4. Inert core vessel atmosphere with helium or vacuum mode of core vessel operation. (IC)	1. Loss of local power. 2. Valve misalignment. 3. Pump failure/seizure. 4. Material defect.	**A**

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Loss of flow leads to target overheating and loss of confinement. 2. Target shroud boundary failure resulting in water accumulation in core vessel. 3. Core vessel atmosphere rupture disk may rupture due to expanding steam. 4. Extended shutdown for target segment replacement.	**Public**: Low **WG1**: Moderate **WG2**: Low	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Reduce probability of loss of Loop 1 cooling water flow leading to a release of significant amount of radiological material impacting WG1..

Method of Detection:	
Pump status and/or low Loop 1 flow alarms indicates loss of flow condition.	
Core Vessel Drain Liquid Detection Probe. (EC) • Alarm in Control Room on detection of a leak in the Core Vessel Drain Line. (EC) • MPS trip on High Level in the Core Vessel Drain LIne. (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line. (EC)	
Core vessel pressure indicator increase.	
Loop 1 GLS tank level indicator.	
Loop 1 system pressure out of bounds.	

Event Number
CW3-1a

Preventive Features – Attributes:	Credited:
Specific valve positions interlocked in control circuitry with pump start/run condition. (EC)	
Redundant (one standby redundant pump and two operating pumps) Loop 1 pumps. (DF)	
Preventive maintenance and inspection program for pumps and control circuitry. (AC)	
Valve line-up checklist. (AC)	

Mitigative Features – Attributes:	Credited:
TPS Cooling water Loop 1 return flow interlocked with automatic beam trip. (EC)	X
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	X
Emergency Response procedures. (AC)	
Core Vessel Drain Line Liquid Detection Probe. (EC) • Alarm in Control Room on detection of a leak in the Core Vessel Drain Line . (EC) • MPS trip on High Level in the Core Vessel Drain Line (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line (EC)	
MPS beam trip on Loop 1 return temperature. (EC)	
MPS beam trip on loss of Loop 1 return flow. (EC)	
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
Backup power and pump to maintained reduced flow to target. (EC)	
Core vessel liquid containment. (DF)	
Operating procedures. (AC)	
Worker training. (AC)	
Pump status and/or low flow sensor in pump control circuitry energizes standby pump. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:
1. Common accident analysis with TS events
2. When the final target design is selected, this event will be reevaluated.
3. Align MPS trip with pump operation to provide a Soft Trip of the Linac front end impacting both the FTS and STS.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Event Number CW3-1a	
Notes: 1. See event TS, HPV, CMS/MRA, and AIC event tables. 2. TS events address continued beam operation and full consequences of this event including hydrogen release and target vaporization. 3. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.	**Mitigated Frequency** **A**

Event Number
CW3-1b

Event Description:
Loss of flow of cooling water Loop 2 leading to a failure of the loop cooled systems in the core vessel near the target.

Assumptions and Initial Conditions:
1. Event includes potential failures of reflector boundary or near field shielding boundary. (IC)
2. Redundant power supply busses for Loop 2 pumps. (DF)
3. Loop 2 provides cooling water for the Proton Beam Window, TVP, MRA, and water-cooled shielding. (DF)
4. Inert core vessel atmosphere with helium or vacuum mode of core vessel operation. IC)
5. Proton beam window will not fail for nominally an hour without cooling so that it is not impacted by this event and does not provide a passive beam trip. (DF)

Causes:
1. Loss of local power.
2. Valve misalignment.
3. Pump seizure.
4. Material defect.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Reflector boundary or near field shielding boundary could fail due to material defect or overheating.
2. Reflector fails due to steam expansion.
3. Core vessel atmosphere rupture disk may rupture due to expanding steam.
4. Extended shutdown for component replacement.
5. Reflector boundary failure could cause hydrogen moderator to vent.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Reduce probability of loss of cooling water flow leading to a release of significant quantities of radiological material impacting WG1.

Method of Detection:	
Pump status and/or low Loop 2 flow alarms indicates loss of flow condition.	
Core Vessel Drain Line Liquid Detection Probe. (EC) • Alarm in Control Room on detection of a leak in the Core Vessel Drain Line. (EC) • MPS trip on High Level in the Core Vessel Drain Line. (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line. (EC)	
Loop 2 GLS level indicator.	
Loop 2 system pressure out of bounds.	
Core vessel pressure indicator increase.	

Event Number CW3-1b				
Preventive Features – Attributes:				**Credited:**
Specific valve positions interlocked in control circuitry with pump start/run condition. (EC)				
Redundant (one on standby) Loop 2 pumps. (DF)				
Preventive maintenance and inspection program for pumps and control circuitry. (AC)				
Valve line-up checklist. (AC)				
Mitigative Features – Attributes:				**Credited:**
Loop 2 pump status and/or low flow sensor in pump control circuitry energizes standby pump. (EC)				
Core Vessel Drain Line Liquid Detection Probe. (EC) • Alarm in Control Room on detection of a leak in the Core Vessel Drain Line. (EC) • MPS trip on High Level in the Core Vessel Drain Line. (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line. (EC)				
MPS beam trip on return temperature. (EC)				
MPS beam trip on loss of Loop 2 return flow. (EC)				
Core vessel liquid containment. (DF)				
Operating procedures. (AC)				
Emergency Response procedures. (AC)				
Worker training. (AC)				
Planned analysis, assumption validations, and Risk/Opportunities: 1. Align MPS trip with pump operation to provide a Soft Trip of the Linac front end impacting both the FTS and STS.	**Mitigated Consequences:**			
	Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A	
Notes: 1. See event HPV, CMS/MRA, and AIC event tables. 2. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.				**Mitigated Frequency** **A**

Event Number
CW3-1c **Event Deleted (included in TS events)**

Event Description:
Loss of flow of cooling water to one segment of the segmented target cooled by Loop 1
See Event TS3-6 and TS3-23.

Event Number CW3-1d			
Event Description: Failure in the Loop 2 cooling water system results in a loss of cooling to a single Loop 2 component (PBW, TVP, MRA, or water-cooled shielding).			
Assumptions and Initial Conditions: 1. Loop 1 provides cooling water for the Target. (DF) 2. Loop 2 provides cooling water for the Proton Beam Window, TVP, MRA, and water-cooled shielding. (DF) 3. Core vessel ullage, burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. (DF) 4. Core vessel operating in inert helium near atmospheric pressure or in vacuum. (IC) 5. Proton beam remains on. (IC) 6. Proton beam window will not fail for nominally an hour without cooling and does not provide a short-term passive beam trip. (DF)	**Causes**: 1. Valve misalignment. 2. Operator Error. 3. Equipment fault.		**Initiating Event Frequency** **A**
Unmitigated Impact on Systems: 1. TVP, MRA, or near field shielding boundary could fail due to material defect or overheating. 2. Core vessel atmosphere rupture disk may rupture due to expanding steam. 3. Extended shutdown for component replacement. 4. Bulk of water released from coolant system into the core vessel retained in core vessel ullage and drain line. 5. Failures within the moderator addressed in MRA events. 6. Contamination of Core Vessel, Core Vessel Vacuum or He System, and RTST Line.	**Unmitigated Consequences** **Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Limit the radiological impact to WG1 of a Loop 2 cooling water failure on a single component (PBW, MRA, TVP, and water-cooled shielding).			
Method of Detection:			
PBW, TVP, CMS/MRA monitoring systems.			
Core Vessel Drain Line Liquid Detection Probe. (EC) • Alarm in Control Room on detection of a leak in the Core Vessel Drain LIne. (EC) • MPS trip on High Level in the Core Vessel Drain Line. (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line. (EC)			
Loop 2 GLS level indicator.			
Loop 2 system pressure out of bounds.			
Core vessel pressure indicator increase.			

Event Number CW3-1d	
Preventive Features – Attributes:	**Credited:**
Operator training and procedures. (AC)	
Valve line-up checklist. (AC)	
Preventive maintenance and inspection program for pumps and control circuitry. (AC)	
Mitigative Features – Attributes:	**Credited:**
MPS beam trip for out-of-range Loop 2 return flow (EC)	
PBW, TVP, MRA, or shielding status monitoring (EC)	
Core Vessel Drain Line Liquid Detection Probe. (EC) • Alarm in Control Room on detection of a leak. (EC) • MPS trip on High Level in the Core Vessel Drain Line. (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line. (EC)	
Core vessel burst disk rupture causes an alarm in the control room. (EC)	
Inert core vessel atmosphere. (EC)	
Core vessel pressure relief system – burst disk and hydrogen safe vent (See Note 4). (EC)	
Collection of Water by the Core Vessel; Confinement by Core Vessel, Core Vessel Drain Line, RTST, and neutron beam windows. (DF/EC)	
Emergency Operating Procedures and Training. (AC)	
Location ensures significant shielding for personnel in the Target Building or outside the RTST tunnel. (DF)	
MPS beam trip on Loop 2 pump exit pressure. (EC) (See Note 1)	
MPS beam trip for water Loop 2 GLS tank low level. (EC)	
TPPS Sweep and Evict Procedure - Proper procedures and training for the sweep and evict protocols prior to securing the TDR before beam operations. (AC)	
PPS Access Control to the Target Drive Room (EC)	
Area Radiation Monitors are located in the High Bay to alarm locally and provide TPPS trip for the beam if elevated radiation levels are detected, (EC)	

Event Number			
CW3-1d			
Planned analysis, assumption validations, and Risk/Opportunities: 1. Analysis to determine consequences of Loop 2 release. 2. Align MPS trip with pump operation to provide a Soft Trip of the Linac front end impacting both the FTS and STS.	**Mitigated Consequences:** **Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A
Notes: 1. Delay built into the MPS trip to provide recovery time prior to the required trip. Delay time TBD 2. See Event AIC3-10 3. Collection of water by a proton beam window failure will either go to the core vessel (if leak from the vessel side of the window), the RTST (if leaked from the RTST side of the window), or to the bulk shielding liner drain collection system if leaked form the assembly away from the window. 4. The burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. 5. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.			**Mitigated Frequency** **A**

Event Number
CW3-2a

Event Description:
Loss of cooling water Loop 1 heat sink.

Assumptions and Initial Conditions:

1. Assumes Proton Beam Window cooled by Loop 2 and the target cooling is the only component cooled by Loop 1. (DF)
2. Redundant power supply busses for pumps. (DF)
3. Core vessel operating in inert helium near atmospheric pressure or in vacuum. (IC)Proton beam remains on. (IC)
4. Proton beam window will not fail for nominally an hour without cooling and does not provide a short-term passive beam trip. (DF)
5. Proton beam remains on. (IC)
6. Double walled heat exchanger for both Loop 1 and Loop 2 to the cooling tower water with valve isolation capability on each loop eliminates the need for a secondary DI water loop. (DF)

Causes:

1. Loss of tower water primary pump power supply.
2. Pump breaker trip.
3. Valve misalignment.
4. Pump seizure.

Initiating Event Frequency
A

Unmitigated Impact on Systems:

1. Loss of Loop 1 cooling could result in boiling in water within target, with resulting breach of vessel due to overheating and boiling pressure pulses.
2. Hot loop water leaks from target shroud.
3. Core vessel atmosphere rupture disk may rupture due to expanding steam.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Low	**Public**: N/A	**Public**: N/A
WG1: High	**WG1**: N/A	**WG1**: N/A
WG2: Moderate	**WG2**: N/A	**WG2**: N/A

Safety Function:
Reduce probability of a loss of Loop 1 cooling water heat sink leading to a release of significant amount of radiological material impacting WG1.

Method of Detection:	
Central tower water system pump status and/or low flow alarms.	
Core vessel pressure indicator increase.	
Tower water system pressure decrease.	
High Temperature in Loop 1 system.	
Core Vessel Drain Line Liquid Detection.	
Loop 1 GLS level indicator.	

Preventive Features – Attributes:	**Credited:**
Preventive maintenance and inspection program for pumps and control circuitry. (AC)	
Valve line-up checklist. (AC)	

Event Number
CW3-2a

Mitigative Features – Attributes:	Credited:
Core vessel containment of spilled water. (DF)	
Tower water cooling water flow or high loop system temperature interlocked with beam trip. (EC)	
TPS beam trip on Loop 1 cooling water out of range condition. (EC)	X
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	X
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
Core vessel shielding. (DF)	
Core vessel pressure increase signals operator to take action to mitigate a leak. (AC)	
Operating procedures. (AC)	
Emergency Response procedures. (AC)	
Trained operators. (AC)	
Tower water pump status and/or low flow sensor in pump control circuitry energizes standby pump. (EC)	
Core Vessel Drain Line Liquid Detection Probe (EC) • Alarm in Control Room on detection of a leak in the Core Vessel Drain Line (EC) • MPS trip on High Level in the Core Vessel Drain Line (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line (EC)	X

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:	Mitigated Frequency
1. See events in TS, HPV, CMS/MRA, and AIC event tables. 2. Common accident analysis with TS events 3. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.	**A**

Event Number
CW3-2b

Event Description:
Loss of cooling water Loop 2 heat sink.

<table>
<tr>
<td colspan="3">Assumptions and Initial Conditions:
1. Loop 1 provides cooling water for the Target. (DF)
2. Loop 2 cools the PBW, TVP, MRA, and CV shielding. (DF/IC)
3. Proton beam window will not fail for nominally an hour without cooling and does not provide a short-term passive beam trip. (DF)
4. Redundant power supply busses for Loop 2 pumps. (DF)
5. Core vessel operating in inert helium near atmospheric pressure or in vacuum. (IC)
6. Double walled heat exchanger for both Loop 1 and Loop 2 to the cooling tower water with valve isolation capability on each loop eliminates the need for a secondary DI water loop. (DF)</td>
<td colspan="2">Causes:
1. Loss of central DI water flow primary pump power supply.
2. Pump breaker trip.
3. Valve misalignment.
4. Pump seizure.</td>
<td>Initiating Event Frequency
A</td>
</tr>
<tr>
<td colspan="3" rowspan="2">Unmitigated Impact on Systems:
1. TVP, CMS/MRA, or near field shielding boundary could fail due to material defect or overheating.
2. Loss of Loop 2 cooling could result in boiling in stagnant water within reflector or near field shielding, with resulting breach of vessel due to overheating and boiling pressure pulses.
3. Hot loop water leaks from reflector.
4. Core vessel atmosphere rupture disk may rupture due to expanding steam.
5. Extended shutdown for component replacement.
6. Contamination of Core Vessel, Core Vessel Vacuum or He System, and RTST Line.
7. Bulk of water released from coolant system into the core vessel retained in core vessel ullage and drain line.</td>
<td colspan="3">Unmitigated Consequences</td>
</tr>
<tr>
<td>Radiological
Public: Negligible
WG1: Low
WG2: Negligible</td>
<td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td>
<td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td>
</tr>
</table>

Safety Function:
Reduce probability of loss of Loop 2 cooling water heat sink resulting in a release of significant quantities of radiological material impacting WG1.

Event Number CW3-2b	
Method of Detection:	
High Temperature in Loop 2 system.	
Central tower water system pump status and/or low flow alarms.	
Tower water system pressure decrease.	
Core vessel pressure indicator increase.	
Core Vessel Drain Line Liquid Detection Probe. (EC) • Alarm in Control Room on detection of a leak in the Core Vessel Drain Line. (EC) • MPS trip on High Level in the Core Vessel Drain Line. (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line. (EC)	
Loop 2 GLS tank level indicator.	
Preventive Features – Attributes:	**Credited:**
Preventive maintenance and inspection program for pumps and control circuitry. (AC)	
Valve line-up checklist. (AC)	
Mitigative Features – Attributes:	**Credited:**
Core vessel containment of spilled water. (DF)	
Tower water pump status and/or low flow sensor in pump control circuitry energizes standby pump. (EC)	
Core Vessel Drain Line Liquid Detection Probe. (EC) • Alarm in Control Room on detection of a leak in the Core Vessel Drain Line. (EC) • MPS trip on High Level in the Core Vessel Drain Line. (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line. (EC)	
MPS Cooling water out of range condition automatic beam shutdown. (EC)	
Core vessel shielding. (DF)	
Core vessel pressure increase signals operator to take action to mitigate a leak. (AC)	
Operating procedures. (AC)	
Emergency Response procedures. (AC)	
Trained operators (AC)	
Tower water cooling water flow or high loop system temperature interlocked with MPS beam trip. (EC)	

<table>
<tr><td colspan="4">Event Number
CW3-2b</td></tr>
<tr><td rowspan="2">Planned analysis, assumption validations, and Risk/Opportunities:</td><td colspan="3">Mitigated Consequences</td></tr>
<tr><td>Radiological
Public: Negligible
WG1: Low
WG2: Low</td><td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
<tr><td colspan="3">Notes:
1. Unmitigated consequences assumed similar to CW3-4 event.
2. Similar to CW3-1b.
3. See events in the HPV, CMS/MRA, and AIC event tables.
4. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.</td><td>Mitigated Frequency
A</td></tr>
</table>

Event Number
CW3-2c **(Event Deleted with PBW moved to Loop 2)**

Event Description:
Loss of cooling water Loop 2 heat sink without impact on Loop 1.

Event Number
CW3-3a

Event Description:
Leak of cooling water in Loop 1 cooling that collects in core vessel.

Assumptions and Initial Conditions:
1. Pump continues running. (IC)
2. Loop 1 provides cooling water for the Target. (DF)
3. Loop 2 provides cooling water for the Proton Beam Window, TVP, MRA, and water-cooled shielding. (DF)
4. Core vessel operating in inert helium near atmospheric pressure or in vacuum. (IC)
5. Proton beam remains on. (IC)
6. Beam is terminated preventing target loss (target events with beam continuing to operate are addressed in TS event tables) (IC)
7. Core vessel rupture disk ruptures releasing activated water vapor and tritium. (IC)
8. It is assumed that Loop 1 cooling water systems assumed to be able to fill the core vessel up to the level of the proton beam. (IC)

Causes:
1. Piping material defect.
2. Corrosion.
3. Fatigue from vibration.
4. Internal erosion.
5. Irradiation damage.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Eventual loss of Loop 1 cooling system.
2. Covering of target and moderators with water.
3. Draining of core vessel may be required.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Reduce probability of Loop 1 cooling water leakage in the core vessel resulting in a release of significant quantities of radiological material impacting WG1.

Method of Detection:

Pressure increase in core vessel monitored by core vessel helium or vacuum system.

Core Vessel Drain Line Liquid Detection Probe. (EC)
- Alarm in Control Room on detection of a leak in the Core Vessel Drain Line. (EC)
- MPS trip on High Level in the Core Vessel Drain Line. (EC)
- TPS beam trip on high-high level in the Core Vessel Drain Line. (EC)

Neutron Scattering Instruments loss of performance.

GLS tank level.

Abnormal flow or pressure in Loop 1 cooling system.

Event Number
CW3-3a

Preventive Features – Attributes:	Credited:
Loop1 mechanical and material design (DF)	
Mounting and bracing inside the reflector (DF)	

Mitigative Features – Attributes:	Credited:
TPS beam trip upon abnormal Loop 1 system return flow. (EC)	
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip on abnormal Loop 1 system indications (return flow). (EC)	
MPS beam trip on abnormal GLS level. (EC)	
Core Vessel Drain Line Liquid Detection Probe. (EC) • Alarm in Control Room on detection of a leak in the Core Vessel Drain Line. (EC) • MPS trip on High Level in the Core Vessel Drain Line. (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line. (EC)	
Core vessel ullage and drain operations supports continued operations in core vessel helium mode operations. (See Note 3) (DF)	
Emergency operating procedures (AC)	
Trained operators (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Loop 1 evaluation of maximum water leak to core vessel.
2. Determine Loop 1 volume and the level water could fill the core vessel before the GLS tank would no longer permit flow to the target segments.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Event Number CW3-3a	
Notes: 1. In the helium mode drain is possible without shutting down. Shutdown required for vacuum mode. 2. See events in the TS, HPV, CMS/MRA, and AIC event tables. 3. Target cooling system design basis document provides conditions under which the core vessel drain can remain open and permit continued operations. 4. To maintain the core vessel drain open during operation, the design must address the loop seal (P-Trap) design and associated controls when balanced against: a. The height requirement of the core vessel drain loop seal and the core vessel rupture disk setting; b. The margin available between the core vessel leak detection alarm, MPS trip, and TPS trip levels; c. Leak rate permitted vs continued GLS tank operation; d. Core Vessel Drain Tank volume; e. etc. 5. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.	**Mitigated Frequency** **A**

Event Number CW3-3b				
Event Description: Leak of cooling water in Loop 2 cooling within reflector shielding that collects in core vessel.				
Assumptions and Initial Conditions: 1. Pump continues running. (IC) 2. Loop 1 provides cooling water for the Target. (DF) 3. Loop 2 provides cooling water for the Proton Beam Window, TVP, MRA, and water-cooled shielding. (DF) 4. Core vessel operating in inert helium near atmospheric pressure or in vacuum. (IC) 5. Proton beam stays on and boils water producing steam. (IC) 6. Beam termination is not required to prevent target loss as Loop 1 cooling continues for the target (target events with beam continuing to operate are addressed in TS event tables) (IC) 7. Proton beam window will not fail for nominally an hour without cooling and does not provide a short-term passive beam trip. (DF) 8. Core vessel rupture disk ruptures releasing activated water vapor and tritium. (IC) 9. It is assumed that Loop 2 cooling water systems are able to fill the core vessel up to the level of the proton beam. (IC)	**Causes**: 1. Piping material defect 2. Corrosion 3. Fatigue from vibration 4. Internal erosion 5. Irradiation damage.		**Initiating Event Frequency** A	
Unmitigated Impact on Systems: 1. Eventual loss of Loop 2 cooling system. 2. Covering of target and moderators with water. 3. Draining of core vessel required. 4. Premoderator leak from Loop 2 onto target could destroy the phosphor coating and therefore TVP operation.	**Unmitigated Consequences**			
	Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Safety Function: Reduce probability of Loop 2 cooling water leakage resulting in a release of significant quantity of radiological material impacting WG1.				
Method of Detection:				
Pressure increase in core vessel monitored by core vessel helium or vacuum system.				
Core Vessel Drain Line Liquid Detection Probe. (EC) • Alarm in Control Room on detection of a leak in the Core Vessel Drain Line. (EC)				
Neutron Scattering Instruments loss of performance.				
Loop 2 GLS tank level indicator.				
Abnormal level or pressure in Loop 2 cooling system.				

Event Number CW3-3b	
Preventive Features – Attributes:	**Credited:**
Loop 2 mechanical and material design (DF)	
Mounting and bracing inside the reflector (DF)	
Mitigative Features – Attributes:	**Credited:**
MPS beam trip upon low Loop 2 total return flow. (EC)	
MPS beam trip on supply flow to the various Loop 2 cooled components. (EC)	
Core Vessel Drain Line Liquid Detection Probe. (EC) • Alarm in Control Room on detection of a leak in the Core Vessel Drain Line. (EC) • MPS trip on High Level in the Core Vessel Drain Line. (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line. (EC)	
MPS beam trip on abnormal Loop 2 GLS level. (EC)	
Core vessel ullage and drain operations supports continued operations in core vessel helium mode operations. (See Note 2) (DF)	
Emergency operating procedures. (AC)	
Trained operators. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Loop 2 evaluation of maximum water leak to core vessel. 2. Loop 2 GLS tank level trip setpoint and total water that can go into the core vessel before a trip.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Event Number CW3-3b	
Notes: 1. See events in the HPV, CMS/MRA, and AIC event tables. 2. Target cooling system design basis document provides conditions under which the core vessel drain can remain open and permit continued operations. 3. To maintain the core vessel drain open during operation, the design must address the loop seal (P-Trap) design and associated controls when balanced against: a. The height requirement of the core vessel drain loop seal and the core vessel rupture disk setting; b. The margin available between the core vessel leak detection alarm, MPS trip, and TPS trip levels; c. Leak rate permitted vs continued GLS tank operation; d. Core Vessel Drain Tank volume; 4. etc. 5. The burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. 6. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.	**Mitigated Frequency** **A**

Event Number
CW3-4a

Event Description:
Leak of cooling water from Loop 1 cooling system to the secondary side of its heat exchanger.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Loop 1 includes a double walled heat exchanger, replacing the secondary cooling loop. (DF)	1. N/A	BEU

<table>
<tr><td rowspan="2">Unmitigated Impact on Systems:
1. N/A</td><td colspan="3">Unmitigated Consequences</td></tr>
<tr><td>Radiological
Public: N/A
WG1: N/A
WG2: N/A</td><td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
</table>

Safety Function:
Prevent Leak of cooling water from Loop 1 cooling system to the secondary side of its heat exchanger leading to a contamination of the Secondary loop with Loop 1 cooling water.

Method of Detection:	

Preventive Features – Attributes:	**Credited:**
Loop 1 includes a double walled heat exchanger, replacing the secondary cooling loop. (DF)	

Event Number CW3-4a				
Mitigative Features – Attributes:				**Credited:**
Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**			
	Radiological **Public**: N/A **WG1**: N/A **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Notes:				**Mitigated Frequency BEU**

Event Number
CW3-4b

Event Description:
Leak of cooling water from Loop 2 cooling system to the secondary side of its heat exchanger.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Loop 2 includes a double walled heat exchanger, replacing the secondary cooling loop. (DF)	1. N/A	BEU

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent Leak of cooling water from Loop 2 cooling system to the secondary side of its heat exchanger leakage leading to a contamination of the Secondary loop with Loop 2 cooling water

Method of Detection:	

Preventive Features – Attributes:	**Credited:**
Loop 2 includes a double walled heat exchanger, replacing the secondary cooling loop. (DF)	

Event Number CW3-4b				
Mitigative Features – Attributes,				**Credited:**
Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**			
	Radiological **Public**: N/A **WG1**: N/A **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Notes:				**Mitigated Frequency BEU**

Event Number
CW3-5a

Event Description:
Leak of Secondary DI cooling water into Loop 1 via the Loop 1 heat exchanger.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Loop 1 includes a double walled heat exchanger, replacing the secondary cooling loop. (DF)	1. N/A	BEU

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
1.	**Radiological** **Public**: N/A **WG1**: N/A **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent Secondary DI cooling water leakage into Loop 1 via the Loop 1 heat exchanger impacting target cooling.

Method of Detection:	

Preventive Features – Attributes:	**Credited:**
Loop 1 includes a double walled heat exchanger, replacing the secondary cooling loop. (DF)	

Event Number CW3-5a				
Mitigative Features – Attributes:				**Credited:**
Planned analysis, assumption validations, and Risk/Opportunities: 1.	**Mitigated Consequences:**			
	Radiological **Public**: N/A **WG1**: N/A **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Notes: 1.				**Mitigated Frequency** **BEU**

Event Number CW3-5b					
Event Description: Leak of Secondary DI cooling into Loop 2 via the Loop 2 heat exchanger.					
Assumptions and Initial Conditions: 1. Loop 2 includes a double walled heat exchanger, replacing the secondary cooling loop. (DF)		**Causes**: 1. N/A			**Initiating Event Frequency** BEU
Unmitigated Impact on Systems: 1. N/A.		**Unmitigated Consequences**			
		Radiological **Public**: N/A **WG1**: N/A **WG2**: N/A		**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Prevent Secondary DI cooling leakage into Loop 2 via the Loop 2 heat exchanger impacting Loop 2 cooled components.					
Method of Detection:					
Preventive Features – Attributes:					**Credited:**
Loop 2 includes a double walled heat exchanger, replacing the secondary cooling loop. (DF)					

Event Number CW3-5b			
Mitigative Features – Attributes,			**Credited:**
Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: N/A **WG1**: N/A **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Notes:			**Mitigated Frequency BEU**

Event Number
CW3-7a

Event Description:
Leak of cooling water from Loop 1 cooling system from piping inside the core vessel and to the core vessel Line.

Assumptions and Initial Conditions:
1. Activated water from the Loop 1 cooling system leaks inside vessel from primary piping or components. (IC)
2. Beam termination for a significant leak are addressed in TS event tables. (IC)
3. Beam operation is assumed to continue with a small leak either with inert or vacuum core vessel operation. (IC)
4. No automatic Loop 1 water makeup is provided. (IC)
5. Drain line valve will be located in the HPV and is normally closed during operation. (IC)
6. Personnel are not permitted in the HPV during beam operation. (IC)
7. During vacuum operation, this will require beam termination to drain the water in the Drain Line and repair the leak. (IC)
8. During helium operation, the design permits draining the Drain Line when the alarm level is reached (See Note 2). ((IC)

Causes:
1. Pipe material defect or corrosion.
2. Fatigue from vibration.
3. Internal erosion.
4. Irradiation damage.
5. Flange gasket leak.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Eventual loss of Loop 1 cooling water system due to loss of water level in the Loop 1 GLS tank.
2. Target and Proton or Neutron Beam Window Damage is possible.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Moderate	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Reduce probability of Loop 1 cooling water leakage inside the core vessel leading to a release of significant quantities of radiological material to WG1.

Method of Detection:	
Abnormal pressure or flow indications for Loop 1 cooling system(s).	
Pressure in core vessel.	
RGA detection of leak.	
Loop 1 GLS tank level.	
Core Vessel Drain Line Liquid Detection Probe. (EC) • Alarm in Control Room on detection of a leak in the Core Vessel Drain Line. (EC)	

Event Number
CW3-7a

Preventive Features – Attributes:	Credited:
Loop 1 piping material selection and design, mounting, and bracing. (DF)	
Piping designed to meet ASME Code B31.3. (DF)	
Installation procedures. (AC)	

Mitigative Features – Attributes:	Credited:
Vacuum or Helium inerting accommodates moisture in core vessel. (EC)	
Emergency response procedures. (AC)	
Core Vessel Pressure detection. (EC)	
TPS beam trip upon abnormal Loop 1 return flow from the target. (EC)	X
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	X
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip on abnormal Loop 1 system indications (return flow). (EC)	
MPS beam trip on abnormal GLS level. (EC)	
Core Vessel Drain Line Liquid Detection Probe. (EC) • Alarm in Control Room on detection of a leak in the Core Vessel Drain Line (EC) • MPS trip on High Level in the Core Vessel Drain Line. (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line. (EC)	
Core vessel ullage and drain operations supports continued operations in core vessel helium mode operations. (See Note 3) (DF)	
Worker training. (AC)	
Vacuum or Helium inerting provides continuous monitoring of moisture (RGA). (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Analysis of the permissible amount of water leaked into the vessel and the peak rate to set trip set points.
2. There will be a P-trap/loop seal to isolate the core vessel and CV drain tank atmospheres and allow continuous drainage to the tank during helium core vessel inerting operation. Verify functionality of the instrumentation in the Core Vessel Drain Line and the ability to drain the line during helium operations.
3. Target cooling system design basis document provides conditions under which the core vessel drain can remain open and permit continued operations.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible **WG1**: Low **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Event Number CW3-7a	
Notes: 1. If the leak is small enough, it may not be detected until the GLS tank level reaches an alarm/trip point, as the vacuum operation will consume the small leak of cooling water. 2. Similar to CW3-3a. 3. See events in the TS, HPV, CMS/MRA, and AIC event tables. 4. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.	**Mitigated Frequency** **A**

Event Number
CW3-7b

Event Description:
Leak of cooling water from Loop 2 cooling system from piping inside the core vessel and to the core vessel Drain Line.

Assumptions and Initial Conditions:

1. Loop 1 provides cooling water for the Target. (DF)
2. Loop 2 provides cooling water for the Proton Beam Window, TVP, MRA, and water-cooled shielding. (DF)
3. Inert core vessel atmosphere with helium or vacuum mode of core vessel operation. (IC)
4. Activated water from the Loop 2 cooling system leaks inside vessel from primary piping or components. (IC)
5. Beam is assumed to continue with no impact on the Target as it is cooled by Loop 1. Target events are addressed in TS event tables. (IC)
6. Beam is assumed to continue with a small leak either with inert or vacuum core vessel operation. (IC)
7. No automatic Loop 2 water makeup is provided. (IC)
8. Drain line valve will be located in the HPV and is normally closed during operation. (IC)
9. During vacuum operation, this will require beam termination to drain the water in the drain line and repair the leak. (IC)
10. During helium operation, the design permits draining the drain line when the alarm level is reached (See Note 2). (IC)
11. Personnel are not permitted in the HPV during beam operation. (IC)
12. Proton beam window will not fail for nominally an hour without cooling so that it is not impacted by this event and does not provide a timely passive beam trip. (DF)
13. CMS3-5 addresses a loss of or reduction of Loop 2 pre-moderator/reflector water flow results in overheating and boiling of pre-moderator/reflector water and breach of reflector vessel releasing water to core vessel. (IC)
14. Damage to the TVP, and water-cooled shielding is addressed in AIC3-9. (IC)

Causes:

1. Pipe material defect or corrosion
2. Fatigue from vibration
3. Internal erosion
4. Irradiation damage.
5. Flange gasket leak

Initiating Event Frequency
A

Unmitigated Impact on Systems:

1. Eventual loss of Loop 2 cooling water system due to loss of system level in the GLS tank.
2. Decontamination and cleanup required in area with potential exposure to personnel.
3. Damage to Loop 2 cooled components.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Reduce probability of Loop 2 cooling water leakage inside the core vessel leading to damage to Loop 2 cooled components and a release of significant quantities of radiological material impacting WG1.

Event Number CW3-7b	
Method of Detection:	
Abnormal pressure or flow indications for Loop 2 cooling system(s).	
Pressure in core vessel.	
Loop 2 GLS tank level.	
Core Vessel Drain Line Liquid Detection Probe. (EC)	
Alarm in Control Room on detection of a leak. (EC)	
RGA detection of leak.	
Preventive Features – Attributes:	**Credited:**
Loop 2 piping material selection and design, mounting, and bracing. (DF)	
Piping designed to meet ASME Code B31.3. (DF)	
Installation procedures. (AC)	
Mitigative Features – Attributes:	**Credited:**
Vacuum or Helium inerting accommodates moisture in core vessel .(EC)	
Emergency response procedures. (AC)	
Vacuum or Helium inerting provides continuous monitoring of moisture (RGA). (EC)	
Core Vessel pressure detection. (EC)	
MPS beam trip on abnormal Loop 2 system indications (return flow). (EC)	
MPS beam trip on abnormal GLS level. (EC)	
Core vessel ullage and drain operations supports continued operations in core vessel helium mode operations. (See Note 3) (DF)	
Worker training. (AC)	
Core Vessel Drain Line Liquid Detection Probe. (EC) • Alarm in Control Room on detection of a leak in the Core Vessel Drain Line. (EC) • MPS trip on High Level in the Core Vessel Drain Line. (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line. (EC)	

Event Number
CW3-7b

Planned analysis, assumption validations, and Risk/Opportunities:
1. Evaluation of the permissible amount of water leaked into the vessel and the peak rate to set trip set points.
2. Determine if it is reasonable to drain water in the drain line during helium core vessel inerting operation.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:
1. See event TS, HPV, CMS/MRA, and AIC event tables.
2. There will be a P-trap/loop seal to isolate the core vessel and CV drain tank atmospheres and allow continuous drainage to the tank during helium core vessel inerting operation. Verify functionality of the instrumentation in the Core Vessel Drain Line and the ability to drain the line during helium operations.
3. Target cooling system design basis document provides conditions under which the core vessel drain can remain open and permit continued operations.
4. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition

Mitigated Frequency
A

Event Number
CW3-9

<table>
<tr><td colspan="5">Event Description:
Contamination of tower water from Secondary cooling loop for Loop 1 or 2</td></tr>
<tr><td>Assumptions and Initial Conditions:
1. Loop 1 includes a double walled heat exchanger, replacing the secondary cooling loop. (DF).
2. Loop 2 includes a double walled heat exchanger, replacing the secondary cooling loop. (DF)
3. Loop 1 provides cooling water for the Target. (DF)
4. Loop 2 provides cooling water for the Proton Beam Window, TVP, MRA, and water-cooled shielding. (DF)</td><td colspan="3">Causes:
1. Leak in heat exchanger</td><td>Initiating Event Frequency
BEU</td></tr>
<tr><td rowspan="2">Unmitigated Impact on Systems:
1.</td><td colspan="4">Unmitigated Consequences</td></tr>
<tr><td>Radiological
Public: N/A
WG1: N/A
WG2: N/A</td><td colspan="2">Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
<tr><td colspan="5">Safety Function:
Prevent contaminating the cooling tower water.</td></tr>
<tr><td colspan="4">Method of Detection:</td><td></td></tr>
<tr><td colspan="4"></td><td></td></tr>
<tr><td colspan="4"></td><td></td></tr>
<tr><td colspan="4">Preventive Features – Attributes:</td><td>Credited:</td></tr>
<tr><td colspan="4"></td><td></td></tr>
<tr><td colspan="4"></td><td></td></tr>
</table>

Event Number CW3-9			
Mitigative Features – Attributes:			**Credited:**
Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: N/A **WG1**: N/A **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Notes:			**Mitigated Frequency** BEU

Event Number
CW3-10

Event Description:
With proton beam off a leak of reflector water into core vessel occurs.

Assumptions and Initial Conditions	Causes	Initiating Event Frequency
1. A vacuum layer is in the cryogenic moderator vessel serves as insulation between the cold hydrogen (17 degrees K) and the pre-moderator water. (DF) 2. The proton beam is off, so that no heating of the pre-moderator occurs. (IC) 3. With no insulation (vacuum layer), and with no heating from the proton beam, the pre-moderator could freeze due to the nearby hydrogen. (IC) 4. Loop 2 provides cooling water for the Proton Beam Window, TVP, MRA, and water-cooled shielding. (DF)	1. Pipe breach in pre-moderator piping that is outside the vacuum system.	A

Unmitigated Impact on Systems:
1. Moderator Reflector Assembly replacement needed.
2. Recovery time (including operational verification that the system is safe to operate) to restore normal operation.
3. Removing water from the bottom of the Core Vessel.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent a leak of reflector water into core vessel from leading to a failure with release of significant quantities of radiological material impacting WG1 during beam off conditions.

Method of Detection:	
Vacuum monitors.	
Core Vessel liquid detection probe.	
Loop 2 monitoring (pressure, flow, or GLS water level.	
Premoderator water loop flow, pressure, and temperatures.	
System indicators and alarms.	

Preventive Features – Attributes:	Credited:
Moderator vessel design. (DF)	
Loop 2 moderator support piping design. (DF)	

Event Number CW3-10	
Mitigative Features – Attributes:	**Credited:**
Core vessel liquid detection. (EC)	
Water leak is collected by the Core Vessel and alarmed by the leak detection instruments. (EC)	
Confinement capability of the core vessel at pressures less than 1.5 atmosphere (gage pressure). (DF)	
Moderator design. (DF)	
Emergency response procedures. (AC)	
Worker training. (AC)	
Core vessel pressure relief burst disk and hydrogen safe vent (See Note 3). (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Thermal analysis of hydrogen system to evaluate potential for water freezing. 2. Determine activation level of the water in Loop 2 after shutdown. 3. Determine activation level of the hydrogen after shutdown.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. The vacuum layer in the cryogenic moderator vessel serves as insulation between the cold hydrogen (17 degrees K) and the pre-moderator water. 2. Leak detection instrumentation is not in the core vessel, but in a drain line from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and Drain Line by a valve. The Core Vessel Drain Line provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. This allows operation with a small leak in the water systems. 3. The burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures.	**A**

Event Number
CW4-1

Event Description:
Direct Radiological exposure of personnel to activated cooling water Loops 1 or 2.

Assumptions and Initial Conditions:
1. Consequences depend on location of worker and the length of time the worker was in the high radiation area. Conservatively assumes 0.5 hours in a 100 R/hr field. (IC)
2. Includes HPV and Target Drive Room location. (IC)
3. Workers are not permitted in the HPV or Target Drive Room when the beam is on. (AC/IC)
4. Loop 1 provides cooling water for the Target. (DF)
5. Loop 2 provides cooling water for the Proton Beam Window, TVP, MRA, and water-cooled shielding. (DF)

Causes:
1. Personnel in direct line-of-sight and in immediate vicinity of Loop 1 or 2 cooling systems in HPV or high bay (with shielding blocks removed during beam operations or immediately after beam shutdown prior to short-lived nuclide decay.

Initiating Event Frequency
U

Unmitigated Impact on Systems:
1. No impact on systems, but delay in operations

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Moderate	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent personnel exposure above allowable levels from activated cooling water in Loops 1 or 2..

Method of Detection:	
TPPS Access door beam trip and alarms.	
TPPS Area Radiations Monitors (ARM).	
Personnel surveys and dosimetry.	

Preventive Features – Attributes:	**Credited:**
Permanent or portable shielding. (EC)	
RCT survey prior to entering the HPV or Target Drive Room for work. (AC)	X
TPPS alarm on area doorway to Target Drive Room and HPV. (EC)	X
Radiation locks on shielded cover blocks. (EC)	
Radiation protection program. (AC)	
Worker training. (AC)	

Event Number CW4-1				
Mitigative Features – Attributes:				**Credited:**
TPPS Automatic beam shutdown on breach of access into HPV. (EC)				
Permanent or portable shielding. (DF)				
Radiation protection program including RCT surveys. (AC)				
Worker training. (AC)				
Work planning. (AC)				
TPPS Area Radiations Monitors (ARM) (EC).				
Planned analysis, assumption validations, and Risk/Opportunities: 1. Determine activation level and potential dose from components in Loop 1 accessible areas. 2. Determine activation level and potential dose from components in Loop 2 accessible areas.	**Mitigated Consequences:**			
	Radiological **Public**: N/A **WG1**: N/A **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Notes: 1. HPV4-1 addresses the HPV where personnel receive external exposure to radiation higher than anticipated in the HPV.				**Mitigated Frequency Prevented**

Event Number
CW4-2

Event Description:
Tungsten-water corrosion in target.

Assumptions and Initial Conditions:
1. Alternate design not consistent with the current Lasagna target module design. (IC)
2. Tantalum cladding on tungsten target cracks. (IC)
3. Corrosion products load up hydrocylone upstream of Cooling Loop 1 GLS. (Not applicable for current target design) (IC)
4. Cladding failure will result in corrosion of tungsten when in contact with water, which could occur over a long period of time. (IC)
5. Corrosion rate permits detection and response before total loss of cooling flow. (IC)
6. Beam is terminated preventing target loss (target events are addressed in TS event tables. (IC)
7. Loop 1 provides cooling water for the Target. (DF)
8. Loop 2 provides cooling water for the Proton Beam Window, TVP, MRA, and water-cooled shielding. (DF)

Causes:
1. Fabrication flaw in cladding
2. Stresses during beam operation

Initiating Event Frequency
BEU
(See Note 2)

Unmitigated Impact on Systems:
1. Activated tungsten collected in hydrocyclone (See Note 1), ion exchange columns, filters, and piping causing a high dose rate impacting maintenance operations.
2. Distribution of particulates throughout cooling Loop 1 components
3. Significant downtime for recovery of operations.
4. Challenge to process resin in ion exchange columns.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible **WG1**: Moderate **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Reduce probability tungsten corrosion causing high activation in components impacting maintenance and operations.

Method of Detection:	
dP across filters and ion exchange columns.	
Gamma detector on Loop 1 return line. (See Note 3)	
RCT survey detection in pump room.	
Increase in hydrogen generation rate detected in GLS tanks.	
Water loop conductivity.	
Higher generation of radioactive gases requiring releases.	
Loop 1 flowrate decrease.	
Higher purge flow resulting in higher stack releases.	

Event Number
CW4-2

Preventive Features – Attributes:	Credited:
Target cladding design and fabrication process testing and validation. (AC)	
Ability to maintain water quality. (AC)	

Mitigative Features – Attributes:	Credited:
Full flow hydrocyclone removes larger particles, reduces inventory of particulates. (Not applicable for current target design.) See Note 1) (EC)	
Shielded hydrocyclone, ion exchange columns, and filters. (Not applicable for current target design.) (See Note 1) (EC)	
Ability to isolate leaking segment from beam pulse could reduce corrosion rate. (EC)	
Interlocks to alarm and notify operations if dP across filters and ion exchange columns gets too high. (Not applicable for current target design.) (EC)	
Low corrosion rate if small cladding breach. (DF)	
Radiological protection program. (AC)	
Maintain loop water quality. (AC)	
EOPs. (AC)	
Operator training. (AC)	
Alarm response procedures and operator action. (AC)	
RCT survey detection in pump room. (AC)	X

Planned analysis, assumption validations, and Risk/Opportunities:
1. Need to evaluate this event when the final target design is selected.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible **WG1**: Low **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:
1. Should an alternate target configuration be selected or identified in the future that posed the potential for increased contamination products, then design changes may be required. Space has been provided in the design to provide for the installation of a full flow hydrocyclone to remove larger particles and thus reduce the inventory of particulates. Additionally, this event will need to be reconsidered to provide for appropriate credited controls and defense in depth controls to provide protection for WG1 receptors.
2. This event is BEU with the current Lasagna design because of the cooling tube design and layers of material between the tungsten and water. However, it is held in the PHAR to address alternative designs that do no have this multiple layer of protection.
3. Should an alternate target configuration be selected or identified in the future that posed the potential for increased contamination products, then design changes may be required. As part of the evaluation for this condition a gamma detector may be warranted, but is not included in the initial design.

Mitigated Frequency
BEU

APPENDIX F. OFFGAS TREATMENTS – HOG AND VACUUM SYSTEMS (GW) HAZARD EVENT TABLES

APPENDIX F. OFFGAS TREATMENTS – HOG AND VACUUM SYSTEMS (GW) HAZARD EVENT TABLES

<table>
<tr><td colspan="6">Event Number
GW1-1</td></tr>
<tr><td colspan="6">Event Description:
Fire initiated in the hot offgas system.</td></tr>
<tr><td colspan="2">Assumptions and Initial Conditions:
1. HOG system operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC)</td><td colspan="3">Causes:
1. Combustibles in the vicinity of the hot offgas system; HEPA filters; iodine adsorber; instrumentation wiring; hydrogen or oxygen leak.
2. Pressure excursion in CV injects hydrogen into HOG
3. Leak in CMS injects hydrogen into HOG through vacuum or He purge
4. Hydrogen in HOG system ignites.
5. Charcoal in iodine adsorber ignites.
6. Ignition source: Sparks generated by malfunctioning electrical equipment in or near the offgas system, Welding upstream of iodine adsorber, fan motor overheating, other unidentified ignition source.</td><td>Initiating Event Frequency
A</td></tr>
<tr><td colspan="3" rowspan="2">Unmitigated Impact on Systems:
1. Leakage of radioactive gases to building atmosphere.
2. Release of gases from fire to environment through Core Vessel vent open rupture disk
3. Shutdown of the affected area.
4. Potential for considerable damage to and/or contamination of operating areas or equipment in the vicinity of the fire.
5. Plugging of HEPA filters from smoke.</td><td colspan="3">Unmitigated Consequences</td></tr>
<tr><td>Radiological
Public: Negligible
WG1: Low
WG2: Negligible</td><td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
<tr><td colspan="6">Safety Function:
Reduce probability of fire in the HOG that could lead to the release of significant quantities of radiological material impacting WG1.</td></tr>
<tr><td colspan="5">Method of Detection:</td><td></td></tr>
<tr><td colspan="5">Fire detection system.</td><td></td></tr>
<tr><td colspan="5">Out of range instrumentation indications for HOG system.</td><td></td></tr>
<tr><td colspan="5">Preventive Features – Attributes:</td><td>Credited:</td></tr>
<tr><td colspan="5">Dilution of radiolysis gases with nitrogen. (EC)</td><td></td></tr>
<tr><td colspan="5">Dilution of gases with air in HOG system to below flammable limits. (Note 1) (DF)</td><td></td></tr>
<tr><td colspan="5">Electrical equipment design codes. (AC)</td><td></td></tr>
<tr><td colspan="5">Operating Procedures. (AC)</td><td></td></tr>
<tr><td colspan="5">NFPA standards. (AC)</td><td></td></tr>
<tr><td colspan="5">Preventive maintenance program for exhaust fans. (AC)</td><td></td></tr>
</table>

Event Number GW1-1	
Mitigative Features – Attributes:	**Credited:**
Control system designed to maintain negative pressure with respect to the atmosphere in building ductwork during abnormal conditions. (EC)	
Fire detection and suppression system. (EC)	
Hydrogen analyzer in GLS tank offgas to control nitrogen feed. (DF)	
Materials of construction minimize combustible materials. (DF)	
System design is passive. (DF)	
Facility fire response training and procedures. (AC)	
Fire department response. (AC)	
Combustible material control program. (AC)	
Radiological protection and control procedures. (AC)	
Trained operators. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Consequence analysis of this event. 2. A Project Fire Hazard Analysis will be performed in support of CD-2 and inform the fire events in the PHAR. 3. Assessment of fires per NFPA 801.	**Radiological** **Public:** Negligible **WG1:** Low **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. Dilution of gases with air in HOG system to below flammable limits is part of normal operations and not part of an event response.	**A**

Event Number
GW1-3

Event Description:
Fire is initiated in the vacuum system.

Assumptions and Initial Conditions:
System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. Release of radiological material to the environment. (IC)
Vacuum systems covered are:

- PBW Inflatable Seal Vacuum System.
- Core Vessel Vacuum System.
- Cryogenic Moderator System Vacuum System.
- Central Guide Vacuum System.

Causes:

1. Combustibles in the vicinity of the vacuum system; instrumentation wiring.
2. Pressure excursion in core vessel.
3. Leak of hydrogen moderator into core vessel.
4. Hydrogen ignites in vacuum pump discharge.
5. Ignition source: sparks generated by malfunctioning electrical equipment in or near the vacuum system.
6. Vacuum pump motor overheating.
7. Other unidentified ignition source.

Initiating Event Frequency
A

Unmitigated Impact on Systems:

1. Shutdown of the affected area.
2. Potential for considerable damage to and/or contamination of operating areas or equipment in the vicinity of the fire.
3. If fire is in Cryogenic Moderator System Vacuum System while actively pumping, the hydrogen inventory will be released through the hydrogen safe system vent due to the heat input from loss of vacuum.
4. Plugging of HEPA filters from smoke.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Reduce probability of fire in the vacuum systems that could lead to the release of significant quantities of radiological material impacting WG1.

Method of Detection:	
Fire detection system.	
Out of range instrumentation indications for vacuum system.	

Preventive Features – Attributes:	**Credited:**
Electrical equipment design codes. (AC)	
Operating Procedures. (AC)	
NFPA standards. (DF)	
Preventive maintenance program for vacuum pumps. (AC)	
Dilution of gases with air in HOG system to below flammable limits. (Note 1) (DF)	

Event Number GW1-3	
Mitigative Features – Attributes:	**Credited:**
Fire detection and suppression system. (EC)	
Materials of construction minimize combustible materials. (DF)	
System design is passive. (DF)	
Facility fire response training and procedures. (AC)	
Fire department response. (AC)	
Combustible material control program. (AC)	
Trained operators. (AC)	
Radiological protection and control procedures. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. A Project Fire Hazard Analysis will be performed in support of CD-2 and inform the fire events in the PHAR. 2. Assessment of fires per NFPA 801.	**Radiological** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. Dilution of gases with air in HOG system to below flammable limits is part of normal operations and not part of an event response.	**A**

Event Number
GW2-1

Event Description:
Explosion in the HOG system releasing radioactive gases and particulates.

Assumptions and Initial Conditions:	**Causes:**	**Initiating Event Frequency**
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC)	1. Buildup of hydrogen gas leaking from an inadequate purge. 2. Gas fraction measurement instrumentation failure. 3. Pressure excursion in CV vents hydrogen to HOG. 4. Leak in CMS injects hydrogen into HOG through vacuum or He purge 5. Mixture is ignited by a spark from friction or electric motor, or other unidentified ignition source (such as a static charge).	U

Unmitigated Impact on Systems:
1. Loss of affected area of HOG system.
2. Release of gases and particulates from affected area of HOG system to local atmosphere.
3. Release of gases and particulates from affected area of HOG system to environment through CV vent.
4. Explosion damage to offgas system and collateral damage to adjacent equipment or systems.
5. Loss of filtration; migration of contaminated filter media to offgas fans and release from CEF-II.

Unmitigated Consequences

Radiological	**Chemical**	**ODH**
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Reduce probability of explosion in the HOG system that could lead to the release of significant quantities of radiological material impacting WG1.

Method of Detection:	
Audible.	
Visual.	
Out of range HOG system pressure indications.	

Preventive Features – Attributes:	**Credited:**
Dilution of radiolysis gases with nitrogen. (Note 1) (EC)	
Exposure of mixture to external ignition sources is minimized while contained within the HOG system. (DF)	
Dilution of gases with air in HOG system to below explosive limits. (Note 1) (DF)	
Appropriately rated electrical equipment will be used as required by Code. (DF)	
Operating Procedures and Training. (AC)	
Trained operators. (AC)	
Preventive maintenance of HOG system. (AC)	

Event Number
GW2-1

Mitigative Features – Attributes:	Credited:
In the case of a breach, the HOG exhaust fans will continue to create a negative pressure in the system, thereby maintaining a flow to the stack from the breached area of the HOG system. (DF)	
Hydrogen analyzer in GLS tank offgas to control nitrogen feed. (DF)	
HEPA filtration will filter released particulates from explosion. (DF)	
EOPs. (AC)	
Trained personnel. (AC)	
Radiation and contamination control procedures. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public:** Negligible **WG1:** Low **WG2:** Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. Dilution of gases with air in HOG system to below flammable limits and Dilution of radiolysis gases with nitrogen is part of normal operations and not part of an event response.	**U**

Event Number
GW2-3

Event Description:
Explosion in the vacuum system releasing radioactive gases and particulates.

Assumptions and Initial Conditions:
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC)
2. Vacuum systems covered are:
   - PBW Inflatable Seal Vacuum System
   - Core Vessel Vacuum System
   - Cryogenic Moderator System Vacuum System
   - Central Guide Vacuum System

Causes:
1. Introduction of oxygen and hydrogen into vacuum system from sources such as: radiolysis of water in cooling systems, leaked cryogenic moderator into core vessel or into the confined space above core vessel.
2. Pressure excursion in Core Vessel vents hydrogen to HOG.
3. Leak in CMS injects hydrogen into HOG through vacuum or He purge
4. Mixture is ignited by a spark from vacuum pump friction or electric motor, or other unidentified ignition source (such as a static charge).

Initiating Event Frequency
U

Unmitigated Impact on Systems:
1. Loss of affected area of vacuum system.
2. Release of offgas and particulates from affected area of vacuum system to local atmosphere.
3. Release of gases and particulates from affected area of HOG system to environment through Core Vessel vent.
4. Collateral explosion damage to adjacent equipment or systems.
5. If fire is in Cryogenic Moderator System Vacuum System while actively pumping, the hydrogen inventory will be released through the hydrogen safe system vent due to the heat input from loss of vacuum.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Reduce probability significant radiological material impacting WG1 from release from explosion in the vacuum systems.

Method of Detection:	
Audible and visual.	
Out of range vacuum system pressure indications.	
Core Vessel Liquid Detection systems.	

Preventive Features – Attributes:	**Credited:**
Exposure of mixture to external ignition sources is minimized while contained with the vacuum system. (DF)	
Dilution of radiolysis gases with nitrogen. (Note 1) (EC)	
Dilution of gases with air in HOG system to below explosive limits. (Note 1) (DF)	
Operating Procedures and Training. (AC)	
Preventive maintenance of vacuum pumps. (AC)	
Trained operators. (AC)	

Event Number
GW2-3

Mitigative Features – Attributes:	Credited:
EOPs. (AC)	
Hydrogen analyzer in GLS tank offgas to control nitrogen feed. (DF)	
Trained personnel. (AC)	
Radiation and contamination control procedures. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. Evaluation of the need of a beam cut-off system for loss of core vessel vacuum.	**Radiological** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
1. Dilution of gases with air in HOG system to below flammable limits and Dilution of radiolysis gases with nitrogen is part of normal operations and not part of an event response	U

Event Number
GW3-1

Event Description:
Leak or rupture of hot offgas piping releasing activated gases and particulates to building either in vaults or the areas piping is routed through.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC)	1. Leak or rupture of piping/valves due to material defect. 2. Corrosion. 3. Fatigue due to vibration. 4. Over pressurization caused by block valve closure, excess gas flow, or plugged HEPA filter 5. Collision of crane or forklift. 6. Improper maintenance or damage. 7. Operator error.	U

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. A leak in the offgas piping would release radioactive gases and particulates into the building area and eventually out the STS stack.	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Reduce probability of offgas leakage leading to excessive personnel exposure to radiological material.

Method of Detection:	
Visual.	
Audible.	
STS stack monitor.	

Preventive Features – Attributes:	Credited:
HOG piping is operated at negative pressure relative to its surroundings. (DF)	
Mounting and bracing of components. (DF)	
Design of piping - certified material. (AC)	
Routing of piping away from areas where collisions can occur. (DF)	
Operating Procedures and Training. (AC)	
Periodic system inspection and preventive maintenance. (AC)	

Event Number GW3-1				
Mitigative Features – Attributes:				**Credited:**
Secondary Confinement Exhaust System. (EC)				
HEPA filtration for released radioactive particulates. (DF)				
EOPs. (AC)				
Trained personnel. (AC)				
Stack Monitor and alarm (EC)				
Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**			
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Notes:				**Mitigated Frequency** **U**

Event Number
GW3-2

Event Description:
Loss of hot offgas system exhaust fans.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC)	1. Loss of power to exhaust fans. 2. Failure of drive motor. 3. Failure of coupling or drive belts. 4. Motor overheat and trip on thermal overload. 5. Failure of motor or fan bearing. 6. Operator Error.	**A**

Unmitigated Impact on Systems:
1. Much reduced offgas flow through hot offgas system (stack has a natural draft tendency; discharges to offgas system tend to pressurize system).
2. Buildup of pressure upstream in system at source components of offgas.
3. Backflow of gases from GLS to service cell and other offgas served areas.
4. Backflow of gases through experiment area inlet filter.

Unmitigated Consequences		
Radiological	**Chemical**	**ODH**
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Reduce probability of GW fan loss leading to excessive personnel exposure to radiological material.

Method of Detection:	
Loss of exhaust flow indication.	
Upstream pressure increase indication in offgas system.	
Fan rotation sensor.	

Preventive Features – Attributes:	**Credited:**
Exhaust fan design, drive motor design, redundant fans with one fan in automatic standby upon loss of flow. (EC)	
Preventive maintenance exhaust fans. (AC)	
Use of proper valve/damper line-ups. (AC)	
Operating Procedures and Operator Training. (AC)	
Standby power to offgas fans (DF)	

Event Number
GW3-2

Mitigative Features – Attributes:	Credited:
Residual exhaust gas flow due to exhaust from vacuum system pumps into offgas system. (DF)	
Natural draft effect will tend to draw hot offgas out the stack at a reduced rate. (DF)	
EOPs. (AC)	
Trained personnel. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public:** Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency A

Event Number
GW3-3

Event Description:
Loss of Hot offgas system HEPA filtration in exhaust ducting.

<table>
<tr><td colspan="2">Assumptions and Initial Conditions:
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC)</td><td colspan="2">Causes:
1. Breach due to filter media failure.
2. Defective filter.
3. Filter overloaded or plugged and vacuum causes media to be sucked out.
4. Mechanical impact external to enclosure.
5. Improper filter installation.
6. Leak-by gasket.
7. Overfilling of cooling water loop tank, backs up in HOG line and causes filters to become waterlogged.</td><td>Initiating Event Frequency
A</td></tr>
<tr><td rowspan="2" colspan="2">Unmitigated Impact on Systems:
1. Radioactive particulates are released to the target building stack and the environment.</td><td colspan="3">Unmitigated Consequences</td></tr>
<tr><td>Radiological
Public: Negligible
WG1: Negligible
WG2: Negligible</td><td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
</table>

Safety Function:
Reduce probability of filter loss resulting in excessive personnel exposure to radiological material from release to the environment (worker locations).

Method of Detection:	
Out of range filter differential pressure indications.	
STS stack activity monitor.	

Preventive Features – Attributes:	**Credited:**
Two filters in series, second filter can stop particulates that get through first filter. (DF)	
Filter delta-P instrumentation. (EC)	
Purchase only certified and tested filters. (AC)	
Preventative maintenance (periodic filter changes based on filter ageing). (AC)	
Biannual penetration test. (AC)	

Event Number GW3-3				
Mitigative Features – Attributes:				**Credited:**
STS stack activity monitor and alarm. (EC)				
Redundant HEPA filter banks. (DF)				
EOPs. (AC)				
Trained personnel. (AC)				
Radiological and contamination control procedures. (AC)				
Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**			
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Notes: See GW2-1 for loss of HEPA filter effects from explosion in HOG system.				**Mitigated Frequency** **A**

Event Number GW3-4				
Event Description: HEPA filter media breakthrough.				
Assumptions and Initial Conditions: 1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC) 2. Potential for release of activity to environment. (IC)	**Causes**: 1. Filter media degrades allowing passage of particulate. 2. Damage to filter during installation. 3. Defective filter. 4. Wrong filter type used. 5. Overfilling of cooling water loop tank, backs up in HOG line and causes filters to become waterlogged.			**Initiating Event Frequency** **A**
Unmitigated Impact on Systems: 1. Contamination of downstream ductwork and fans; airborne contamination spread to surrounding area. 2. Recovery time required for filter replacement.	**Unmitigated Consequences**			
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A		**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Reduce probability of filter breakthrough resulting in significant quantities of radiological material release to the environment (worker locations).				
Method of Detection:				
Stack monitor.				
Differential pressure instrumentation across filter banks.				
Radiological survey.				
Failure of semi-annual penetration test.				
Preventive Features – Attributes:				**Credited:**
Housings designed per ASME-AG1. (DF)				
Specify proper HEPA filter. (AC)				
Operating Procedures and Training. (AC)				
Radiation Protection program. (AC)				
Semi-annual penetration test. (AC)				
ORNL SBMS procedure for HEPA filter purchasing. (AC)				
Penetration testing of new HEPA filters prior to installation. (AC)				
Preventative maintenance (periodic filter changes based on filter ageing). (AC)				

Event Number GW3-4	
Mitigative Features – Attributes:	**Credited:**
Stack monitor and alarm. (EC)	
Area Radiation Monitors (ARM). (Note 2) (EC)	
HEPA filters in series reduce releasable activity level. (DF)	
Parallel filter train. (DF)	
Emergency Response Procedures. (AC)	
Worker training. (AC)	
Radiation and contamination control procedures. (AC)	
Vented tank level interlock that turns off fill pump. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. See GW2-1 for loss of HEPA filter effects from explosion in HOG system. 2. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.	**A**

Event Number
GW3-5

Event Description:
HEPA filter plugging results in reduced exhaust flow.

Assumptions and Initial Conditions	Causes	Initiating Event Frequency
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC)	1. Differential pressure instrumentation across filter fails to indicate need for filter replacement. 2. Worker error (e.g., failure to monitor differential pressure across the filter bank, failure to replace filter when necessary). 3. Roughing pre-filter removed. 4. Particulate loading increases. 5. Overfilling of cooling water loop tank, backs up in HOG line and causes filters to become waterlogged.	**A**

Unmitigated Impact on Systems:
1. Loss of HOG system resulting in pressurization and potential local release of radioactivity.
2. Recovery time required for decontamination efforts and for restoration of ventilation system function.
3. Potential release of radioactivity to environment.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Reduce probability of filter plugging leading to a significant radiological release to the environment (worker locations).

Method of Detection:	
Filter differential pressure.	
Confinement area differential pressure monitors.	
Loss of HOG vacuum.	
Decrease in HOG flow.	
Increase in HOG vacuum at the stack fan.	

Preventive Features – Attributes:	Credited:
Specify proper roughing pre-filter. (AC)	
Maintenance Procedures. (AC)	
Operating Procedures and Training. (AC)	
Filter testing and replacement program. (AC)	

Event Number
GW3-5

Mitigative Features – Attributes:	Credited:
Modulating exhaust control dampers adjust to changing exhaust vacuum. (EC)	
Offgas duct has alarmed drainage collection point. (EC)	
Tank level interlock that turns off fill pump. (EC)	
Redundant HEPA filter banks. (DF)	
Filter differential pressure monitor. (EC)	
Worker training. (AC)	
Radiation and contamination control procedures. (AC)	
High air activity response procedures. (AC)	
Specify proper roughing pre-filter, pressure, and flow instrumentation. (AC)	
Emergency Response Procedures. (AC)	
Air activity monitoring. (AC/EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes: See GW1-1 for plugging of HEPA filter effects from fire in HOG system.	**Mitigated Frequency** **A**

Event Number GW3-6					
Event Description: Breach of HEPA filter confinement package results in release of radiological material (during replacement).					
Assumptions and Initial Conditions: 1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC)	**Causes**: 1. Worker accidently cuts containment bag during installation. 2. Damage to filter bag during storage. 3. Radiation damage to containment bag during service life.				**Initiating Event Frequency** **A**
Unmitigated Impact on Systems: 1. Spread of contamination from filter. 2. Recovery time required for decontamination efforts.		**Unmitigated Consequences**			
		Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A		**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Prevent filter package breach resulting in a significant quantity of radiological material release to the environment (worker locations).					
Method of Detection:					
Visual.					
Radiological survey.					
Preventive Features – Attributes:					**Credited:**
Filter removal system design (minimization of sharp edges and sharps program). (DF/AC)					
Maintenance Procedures. (AC)					
Specify rad hard polymer for bag. (AC)					
Operating Procedures and Training. (AC)					

Event Number
GW3-6

Mitigative Features – Attributes:	Credited:
Building design minimizing releases out of the building in conjunction with the ventilation system. (DF)	
Building ventilation system. (EC)	
Emergency Response Procedures. (AC)	
Worker training. (AC)	
Person protective equipment. (AC)	
Radiation and contamination control procedures. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
	A

Event Number
GW3-7

Event Description:
Release of radiological material as the result of a breach of a HEPA filter housing or exhaust ductwork.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC) 2. Potential for release of radiological material to the environment. (IC)	1. Material movement damages duct. 2. Defective duct joint. 3. Corrosion. 4. Vibration induced cracking. 5. Degraded joint or gasket/valve packing. 6. Crane or forklift impacts duct.	**U**

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. Spread of contamination to surrounding areas. 2. Recovery time required for decontamination efforts or for repairs as necessary.	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent housing breach resulting in a significant quantity of radiological material release to the environment (worker locations).

Method of Detection:	
Audible/visual.	
Loss of HOG vacuum.	
Differential pressure alarms.	

Preventive Features – Attributes:	Credited:
Ductwork designed to ASME-N509/AG1. (DF)	
Offgas system operates at negative pressure relative to surroundings. (DF)	
Maintenance procedures and preventive maintenance program. (AC)	
Operating Procedures and Training. (AC)	
Routing of offgas ducts (DF)	

Event Number
GW3-7

Mitigative Features – Attributes:	**Credited:**
Building design and confinement capability. (DF)	
System designed to maintain airflow from areas of lower potential contamination to areas of greater potential contamination. (EC)	
Seismic design improves impact resistance. (DF)	
Some confinement could be provided by the functional portions of the building HVAC. (EC)	
Stack monitoring. (AC)	
Emergency Response Procedures. (AC)	
Radiation and contamination control procedures. (AC)	
Worker training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency** **U**

Event Number
GW3-10

Event Description:
Pressure relief device failure in any of the GW systems.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC) 2. HOG system relief device that prevents excess vacuum in HOG system. (IC)	1. Operator error. 2. Defective relief device. 3. Relief device set pressure too high. 4. Relief device set pressure too low. 5. Lack of maintenance.	**A**

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
Release of confined gases to HOG system and to the environment. Excess vacuum in HOG system damages HEPA enclosures. Excess flow into HOG system.	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Reduce probability of pressure relief device failure leading to a significant quantity of radiological material release from any of the GW systems.

Method of Detection:	
Burst disk detector.	
HOG flow sensor.	

Preventive Features – Attributes:	Credited:
Select and size relief device properly. (AC/EC)	
Operating Procedures and Training. (AC)	
Preventative maintenance program. (AC)	

Event Number
GW3-10

Mitigative Features – Attributes:	Credited:
Radiation alarms. (EC)	
Stack monitor. (EC)	
HEPA filters remove particulates. (EC)	
HOG system ensures stack release. (EC)	
Emergency Response Procedures. (AC)	
Worker training. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
	A

Event Number
GW3-11

Event Description:
Loss of vacuum system pumps exhausting to HOG system.

Assumptions and Initial Conditions	Causes	Initiating Event Frequency
System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC) Vacuum systems covered are: • PBW Inflatable Seal Vacuum System. • Core Vessel Vacuum System. • Cryogenic Moderator System Vacuum System. • Central Guide Vacuum System.	1. Loss of local power to vacuum pumps. 2. Seized pump. 3. Pumps overheat and trip on thermal overload. 4. Mechanical impact. 5. Improper suction or exhaust valve positions. 6. Open offgas valves to CV. 7. Operator error.	A

Unmitigated Impact on Systems:
1. Loss of vacuum system booster pumps would result in a loss of vacuum in the affected vacuum serviced systems.
2. Reduced offgas flow and slow build-up of gases in vacuum serviced systems.
3. If Cryogenic Moderator System Vacuum System fails while actively pumping, the hydrogen inventory will be released through the hydrogen safe system vent due to the heat input from loss of vacuum.
4. If core vessel vacuum system fails, beam operation will have to be stopped due to loss of inerting (if in vacuum mode).

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Reduce probability of vacuum pump failure leading to a significant quantity of radiological material release to the environment (worker locations).

Method of Detection:	
Increase in pressure or out of range differential pressure indications in vacuum system.	
Short decrease in pressure in hot offgas system.	
Increase in pressure in vacuum-serviced components.	

Preventive Features – Attributes:	Credited:
Pump design. (DF)	
Redundant vacuum pumps with one in automatic standby. (DF/EC)	
Operating Procedures and Operator Training. (AC)	
Preventive maintenance of vacuum pumps. (AC)	
Use of proper valve line-ups. (AC)	

Event Number
GW3-11

Mitigative Features – Attributes:	Credited:
HOG system exhaust fans may continue to create a slight negative pressure in portions of the vacuum system despite the loss of the vacuum booster pumps, thereby maintaining a reduced flow of gas from the vacuum system. (EC)	
EOPs. (AC)	
Trained personnel. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. Evaluate the need for a beam trip system for loss of core vessel vacuum.	**Radiological** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency A

Event Number GW3-12					
Event Description: Leak or breach in a vacuum system.					
Assumptions and Initial Conditions: System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC) Vacuum systems covered are: • PBW Inflatable Seal Vacuum System • Core Vessel Vacuum System • Cryogenic Moderator System Vacuum System • Central Guide Vacuum System	**Causes**: 1. Pipe/duct material defect. 2. Corrosion. 3. Fatigue failure resulting from prolonged vibration. 4. Mechanical impact from external source. 5. Faulty joint seal during installation or maintenance. 6. Leaking offgas valve in CV. 7. Operator error.				**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. If the associated vacuum pump continues to run, air from the space surrounding the breach will be drawn into the vacuum system. 2. If Cryogenic Moderator System Vacuum System leaks while actively pumping, the hydrogen inventory will be released through the hydrogen safe system vent due to the heat input from loss of vacuum. 3. If core vessel vacuum system fails, beam operation will have to be stopped due to loss of inerting (if in vacuum mode).		**Unmitigated Consequences**			
		Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A		**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Reduce probability of vacuum system breach leading to a significant quantity of radiological material release to the environment (worker locations).					
Method of Detection:					
Out of range pressure indications in vacuum system.					
Target utility cooling systems.					
Visual.					
Core vessel and/or offgas system as applicable.					

Event Number
GW3-12

Preventive Features – Attributes:	Credited:
Physical piping or component barriers to prevent mechanical impact. (EC)	
Proper mounting and bracing of components. (DF)	
Welded connections. (DF)	
Piping and equipment material selection and design. (DF)	
Periodic system inspection and preventive maintenance. (AC)	
Operating Procedures and Operator Training. (AC)	

Mitigative Features – Attributes:	Credited:
SCE system filters particulates released from breached vacuum system. (EC)	
EOPs. (AC)	
Trained personnel. (AC)	
Radiation and contamination control procedures. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:
1. Evaluate the need for a beam trip system for loss of core vessel vacuum.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:

Mitigated Frequency
A

Event Number
GW4-1

Event Description:
Direct radiation exposure of worker(s) to the offgas piping.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC)	1. Improper monitoring for radiation levels. 2. Personnel enter areas of high radiation. 3. Shielding around offgas piping allows pathway for direct radiological exposure. 4. Inadequate delay/decay. 5. Source term higher than design basis.	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
None	**Radiological** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent radiation exposure above allowable levels around GW systems.

Method of Detection:	
Radiological survey.	

Preventive Features – Attributes:	**Credited:**
Routing of offgas line in shielded HPV. (DF)	
TPPS system controls access to the HPV. (EC)	
Offgas decay tank is located below grade (EC)	
Radiation Protection program. (AC)	
Radiation postings and personnel training reduce likelihood of personnel entering high radiation areas. (AC)	
Operating Procedures and Training. (AC)	
Delay/decay tank design (DF)	

<table>
<tr><td colspan="4">Event Number
GW4-1</td></tr>
<tr><td colspan="3">Mitigative Features – Attributes:</td><td>Credited:</td></tr>
<tr><td colspan="3">Radiation Safety Program –
Radiological Work Permit (RWP) (AC)
Radiation Survey (AC)
Training of personnel authorized to be in the area. (AC)</td><td></td></tr>
<tr><td colspan="3">Emergency Response Procedures. (AC)</td><td></td></tr>
<tr><td colspan="3">Worker training. (AC)</td><td></td></tr>
<tr><td colspan="3">Radiation control procedures. (AC)</td><td></td></tr>
<tr><td rowspan="2">Planned analysis, assumption validations, and Risk/Opportunities:</td><td colspan="3">Mitigated Consequences:</td></tr>
<tr><td>Radiological
Public: Negligible
WG1: Negligible
WG2: Negligible</td><td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
<tr><td colspan="3">Notes:</td><td>Mitigated Frequency
A</td></tr>
</table>

Event Number GW4-2				
Event Description: Inadvertent radiation exposure to personnel while changing offgas HEPA filters.				
Assumptions and Initial Conditions: 1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC)	**Causes**: 1. Release of filterable activity to offgas system. 2. Improper monitoring for radiation levels. 3. Personnel enter areas of high radiation. 4. Source term higher than design basis			**Initiating Event Frequency** **A**
Unmitigated Impact on Systems: None	**Unmitigated Consequences**			
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A		**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Prevent radiation exposure above allowable levels while changing offgas HEPA filters.				

Method of Detection:	
Radiological survey.	

Preventive Features – Attributes:	**Credited:**
Locate HEPA filter bank away from high occupancy areas. (DF)	
ASME-AG1 design code. (DF)	
Limited access to offgas filter bank. (EC)	
Operating Procedures and Training. (AC)	

Event Number
GW4-2

Mitigative Features – Attributes:	Credited:
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	
Radiation control procedures. (AC)	
Emergency Response Procedures (AC)	
Worker training. (AC)	
Radiation postings and personnel training reduce likelihood of personnel entering high radiation areas. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency** **A**

Event Number
GW4-3

Event Description:
Facility worker receives inadvertent direct radiological exposure in vicinity of HEPA filter bank.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC)	1. Improper monitoring for radiation levels. 2. Personnel enter areas of high radiation. 3. Source term higher than design basis. 4. Inadequate delay/decay. 5. Valve failure or operator error.	**A**

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
None	**Radiological** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent radiation exposure above allowable levels in the vicinity of HEPA filter bank.

Method of Detection:	
Radiological survey.	

Preventive Features – Attributes:	**Credited:**
Location of HEPA bank in low access areas. (DF)	
Limited access to HEPA banks. (EC)	
Delay/decay tank design (DF)	
Radiation Protection program. (AC)	
Radiation postings and personnel training reduce likelihood of personnel entering high radiation areas. (AC)	
Operating Procedures and Training. (AC)	

Event Number GW4-3	
Mitigative Features – Attributes:	**Credited:**
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	
Radiation control procedures. (AC)	
Emergency Response Procedures. (AC)	
Worker training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency** **A**

APPENDIX G. HIGH BAY (HB) HAZARD EVENT TABLES

Event Number
HB1-1

Event Description:
Release of radiological material due to localized fire in the High Bay Area.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. The fire described in this event is not expected to propagate to other areas of the facility. (IC) 2. Potential for release of radiological material to the environment. (IC) 3. This event is assumed to occur in an area that is likely to have surface contamination or transient material (e.g., contaminate cleaning material). (IC) 4. This also assumes that workers can react to obvious hazardous conditions, that they are physically able to evacuate, and that an evacuation route is available during the event. (IC) 5. Natural Gas is not permitted in the Target Building. (DF)	1. Electrical short. 2. Thermal energy from electrical equipment. 3. Friction from bearings, gears, motors, and power tools. 4. Hydraulic fluid leaks and is ignited. 5. Human error. 6. Combustibles in facility. 7. Other unidentified ignition source. 8. Cleaning or decontamination agents contact other materials and produce flammable fumes.	A

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. Plugging of SCE recirculation and exhaust filters with smoke. 2. Recovery time required for decontamination efforts or for repairs to equipment affected by the fire.	**Public**: Negligible **WG1**: Low **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Limit the likelihood and radiological consequences from a localized fire in the high bay.

Method of Detection:	
Fire detection system.	
Smoke smell.	
Visual.	

Preventive Features – Attributes:	Credited:
Electrical equipment designed to applicable codes. (DF)	
NFPA standards. (DF)	
FM Approved hydraulic fluid. (AC)	
Preventive maintenance program. (AC)	
Procedures and Training. (AC)	

Event Number HB1-1	
Mitigative Features – Attributes:	**Credited:**
Building design (e.g., materials of construction). (DF)	
Emergency response procedures and worker training. (AC)	
Combustible material control program. (AC)	
Fire detection and suppression system. (EC)	
SCE ventilation system. (EC)	
Radiation and contamination control procedures. (AC)	
Fire Department response. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. A Project Fire Hazard Analysis will be performed in support of CD-2 and inform the fire events in the PHAR. 2. Assessment of fires per NFPA 801.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. Fires inherently release hazardous chemicals, but no chemicals specific to STS operation are different from a standard industrial fire situation.	**A**

Event Number
HB1-2

Event Description:
Release of radiological material due to a large fire in the High Bay Area.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. The fire described in this event could propagate to other areas of the facility and could ultimately result in the release of significant quantities of radiological material. (IC) 2. This event is assumed to occur in an area that is likely to have surface contamination or transient material (e.g., contaminate cleaning material). (IC). 3. This also assumes that workers can react to obvious hazardous conditions, that they are physically able to evacuate, and that an evacuation route is available during the event. (IC) 4. Storage Casks containing a Spent target or target module(s) are not stored in the High Bay. (IC) 5. Potential for release of radiological material (IC) 6. Natural Gas is not permitted in the Target Building. (DF) 7. Spent target segments and other activated components out of the core vessel are not stored in the High Bay. (AC/IC)	1. Electrical short. 2. Thermal energy from electrical equipment. 3. Friction from bearings, gears, motors, and power tools. 4. Hydraulic fluid leaks and is ignited. 5. Human error. 6. Combustibles in facility. 7. Other unidentified ignition source. 8. Cleaning or decontamination agents contact other materials and produce flammable fumes.	U

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. Plugging of SCE recirculation and exhaust filters with smoke 2. Recovery time required for decontamination efforts or for repairs to equipment affected by the fire. 3. Severe damage possible to High Bay components and structures. 4. Long term loss of facility possible depending on severity of fire.	**Public**: Negligible **WG1**: Moderate **WG2**: Low	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Limit the likelihood and radiological consequences from a large fire in the high bay.

Method of Detection	
Fire detection system.	
Visual.	
Smoke smell.	

Preventive Features – Attributes:	Credited:
Electrical equipment designed to code. (DF)	
Operating Procedures and Training. (AC)	
NFPA standards. (DF)	
FM Approved hydraulic fluid. (AC)	
Preventive maintenance program. (AC)	

Event Number
HB1-2

Mitigative Features – Attributes:	Credited:
Building design (e.g., materials of construction). (DF)	
Emergency response procedures. (AC)	X
Combustible material control program. (AC)	
Radiation and contamination control procedures. (AC)	
Worker training. (AC)	
Fire detection and suppression system. (EC)	
SCE ventilation system. (EC)	
Fire Department response. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. Analysis to be done under BG1-1 accident analysis. 2. Evaluation of ability of spent target storage cask to prevent release of hazardous material because of fire in High Bay. 3. A Project Fire Hazard Analysis will be performed in support of CD-2 and inform the fire events in the PHAR. 4. Assessment of fires per NFPA 801.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Low	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
1. Bounded by event BG1-1. 2. Transfer or Shipping Casks are only in the High Bay during transport and are not stored in the High Bay.	**U**

Event Number
HB2-1

Event Description:
Breach of hydrogen transfer line piping in the High Bay allows hydrogen to escape (large leak) to the High Bay. Hydrogen accumulates in concentrations greater than the LEL in air and resulting in a detonation releasing trace quantities of tritium, activated particulates contained in the hydrogen, and surface contamination on material in the high bay. (See event CMS2-4 also)

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. HUR in STS located outside of Target Building crane coverage and in a room close to the target drive room. (DF) 2. Hydrogen transfer lines are within crane coverage. (IC) 3. This event could cause a burn or detonation of H2 released to the high bay. (IC) 4. Natural Gas is not permitted in the Target Building. (DF) 5. Spent target segments and other activated components out of the core vessel are not stored in the High Bay. (AC/IC)	1. Crane load drop. 2. Worker or Maintenance error. 3. Piping material failure.	U

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. A hydrogen detonation in the High Bay could result in severe damage to equipment in the High Bay and surrounding areas. 2. It is unlikely that the assumed H2 explosion would cause a catastrophic impact on the core vessel or equipment in the core vessel, however, damage to Target Drive Room components is credible.	**Public**: Negligible **WG1**: Low **WG2**: Low	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Minimize the potential for a large hydrogen leak inside the High Bay or minimize the potential for a hydrogen detonation in the High Bay leading to a significant radiological release. .

Method of Detection:	
Hydrogen monitoring instrumentation.	
Cryogenic vacuum monitoring instrumentation.	
Fire detection system.	
Loss of hydrogen system pressure detected by instrumentation.	
Visual and audible.	

Preventive Features – Attributes:	Credited:
Hydrogen Transfer line cover plates or physical protection. (DF)	
Restrictions on crane travel in vicinity of hydrogen transfer piping. (AC/EC)	
Crane inspection and certification program. (AC)	

Event Number
HB2-1

Mitigative Features – Attributes:	**Credited:**
Target building structure minimizes the impact of the explosion on other areas of the facility. (DF)	
Emergency response procedures. (AC)	
High Bay volume (DF) and building ventilation system (EC) limit potential for accumulation of hydrogen in concentrations exceeding LEL. (DF)	
MPS beam trip on abnormal hydrogen parameters. (EC)	
Radiation and contamination control procedures. (AC)	
Worker training. (AC)	
Fire detection and suppression system. (EC)	
SCE ventilation system. (EC)	
Fire Department response. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Low	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. Event evaluates radiological consequences and not the explosion as the explosion is a standard industrial hazard. 2. The hydrogen transfer lines between the core vessel and HUR are buried or routed in trenches or recesses with a protective cover to prevent a release of hydrogen from an external impact.	**U**

Event Number HB2-2				
Event Description: Release of radiological material from the core vessel as the result of a high bay crane or load drop onto the monolith and target drive motor or drive shaft. The impact causes sufficient displacement and shock of core vessel components (e.g., target and cryogenic moderator components), releasing hydrogen within the core vessel. Released hydrogen results in a detonation within the core vessel.				
Assumptions and Initial Conditions: 1. Fractional and energetic release of solid target radiological inventory. (IC) 2. Shine shield in place over core vessel (IC) 3. Load drop breaks through shine shield and breaks cryogenic transfer line and causes loss of core vessel vacuum, or helium Inerting. (IC) 4. Operational mode and beam do not result in a passive beam shutdown. (IC) 5. Target drive room includes T-Beams that are removed for shine shield installation. (IC) 6. Inert core vessel atmosphere with helium or vacuum mode of core vessel operation. IC)	**Causes:** 1. Crane mechanical or electrical failure. 2. Worker or Maintenance error. 3. Piping material failure 4. Ignition source: impact friction within the inner plug assembly. Sparks from core vessel monitoring devices (e.g., thermocouples).			**Initiating Event Frequency** U
Unmitigated Impact on Systems: 1. Potential for major damage to core vessel components, high bay area surrounding core vessel. 2. Extensive shutdown of operations.	**Unmitigated Consequences**			
	Radiological **Public**: Negligible **WG1**: Moderate **WG2**: Low	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A		**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Prevent a load drop from resulting in damage to the core vessel components such that a breach in the hydrogen system releases hydrogen within the core vessel.				
Method of Detection:				
Visual and audible.				
High pressure indication in the core vessel.				
Abnormal cryogenic moderator system pre-moderator water system parameters.				
Hydrogen monitoring instrumentation.				
Preventive Features – Attributes:				**Credited:**
Crane design. (DF)				X
Critical Lift procedures. (AC)				X
Crane inspection and certification program. (AC)				X
Hoisting and rigging program. (AC)				X
Trained crane operators. (AC)				
Operating Procedures and Training. (AC)				

Event Number
HB2-2

Mitigative Features – Attributes:	**Credited:**
Core vessel internal components and surrounding shielding design. (DF)	
Shielding streaming step structural support design for moderator/reflector assembly. (Layers of aluminum clad stainless-steel shielding in and around the core vessel inner plug assembly which would dissipate or limit the impact energy and reduce the probability of significant inner plug assembly displacement within the core vessel, thereby minimizing the possibility of target or moderator vessel damage. (DF)	
MPS beam trip system response to abnormal hydrogen parameters (e.g., pressure and flow) to mitigate consequences. (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of monitored signal to the MPS panel. (EC)	
MPS beam trip for Target cooling Loop 1 return flow out of limits (EC)	
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip on abnormal operating parameters in Loop 2 systems. (EC)	
TPS beam trip due to TPS fail safe design providing a trip on loss of monitored signal to the TPS panel. EC)	
TPS beam trip if permissive rotation signal lost. (EC)	
TPS beam trip if target rotation stops or slows beyond limits. (EC)	
TPS beam trip for abnormal Loop 1 return flow. (EC)	
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
Core Vessel Drain Line Liquid Detection Probe. (EC) • Alarm in Control Room on detection of a leak. (EC) • MPS trip on High Level in the Core Vessel Drain Line. (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line. (EC)	
Building design and confinement capability. (DF)	
Building HVAC system. (EC)	
Seismically qualified / restrained / protected hydrogen equipment for an SDC-2 level event. (DF)	
High Bay floor design. (DF)	
Emergency response procedures. (AC)	
Radiation and contamination control procedures. (AC)	
Worker training. (AC)	
Design of Target Drive Room T-Beams above core vessel. (DF)	
SOPs for crane operation above the core vessel during beam operation. (AC)	

Event Number HB2-2			
Planned analysis, assumption validations, and Risk/Opportunities: 1. H2 explosion inside core vessel, analyzed during conceptual design phase will be re-analyzed during preliminary design phase.	**Mitigated Consequences:** **Radiological** **Public**: N/A **WG1**: N/A **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Notes: 1. CMS2-5b evaluates a detonation in the target drive space. 2. CMS7 events evaluate consequences of an NPH generated failure. 3. The hydrogen transfer lines between the core vessel and HUR are buried or routed in trenches or recesses with a protective cover to prevent a release of hydrogen from an external impact. 4. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.			**Mitigated Frequency** Prevented

Event Number
HB2-3

Event Description:
Release of radiological material from the core vessel as the result of a high bay crane or load drop onto the monolith and target drive motor or target shaft when the beam is off and the STS operation is set for target replacement or other operations in the core vessel. The impact causes sufficient displacement and shock of the inner plug assembly to breach the cryogenic moderator vessels, releasing hydrogen within the core vessel. Released hydrogen is ignited and explodes within the core vessel.

Assumptions and Initial Conditions:
1. Fractional release of solid target radiological inventory. (IC)
2. Shine shield in place over core vessel. (IC)
3. Load drop breaks through shine shield and breaks cryogenic transfer line and causes loss of core vessel vacuum, or helium Inerting. (IC)
4. Ignition source: impact friction within the inner plug assembly. Sparks from core vessel monitoring devices (e.g., thermocouples). (IC)
5. Beam is shut down for target maintenance operations. (IC)
6. Energetic release of small fraction of target radionuclides. (IC)
7. Target Drive Room T-Beams have been removed to permit crane access. (IC)
8. Workers are in the region of the target drive room, but not in the crane lift path. (IC/AC)

Causes:
1. Overhead Crane mechanical failure.
2. Lifting hook failure.
3. Failure to properly rig the roof beam or wall for the lift.
4. Mechanical failure on the “hook or ring feature” on the component being lifted.
5. Operator error – crane operator impacts the water-cooling lines.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Potential for major damage to core vessel components, high bay area surrounding core vessel.
2. Extensive shutdown of operations.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Moderate	**WG1**: N/A	**WG1**: N/A
WG2: Low	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent H2 release within the core vessel due to dropping a heavy load onto the monolith or target shaft during a maintenance outage.

Method of Detection:	
Visual.	
Audible.	

Preventive Features – Attributes:	**Credited:**
Crane design. (DF)	X
Critical Lift procedures including hoisting and rigging program. (AC)	X
Crane inspection and certification program. (AC)	X
Critical Lift procedures. (AC)	X
Trained crane operators. (AC)	
Operating Procedures and Training. (AC)	

Event Number
HB2-3

Mitigative Features – Attributes:	Credited:
Core vessel internal components and surrounding shielding design (DF)	
Shielding streaming step structural support design for moderator/reflector assembly. (Layers of aluminum clad stainless-steel shielding in and around the core vessel inner plug assembly which would dissipate or limit the impact energy and reduce the probability of significant inner plug assembly displacement within the core vessel, thereby minimizing the possibility of target or moderator vessel damage. (DF)	
Building design and confinement capability. (DF)	
Building HVAC system. (DF)	
Seismically qualified / restrained / physically protected hydrogen equipment for an SDC-2 level event. (EC)	
High Bay floor design. (DF)	
Emergency response procedures. (AC)	
Radiation and contamination control procedures. (AC)	
Worker training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. H2 explosion inside core vessel, analyzed during conceptual design phase will be re-analyzed during preliminary design phase.
2. Determine maintenance operations when Hydrogen should be removed from the MRA prior to starting target removal operations or other core vessel operations.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:

1. The anticipated initiating event frequency is based on the assumption that this facility configuration and activity is performed at least once a year.
2. The hydrogen transfer lines between the core vessel and HUR are buried or routed in trenches or recesses with a protective cover to prevent a release of hydrogen from an external impact.

Mitigated Frequency
Prevented

Event Number
HB3-1

Event Description:
Release of radiological material due to a leak in a storage/transfer cask during transport from the core vessel to the service cell.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. Radioactive materials in storage/transfer cask may include both activated water or be in a solid form that does not easily become airborne. (IC) 2. Component drying is assumed to occur in the service cell. (IC/AC) 3. Component initial dewatering is assumed to occur inside the core vessel. (IC/AC)	1. Failure of the cask due to corrosion. 2. Cask lower closure leak due t worker error or wear from normal operation. . 3. Cask lid gasket failure.	A

Unmitigated Impact on Systems:	Unmitigated Consequences		
1. Extensive decontamination of High Bay may be required.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Cask designed and maintained to limit the potential for a release of contamination from within the cask during transport to from the core vessel to the service cell. .

Method of Detection.	
Rad Survey detection of surface contamination.	

Preventive Features – Attributes:	Credited:
Cask design. (DF)	
Cask material selection. (DF)	
Gasket material selection. (AC)	
Cask inspection. (AC)	
Cask handling and operational procedures. (AC)	

Event Number HB3-1				
Mitigative Features – Attributes:				**Credited:**
Building ventilation system. (EC)				
Radiation and contamination control procedures. (AC)				
Building confinement capability. (DF)				
Worker training. (AC)				
Normal operating procedures will limit water in the component prior to transport from the core vessel. (AC)				
Component dewatering procedures (AC)				
Component dewatering equipment (AC)				
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)				
Planned analysis, assumption validations, and Risk/Opportunities: 1. Evaluate cask operations and design to determine potential consequences of leakage.	**Mitigated Consequences:**			
	Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Notes: 1. Consequences of a dropped cask resulting in a leak are addressed in HB3-2.				**Mitigated Frequency** A

Event Number
HB3-2

Event Description:
Release of radiological material from storage/transfer cask due to dropping cask.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency:
1. Radioactive materials in storage/transfer cask may include both activated water or be in a solid form that does not easily become airborne. (IC) 2. Component drying is assumed to occur in the service cell. (IC/AC) 3. Component initial dewatering is assumed to occur inside the core vessel. (IC/AC)	1. Drop from crane as the result of crane or hoist equipment failure. 2. Drop caused by operator error.	U

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. Potential for considerable damage to High Bay floor. 2. Damage to storage/transfer cask. 3. Shutdown of the affected area. 4. Recovery time required for decontamination and repairs.	**Public**: Negligible **WG1**: Moderate **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Limit the potential for a release of contamination from within the cask due to a drop.

Method of Detection.	
Visual and Audible.	
Vibratory.	

Preventive Features – Attributes:	Credited:
Crane design. (DF)	
Cask design (including lifting device). (DF)	
Crane inspection and certification program. (AC)	
Hoisting and rigging program. (AC)	
Personnel training. (AC)	
Maintenance procedures. (AC)	
Operating Procedures. (AC)	
Critical lift procedure. (AC)	
Trained crane operators. (AC)	

Event Number HB3-2			
Mitigative Features – Attributes:			**Credited:**
Cask design. (DF)			
Cask lift procedures, including lift height and load path. (AC)			X
Emergency response procedures. (AC)			
Building confinement capability. (EC)			
Building HVAC system. (EC)			
Radiation and contamination control procedures. (AC)			
Worker training. (AC)			
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)			
Critical Lift procedures. (AC)			X
Crane design. (DF)			X
Critical Lift procedures including hoisting and rigging program. (AC)			X
Crane inspection and certification program. (AC)			X
Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Consequence and design analysis of a dropped storage/transfer cask at any location during cack handling operations.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Notes: 1. This event does not address possible loss of cask shielding (and possible radiation exposure) as a result of the cask being dropped—see event HB4-1.			**Mitigated Frequency** U

Event Number HB4-1					
Event Description: Storage/transfer cask with spent target inside is dropped, causing closure to fail and either top or bottom cask closure lid dislodge, resulting in partial loss of shielding.					
Assumptions and Initial Conditions: 1. Radiation field in vicinity of failed shielding and in the view of the waste items could be on order of 1000 rem/h after cask drop. 2. Component drying is assumed to occur in the service cell. (IC/AC) 3. Component initial dewatering is assumed to occur inside the core vessel. (IC/AC)		**Causes:** 1. Failure of crane or lift device. 2. Worker/operator error.			**Initiating Event Frequency** U
Unmitigated Impact on Systems: 1. Potential for considerable damage to High Bay floor. 2. Damage to storage/transfer cask. 3. Shutdown of the affected area. 4. Recovery time required for decontamination and repairs..		**Unmitigated Consequences**			
		Radiological **Public**: Negligible **WG1**: High **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A		**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Limit the potential for a loss of cask shielding (including top or bottom lid closure) due to a drop leading to a direct exposure to workers above allowable limits.					
Method of Detection:					
Personal dosimetry.					
Visual and Audible.					
Preventive Features – Attributes:					**Credited:**
Crane design. (DF)					
Cask design (including lifting device). (DF)					
Crane inspection and certification program. (AC)					
Hoisting and rigging program. (AC)					
Personnel training. (AC)					
Maintenance procedures. (AC)					
Operating Procedures and Training. (AC)					
Critical lift procedure. (AC)					
Trained crane operators. (AC)					

Event Number HB4-1				
Mitigative Features – Attributes:				**Credited:**
Cask Design (DF)				
Cask lift procedures, including lift height, load path, and worker location during transport. (AC)				X
Radiation Protection Program and radiation control procedures (AC)				
Worker training (AC)				
Shielding design (DF)				
Radiation Protection Program (AC)				
Radiation postings (AC)				
Emergency response procedures (AC)				
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)				
Crane design. (DF)				X
Critical Lift procedures including hoisting and rigging program. (AC)				X
Crane inspection and certification program. (AC)				X
Planned analysis, assumption validations, and Risk/Opportunities: 1. Consequent and design analysis of a dropped storage/transfer cask at any location during cack handling operations.	**Mitigated Consequences:** **Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Notes: 1. This event does not address possible airborne exposure as a result of the cask being dropped—see event HB3-2.				**Mitigated Frequency** U

APPENDIX H. HOT PROCESS VAULTS (HPV) HAZARD EVENT TABLES

APPENDIX H. HOT PROCESS VAULTS (HPV) HAZARD EVENT TABLES

<table>
<tr><td colspan="5">Event Number
HPV1-1</td></tr>
<tr><td colspan="5">Event Description:
Release of radiological material due to localized fire in the General Area of the Hot Process Vault (HPV).</td></tr>
<tr><td>Assumptions and Initial Conditions:
1. This event is assumed to occur in an area that is likely to have surface contamination or transient material (e.g., contaminate cleaning material and water leaks from activated systems). (IC)
2. Small fire in area of the HPV. (IC)
3. The fire described in this event is not expected to propagate to other areas of the facility. (IC)
4. Potential for release of radiological material to the environment. (IC)
5. This also assumes that workers can react to obvious hazardous conditions, that they are physically able to evacuate, and that an evacuation route is available during the event. (IC)</td><td colspan="3">Causes:
1. Electrical short generates spark.
2. Thermal energy from such equipment as heaters or welding equipment.
3. Friction from such equipment as motors and power tools.
4. Hydraulic fluid leaks from forklift and is ignited.
5. Worker error.
6. Combustibles in area.
7. Other unidentified ignition source.
8. Cleaning or decontamination agents contact other materials and produce flammable fumes.</td><td>Initiating Event Frequency
A</td></tr>
<tr><td colspan="2" rowspan="2">Unmitigated Impact on Systems:
1. Shutdown of the affected area.
2. Potential for damage to surrounding operating areas or equipment.</td><td colspan="3">Unmitigated Consequences</td></tr>
<tr><td>Radiological
Public: Negligible
WG1: Low
WG2: Negligible</td><td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
<tr><td colspan="5">Safety Function:
Limit the potential for release of significant quantities of radiological material impacting WG1 in the event of a fire in the HPV.</td></tr>
<tr><td colspan="4">Method of Detection:</td><td></td></tr>
<tr><td colspan="4">Fire detection system.</td><td></td></tr>
<tr><td colspan="4">Smoke smell.</td><td></td></tr>
<tr><td colspan="4">Visual.</td><td></td></tr>
<tr><td colspan="4">Preventive Features – Attributes:</td><td>Credited:</td></tr>
<tr><td colspan="4">Electrical equipment design code. (DF)</td><td></td></tr>
<tr><td colspan="4">Operating Procedures and Training. (AC)</td><td></td></tr>
<tr><td colspan="4">Forklift or other lift system design and Non-combustible hydraulic fluid. (DF/AC)</td><td></td></tr>
<tr><td colspan="4">Preventive maintenance program (Forklift maintenance). (AC)</td><td></td></tr>
<tr><td colspan="4">NFPA standards. (DF)</td><td></td></tr>
</table>

Event Number
HPV1-1

Mitigative Features – Attributes:	Credited:
Building design (e.g., materials of construction). (DF)	
Emergency Operating Procedures. (AC)	
Combustible material control program. (AC)	
Building ventilation system. (DF)	
Radiation and contamination control procedures. (AC)	
Fire Department response. (AC)	
Worker training. (AC)	
Fire detection and suppression system. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:
1. A Project Fire Hazard Analysis will be performed in support of CD-2 and inform the fire events in the PHAR.
2. Assessment of fires per NFPA 801.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes

Mitigated Frequency
A

Event Number
HPV1-2

Event Description:
Small fire in HPV releases radioactive material.

Assumptions and Initial Conditions	Causes	Initiating Event Frequency
1. It is assumed that water from the LCS and in the cooling loop and Ion Exchange Column material is released. (IC) 2. Personnel access is restricted when the beam is on and before required dose level decay has occurred. (IC) 3. Beam is terminated preventing target loss (target events with beam continuing to operate are addressed in TS and CW event tables). (IC) 4. The fire described in this event is not expected to propagate to other areas of the facility. (IC) 5. This also assumes that workers can react to obvious hazardous conditions, that they are physically able to evacuate, and that an evacuation route is available during the event. (IC)	1. Spark. 2. Electrical short. 3. Malfunctioning electric heaters ignite motor or wiring insulation or other combustible material or flammable liquids or gases located in HPV. 4. Worker error during maintenance.	A

Unmitigated Impact on Systems	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. Fire damage to systems located in the HPV. 2. Contamination in the HPV delaying operations.	**Public**: Negligible **WG1**: Low **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Reduce probability of fire occurrence in the HPV leading to a release of significant quantities of radioactive water from the LCS, cooling loop, and IX Column impacting WG1.

Method of Detection:	
Fire detection system.	
Visual.	
Smoke smell.	
Abnormal remote indications for cooling water systems.	

Preventive Features – Attributes:	Credited:
Electrical equipment, connections, and cabling designed per NFPA standards. (DF)	
Electrical equipment designed to IEEE design codes. (DF)	
Operating Procedures and Training. (AC)	

Event Number HPV1-2	
Mitigative Features – Attributes:	**Credited:**
Fire detection and suppression system. (EC)	
Combustible material control program. (AC)	
Concrete fire barriers. (DF)	
No natural gas in building. (DF)	
Fire department response. (AC).	
Worker training to evacuate in the event of a fire. (AC)	X
Sumps collect spilled water. (EC)	
TPPS access controls to the HPV. (EC)	
Radiation and contamination control procedures. (AC)	
Building ventilation system. (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. A Project Fire Hazard Analysis will be performed in support of CD-2 and inform the fire events in the PHAR. 2. Assessment of fires per NFPA 801.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Notes:			**Mitigated Frequency** A

Event Number
HPV1-3

Event Description:
Large fire in HPV releases radiological material.

Assumptions and Initial Conditions:

1. It is assumed that water from the LCS and in the cooling loop and Ion Exchange Column material is released.. (IC)
2. Ion exchange column material is released. (IC)
3. Personnel access is restricted when the beam is on and before required dose level decay has occurred. (AC/IC)
4. Beam is terminated preventing target loss (target events with beam continuing to operate are addressed in TS and CW event tables). (IC)
5. Ion exchange resin is not required to be maintained wet to prevent autoignition of the resin. The radionuclide inventory is not high enough for this to occur. (DF)
6. The fire described in this event is not expected to propagate to other areas of the facility. (IC)
7. This also assumes that workers can react to obvious hazardous conditions, that they are physically able to evacuate, and that an evacuation route is available during the event. (IC)

Causes:

1. Small fire ignites combustible material and spreads through HPV.
2. Spark; electrical short, malfunctioning electric heaters.
3. Worker error during maintenance.
4. Ignition of motor or wiring insulation.
5. Other combustible material or flammable liquids or gases located in HPV.
6. Waste repacking area combustibles.

Initiating Event Frequency
U

Unmitigated Impact on Systems:

1. Fire damage to HPV systems.
2. Contamination in the HPV delaying operations.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Moderate	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Reduce probability of fire occurrence resulting in a release of significant quantities of radioactive coolant or material in an Ion exchange column impacting WG1.

Method of Detection:	
Fire detection system	
Visual	
Smoke smell.	
Abnormal remote indications for cooling water systems	

Event Number HPV1-3			
Preventive Features – Attributes:			**Credited:**
Electrical equipment, connections and cabling designed per NFPA standards (DF)			
Electrical equipment designed to IEEE design codes. (DF)			
Operating Procedures and Training. (AC)			
Mitigative Features – Attributes:			**Credited:**
Fire detection and suppression system. (EC)			
Combustible material control program. (AC)			
Concrete fire barriers. (DF)			
Sumps collect spilled water. (EC)			
Fire department response. (AC)			
Worker training. (AC)			
No natural gas in building. (DF)			
TPPS access control to the HPV. (EC)			X
Radiation and contamination control procedures. (AC)			
Planned analysis, assumption validations, and Risk/Opportunities: 1. A Project Fire Hazard Analysis will be performed in support of CD-2 and inform the fire events in the PHAR. 2. Assessment of fires per NFPA 801.	**Mitigated Consequences:** **Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Notes:			**Mitigated Frequency** **U**

Event Number
HPV3-1

Event Description:
Release of radiological material due to loss of confinement from the Hot Process Vault.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. Radioactive material in this area is assumed to be from leaks collected in HPV pits and to surface contamination. (IC) 2. Confinement function lost just for the HPV area. (IC)	1. SCE system upset or failure causes airflow reversal. 2. Worker error – improper monitoring for contamination.	A

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. Shutdown of the affected area. 2. Recovery time. 3. Required for decontamination efforts.	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Minimize the potential for radioactive contamination from escaping from the HPV impacting WG1.

Method of Detection:	
SCE system failure alarms.	

Preventive Features – Attributes:	Credited:
SCE system design. (EC)	
Operating Procedures and Training. (AC)	
Backup power source. (EC)	
HEPA filter testing and replacement program. (AC)	
Redundant HEPA filters and exhaust fans. (EC)	
Preventive maintenance program for exhaust fans. (AC)	

Event Number
HPV3-1

Mitigative Features – Attributes:	Credited:
Building design and confinement capability. (DF)	
Emergency response procedures. (AC)	
Radiation and contamination control procedures. (AC)	
Worker training. (AC)	
SCE system monitoring instrumentation. (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency** **A**

Event Number
HPV3-2

Event Description:
Exposure or Inhalation of released (Loop 1 or 2) Cooling Water in the Hot Process Vault.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Leak occurs during maintenance operation without beam with system not drained. (IC) 2. Water tritium inventory of 30 years of beam operation. (IC)	1. Loss of Material integrity. 2. Leak of cooling water from piping, joint, or heat exchanger shell due to material defect, corrosion, fatigue from vibration. 3. Pump seal deterioration. 4. Impact to system from moving forklift or another lifting device.	**A**

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Loss of operability of Loop 1 or 2 cooling water system. 2. Shutdown of process operations. 3. Contamination of Hot Process Vault. 4. Recovery time required for decontamination.	**Public**: Negligible **WG1**: Moderate **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent exposure to workers above allowable limits in the event of a cooling loop leak in the HPV.

Method of Detection:	
Cameras in vault.	
Visual from workers in the area.	
Pits with conductivity probes.	
Loop cooling water indications in control room.	

Preventive Features – Attributes:	**Credited:**
Loop cooling water system piping and equipment design (e.g., vibration isolators; welded joints, and pump design. (DF)	
Impact barriers surrounding system to prevent inadvertent impact (EC)	
Operating Procedures and Training. (AC)	
Surveillance & Maintenance Program. (AC)	
Radiography of welded connections. (AC)	
Trained forklift or lifting device operator. (AC)	

Event Number
HPV3-2

Mitigative Features – Attributes:	Credited:
Personal Protective Equipment. (AC)	
Sumps/Pits for water collection. (DF)	
Building ventilation system. (EC)	
Stainless steel vault floor liners. (DF)	
Radiation Control Procedures. (AC)	X
Trained personnel. (AC)	
ALARA Program. (AC)	
Rad Con checks before access to the Utility Vault. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Loop 1 and 2 tritium concentration calculation.
2. Radiological and chemical exposure consequence evaluation.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:

Mitigated Frequency
A

Event Number HPV3-3a				
Event Description: Leak of cooling water from Loop 1 cooling water into HPV.				
Assumptions and Initial Conditions: 1. Eventual loss of Loop 1 cooling system. (IC) 2. Beam is terminated preventing target loss (target events with beam continuing to operate are addressed in TS and CW event tables) (IC) 3. Consequences use bounding release of Loop 1 system. (IC) 4. Workers are not permitted in the HPV during beam operation. (AC)	**Causes**: 1. Piping, joint, or heat exchanger plate bundle due failure: • Material defect • Corrosion • Fatigue from vibration • Internal erosion • Improper seal at system joints • Material irradiation damage • Pump mag drive deterioration • Impact to system from moving forklift/hoist			**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. Loss of operability of Loop 1 system. 2. Contamination of HPV, cleanup, and decontamination.	**Unmitigated Consequences**			
	Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A		**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Reduce probability of cooling water leakage in the HPV leading to a release of significant quantities of radiological material and worker exposure above allowable limits.				

Method of Detection:	
Sumps/pits with leakage probes in HPV for each system.	
Visual.	
Abnormal Loop 1 indications in control room.	
Preventive Features – Attributes:	**Credited:**
Loop 1 system /piping / heat exchanger design, welded connections, pump design. (DF)	
Shielding and/or impact barriers surrounding activated/ contaminated systems to prevent inadvertent impact from moving forklift or lifting device. (DF)	
Pipe mounting and bracing. (DF)	
Preventive maintenance program by trained maintenance personnel. (AC)	
Trained forklift/hoist operators. (AC)	
Periodic piping inspection. (AC)	

Event Number HPV3-3a	
Mitigative Features – Attributes:	**Credited:**
Sloped floors, pits, and drainpipes for water collection testing and processing as waste for transfer to LLLW tanks. (DF)	
HPV / target HVAC filtration. (EC)	
EOPs and trained operators. (AC)	
Operating Procedures and Training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes: Also, see event TS, HPV, CMS, and AIC event tables.	**Mitigated Frequency** **A**

Event Number
HPV3-3b

Event Description:
Leak of cooling water from Loop 2 cooling water into HPV.

Assumptions and Initial Conditions:
1. Consequences use bounding release of Loop 2 system. (IC)
2. Eventual loss of Loop 2 cooling system. (IC)
3. Beam is terminated preventing damage to Loop 2 cooled components loss (Moderator events are covered in CMS; window, periscope, and collimator events are addressed in AIC and CW event tables (IC)
4. Workers are not permitted in the HPV during beam operation. (AC)

Causes:
1. Piping, joint, or heat exchanger plate bundle due failure:
   - Material defect
   - Corrosion
   - Fatigue from vibration
   - Internal erosion
   - Improper seal at system joints
   - Material irradiation damage
   - Pump mag drive deterioration
   - Impact to system from moving forklift/hoist

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Loss of operability of Loop 2 system.
2. Contamination of HPV, cleanup and decontamination.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Reduce probability of cooling water leakage in the HPV leading to a release of significant quantities of radiological material and worker exposure above allowable limits.

Method of Detection:	
Sumps/pits with leakage probes in HPV for each system.	
Abnormal Loop 2 indications in control room.	
Visual.	
Preventive Features – Attributes:	
Loop 2 system /piping / heat exchanger design, welded connections, pump design. (DF)	**Credited:**
Shielding and/or impact barriers surrounding activated/ contaminated systems to prevent inadvertent impact from moving forklift or lifting device. (DF)	
Pipe mounting and bracing. (DF)	
Preventive maintenance program by trained maintenance personnel. (AC)	
Trained forklift/hoist operators. (AC)	
Periodic piping inspection. (AC)	

Event Number
HPV3-3b   Previously (CW3-4b)

Mitigative Features – Attributes:	Credited:
Sloped floors, pits, and drainpipes for water collection testing and processing as waste for transfer to LLLW tanks. (DF)	
HPV HVAC filtration (EC)	
EOPs and trained operators (AC)	
Operating Procedures and Training (AC).	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
Also, see event HPV, CMS, and AIC event tables.	**A**

Event Number HPV3-4a (Event Deleted as PBW was moved to Loop 2)
Event Description: Leak of cooling water from Loop 1 cooling system in bulk shielding leak collection system.

Event Number
HPV3-4b

Event Description:
Leak of cooling water from Loop 2 cooling system in bulk shielding to the bulk shielding leak collection system.

Assumptions and Initial Conditions	Causes	Initiating Event Frequency
1. Release of activated water to top of shield stack outside vessel and outside pipe pan between delay tank cavity and core vessel, inside bulk shield. (IC) 2. Beam is terminated preventing damage to Loop 2 cooled components loss (Moderator events are covered in CMS; window, periscope, and collimator events are addressed in AIC and CW event tables. (IC) 3. Event would not likely be noticed until detected in cooling loop loss of inventory. (IC) 4. Loop 2 provides cooling water for the Proton Beam Window, TVP, CMS/MRA, and water-cooled shielding. (DF) 5. Proton beam window will not fail for nominally an hour without cooling and does not provide a short-term passive beam trip. (DF)	1. Material defect. 2. Corrosion. 3. Fatigue from vibration. 4. Internal erosion. 5. Irradiation damage.	A

Unmitigated Impact on Systems:
1. Eventual loss of Loop 2 cooling water system due to loss of system level.
2. Decontamination and cleanup required in area with potential exposure to personnel.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Reduce probability of cooling water leakage leading to a significant release of radiological material and worker exposure above allowable limits.

Method of Detection:	
Visual.	
Abnormal flow or pressure or level indication in affected system.	

Preventive Features – Attributes:	Credited:
Loop 2 cooling piping material selection, design, mounting, and bracing per mechanical codes. (DF)	
Periodic piping inspection program. (AC)	

Event Number HPV3-4b	
Mitigative Features – Attributes:	**Credited:**
Catch pan under piping run to contain leakage and divert to bulk shielding leak collection system. (DF)	
Procedures to isolate leak. (AC)	
Worker training. (AC)	
Monolith structural confinement. (DF)	
SCE system. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes: 1. Also, see event TS, HPV, CMS, and AIC event tables.	**Mitigated Frequency** A

Event Number
HPV3-5a

Event Description:
Leak in Loop 1 water to the HPV Tank Pits.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. Leaks from primary piping in HPV or leaks from primary lines from the Target Drive Room to the HPV (which drain to HPV inside secondary piping). (DF) 2. Beam is terminated preventing target loss (target events are addressed in TS event tables. (IC) 3. Loop 1 provides cooling water for the Target. (DF)	1. Pipe material defect. 2. Corrosion. 3. Fatigue from vibration. 4. Internal erosion. 5. Irradiation damage.	A

Unmitigated Impact on Systems:
1. Loss of operability of Loop 1 system.
2. Contamination of HPV. Cleanup and decontamination.

Unmitigated Consequences		
Radiological	**Chemical**	**ODH**
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Reduce probability of cooling water leakage or mitigate consequences of cooling water leakage and release of significant quantiles of radiological material and worker exposure above allowable limits.

Method of Detection:	
Abnormal pressure or flow indications for Loop 1 cooling system(s).	
Leak detection in collection sump.	

Preventive Features – Attributes:	Credited:
Loop 1 piping material selection and design, mounting, and bracing. (DF)	
Periodic inspections of piping where accessible. (AC)	
Pipe mounting and bracing. (DF)	
Preventive maintenance program by trained maintenance personnel. (AC)	

Event Number HPV3-5a	
Mitigative Features – Attributes:	**Credited:**
Liners and drainpipes drain to collection sump to contain leaks in HPV. (DF)	
Emergency response procedures. (AC)	
Worker training. (AC)	
HPV / target HVAC filtration. (EC)	
EOPs and trained operators. (AC)	
Operating Procedures and Training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Notes:			**Mitigated Frequency** **A**

Event Number
HPV3-5b

Event Description:
Leak in Loop 2 water to the HPV Tank Pits.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. Leaks from primary piping in HPV or leaks from primary lines to the HPV (which drain to HPV inside secondary piping in chase). (IC) 2. Beam is terminated preventing damage to Loop 2 cooled components loss (Other events are covered in CMS; PBW, periscope, and collimator events are addressed in AIC and CW event tables. (IC) 3. Loop 2 provides cooling water for the Proton Beam Window, TVP, CMS/MRA, and water-cooled shielding. (DF) 4. Proton beam window will not fail for nominally an hour without cooling and does not provide a short-term passive beam trip. (DF)	1. Leak of Loop 2 cooling water due to pipe material defect, corrosion, fatigue from vibration, internal erosion, or irradiation damage.	A

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. Loss of operability of Loop 2 system. 2. Contamination of HPV. 3. Cleanup and decontamination with potential exposure to personnel. 4. Loss, downgrade, or contamination of cooling water.	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Reduce probability of Loop 2 cooling water leakage or mitigate consequences of cooling water leakage and release of significant quantities of radiological material and worker exposure above allowable limits.

Method of Detection:	
Abnormal pressure or flow indications for Loop 2 cooling system(s).	
Leak detection in collection sump.	

Preventive Features – Attributes:	Credited:
Loop 2 piping material selection and design, mounting, and bracing. (DF)	
Periodic inspections of piping where accessible. (AC)	

Event Number HPV3-5b				
Mitigative Features – Attributes:				**Credited:**
Liners and drainpipes drain to collection sump to contain leaks in HPV. (EC)				
Emergency response procedures. (AC)				
Worker training. (AC)				
Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**			
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Notes: 1. Also, see event HPV, CMS, and AIC event tables.				**Mitigated Frequency** **A**

Event Number
HPV3-6a

Event Description:
Leak in Loop 1 water to the HPV and (Delay and GLS) tank cavity leak collection system.

Assumptions and Initial Conditions:

1. Leaks from pipe pan between delay vault & vessel drains to a collection pipe in the HPV that can go to the core vessel drain tank pit, LLLW, or either cooling loop's drain tank, depending on which valve is open. (DF)
2. Leaks from the GLS and Delay Tank locations in the HPV will drop to the HPV floor, and from there flow downslope to a tank pit, where the water will collect for disposal. (DF)
3. Leaks in HOG condensers drain to the HPV floor and from there to an HPV pit.. (DF
4. Leaks from bunker catch pans drain to a core vessel drain tank pit (with a valve to open the drain. (DF)
5. Beam is terminated preventing target loss (target events with beam continuing to operate are addressed in TS and CW event tables). (IC)

Causes:

1. Pipe material defect.
2. Corrosion.
3. Fatigue from vibration.
4. Internal erosion.
5. Irradiation damage.

Initiating Event Frequency
A

Unmitigated Impact on Systems:

1. Loss of operability of Loop 1 system.
2. Contamination of HPV.
3. Cleanup and decontamination.

Unmitigated Consequences

Radiological	**Chemical**	**ODH**
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Reduce probability of cooling water leakage or mitigate consequences of cooling water leakage and release of significant quantities of radiological material and worker exposure above allowable limits.

Method of Detection:	
Abnormal pressure or flow indications for Loop 1 cooling system(s).	
Leak detection in collection tank	
Preventive Features – Attributes:	
Loop 1 piping material selection and design, mounting, and bracing. (DF)	
Periodic inspections of piping where accessible. (AC)	**Credited:**

Event Number HPV3-6a				
Mitigative Features – Attributes:				**Credited:**
Component area floor design and drain to a tank pit. (DF)				
Emergency response procedures. (AC)				
Worker training. (AC)				
Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**			
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Notes: Also, see event TS, HPV, CMS, and AIC event tables.				**Mitigated Frequency** **A**

Event Number
HPV3-7a **Event Deleted based on design change**

Event Description:
Release of radioactivity from ion exchange resin during Loop 1 or 2 column sluicing on site

Assumptions and Initial Conditions:
1. Tungsten has been transported from target to loop
2. Assumes this process is performed on site and not sent out to external company for processing.
3. Waste is shipped off site as normal waste
4. Assume 75% of the transported spallation products in deposited on the resin
5. Assume 0.1% of the tantalum cladding leaks
6. Assume 20y operation of target with 1-minute cooling.

Causes:
1. Damage to sluicing connections during assembly
2. Operator error
3. Improper connection or sealing of sluicing connections

Initiating Event Frequency
A

Unmitigated Impact on Systems:
Contamination of area; cleanup and decontamination required

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent radiological release from ion exchange column sluicing operations

Method of Detection:	
Visual	
Radiation survey	

Preventive Features – Attributes:	**Credited:**
Sluicing procedures (AC)	
Radiological protection program and RCT surveys (AC)	
Worker training (AC)	
Hoisting and rigging program (AC)	
Design of sluicing equipment (DF)	

Event Number
HPV3-7a   Previously (CW3-13) **Event Deleted based on design change**

Mitigative Features – Attributes:	Credited:
Local shielding (EC)	
Radiological protection program and RCT surveys (AC).	
Worker training (AC)	
Sluicing procedures (AC)	
EOPs (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
Evaluate the need for on-site resin exchange capability	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
	A

Event Number
HPV3-7b (CW3-13) **Event Deleted and addressed in Appendix N (RW events)**

Event Description:
Release of radioactivity from ion exchange resin during Loop 1 or 2 column change

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Tungsten has been transported from target to loop 2. Assumes sluicing process is performed off site by an external company 3. Assume 75% of the transported spallation products in deposited on the resin 4. Assume 0.1% of the tantalum cladding leaks 5. Assume 20y operation of target with 1-minute cooling.	1. Damage to column during removal 2. Filter column dropped when loading into transport container 3. Operator error	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
Contamination of area; cleanup and decontamination required	**Radiological** **Public**: Negligible **WG1**: Moderate **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent radiological release from ion exchange column operations and maintenance

Method of Detection:	
Visual	
Radiation survey	

Preventive Features – Attributes:	**Credited:**
Hoisting and rigging program (AC)	
Radiological protection program and RCT surveys (AC)	
Worker training (AC)	
Maintenance Procedures (AC)	

Event Number
HPV3-7b Previously (CW3-13) **Event Deleted and addressed in Appendix N (RW events)**

Mitigative Features – Attributes:	Credited:
Local shielding (EC)	
Radiological protection program and RCT surveys (AC)	X
Worker training (AC)	
Maintenance procedures (AC)	X

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
Evaluate the need for on-site resin exchange capability	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
See event TS, HPV, CMS, and AIC event tables.	A

Event Number
HPV3-8

Event Description:
Release of radioactivity from filter change operations for the Ion Exchange Column discharge line.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Assume 20y operation of target with 1-minute cooling. (IC)	1. Release of activity when filter is being removed. 2. Damage to transport container. 3. Operator maintenance error.	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Delay in operations. 2. Contamination of area. 3. Cleanup and decontamination required.	**Public**: Negligible **WG1**: Moderate **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent radiological release from Ion Exchange Column filter operations and maintenance and worker exposure above allowable limits..

Method of Detection:	
Visual.	
Radiation survey.	

Preventive Features – Attributes:	**Credited:**
Design of filter removal mechanism (DF)	
Radiological protection program. (AC)	
Hoisting and rigging program. (AC)	
Worker training. (AC)	
Design of filter housing. (DF)	

Event Number
HPV3-8

Mitigative Features – Attributes:	Credited:
Shielding of filter element. (DF)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	X
EOPs. (AC)	
Worker training. (AC)	
Filter replacement procedures and worker training. (AC)	X

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
1. Consequences similar to leaks in the Ion Exchange Column lines during sluicing operations (See RW event tables).	A

Event Number
HPV3-9

Event Description:
Leak of cooling water from Loop 1 or Loop 2 cooling system from piping inside the core vessel and to the core vessel drain line spilling into the HPV floor when fault occurs in the HPV during continued operation with a small leak into the core vessel.

Assumptions and Initial Conditions:
1. Activated water from the cooling system leaks inside vessel from primary piping or components. (IC)
2. Beam is terminated if the leak is significant, preventing target loss (target events are addressed in TS and CW event tables. (IC)
3. Beam operation may continue with a small leak with inert core vessel operation. (IC)
4. No automatic Loop 1 or Loop 2 water makeup is provided. (DF)
5. Drain line valve will be located in the HPV and is normally closed during beam operation but can be opened to permit core vessel draining. (IC).
6. A very small leak in vacuum operation could continue until the GLS tank level alarms or trips. (IC)
7. During inert core vessel operation during a beam off condition, the core vessel drain line may be drained to the drain tank. (IC)

Causes:
1. Pipe material defect or corrosion.
2. Fatigue from vibration.
3. Internal erosion.
4. Irradiation damage.
5. Flange gasket leak.

Initiating Event Frequency
EU

Unmitigated Impact on Systems:
1. Eventual loss of Loop 1 or Loop 2 cooling water system due to loss of system level.
2. Decontamination and cleanup required in area with potential exposure to personnel.
3. Contamination of HPV and cleanup required.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Moderate	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Reduce probability of cooling water leakage leading to a release of significant quantities of radiological material in the HPV and worker exposure above allowable limits.

Method of Detection:	
RCT Survey on HPV entry.	
Area Radiation Monitors (ARM).	
Visual.	

Preventive Features – Attributes:	**Credited:**
Material selection and design, mounting, and bracing for piping and components in the HPV. (DF)	
Installation and operation procedures. (AC)	
Piping designed to meet ASME Code B31.3. (DF)	

Event Number	
HPV3-9	
Mitigative Features – Attributes:	**Credited:**
Worker training. (AC)	
Emergency response procedures. (AC)	
TPPS access controls to HPV. (EC)	X

Planned analysis, assumption validations, and Risk/Opportunities:

1. Analysis of the permissible amount of water leaked into the vessel and the peak rate to set trip set points.
2. Evaluated requirements and controls required to permit draining the core vessel with beam on.
3. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:

1. Currently there is a plan to permit draining the core vessel drain line with beam on.
2. The event is EU based on the anticipated limited operational condition with the core vessel drain line open.
3. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.

Mitigated Frequency
EU

Event Number HPV3-10					
Event Description: Vacuum pump or connection line leaks gas to the HPV during spent target, PBW, MRA, or TVP drying operations.					
Assumptions and Initial Conditions: 1. Assume spent target, PBW, MRA, or TVP is stored in the service cell; contains bounding equilibrium nuclides for that component from operating the tungsten target. (See Note 2) (IC) 2. Vacuum pumping system is located in the HPV. (DF) 3. Flexible connections will be provided in the Service Cell to connect to the equipment for drying and hard piped connections to the hot offgas are provided in the HPV. (DF) 4. Personnel are permitted in the HPV during drying operations, but not with beam operations. (AC)		**Causes**: 1. Discharge line leakage or disconnected. 2. Operator error.			**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. Airborne activity with exposure to operating staff. 2. Contamination of surrounding operating areas or equipment. 3. Release of off-gas and tritium oxides. 4. Contamination of surrounding areas.		**Unmitigated Consequences**			
		Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible		**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Prevent a release of significant quantities of radiological material to the HPV during vacuum drying operations of equipment in the Service Cell and worker exposure above allowable limits.					
Method of Detection:					
Ventilation system alarms.					
Air activity monitor in the stack.					
Radiation monitoring of personnel if potential contamination.					
RCT routine monitoring for contamination.					

Event Number HPV3-10			
Preventive Features – Attributes:			**Credited:**
Mechanical design codes and standards. (DF)			
Trained personnel. (AC)			
Operating Procedures and Training. (AC)			
Preventive maintenance program. (AC)			
Mitigative Features – Attributes:			**Credited:**
Radiation Protection Program including Air activity monitoring by RCT (if needed). (EC)			
Emergency Operating Procedures. (AC)			
Radiation and contamination control procedures. (AC)			
Worker training. (AC)			
Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Notes: 1. The process for drying components has not been finalized, but the event is not expected to significantly change. 2. Radionuclide inventories are based on the component or system. For example, target segments are assumed to have a 10-year life and more permanent components such as the target drive shaft is assumed to have a 40-year life. Evaluations are based on the worst-case radionuclide inventory anticipated for the activity. Event scenarios are evaluated based on the worst inventory for activities that could be present.			**Mitigated Frequency** **A**

Event Number
HPV4-1

Event Description:
Personnel receive external exposure to radiation higher than anticipated in the HPV.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. The radiation exposure rate in the General Area of the HPV is typically expected to be relatively low except during beam operation. (IC) 2. Personal dosimetry is anticipated to be required throughout the facility. (IC) 3. Personnel are not permitted in the HPV with excessive radiation in the HPV (AC/IC)	1. Worker error - improper monitoring for radiation levels. 2. Personnel enter areas of high radiation. 3. Improper signage in the area.	A

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
None	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent excessive (above allowable limits) worker exposure to radiation in the HPV.

Method of Detection:	
Personal dosimetry.	
Area radiation alarms.	

Preventive Features – Attributes:	Credited:
Shielding walls between worker and equipment containing significant quantities of radioactive material. (DF)	
Operating Procedures and Training. (AC)	
Target Personnel Protection System (TPPS). (EC)	
Radiation Protection Program. (AC)	
Radiation postings and personnel training reduces likelihood of personnel entering high radiation areas. (AC)	

Event Number
HPV4-1

Mitigative Features – Attributes:	**Credited:**
TPPS access controls to the HPV. (EC)	X
Radiation control procedures. (AC)	
Worker training. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Unmitigated Consequences**		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public: N/A** **WG1: N/A** **WG2: N/A**

Notes	**Mitigated Frequency** **A**

Event Number HPV4-2					
Event Description: Personnel inadvertently enter HPV during beam operation.					
Assumptions and Initial Conditions: 1. The radiation exposure rate in the General Area of the HPV is typically expected to be relatively low except during beam operation. (IC) 2. Personal dosimetry is anticipated to be required throughout the facility. (IC)		**Causes:** 1. Worker error – attempting to enter secured area. 2. Personnel enter areas of high radiation. 3. Improper signage in the area.			**Initiating Event Frequency** A
Unmitigated Impact on Systems: None		**Unmitigated Consequences**			
		Radiological **Public**: Negligible **WG1**: High **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A		**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Prevent personnel access to the HPV or delay tank vault during beam operation.					
Method of Detection:					
Personal dosimetry.					
TPPS detection and alarm.					
Preventive Features – Attributes:					**Credited:**
Target Personnel Protection System (TPPS) – prevents personnel access to the HPV during beam operation and until authorization is provided. (EC)					X
Operating Procedures and Training. (AC)					X
Radiation postings and personnel training reduces likelihood of personnel entering high radiation areas. (AC)					
Radiation Protection Program. (AC)					
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Training of personnel authorized to be in the area. (AC)					

Event Number
HPV4-2

Mitigative Features – Attributes:	Credited:
Radiation Protection Program. (AC)	
Radiation control procedures. (AC)	
Worker training. (AC)	
TPPS beam trip on access violation during beam on. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Unmitigated Consequences		
	Radiological **Public**: N/A **WG1**: N/A **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public: N/A** **WG1: N/A** **WG2: N/A**

Notes	Mitigated Frequency Prevented

Event Number
HPV4-3

Event Description:
Personnel remain in the HPV when the beam is started and receives significant exposure from normal beam operations.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. The radiation exposure rate in the general area of the HPV is typically expected to be relatively low except during beam operation. (IC) 2. Personal dosimetry is anticipated to be required throughout the facility. (IC) 3. The number of procedures and systems involved in this operation and for this event to occur reduces the likelihood of this event. (IC) 4. Only WG1 is impacted by this event. (IC)	1. Worker error – remaining in secured area. 2. Failure to follow RTST and Target Systems startup procedures and search and evict protocols prior to starting the beam. 3. Search and evict system failures.	A

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
None	**Public**: Negligible **WG1**: High **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
To assure that no personnel are in the HPV during beam operation.

Method of Detection:	
E-Stop Button action for PPS.	

Preventive Features – Attributes:	Credited:
Personnel Protection System (PPS)	
• Audible and visible alarm of impending beam operation (EC)	X
• E-Stop Buttons (EC)	X
Sweep and Evict Procedure - Proper procedures and training for the HPV sweep and evict protocols prior to beam operations. (AC)	X
Verbal PA announcement of beginning sweep and evict prior to beam operation. (AC)	
Operating Procedures. (AC)	
Training. (AC)	

Event Number				
HPV4-3				
Mitigative Features – Attributes:				**Credited:**
None				
Planned analysis, assumption validations, and Risk/Opportunities:	**Unmitigated Consequences**			
	Radiological **Public**: N/A **WG1**: N/A **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public: N/A** **WG1: N/A** **WG2: N/A**	
Notes				**Mitigated Frequency** Prevented

APPENDIX I. CONFINEMENT VENTILATION SYSTEMS (HV) HAZARD EVENT TABLES

APPENDIX I. CONFINEMENT VENTILATION SYSTEMS (HV) HAZARD EVENT TABLES

Event Number
HV-SCE1-1

Event Description:
Fire is initiated in the SCE Ventilation System; fire in an area that is ventilated by SCE, exhausting smoke and fire to SCE.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC)	1. Combustibles in the vicinity of the SCE system. 2. Combustible gases or vapors enter SCE system (from maintenance, experiment, or other source). 3. Instrumentation or electrical wiring. 4. Sparks generated by malfunctioning electrical equipment on the HVAC system. 5. Fan motor overheating. 6. Other unidentified ignition source. 7. Fire and/or smoke enter SCE from area fire.	A

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. Shutdown of the affected area. 2. Potential for considerable damage to operating areas or equipment in the vicinity of the fire. 3. Damage or plugging of filters resulting in loss of HEPA filtration	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Reduce probability of fire in the SCE resulting in the release of significant quantities of radiological material impacting WG1.

Method of Detection:	
Fire detection system.	
Out of range indications on ventilation system monitoring instrumentation.	

Preventive Features – Attributes:	Credited:
NFPA standards. (AC/DF)	
Electrical equipment design code. (DF)	
Preventive maintenance program for exhaust fans and air handler fans. (AC)	
Combustible material control program. (AC)	

Event Number
HV-SCE1-1

Mitigative Features – Attributes:	Credited:
Fire detection and suppression system. (EC)	
Control system designed to maintain negative pressure in building with respect to the atmosphere during abnormal conditions. (EC)	
Building design (e.g., materials of construction). (DF)	
Generally low activity levels in SCE. (DF)	
Facility fire response training and procedures. (AC)	
Fire Department response. (AC)	
Radiological protection / control procedures. (AC)	
Worker training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. A Project Fire Hazard Analysis will be performed in support of CD-2 and inform the fire events in the PHAR. 2. Assessment of fires per NFPA 801.	**Radiological** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
Event evaluates radiological consequences and not the fire as the fire is a standard industrial hazard. See also SS1-1.	**A**

Event Number
HV-SCE2-1

Event Description:
Explosion in the SCE ventilation releasing radioactive gases and particulates.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC)	1. Leakage of hydrogen gas from hydrogen transfer lines into High Bay system. 2. Experimenter releases flammable mixture of gases or vapors to SCE system. 3. Mixture is ignited by a spark from friction or electric motor, or other unidentified ignition source (static discharge).	U

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. Loss of affected area of SCE system. 2. Release of gases and particulates from affected area of SCE system to local atmosphere. 3. Collateral explosion damage to adjacent equipment or systems. 4. Loss of HEPA filtration; filter media blown out of its frame into fan; release of contaminated filter media from CEF-II.	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Reduce probability of explosion in the SCE resulting in a release of significant quantities of radiological material impacting WG1.

Method of Detection:	
Audible	
Visual	
Out of range SCE system pressure indications	

Preventive Features – Attributes:	Credited:
Exposure of mixture to external ignition sources is minimized while contained with the SCE system (DF)	
Operating Procedures and Operator Training (AC)	
Policy for control of gases discharged from Neutron instrument areas (AC)	
Preventive maintenance of SCE system (AC)	

Event Number
HV-SCE2-1

Mitigative Features – Attributes:	Credited:
In the case of a breach, the SCE exhaust fans will continue to create a negative pressure in the system, thereby maintaining a flow to the stack from the breached area of the SCE system (EC)	
HEPA filtration will filter released particulates from explosion, if not damaged by the explosion (DF)	
Trained personnel (AC)	
Radiation and contamination control procedures (AC)	
EOPs (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
1. See also SS2-1, CM1-3 and CM2-3. 2. Event evaluates radiological consequences and not the explosion as the explosion is a standard industrial hazard.	U

Event Number
HV-SCE3-1

Event Description:
Release of radiological material as the result of a breach of an SCE HEPA filter housing or exhaust ductwork.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC)	1. Material movement damages housing or duct. 2. Corrosion. 3. Cracking in ductwork as the result of vibration. 4. Cracking in weld. 5. Degraded joint or leaking gasket/valve packing.	A

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. Spread of contamination to surrounding area. 2. Recovery time required for decontamination efforts or for repairs as necessary.	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Reduce probability of or consequences of an SCE HEPA filter housing or ductwork breach resulting in a significant release of radiological material impacting WG1.

Method of Detection:	
Audible.	
Visual.	
Loss of SCE negative pressure.	
Differential pressure alarms.	

Preventive Features – Attributes:	Credited:
SCE negative pressure in ductwork. (EC)	
Ductwork design including location. (DF)	
Seismic bracing. (DF)	
Ductwork designed to ASME-N509/AG1 and selection of material used for ductwork. (DF)	
Maintenance procedures and preventive maintenance program. (AC)	
Operating Procedures and Training. (AC)	
Leak testing during construction. (AC)	

Event Number
HV-SCE3-1

Mitigative Features – Attributes:	Credited:
Building design and confinement capability. (DF/EC)	
Building HVAC System (system designed to maintain airflow from areas of lower potential contamination to areas of greater potential contamination). (EC)	
Ductwork that contains higher activity routed through low access areas. (DF)	
Seismic design improves impact resistance. (DF)	
Emergency Operating Procedures. (AC)	
Radiation and contamination control procedures. (AC)	
Worker training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
	A

Event Number
HV-SCE3-2

Event Description:
SCE HEPA filter media breakthrough.

Assumptions and Initial Conditions:	**Causes:**	**Initiating Event Frequency**
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC)	1. Filter media degrades allowing passage of particulate. 2. Damage to filter during installation. 3. Defective filter. 4. Wrong filter type used. 5. Excessive filter loading causes media breakage.	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Contamination of downstream ductwork and fans. 2. Airborne contamination spread to surrounding area. 3. Recovery time required for filter replacement and cleanup.	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Reduce probability or consequences of an SCE HEPA filter breakthrough resulting in a significant release of radiological material impacting WG1.

Method of Detection:	
Stack monitors.	
Differential pressure instrumentation across filter banks.	
Failure of semi-annual penetration testing.	
Radiological survey.	

Preventive Features – Attributes:	**Credited:**
Filter system design (HEPA plus roughing filter). (DF)	
Design housings to ASME-AG1. (DF)	
Specify proper HEPA filter. (AC)	
ORNL SBMS procedure for HEPA filter purchasing. (AC)	
Penetration testing of new HEPA filters prior to installation. (AC)	
Filter replacement (10-y service life). (AC)	
Operating Procedures and Training. (AC)	

Event Number HV-SCE3-2	
Mitigative Features – Attributes:	**Credited:**
Stack monitor. (EC)	
Area Radiation Monitors (ARM). (EC)	
Parallel filter train. (DF)	
Roughing filter loads before HEPA filter. (DF)	
Filter system design with roughing filter. (DF)	
Service cell HEPAs are backed up by SCE HEPAs as a second stage. (DF)	
Semi-annual penetration test. (AC)	
Radiation Protection program. (AC)	
Emergency Response Procedures. (AC)	
Worker training. (AC)	
Radiation and contamination control procedures. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes	**Mitigated Frequency** A

Event Number
HV-SCE3-3

Event Description:
SCE HEPA filter plugging results in reduced exhaust flow and area pressure reversals.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC)	1. Differential pressure instrumentation across filter fails to indicate need for filter replacement. 2. Operator error (e.g., failure to monitor differential pressure across the filter bank). 3. Failure to replace filter when loaded. 4. Roughing pre-filter removed. 5. Particulate loading rate increases. 6. Condensate from water source causes filters to become waterlogged.	A

Unmitigated Impact on Systems:	Unmitigated Consequences		
1. Loss of SCE negative pressure resulting in inability to maintain confinement negative pressure and potential local release of radioactivity. 2. Pressurization of area by inlet air system causes local release of radioactivity. 3. Recovery time required for decontamination efforts and for restoration of ventilation system function.	**Radiological** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Reduce probability of an SCE HEPA filter plugging resulting in a release of significant quantiles of radiological material impacting WG1.

Method of Detection:	
Confinement area differential pressure sensors.	
Filter differential pressure gages.	
SCE negative pressure sensors.	
SCE flow sensors.	
SCE negative pressure sensor at the stack fan.	

Preventive Features – Attributes:	Credited:
Specify proper roughing pre-filter. (AC)	
Biannual filter penetration testing. (AC)	
Maintenance Procedures. (AC)	
Operating Procedures and Training. (AC)	
Filter replacement (10y service life). (AC)	

Event Number HV-SCE3-3	
Mitigative Features – Attributes:	**Credited:**
Modulating exhaust control dampers adjust to changing exhaust negative pressure. (EC)	
Parallel HEPA filter banks. (DF)	
Worker training. (AC)	
Radiation and contamination control procedures. (AC)	
Filter system design with roughing filter. (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Notes:			**Mitigated Frequency** **A**

Event Number
HV-SCE3-4

Event Description:
Breach of SCE HEPA filter containment bag results in release of radiological material (during replacement).

Assumptions and Initial Conditions:	**Causes:**	**Initiating Event Frequency**
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC)	1. Worker accidently cuts containment bag during installation. 2. Damage to filter bag during storage. 3. Radiation damage to containment bag during service life. 4. Improper installation of filter bag (or bag not installed).	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Spread of contamination from filter resulting in internal exposure. 2. Recovery time required for decontamination efforts.	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent SCE HEPA filter containment bag breach.

Method of Detection:	
Visual.	
Radiological survey.	

Preventive Features – Attributes:	**Credited:**
Filter removal system design (minimization of sharp edges). (DF)	
Maintenance procedures. (AC)	
Specify rad hard polymer for bag. (AC)	
Operating Procedures and Training. (AC)	

Event Number
HV-SCE3-4

Mitigative Features – Attributes:	Credited:
Building design. (DF)	
Building ventilation system. (EC)	
Personal protective equipment. (AC)	
Emergency Response Procedures. (AC)	
Radiation and contamination control procedures. (AC)	
Worker training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
	A

Event Number
HV-SCE3-5

Event Description:
Loss of SCE ventilation system HEPA filtration in exhaust ducting.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC)	1. Breach due to filter media failure. 2. Defective filter. 3. Filter overloaded or plugged and fan suction causes media to be removed from frame. 4. Mechanical impact external to enclosure. 5. Improper filter installation. 6. Leak-by gasket.	U

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. Radioactive particulates are released to the target building stack and the environment.	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Reduce probability of SCE filtration loss leading to a significant release of radiological material impacting WG1.

Method of Detection:	
Out of range filter differential pressure indications.	
STS stack activity alarm.	

Preventive Features – Attributes:	Credited:
Two filters in series design (roughing and HEPA) - second filter stops particulates that get through first filter. (DF)	
Biannual penetration test. (AC)	
Filter delta-P instrumentation. (EC)	
Purchase only certified and tested filters. (AC)	
Preventative maintenance. (AC)	

Event Number HV-SCE3-5				
Mitigative Features – Attributes:				**Credited:**
STS stack activity alarm. (EC)				
Parallel HEPA filter banks. (DF)				
Trained personnel. (AC)				
Radiation and contamination control procedures. (AC)				
EOPs. (AC)				
Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**			
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Notes:				**Mitigated Frequency** **U**

Event Number
HV-SCE3-6

Event Description:
Loss of SCE ventilation system main exhaust fans.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC)	1. Loss of power to exhaust fans. 2. Failure of drive motor. 3. Failure of coupling or drive belts. 4. Motor overheat and trip on thermal overload. 5. Failure of bearing in motor or fan. 6. Wrong control damper set opened. 7. Operator error.	**A**

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. Much reduced SCE flow through SCE system (stack has a natural draft tendency). 2. Buildup of pressure upstream in system at source components of SCE. 3. Loss of gases through experiment area inlet filter. 4. Service cell booster fans pressurize SCE system unless they are also shut down; Service cell air (filtered) exhausted into SCE ventilated rooms	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Reduce probability of fan loss resulting in a significant release of radiological material impacting WG1.

Method of Detection:	
Exhaust flow sensor.	
SCE pressure sensor.	
Fan rotation sensor.	

Preventive Features – Attributes:	Credited:
Redundant fans with one fan in automatic standby upon loss of flow. (EC)	
Exhaust fan, drive motor design. (DF)	
Controls design (shut down service cell booster fans upon SCE fan loss). (DF)	
Operating Procedures and Training. (AC)	
Trained operators. (AC)	
Preventive maintenance exhaust fans. (AC)	
Use of proper valve/damper line-ups. (AC)	

Event Number HV-SCE3-6	
Mitigative Features – Attributes:	**Credited:**
Natural draft effect will tend to draw SCE out the stack at a reduced rate. (DF)	
Generally low activity levels in SCE. (DF)	
EOPs .(AC)	
Trained personnel. (AC)	
Loss of SCE system also shuts down service cell booster fans. (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Notes:			**Mitigated Frequency** **A**

Event Number
HV-SCE4-1

Event Description:
Radiation exposure to personnel while changing SCE HEPA filters.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC)	1. Release of filterable activity to SCE system 2. Improper monitoring for radiation levels. 3. Failure or removal of in-cell filter in PIE cell. 4. Personnel enter areas of high radiation. 5. Source term higher than design basis.	A

Unmitigated Impact on Systems:	Unmitigated Consequences		
None.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent personnel exposure above allowable levels while changing SCE HEPA filters.

Method of Detection:	
Radiological survey.	

Preventive Features – Attributes:	Credited:
Locate HEPA filter bank away from high occupancy areas. (DF)	
Operating Procedures and Training. (AC)	
Radiation Protection program. (AC)	
Radiation postings and personnel training. (AC)	

Event Number
HV-SCE4-1

Mitigative Features – Attributes:	Credited:
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	
Radiation control procedures. (AC)	
Emergency Response Procedures. (AC)	
Worker training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Determine if alarming dosimeters are to be used.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:

Mitigated Frequency
A

Event Number HV-SCE4-2				
Event Description: Facility worker receives excessive direct radiological exposure in vicinity of SCE HEPA filter bank.				
Assumptions and Initial Conditions: 1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC)	**Causes:** 1. Release of filterable activity to SCE system. 2. Improper monitoring for radiation levels. 3. Failure or removal of in-cell filter in PIE cell. 4. Personnel enter areas of high radiation. 5. Source term higher than design basis.			**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. None.	**Unmitigated Consequences**			
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A		**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Prevent personnel exposure above allowable levels in the vicinity of SCE HEPA filter bank.				

Method of Detection:	
Radiation Safety Program – • Radiation Survey (AC)	

Preventive Features – Attributes:	**Credited:**
Location of HEPA bank in low access areas. (DF)	
Limited access to HEPA banks. (EC/AC)	
Radiation Protection program. (AC)	
Radiation postings and personnel training reduce likelihood of personnel entering high radiation areas. (AC)	
Operating Procedures and Training. (AC)	

Event Number HV-SCE4-2				
Mitigative Features – Attributes:				**Credited:**
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)				
Emergency Response Procedures. (AC)				
Worker training. (AC)				
Radiation control procedures. (AC)				
Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**			
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Notes:				**Mitigated Frequency** **A**

Event Number

~~HV-PCE1-1~~ EVENT DELETED – COVERED BY HV-SCE1-1

Event Description:
Fire is initiated in the PCE System

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC) 2. The PCE will be a distributed localized system that provides local confinement from a potentially contaminated area and exhausts to the SCE. (DF)	1. Combustibles in the vicinity of the PCE system. 2. Combustible vapors or gases enter PCE system. 3. Instrumentation wiring. 4. Sparks generated by malfunctioning electrical equipment on the HVAC system. 5. Fan motor overheating. 6. Other unidentified ignition source. 7. Fire and/or smoke enter PCE system from a hot cell fire	A

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. Shutdown of the affected area. 2. Potential for considerable damage to operating areas or equipment in the vicinity of the fire; potential for release of radiological material to the environment. 3. Damage to filters resulting in loss of HEPA filtration or loss of hot cell confinement or pressure reversal. 4. See impacts in Appendix P, SS and SSP.	**Public:** Negligible **WG1:** Moderate **WG2:** Negligible	**Public:** **WG1:** **WG2:**	**Public:** **WG1:** **WG2:**

Safety Function:
Reduce probability of fire resulting in the release of radiological material from the PCE.

Method of Detection:	
Fire detection system.	
Out of range indications on ventilation system monitoring instrumentation.	

Preventive Features – Attributes:	Credited:
Electrical equipment design code. (DF)	
NFPA standards. (AC/DF)	
Preventive maintenance program for exhaust fans. (AC)	

Event Number
HV-PCE1-1 **EVENT DELETED – COVERED BY HV-SCE1-1**

Mitigative Features – Attributes:	Credited:
Fire detection and suppression system. (EC)	
Building design. (DF)	
Control system designed to maintain negative pressure in service cell with respect to the atmosphere during abnormal conditions. (EC)	
Fire Department response. (AC)	
Facility fire response training and procedures. (AC)	
Radiological protection / control procedures. (AC)	
Worker training. (AC)	
Combustible material control program. (AC)	
Filter maintenance/replacement program to limit filter buildup of radiological inventory. (AC)	X

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A
Notes:			**Mitigated Frequency** **A**

Event Number
~~HV-PCE2-1~~ **EVENT DELETED – COVERED BY HV-SCE2-1**

Event Description:
Explosion in the PCE ventilation releasing radioactive gases and particulates.

Assumptions and Initial Conditions:	**Causes:**	**Initiating Event Frequency**
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC) 2. The PCE will be a distributed localized system that provides local confinement from a potentially contaminated area and exhausts to the SCE. (DF)	1. Combustible vapors or gases enter PCE system. 2. Mixture is ignited by a spark from friction or electric motor. 3. Other unidentified ignition source (static discharge).	U

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Loss of affected area of PCE system. 2. Release of gases and particulates from affected area of PCE system to local atmosphere. 3. Collateral explosion damage to adjacent equipment or systems.	**Public:** Negligible **WG1:** Moderate **WG2:** Negligible	**Public:** N/A **WG1:** N/A **WG2:** N/A	**Public:** N/A **WG1:** N/A **WG2:** N/A

Safety Function:
Reduce probability of explosion in the PCE ventilation system resulting in a release of radiological material.

Method of Detection:	
Audible.	
Visual.	
Out of range PCE system pressure indications.	

Preventive Features – Attributes:	**Credited:**
Operating Procedures and Training. (AC)	
Preventive maintenance of PCE system. (AC)	

Event Number
HV-PCE2-1 **EVENT DELETED – COVERED BY HV-SCE2-1**

Mitigative Features – Attributes:	Credited:
PCE exhaust fans continue with negative pressure in the system, maintaining a flow to the stack from the breached area of the PCE system. (DF)	
HEPA filtration will filter released particulates from explosion. (DF)	
EOPs. (AC)	
Trained personnel. (AC)	
Radiation and contamination control procedures. (AC)	
Combustible material control program. (AC)	
Filter maintenance/replacement program to limit filter buildup of radiological inventory. (AC)	X

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:	Mitigated Frequency
	U

Event Number ~~HV-PCE3-1~~ **EVENT DELETED – COVERED BY HV-SCE3-1**					
Event Description: Release of radiological material as the result of a breach of a HEPA filter housing or exhaust ductwork in the PCE ventilation system.					
Assumptions and Initial Conditions: 1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC) 2. The PCE will be a distributed localized system that provides local confinement from a potentially contaminated area and exhausts to the SCE. (DF)	**Causes:** 1. Material movement damages duct. 2. Corrosion. 3. Cracking in ductwork as the result of vibration. 4. Condensate accumulates in ductwork. 5. Cracking in weld. 6. Degraded joint or gasket/valve packing.				**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. Spread of contamination to surrounding areas; potential for release of radiological material to the environment; recovery time required for decontamination efforts or for repairs as necessary.		**Unmitigated Consequences**			
		Radiological **Public**: Negligible **WG1**: Negligible **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A		**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A
Safety Function: Reduce probability of or consequences of housing or ductwork breach resulting in a release of radiological material.					
Method of Detection:					
Audible.					
Visual.					
Loss of PCE vacuum.					
Differential pressure alarms.					
Preventive Features – Attributes:					**Credited:**
Seismic design improves impact resistance. (DF)					
Ductwork and housings designed to ASME-N509/AG1. (DF)					
Selection of material used for ductwork and housings. (DF)					
Maintenance procedures. (AC)					
Preventive maintenance program. (AC)					
Operating Procedures and Training. (AC)					

Event Number
HV-PCE3-1 **EVENT DELETED – COVERED BY HV-SCE3-1**

Mitigative Features – Attributes:	Credited:
Building design and confinement capability. (DF)	
Confinement provided by the portions of the SCE system. (DF)	
Ductwork that contains higher activity located in low access areas. (DF)	
System designed to maintain airflow from areas of lower potential contamination to areas of greater potential contamination. (DF)	
Air activity monitoring. (AC)	
Emergency Operating Procedures. (AC)	
Radiation and contamination control procedures. (AC)	
Worker training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:	Mitigated Frequency
	A

Event Number
~~HV-PCE3-2~~ **EVENT DELETED – COVERED BY HV-SCE3-2**

Event Description:
PCE HEPA filter media breakthrough.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC) 2. The PCE will be a distributed localized system that provides local confinement from a potentially contaminated area and exhausts to the SCE. (DF)	1. Filter media degrades allowing passage of particulate; damage to filter during installation. 2. Defective filter. 3. Wrong filter type used. 4. Excessive filter loading.	A

Unmitigated Impact on Systems:	Unmitigated Consequences		
1. Contamination of downstream ductwork and fans. 2. airborne contamination spread to surrounding area. 3. Potential for release of activity to environment; recovery time required for filter replacement.	**Radiological** **Public**: Negligible **WG1**: Negligible **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Safety Function:
Reduce probability or consequences of a PCE filter breakthrough resulting in release of radiological material.

Method of Detection:	
Stack monitors	
Differential pressure instrumentation across filter banks.	
Semi-annual penetration testing.	
Radiological survey.	

Preventive Features – Attributes:	Credited:
Specify proper HEPA filter. (AC)	
Housings designed to ASME-AG1. (DF)	
Operating Procedures and Training. (AC)	
ORNL SBMS procedure for HEPA filter purchasing. (AC)	
Penetration testing of new HEPA filters prior to installation. (AC)	
Periodic filters changes based on ageing. (AC)	
Radiation Protection program. (AC)	

Event Number
HV-PCE3-2 **EVENT DELETED – COVERED BY HV-SCE3-2**

Mitigative Features – Attributes:	Credited:
HEPA filters in series reduce releasable activity level. (DF)	
Area radiation monitors. (DF)	
Radiation and contamination control procedures. (AC)	
Emergency Response Procedures. (AC)	
Worker training. (AC)	
PCE exhaust to the SCE ventilation system. (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:	Mitigated Frequency
	A

Event Number
~~HV-PCE3-3~~ **EVENT DELETED – COVERED BY HV-SCE3-3**

Event Description:
PCE HEPA filter plugging results in reduced exhaust flow and air flow reversals.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC) 2. The PCE will be a distributed localized system that provides local confinement from a potentially contaminated area and exhausts to the SCE. (DF)	1. Differential pressure instrumentation across filter fails. 2. Worker error (e.g., failure to monitor differential pressure; failure to replace filter. 3. Roughing pre-filter removed. 4. Particulate loading increases. 5. Water source causes filters to become waterlogged. 6. Smoke from a fire in the service or PIE cell	A

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. Impact on operations due to loss of function. 2. Loss of PCE system resulting in pressurization and potential local release of radioactivity. 3. Potential for release of radioactivity to environment. 4. Recovery time required for decontamination efforts and for restoration of ventilation system function.	**Public**: Negligible **WG1**: Negligible **WG2:** Negligible	**Public**: N/A **WG1:** N/A **WG2:** N/A	**Public**: N/A **WG1:** N/A **WG2:** N/A

Safety Function:
Reduce probability of PCE HEPA filter plugging resulting in a release of radiological material.

Method of Detection:	
Differential pressure sensors on confinement area and filters.	
Pressure sensors on PCE and service cell.	
PCE flow sensors.	
PCE vacuum sensor at the stack fan.	

Preventive Features – Attributes:	Credited:
Specify proper roughing pre-filter. (AC)	
PCE duct has alarmed drainage collection point. (EF)	
Filter testing and replacement program. (AC)	
Maintenance Procedures. (AC)	
Operating Procedures and Training. (AC)	

Event Number	
HV-PCE3-3 **EVENT DELETED – COVERED BY HV-SCE3-3**	
Mitigative Features – Attributes:	**Credited:**
Modulating exhaust control dampers adjust to changing exhaust vacuum. (DF)	
Radiation and contamination control procedures. (AC)	
High air activity response procedures. (AC)	
Worker training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:	**Mitigated Frequency** **A**

Event Number
~~HV-PCE3-4~~ **EVENT DELETED – COVERED BY HV-SCE3-4**

Event Description:
Breach of PCE HEPA filter containment bag results in release of radiological material (during replacement).

Assumptions and Initial Conditions:	**Causes:**	**Initiating Event Frequency**
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC) 2. The PCE will be a distributed localized system that provides local confinement from a potentially contaminated area and exhausts to the SCE. (DF)	1. Worker accidently cuts containment bag during installation. 2. Damage to filter bag during storage. 3. Radiation damage to containment bag during service life.	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
1. Spread of contamination from filter. 2. Recovery time required for decontamination efforts.	**Radiological** **Public**: Negligible **WG1**: Negligible **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Safety Function:
Prevent PCE HEPA filter containment bag breach.

Method of Detection:	
Visual.	
Area radiation monitors.	
Radiological survey.	

Preventive Features – Attributes:	**Credited:**
Filter removal system design (minimization of sharp edges). (DF)	
Specify rad hard polymer for bag. (AC)	
Maintenance procedures. (AC)	
Operating Procedures. (AC)	
Training. (AC)	

Event Number
HV-PCE3-4 **EVENT DELETED – COVERED BY HV-SCE3-4**

Mitigative Features – Attributes:	Credited:
Personal protective equipment. (AC)	
Building design. (DF)	
Building ventilation system. (DF)	
Emergency Response Procedures. (AC)	
Radiation and contamination control procedures. (AC)	
Air activity monitoring. (AC)	
High air activity response procedures .(AC)	
Worker training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:	Mitigated Frequency
	A

Event Number

~~HV-PCE3-5~~ **EVENT DELETED – COVERED BY HV-SCE3-5**

Event Description:
Loss of PCE ventilation system HEPA filtration in exhaust ducting.

Assumptions and Initial Conditions:

1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC)
2. The PCE will be a distributed localized system that provides local confinement from a potentially contaminated area and exhausts to the SCE. (DF)

Causes:

1. Breach due to filter media failure.
2. Defective filter.
3. Filter overloaded or plugged and vacuum causes media to be sucked out.
4. Mechanical impact external to enclosure.
5. Improper filter installation.
6. Leak-by gasket.

Initiating Event Frequency
U

Unmitigated Impact on Systems:

1. Radioactive particulates are released to the target building stack and the environment.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Safety Function:
Reduce probability of PCE filtration loss leading to a release of radiological material.

Method of Detection:	
Out of range filter differential pressure indications.	
STS stack activity alarm.	

Preventive Features – Attributes:	**Credited:**
Three filters in series (roughing, two HEPA). (DF)	
Second and third filter can stop particulates that get through first filter. (DF)	
Filter delta-P instrumentation. (DF)	
Biannual penetration test. (AC)	
Purchase only certified and tested filters. (AC)	
Preventative maintenance (Periodic filters changes based on ageing). (AC)	

Event Number
HV-PCE3-5 **EVENT DELETED – COVERED BY HV-SCE3-5**

Mitigative Features – Attributes:	Credited:
STS stack activity alarm. (DF)	
EOPs. (AC)	
Trained personnel. (AC)	
Radiation and contamination control procedures. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:	Mitigated Frequency
	U

Event Number HV-PCE3-7 **EVENT DELETED – COVERED BY HV-SCE3-7**				
Event Description: Loss of Service Cell booster fans.				
Assumptions and Initial Conditions: 1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC)	**Causes:** 1. Loss of power to exhaust fans. 2. Failure of drive motor. 3. Failure of coupling or drive belts. 4. Motor overheat and trip on thermal overload. 5. Failure of motor or fan bearing. 6. Valve misalignment. 7. Operator error.			**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. Much reduced flow through service cell filters 2. Much reduced negative pressure in service cell.	**Unmitigated Consequences**			
	Radiological **Public**: Negligible **WG1**: Negligible **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A	
Safety Function: Reduce probability of booster fan loss resulting in a release of radiological material.				
Method of Detection:				
flow sensors.				
Hot cell pressure sensor.				
system pressure sensor.				
Fan rotation sensor.				
Preventive Features – Attributes:				**Credited:**
Exhaust fan and drive motor design. (DF)				
Controls design. (DF)				
Operating Procedures and Operator Training. (AC)				
Preventive maintenance exhaust fans. (AC)				

Event Number
HV-PCE3-7 **EVENT DELETED – COVERED BY HV-SCE3-7**

Mitigative Features – Attributes:	Credited:
SCE fans continued operation will draw service cell air out at a reduced rate (DF)	
EOPs. (AC)	
Trained personnel. (AC)	
Loss of SCE system also shuts down service cell booster fans. (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:	Mitigated Frequency
	A

Event Number

~~HV-PCE4-1~~ **EVENT DELETED – COVERED BY HV-SCE4-1**

Event Description:
Radiation exposure to personnel while changing PCE HEPA filters.

Assumptions and Initial Conditions:	**Causes:**	**Initiating Event Frequency**
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC) 2. The PCE will be a distributed localized system that provides local confinement from a potentially contaminated area and exhausts to the SCE. (DF)	1. Release of filterable activity to PCE system. 2. Improper monitoring for radiation levels. 3. Personnel enter areas of high radiation. 4. Source term higher than design basis.	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. None.	**Public**: Negligible **WG1**: Negligible **WG2:** Negligible	**Public**: N/A **WG1:** N/A **WG2:** N/A	**Public**: N/A **WG1:** N/A **WG2:** N/A

Safety Function:
Prevent personnel exposure above allowable levels.

Method of Detection:	
Area radiation monitors.	
Radiological survey.	

Preventive Features – Attributes:	**Credited:**
Locate HEPA filter bank away from high occupancy areas. (DF)	
Operating Procedures and Training. (AC)	
Radiation Protection program. (AC)	
Radiation postings and personnel training. (AC)	
Limited access to PCE filter bank. (AC)	

Event Number
HV-PCE4-1 **EVENT DELETED – COVERED BY HV-SCE4-1**

Mitigative Features – Attributes:	Credited:
Area radiation monitors. (EC)	
Radiation control procedures. (AC)	
Emergency Response Procedures. (AC)	
Worker training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. Determine if alarming dosimeters are to be used.	**Radiological** **Public**: Negligible **WG1**: Negligible **WG2: N**egligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:	Mitigated Frequency A

Event Number ~~HV-PCE4-2~~ EVENT DELETED – COVERED BY HV-SCE4-2				
Event Description: Facility worker receives excessive direct radiological exposure in vicinity of PCE HEPA filter bank.				
Assumptions and Initial Conditions: 1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC) 2. The PCE will be a distributed localized system that provides local confinement from a potentially contaminated area and exhausts to the SCE. (DF)	**Causes:** 1. Worker error - improper monitoring for radiation levels. 2. Personnel enter areas of high radiation. 3. Source term higher than design basis.			**Initiating Event Frequency** A
Unmitigated Impact on Systems:	**Unmitigated Consequences**			
1. None.	**Radiological** **Public**: Negligible **WG1**: Negligible **WG2: N**egligible		**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A
Safety Function: Prevent personnel exposure above allowable levels.				
Method of Detection:				
Area radiation monitors.				
Radiological survey.				
Preventive Features – Attributes:				**Credited:**
Location of PCE HEPA bank in low access areas. (DF)				
Operating Procedures and Training. (AC)				
Radiation Protection program. (AC)				
Radiation postings and personnel training. (AC)				
Limited access to HEPA banks. (DF)				

Event Number
HV-PCE4-2 **EVENT DELETED – COVERED BY HV-SCE4-2**

Mitigative Features – Attributes:	**Credited:**
Area radiation monitors. (EC)	
Radiation control procedures. (AC)	
Emergency Response Procedures. (AC)	
Worker training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Determine if alarming dosimeters are to be used.	**Radiological** **Public**: Negligible **WG1**: Negligible **WG2: N**egligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:	**Mitigated Frequency** **A**

APPENDIX J. INSTRUMENT SYSTEMS AND BUNKER (IS) HAZARD EVENT TABLES

Appendix J Organization

Appendix J has been organized into two subsections. ISB events address events in the bunker region and ISC events address events in the beam line to the caves and events in the caves. The Instruments Systems included in this Appendix address global instrument hall hazards as well as unique hazard considerations.

Instrument System Evaluations

The SNS is a user facility with most of the time available on individual neutron scattering instruments assigned to researchers (users) via a peer-reviewed proposal system. These proposals are reviewed internally for experimental feasibility. These evaluations combined with the recommendations of a panel assessing the scientific impact are used in awarding beam time to investigators. All approved proposals are reviewed internally for safety. STS reviews and practices are to ensure the safety of these researchers while enabling them to control their measurements within the bounds set by the facility. Use of STS instruments by ORNL or external scientific investigators is governed by STS policies and procedures. An appropriate level of training is a key element to safe operation of a user facility. Training specific to the operation of individual neutron scattering instruments is organized by the relevant instrument team and tracked in the user training records. Additional training may be needed for handling of samples and for operation of sample environment equipment. This training is organized by the instrument team and similarly tracked. The training program is reviewed and approved at the appropriate division level.

Each neutron beam instrument must satisfactorily undergo an Instrument Readiness Review (IRR) and/or review as part of an Accelerator Readiness Review (ARR) prior to operation of the instrument with neutron beam. The IRR is carried out by an expert STS Instrument Systems Safety Committee (ISSC) selected by and reporting to the STS Operations Manager. Each instrument review is intended to verify that the instrument is safe to operate and cover the hazards in detail that are specific to that instrument and assure that the mitigation strategies used for that instrument are in place. Emphasis is placed on review of radiation protection including shielding design and configuration control and the appropriate control measures such as the instrument-specific features of the PPS. However, other industrial hazards such as oxygen deficiency, vacuum, and cryogenic systems are also covered in the review as appropriate to the specific instrument. The review also covers instrument operation and maintenance procedures and staff and user training for instrument operation. Instrument reviews are repeated periodically as needed to address changes. Experiments may involve hazards such as chemical, cryogenic, high pressure, and magnetic fields. Although the key element of the review is the knowledge and experience of the committee, STS will provide the committee with a checklist to assure that all appropriate areas of review are addressed. The IRR approval process for new instruments and for modifications to existing instruments will be reviewed and endorsed by an ARR.

Hazards associated with the initial suite of STS instruments are evaluated as part of the facility hazard analysis process reported within this PHAR. Hazards associated with instruments added after STS has received the initial approval to operate will be evaluated as part of the authorization process for that instrument. As part of that authorization process the Instrument Safety Systems Committee (ISSC) will evaluate the instrument design and operation as well as hazards associated with specialized sample environments intended for use with that instrument. The ISSC review must ensure that the instrument falls within the operating envelope. Any potential exception triggers a USID, and DOE would be involved if it is determined that the instrument introduced a new hazard or would operate outside the bounds of the approved SAD or ASE. This approach provides an effective review process without encumbering the facility hazard analysis, PSAD/FSAD, and ASE with continual changes as long as the instrument stays within the bounds of the ASE and SAD.

APPENDIX J. BUNKER (ISB) HAZARD EVENT TABLES

Event Number
ISB1-1

Event Description:
A small fire in the Bunkers.

<table>
<tr>
<td>Assumptions and Initial Conditions:
1. Activated material is generally fixed or of small quantity and would not be released in a fire. (IC)
2. Electrical circuits are localized and serve relatively few items. (DF)
3. Event can occur either during beam operation or during maintenance operations. (IC)
4. Beamline may be operating or shut down for maintenance. (IC)
5. Fire in bunker limited to the area immediately adjacent to the fire. (IC)</td>
<td>Causes:
1. Electrical short.
2. Electrical overload/overheat.
3. Maintenance failure.
4. Chopper or shutter motor fault.
5. Ignition by motor fault, welding sparks or other unknown ignition source.
6. Accumulation of combustibles.</td>
<td>Initiating Event Frequency
A</td>
</tr>
</table>

<table>
<tr>
<td rowspan="2">Unmitigated Impact on Systems:
1. Loss of electrical equipment powered by affected circuits leads to loss of research capability on one or more Instruments.
2. Fire could lead to equipment damage.
3. Equipment damage from fire water and recovery from the water release in Bunkers would lead to an extended outage.
4. Fire could cause loss of neutron beam availability.
5. Loss of central guide vacuum system and remote viewing system.
6. Possible impact on maintenance shutter and/or operations shutter functionality.</td>
<td colspan="3">Unmitigated Consequences</td>
</tr>
<tr>
<td>Radiological
Public: Negligible
WG1: Negligible
WG2: Negligible</td>
<td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td>
<td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td>
</tr>
</table>

Safety Function:
To control/limit the radiological consequences of a fire in the Bunkers.

Method of Detection:	
Visual.	
Audible.	
Chopper rotation stops, shutters not operational.	
Fire Detection, alarm, and sprinkler actuation.	
Preventive Features - Attributes:	**Credited:**
QA program for chopper and shutter motors. (AC)	
Procedures and training. (AC)	

Event Number
ISB1-1

Mitigative Features - Attributes:	Credited:
Fire Detection and Notification – alarms and monitors. (EC)	
Fire Detection and Suppression. (EC)	
Low activity levels in bunker. (DF)	
TPPS – controls/limits bunker access during beam operation and ensuring that maintenance shutter is in gamma blocking mode during access. (EC)	
Operator Training and Procedures – to respond to fire alarms and evacuate. (AC)	
Combustible control program. (AC)	
Radiation/contamination control procedures. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. Project Fire Hazard Analysis (PFHA). 2. Assessment of fires per NFPA 801.	**Radiological** **Public:** Negligible **WG1:** Negligible **WG2:** Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
1. Activated material is releasable in a fire. 2. A localized fire in the bunker region could impact multiple beam lines.	A

<table>
<tr><td colspan="5">Event Number
ISB1-2</td></tr>
<tr><td colspan="5">Event Description:
Large fire in bunkers.</td></tr>
<tr><td colspan="2">Assumptions and Initial Conditions:
1. Activated material is generally fixed or of small quantity and would not be released in a fire. (IC)
2. Electrical circuits are localized and serve relatively few items. (DF)
3. Event can occur either during beam operation or during maintenance operations. (IC)
4. Beamline may be operating or shut down for maintenance. (IC)
5. Fire in bunker engages entire bunker. (IC)
6. If the fire is large enough it could activate the High Bay sprinkler system and spray water on the equipment in the High Bay with the associated damage to that equipment.</td><td colspan="2">Causes:
1. Electrical short.
2. Electrical overload/overheat.
3. Maintenance failure.
4. Chopper or shutter motor fault.
5. Ignition by motor fault, welding sparks or other unknown ignition source.
6. Accumulation of combustibles.</td><td>Initiating Event Frequency
EU</td></tr>
<tr><td rowspan="2">Unmitigated Impact on Systems:
1. Loss of electrical equipment powered by affected circuits leads to loss of research capability on one or more Instruments.
2. Fire could lead to equipment damage.
3. Equipment damage from fire water and recovery from the water release in Bunker would lead to an extended outage. (Multiple sprinkler head actuation.)
4. Fire could cause loss of neutron beam availability.
5. Damage to entire bunker.
6. Fire could propagate to instrument floor or cave.
7. Loss of central guide vacuum system and remote viewing system.
8. Possible impact on maintenance shutter and/or operations shutter functionality.</td><td colspan="4">Unmitigated Consequences</td></tr>
<tr><td colspan="2">Radiological
Public: Negligible
WG1: Negligible
WG2: Negligible</td><td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
<tr><td colspan="5">Safety Function:
To control/limit the radiologival consequences of a fire in the Bunkers.</td></tr>
<tr><td colspan="4">Method of Detection:</td><td></td></tr>
<tr><td colspan="4">Visual.</td><td></td></tr>
<tr><td colspan="4">Audible.</td><td></td></tr>
<tr><td colspan="4">Fire Detection and Suppression System.</td><td></td></tr>
<tr><td colspan="4">Chopper rotation stops, shutters not operational.</td><td></td></tr>
<tr><td colspan="4">Fire Detection, alarm, and sprinkler actuation.</td><td></td></tr>
<tr><td colspan="4"></td><td></td></tr>
</table>

Event Number

ISB1-2

Preventive Features – Attributes:	**Credited:**
QA program for chopper and shutter motors. (AC)	
Procedures and training. (AC)	

Mitigative Features – Attributes:	**Credited:**
Fire Detection and Notification – alarms and monitors. (EC)	
Fire Detection and Suppression. (EC)	
Low activity levels in bunker. (DF)	
TPPS – controls/limits bunker access during beam operation and ensuring that maintenance shutter is in gamma blocking mode during access. (EC)	
Operator Training and Procedures – to respond to fire alarms and evacuate. (AC)	
Combustible control program. (AC)	
Radiation/contamination control procedures. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Project Fire Hazard Analysis (PFHA).
2. Assessment of fires per NFPA 801.

Mitigated Consequences:

Radiological	**Chemical**	**ODH**
Public: Negligible	**Public:** N/A	**Public:** N/A
WG1: Negligible	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Notes:

1. Activated material is releasable in a fire.
2. A localized fire in the bunker region could impact multiple beam lines.

Mitigated Frequency
EU

Event Number
ISB3-1

Event Description:
Neutron beamline guide, equipment, or chopper fails, and debris is ejected up the beam line, penetrates monolith optic beam windows, enters the core vessel, and penetrates a hydrogen moderator vacuum and hydrogen boundaries.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Chopper aluminum disks have a low probability of failure due to low operating stress. (DF) 2. T0 chopper head has a low probability of failure due to low operating stress. (DF) 3. Part of the boron coating delaminates and rebounds off housing to be directed upstream with a velocity equal to the tip speed of the chopper. (IC) 4. Failure of vacuum window on any upstream guide adds additional energy into the system in the form of rapidly flowing air and a shockwave. (IC) 5. Chopper rotation is perpendicular to beam direction for all but Fermi choppers. (DF)	1. Manufacturing defect. 2. Radiation damage. 3. Corrosion.	**EU**

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Failure of multiple windows and glass guides within vacuum sections. 2. Penetration of monolith insert windows and moderator vessel shells is considered Beyond Extremely Unlikely based on evaluations of SNS first target station beam lines.	**Public**: Negligible **WG1:** Negligible **WG2**: Negligible	**Public:** N/A **WG1:** N/A **WG2:** N/A	**Public:** N/A **WG1:** N/A **WG2:** N/A

Safety Function:
Prevent chopper failure from impacting other systems leading to a significant release of radiological material impacting WG1.

Method of Detection:	
Loss of vacuum in guide sections.	
Chopper vibration.	
Loss of core vessel vacuum.	
Loss of monolith insert helium pressure (if monitored).	

Preventive Features – Attributes:	**Credited:**
QA program for chopper disk and housing fabrication. (AC)	

Event Number
ISB3-1

Mitigative Features – Attributes:	**Credited:**
Neutron beam window design. (DF)	
QA program for chopper disk and housing design. (AC/DF)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Each STS chopper type will be evaluated for the consequences of chopper failures and a safety factor for upstream and downstream failures estimated.	**Radiological** **Public**: Negligible **WG1:** Negligible **WG2**: Negligible	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A

Notes:	**Mitigated Frequency EU**

Event Number
ISB3-2

Event Description:
Neutron beamline guide, equipment, or chopper fails, and debris is ejected up the beam line, penetrates monolith optic beam windows, enters the core vessel, and penetrates a hydrogen moderator vacuum and hydrogen boundaries leading to a hydrogen deflagration or detonation. The focus of this event is the potential for this event to lead to a release of hydrogen from the CMS/Moderator leading to a hydrogen deflagration or detonation. (ISB3-1 and VS3-2 address other consequences.)

Assumptions and Initial Conditions:
1. Chopper aluminum disks have a low probability of failure due to low operating stress. (DF)
2. T0 chopper head has a low probability of failure due to low operating stress. (DF)
3. Part of the boron coating delaminates and rebounds off housing to be directed upstream with a velocity equal to the tip speed of the chopper. (IC)
4. Failure of vacuum window on any upstream guide adds additional energy into the system in the form of rapidly flowing air and a shockwave. (IC)
5. Chopper rotation is perpendicular to beam direction for all but Fermi choppers. (DF)
6. Inert core vessel atmosphere operation with helium in the core vessel. (IC)
7. Event occurs during operation or when the Core Vessel is ready to receive beam. (IC)
8. Monolith Insert design with inner and outer windows. (DF)
9. Helium mode of operation is conducted at a slightly negative pressure below atmospheric pressure. (IC)
10. Failure causing a hydrogen release requires failure of 5 windows and the debris traveling down the beam insert. The open neutron flight path is 50mm x 50mm on the upstream end, 70mm x 70mm on the downstream end. Length of the insert is 4.5m, with the upstream end ~1m from the face of the moderator. (DF)

Causes:
1. Manufacturing defect.
2. Radiation damage.
3. Corrosion.

Initiating Event Frequency
EU

Unmitigated Impact on Systems:
1. Failure of multiple windows and glass guides within vacuum sections.
2. Penetration of monolith insert windows and moderator vessel shells is considered Beyond Extremely Unlikely based on evaluations of SNS first target station beam lines and Assumption and Initial Condition Number 10 above.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public:** N/A	**Public:** N/A
WG1: Negligible	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Safety Function:
Prevent chopper failure from impacting other systems leading to a significant release of radiological material impacting WG1.

Method of Detection:	
Loss of vacuum in guide sections.	
Chopper vibration.	
Loss of core vessel vacuum.	
Loss of monolith insert helium pressure (if monitored).	

Preventive Features – Attributes:	**Credited:**
QA program for chopper disk and housing fabrication. (AC)	

Event Number

ISB3-2

Mitigative Features – Attributes:	Credited:
Neutron beam window design. (DF)	
QA program for chopper disk and housing design. (AC/DF)	
Use of helium in inerting blanket or vacuum in core vessel minimizes activation of gases. (EC)	
Failure causing a hydrogen release requires failure of 5 windows and the debris traveling down the beam insert. The open neutron flight path is 50mm x 50mm on the upstream end, 70mm x 70mm on the downstream end. Length of the insert is 4.5m, with the upstream end ~1m from the face of the moderator. (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Each STS chopper type will be evaluated for the consequences of chopper failures and a safety factor for upstream and downstream failures estimated.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: N/A	**Public:** N/A	**Public:** N/A
WG1: N/A	**WG1:** N/A	**WG1:** N/A
WG2: N/A	**WG2:** N/A	**WG2:** N/A

Notes:

Mitigated Frequency
EU

Event Number
ISB4-1

Event Description:
A worker enters the Bunker when the beam is off and is exposed to unacceptable levels of gamma radiation from the activated target/moderator.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. Beam is not operating. (IC) 2. The neutron beam path is open or inadequately obstructed through the Bunker front wall. (IC) 3. An initial entry radiation survey is either inadequate or not performed prior to worker entry following beam operations. (IC) 4. The neutron guide is removed, allowing workers to get into the neutron beam path, or gammas scatter out of the installed guide. (IC)	1. Control failure. 2. Operator error. 3. Shutter fails to close completely. 4. Inadequate shielding in maintenance shutter. 5. Shutter moved to open position when personnel are present.	A

Unmitigated Impact on Systems:	Unmitigated Consequences:		
	Radiological	**Chemical**	**ODH**
1. There is no impact on systems.	**Public:** Negligible **WG1:** Moderate **WG2**: Negligible	**Public:** N/A **WG1:** N/A **WG2:** N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent inadvertent personnel exposure above allowable levels in the Bunker when the beam is off.

Method of Detection:	
Radiation survey.	
Personal dosimetry.	
TPPS maintenance shutter position.	
Radiation detectors - Workers in the Bunker will wear alarming dosimeters as required by RWPs.	

Preventive Features - Attributes:	Credited:
Shielding and shutter design incorporates design basis source term. (EC)	
Radiological protection program. (AC)	
Permanent or portable shielding if required. (EC)	
RCT survey on entry and periodic surveys as needed. (AC)	
Worker training. (AC)	

Event Number
ISB4-1

Mitigative Features - Attributes:	Credited:
Workers wearing alarming dosimeters will be warned of elevated radiation levels. (AC)	
Workers are trained to evacuate if elevated radiation levels are detected or if the TPPS warns them of a hazard. (AC)	X
Radiological protection program. (AC)	
Periodic surveys. (AC)	
Worker training. (AC)	
Work planning. (AC)	
TPPS shutter gamma blocking mode detection and alarm. (EC)	X
TPPS interlock to prevent shutter motion. (EC)	
TPPS prevent access to the bunker if shutter is not in gamma block position .(EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1.	**Radiological** **Public:** Negligible **WG1:** Low **WG2**: Negligible	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Notes:			**Mitigated Frequency** A

Event Number
ISB4-2

Event Description:
An object falls into the neutron beam in the Bunker leading to scattered neutrons exposing workers in the High Bay to radiation.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. Streaming paths or gaps do not exist in Bunker roof panels. (IC) 2. No personnel are permitted in the Bunker during beam operation. (IC/AC) 3. Roof panels must be in place to permit beam operation. (IC)	1. Mechanical failure of a component in the bunker. 2. Roof panel failure. 3. Neutron Gamma Blocker falls into or remains in the neutron beam line.	EU

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. One or more beamlines will not have neutrons available for experiments. 2. Loss of vacuum to all beamlines. 3. Extended shutdown for repairs to affected beamlines.	**Public:** Negligible **WG1:** Moderate **WG2:** Negligible	**Public**: N/A **WG1:** N/A **WG2:** N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Minimize the potential direct exposure to workers in the High Bay from the Bunker faults.

Method of Detection:	
Area Radiation Monitors (ARM) in the High Bay. (Note 2)	
Instrument operators are notified of the loss of neutrons downstream.	
Loss of beamline vacuum.	

Preventive Features - Attributes:	Credited:
Operator procedures and training. (AC)	
Maintenance procedures. (AC)	
Roof panel design. (EC)	

Event Number
ISB4-2

Mitigative Features – Attributes:	**Credited:**
Area Radiation Monitors are located in the High Bay to alarm locally and provide TPPS trip for the beam if elevated radiation levels are detected. (EC)	X
Bunker roof panels are inspected and certified to be in place before beam operation to the STS is authorized. (AC)	
Bunker roof panels are designed with overlapping edges to prevent streaming paths. (DF)	
TPPS interlock assuring that Bunker ceiling panels are secured in place prior to beam operations. (EC)	
Bunker roof panels are designed to provide adequate shielding for a T0 chopper or a shutter dropping into the beam line. (DF)	X

Planned analysis, assumption validations, and Risk/Opportunities

1. The Radiation Safety Officer inspects shielding prior to beam operations.
2. Shielding analyses will support roof panel design.
3. Roof panels are secured; beam operation is disabled through the TPPS before removal of roof panels is authorized.
4. Radiation Safety Committee will approve number and types of radiation detectors used.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1:** N/A	**WG1**: N/A
WG2: Negligible	**WG2:** N/A	**WG2**: N/A

Notes:

1. As the roof panels are designed to shield for the identified worst case scenario, this event has been identified as EU.
2. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.

Mitigated Frequency
EU

Event Number
ISB4-3

Event Description:
A worker inadvertently remains in the Bunker when the beam becomes operational and receives a significant exposure from normal beam operations.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. Inherent operation of the beam due to losses generates a significant field in the Bunker during operation. (IC) 2. The number of procedures and systems involved in this operation and for this event to occur reduces the likelihood of this event. (IC) 3. Access space in the bunker does not allow easy access between beam lines. (IC)	1. Failure to follow Bunker secure procedures and search/evict protocols prior to securing Bunker. 2. Search and evict system failures. 3. IPPS does not warn of imminent beam operation.	U

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. No unmitigated impact on systems.	**Public:** N/A **WG1:** High **WG2:** N/A	**Public**: N/A **WG1:** N/A **WG2:** N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
To assure that no personnel are in the Bunker during beam operation.

Method of Detection:	
Speaker announcement.	
Audible alarm.	
E-Stop Button action for IPPS.	

Preventive Features - Attributes:	Credited:
TPPS Sweep and Evict Procedure - Proper procedures and training for the sweep and evict protocols prior to closing the Bunker before beam operations. (AC)	X
TPPS audible alarm prior to beam on permits. (AC)	

Event Number ISB4-3			
Mitigative Features - Attributes:			**Credited:**
TPPS - E-Stop Buttons. (Note 1) (EC)			X
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Training of personnel authorized to be in the area. (AC)			

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public:** N/A **WG1:** N/A **WG2:** N/A	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Notes: **1.** E-Stops are located between each beam line in the bunker to permit rapid access.	**Mitigated Frequency** Prevented		

Event Number
ISB4-4

Event Description:
A worker inadvertently enters the Bunker when the beam is operational and receives a significant exposure from normal beam operations.

Assumptions and Initial Conditions:	**Causes:**	**Initiating Event Frequency**
1. Inherent operation of the beam due to losses generates a significant field in the Bunker during operation. (IC) 2. The number of procedures and systems involved in this operation and for this event to occur reduces the likelihood of this event. (IC) 3. Before a worker could enter the bunder with the beam on they must pass through Corridor 202 which also has TPPS access controls (See ISM4-6) (EC/AC)	1. Failure of the TPPS to accomplish access control.	EU

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. No unmitigated impact on systems.	**Public:** N/A **WG1:** High **WG2:** N/A	**Public**: N/A **WG1:** N/A **WG2:** N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
To assure that no personnel can access the Bunker during beam operation.

Method of Detection:	
TPPS Bunker access detection and alarm.	
Preventive Features - Attributes:	**Credited:**
TPPS - Bunker access control. (EC)	X

Event Number ISB4-4				
Mitigative Features - Attributes:				**Credited:**
TPPS beam trip and alarm on access violation. (EC)				
Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**			
	Radiological **Public:** N/A **WG1:** N/A **WG2:** N/A	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Notes:		**Mitigated Frequency** Prevented		

Event Number ISB4-5				
Event Description: A worker inadvertently remains in Corridor 202 when the beam becomes operational and receives a significant exposure from normal beam operations.				
Assumptions and Initial Conditions: 1. Inherent operation of the beam due to losses generates a significant field in Corridor 202 during operation. (IC) 2. The number of procedures and systems involved in this operation and for this event to occur reduces the likelihood of this event. (IC)	**Causes:** 1. Failure to follow Corridor 202 secure procedures and search/evict protocols prior to securing Corridor 202. 2. Search and evict system failures. 3. IPPS does not warn of imminent beam operation.			**Initiating Event Frequency** U
Unmitigated Impact on Systems: 1. No unmitigated impact on systems.	**Unmitigated Consequences**			
	Radiological **Public:** N/A **WG1:** Moderate **WG2**: N/A	**Chemical** **Public:** N/A **WG1**: N/A **WG2:** N/A		**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: To assure that no personnel are in Corridor 202 during beam operation.				

Method of Detection:	
Speaker announcement.	
Audible alarm.	
Preventive Features - Attributes:	**Credited:**
TPPS audible alarm prior to beam on permits. (AC)	
TPPS Sweep and Evict Procedure - Proper procedures and training for the sweep and evict protocols prior to securing Corridor 202 before beam operations. (AC)	X

Event Number ISB4-5			
Mitigative Features - Attributes:			Credited:
E-Stop in Corridor 202. (EC)			
Worker training and procedures. (AC)			
Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public:** N/A **WG1:** N/A **WG2:** N/A	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A
Notes:		**Mitigated Frequency** Prevented	

Event Number ISB4-6				
Event Description: A worker inadvertently enters Corridor 202 when the beam is operational and receives a significant exposure from normal beam operations.				
Assumptions and Initial Conditions: 1. Inherent operation of the beam due to losses generates a significant field in the Bunker during operation. (IC) 2. The number of procedures and systems involved in this operation and for this event to occur reduces the likelihood of this event. (IC)	**Causes:** 1. Failure of the TPPS to accomplish access control.			**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. No unmitigated impact on systems.	**Unmitigated Consequences**			
	Radiological **Public:** N/A **WG1:** High **WG2:** N/A	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A		**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: To assure that no personnel can access Corridor 202 during beam operation.				
Method of Detection:				
TPPS Corridor 202 access detection and alarm.				
Preventive Features - Attributes:				**Credited:**
TPPS - Corridor 202 access control. (EC)				X

Event Number
ISB4-6

Mitigative Features - Attributes:	Credited:
TPPS beam trip and alarm on access violation. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public:** N/A **WG1:** N/A **WG2:** N/A	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
1. Corridor 202 is required to be accessed to gain entry to the Bunker and GLS room.	Prevented

APPENDIX J. INSTRUMENT SYSTEMS AND CAVE (ISC) HAZARD EVENT TABLES

Event Number
ISC1-1

Event Description:
A small fire in the Instrument cave.

Assumptions and Initial Conditions:	**Causes:**	**Initiating Event Frequency**
1. Activated material is generally fixed or of small quantity and would not be released in a fire. (IC) 2. Electrical circuits are localized and serve relatively few items. (DF) 3. Event can occur either during beam operation or during maintenance operations. (IC) 4. Beamline may be operating or shut down for maintenance. (IC) 5. Fire in instrument cave limited to the area immediately adjacent to the fire. (IC)	1. Electrical short. 2. Electrical overload/overheat. 3. Instrument failure (e.g., short). 4. Maintenance failure 5. Ignition by welding sparks or other unknown ignition source. 6. Accumulation of combustibles.	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Loss of electrical equipment powered by affected circuits leads to loss of research capability on Instrument. 2. Fire could lead to equipment damage in the affected cave. 3. Equipment damage from fire water and recovery from the water release in Instrument cave would lead to an extended loss of use of the affected cave. 4. Fire could cause loss of neutron beam availability to the affected cave. 5. If the fire is large enough it could activate the Instrument Hall sprinkler system and spray water on the equipment in the instrument hall with the associated damage to that equipment.	**Public:** Negligible **WG1:** Negligible **WG2:** Negligible	**Public:** N/A **WG1:** N/A **WG2:** N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
To control the radiological consequences to workers from a fire in the Instrument cave(s).

Method of Detection:	
Fire Detection and alarm.	
Visual.	
Audible.	
Abnormal conditions for Instrument monitoring.	

Preventive Features - Attributes:	**Credited:**
Instrument design and QA. (DF/AC)	
Procedures and training. (AC)	

Event Number ISC1-1				
Mitigative Features - Attributes:				**Credited:**
Fire Detection and Notification – alarms and monitors. (EC)				
Fire Detection and Suppression. (EC)				
Low activity levels in instrument cave. (DF)				
IPPS – Controls/limits cave access during beam operation. (EC)				
Operator Training and Procedures – to respond to fire alarms and evacuate. (AC)				
Planned analysis, assumption validations, and Risk/Opportunities: 1. Project Fire Hazard Analysis (PFHA). 2. Assessment of fires per NFPA 801.	**Mitigated Consequences:**			
	Radiological **Public:** Negligible **WG1:** Negligible **WG2:** Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Notes: 1. Activated material is releasable in a fire. .				**Mitigated Frequency** A

Event Number
ISC4-1

Event Description:
Worker in Instrument cave with beam on receives a radiation overexposure by getting in the neutron beam path.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. A worker enters the Instrument cave while neutrons are present. (IC) 2. The worker gets in the neutron path while the neutron beam is on. (IC)	1. The Instrument IPPS allows worker entry without prohibiting neutrons. 2. Operations shutter failure. 3. Operator error.	A

Unmitigated Impact on Systems:	Unmitigated Consequences		
1. There is no impact on systems.	**Radiological** **Public:** Negligible **WG1**: High **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
To prevent worker access to the cave while neutrons are present.

Method of Detection:	
IPPS – detects the Instrument cave door opening.	
IPPS – detects operations shutter failure.	
Radiation detectors - Workers entering the Instrument Cave will use an alarming dosimeter if required by procedure.	

Preventive Features - Attributes:	Credited:
IPPS - triggers the operations shutter on the affected beamline to close if it detects the door open while neutrons are authorized. (EC)	X
IPPS - If the shutter fails to close in a TBD time period, the IPPS issues a fault to the TPPS and it trips the proton beam, terminating all beam capability. (EC)	X
Radiological protection program – Either a proven condition of the cave is available, or a radiation survey is required prior to initial entry. (AC)	
The experiment design is reviewed by the RSC and is only approved if a worker is unlikely to have time to get into the neutron beam path before the IPPS issues a fault trip to the TPPS which trips the proton beam in case of either inadvertent or deliberate entry into the cave with neutrons on. (AC)	
Experiment workers are trained not to attempt to enter the Instrument cave until the IPPS in access mode. (AC)	

Event Number ISC4-1			
Mitigative Features - Attributes:			**Credited:**
The IPPS closes the operations shutter and/or terminates beam operations if the Instrument cave door opens while neutrons are present in the experiment area. (EC)			
Workers wearing alarming dosimeters will be warned of elevated radiation levels. (AC)			
Workers are trained to evacuate the cave if elevated radiation levels are detected or if the IPPS warns them of a hazard. (AC)			
Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Determine operations shutter closing time period for each beamline. 2. The experiment design is reviewed by the RSC and is only approved if a worker is unlikely to have time to get into the neutron beam path before the IPPS issues a fault trip to the TPPS which trips the proton beam in case of either inadvertent or deliberate entry into the cave with neutrons on.	**Radiological** **Public:** N/A **WG1**: N/A **WG2:** N/A	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Notes:			**Mitigated Frequency** Prevented

Event Number
ISC4-2

Event Description:
Failure to install local shielding as required along beam path between the Bunker and Instrument cave, along with an accidental blockage of the neutron beam, resulting in a radiation overexposure to nearby workers.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. Passive installed shielding is adequate to protect workers under accident conditions. (IC) 2. Workers are not permitted along beam path during beam operation. (IC)	1. Failure to have required shielding in place prior to beam operation.	A

Unmitigated Impact on Systems:
1. No unmitigated impact on systems.

Unmitigated Consequences:

Radiological	Chemical	ODH
Public: N/A **WG1:** High **WG2:** Negligible	**Public**: N/A **WG1:** N/A **WG2:** N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Assure that shielding is in an approved configuration prior to authorization of beam operations.

Method of Detection:	
Visual inspection prior to approval of beam operations.	
Area Radiation Monitors (ARM) and alarms. (Note 2)	

Preventive Features - Attributes:	Credited:
Configuration Management Program – RSO verification that shielding is in place and secured prior to beam operation. (AC)	X
Radiation Safety Program – Shielding analysis, approval of safe configuration, and implementation of shielding plan. (AC)	

Event Number	
ISC4-2	
Mitigative Features - Attributes:	**Credited:**
Area Radiation Monitors (ARM) and alarms. (Note 2) (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Shielding design and analysis to assure that the approved shielding configuration protects workers even in case of a beam obstruction.	**Radiological** **Public:** N/A **WG1:** N/A **WG2:** N/A	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Notes: 1. Beamline shielding is intended to be modular to facilitate configuration changes should provide the required shielding for normal operation for the instrument beam line. 2. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.			Mitigated Frequency Prevented

Event Number ISC4-3					
Event Description: Worker is exposed to highly activated sample following sample exposure in Instrument Cave.					
Assumptions and Initial Conditions: 1. Sample is exposed during normal experiment conditions but becomes more activated than expected. (IC)	**Causes:** 1. Sample makeup is different than expected or exposure time is longer than expected. 2. Operator error in sample activity prediction. 3. Software error in sample activity prediction. 4. Failure to follow procedures.				**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. None.		**Unmitigated Consequences:** **Radiological** **Public:** Negligible **WG1:** Moderate **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A		**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: To prevent a direct exposure of worker above allowable limits from an exposed sample.					

Method of Detection:	
Radiation detection instrument scan of sample following exposure to neutrons.	
Preventive Features - Attributes:	**Credited:**
Environmental Safety and Health Management System Program (ESHMS) – assesses the need for specific requirements or training to perform this operation. (AC)	
Sample activation calculation predicts activation level of samples based on sample makeup and exposure parameters. (AC)	X
Appropriate software V&V applied sample calculator. (AC)	X
Sample proposals are reviewed and approved prior to exposure. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) if required. (AC) • Radiological Survey - Post entry. (AC) • Training of personnel authorized to change samples. (AC)	

Event Number ISC4-3			
Mitigative Features - Attributes:			**Credited:**
Personnel authorized to change samples are trained to detect excess radiation levels and to notify RCTs. (AC)			
Radiation Safety Program – • Radiological Work Permit (RWP) if required. (AC) • Radiological Survey - Post entry. (AC) • Training of personnel authorized to change samples. (AC)			
Planned analysis, assumption validations, and Risk/Opportunities: 1. Sample activation calculator software development and V&V.	**Mitigated Consequences:** **Radiological** **Public:** N/A **WG1:** N/A **WG2:** N/A	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Notes:			**Mitigated Frequency** Prevented

Event Number ISC4-4					
Event Description: A thick sample or unintended large object is “inserted” into the neutron beam in the instrument sample location. The object could fall into the path, the wrong object could be placed into the sample location, or other cause. The blockage of the neutron beam results in a radiation overexposure to nearby workers.					
Assumptions and Initial Conditions: 1. Passive installed shielding is adequate to protect workers under accident conditions. (IC) 2. Workers are not permitted along beam path during beam operation. (IC) 3. Samples may be inserted into the instrument beam line during neutron beam operation. (IC)	**Causes:** 1. Failure to follow experiment operational procedures. 2. Failure to have required shielding in place prior to beam operation.				**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. No unmitigated impact on systems.		**Unmitigated Consequences:**			
		Radiological **Public:** N/A **WG1:** High **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Safety Function: Assure that instrument test procedures are followed, and shielding is in an approved configuration prior to authorization of beam operations to ensure that a worker cannot receive an exposure beyond allowable limits.					
Method of Detection:					
Visual inspection prior to approval of beam operations.					
Area Radiation Monitors and alarms. (Note 2)					
Preventive Features - Attributes:					**Credited:**
Configuration Management Program – RSO verification that shielding is in place and secured prior to beam operation. (AC)					X
Radiation Safety Program – Shielding analysis, approval of safe configuration, and implementation of shielding plan. (AC)					
Instrument test procedures controlling test articles placed in the sample location. (AC)					X

Event Number	
ISC4-4	

Mitigative Features - Attributes:	**Credited:**
Area Radiation monitors and alarms. (Note 2) (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Shielding design and analysis to assure that the approved shielding configuration protects workers even in case of a beam obstruction. 2. Neutronics calculation of consequences of a dropped object into the neutron beam line. 3. Instrument review and approval of planned testing and installation by the Instrument Review Committee.	**Radiological** **Public:** N/A **WG1:** N/A **WG2:** N/A	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. This event is directly applicable to the BWAVE and may be applicable to other instruments as well. 2. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.	Prevented

Event Number
ISC4-5

Event Description:
The overhead crane drops a heavy load onto an instrument cave or beam line. The object could fall and damage the shielding causing material to fall into the beam path. The blockage results in a radiation overexposure to nearby workers.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. Passive installed shielding is adequate to protect workers under other accident conditions. (IC) 2. Workers are not permitted along beam path during beam operation. (IC/AC) 3. Workers are not permitted in the instrument cave during beam operation. (IC)	1. Failure to follow operational procedures. 2. Failure to follow hoisting and rigging program requirements.	A

Unmitigated Impact on Systems:
1. No unmitigated impact on systems from radiation exposure.
2. Physical impact to impacted instrument and adjacent instruments could cause an extended loss of experiment time.

Unmitigated Consequences:

Radiological	Chemical	ODH
Public: N/A	**Public**: N/A	**Public**: N/A
WG1: High	**WG1:** N/A	**WG1**: N/A
WG2: Negligible	**WG2:** N/A	**WG2**: N/A

Safety Function:
Assure that crane operations can not drop heavy objects onto the STS instruments or beam lines.

Method of Detection:	
Visual.	
Area Radiation Monitors and alarms. (Note 3)	

Preventive Features - Attributes:	Credited:
Critical lift procedures to assure the lifts over this area are safely executed. (AC)	

Event Number ISC4-5	
Mitigative Features - Attributes:	**Credited:**
Area Radiation Monitors and alarms. (Note 3) (EC)	X
Emergency Response Procedures – reacting to the initial drop and radiation alarm. (AC)	X
Worker location during crane overhead operations with load is not permitted. (AV)	
Workers are not permitted along beam path during beam operation. (IC/AC)	
Workers are not permitted in the instrument cave during beam operation. (IC/AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Shielding design and analysis to assure that the approved shielding configuration protects workers even in case of a beam obstruction. 2. Determine if other protective measures are in place for this event.	**Radiological** **Public:** N/A **WG1:** Low **WG2:** N/A	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. The potential physical impact on workers from the falling object is an SBS consideration and is not considered in the PHAR. 2. This event is directly applicable to the BWAVE and may be applicable to other instruments as well. 3. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.	A

APPENDIX K. LEAK COLLECTION SYSTEMS (LCS) HAZARD EVENT TABLES

The LCS is mainly addressed in the HPV. See Figure K-1 below:

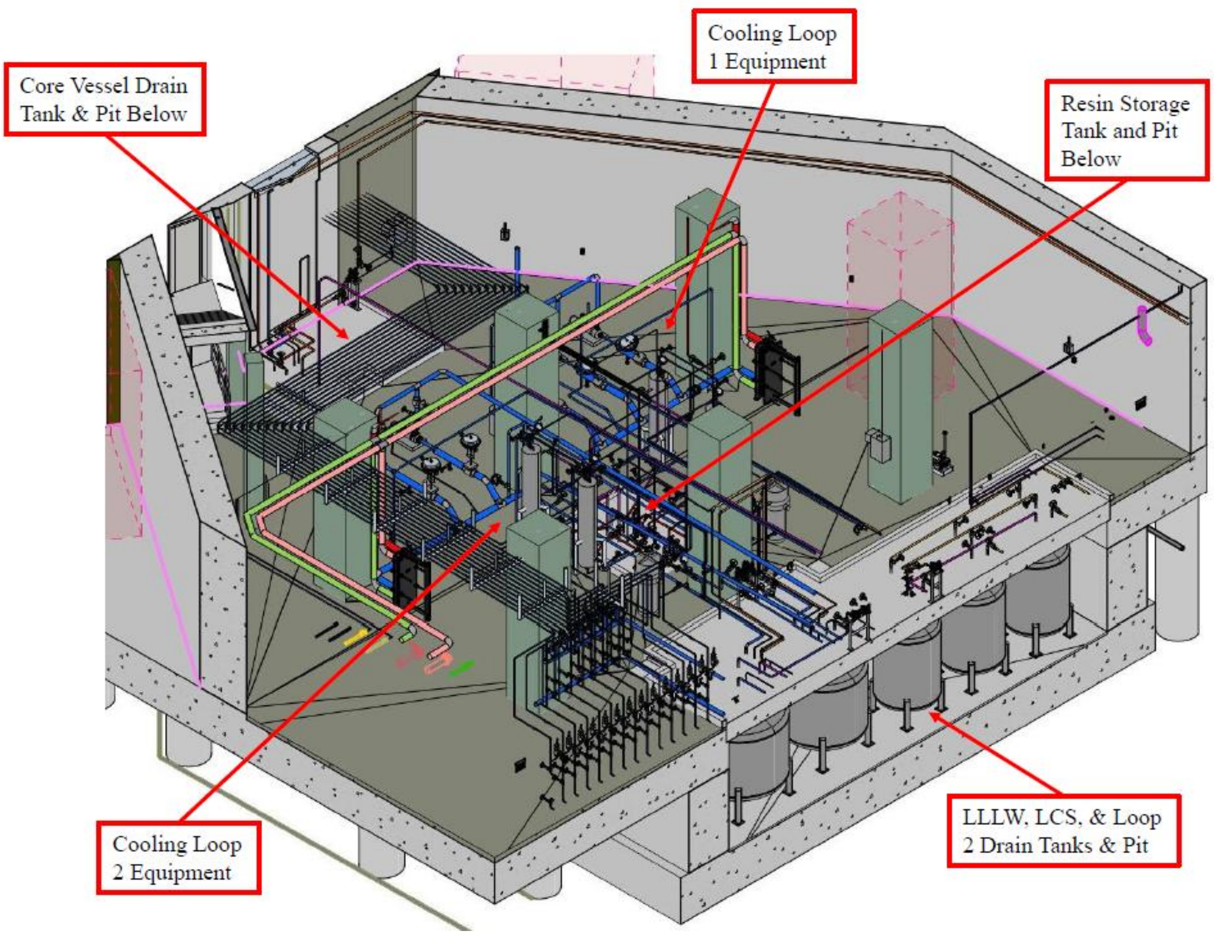

Figure K-1. HPV configuration.

APPENDIX K. LEAK COLLECTION SYSTEM (LCS) HAZARD EVENT TABLES

<table>
<tr><td colspan="4">Event Number:
LCS1-1</td></tr>
<tr><td colspan="4">Event Description:
Fire in area served by Leak Collection System (LCS).</td></tr>
<tr><td>Assumptions and Initial Conditions:
1. Proton beam operating and cooling water at equilibrium activity for short lived isotopes. (IC)
2. Fire sprinklers operate to suppress fire in 30 minutes. (IC)
3. LCS collects leaks and spills from the core vessel drain, GLS tanks, Delay tank, target drive room drain, bulk shielding drain, and area drains from the bunker. (DF)
4. Piping from the bulk shielding, pipe pans, and bunker are routed to the HPV and gravity drain but are instrumented and valved off (including a blind flange in some locations) and only opened when required to sample and drain the line. (See Note 2) (DF)
5. The core vessel drain is connected to the core vessel drain tank and is normally isolated, but during maintenance periods or during helium operation can drain the core vessel to permit continued operation. (DF)
6. Leaks from the GLS and Delay Tank locations in the HPV will drop to the HPV floor, and from there flow downslope to a tank pit, where the water will collect for disposal. (DF)
7. Leaks from the pump room go to the sloped floor, and from there to a tank pit. (DF)</td><td colspan="2">Causes:
1. Combustibles accumulation, insulation, cleaning solvents.
2. Ignition by:
• wiring fault,
• short circuit,
• deterioration of insulation from radiation exposure,
• welding sparks,
• other unknown ignition source.</td><td>Initiating Event Frequency
A</td></tr>
<tr><td rowspan="2">Unmitigated Impact on Systems:
1. Smoke plugs SCE filters.
2. Sprinkler water mixes with activated cooling water from breach caused by fire.
3. Water mixture including fire water and cooling loop water fills the collection tank and overflows. Water would collect in drain lines, including the bunker trench drain. If the sprinklers remain on, the water overflows these drains (the drain pipes would fill up) and end up on the HPV floor and pits within the HPV.</td><td colspan="3">Unmitigated Consequences</td></tr>
<tr><td>Radiological
Public: Negligible
WG1: Negligible
WG2: Negligible</td><td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
<tr><td colspan="4">Safety Function:
Reduce probability of a fire in areas served by the LCS that could result in a significant release of radiological material or causing a release of Loop 1 or Loop 2 coolant impacting WG1.</td></tr>
</table>

Event Number LCS 1-1				
Method of Detection:				
Smoke or heat detectors.				
Fire sprinkler actuation detectors.				
Collection tank level instrument.				
SCE delta-P instruments.				
Leak detection in HPV pits.				
Leak detection in applicable drain line.				
Preventive Features – Attributes:				**Credited:**
Operating procedures. (AC)				
Training. (AC)				
Mitigative Features – Attributes:				**Credited:**
Level detection in collection lines and pits. (EC)				
HPV Floor liner. (DF)				
Fire Detection and Suppression System. (EC)				
Combustible control program. (AC)				
Secondary Confinement Exhaust system. (EC)				
Planned analysis, assumption validations, and Risk/Opportunities: 1. Project Fire Hazard Analysis (PFHA). 2. Assessment of fires per NFPA 801.	**Mitigated Consequences:**			
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Notes: 1. When building arrangement has been finalized the LCS events will need to be updated. 2. The LCS tank is in a pit. The pipe pans, bulk shielding liner, and bunker drain to pipes with leak detection. 3. Some of these, e.g., the pipe pan drain, can be directed to the LLLW tank or to the drain tank, and those lines do not have blind flanges. There will be small sampling valves so the blinds, where they exist, do not have to be removed for sampling. The core vessel drain goes to the CV drain tank and does not have a blind. 4. The LCS collects leaks in the leak collection tank (located in a pit within the HPV), in pipes with leak detection, or in one of the pits in the HPV.				**Mitigated Frequency** **A**

Event Number
LCS2-1

Event Description:
Explosion in location served by the LCS.

Assumptions and Initial Conditions:
1. Proton beam operating and cooling water at equilibrium activity for short lived isotopes. (IC)
2. LCS collects leaks and spills from the core vessel drain, GLS cavity drain, target drive room drain, bulk shielding drain, and area drains from the bunker. (DF)
3. Piping from the bulk shielding, pipe pans, and bunker are routed to the HPV and gravity drain but are instrumented and valved off (including a blind flange) and only opened when required to sample and drain the line. (See Note 2) (DF)
4. The core vessel drain is connected to the core vessel drain tank and is normally isolated, but during maintenance periods or during helium operation can drain the core vessel to permit continued operation. (DF)
5. Leaks from the GLS and Delay Tank locations in the HPV will drop to the HPV floor, and from there flow downslope to a tank pit, where the water will collect for disposal. (DF)
6. Leaks from the pump room go to the sloped floor, and from there to a tank pit. (DF)
7. Radiological release includes both surface contamination and activity in the drained LCS water.

Causes:
1. Inadvertent drainage of flammable liquid to LCS system.
2. Breach of CMS releasing hydrogen to target drive room.
3. Welding sparks.
4. Other unknown ignition source.

Initiating Event Frequency
U

Unmitigated Impact on Systems:
1. Breach of collection tank.
2. Damage to adjacent equipment.
3. Possible initiator of target loss of cooling event if target cooling loop is damaged.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Reduce probability of explosion in the LCS areas with the potential to release significant quantities radioactive coolant and surface contamination impacting WG1.

Event Number LCS2-1	
Method of Detection:	
Collection tank pressure instrument; audible.	
Smoke or heat detectors.	
Fire sprinkler actuation detectors.	
Collection tank level instrument.	
Leak detection in HPV pits.	
SCE delta-P instruments.	
Leak detection in drain lines.	
Preventive Features – Attributes:	**Credited:**
LCS collection tank/pit location. (DF)	
Operating procedures. (AC)	
Training. (AC)	
Mitigative Features – Attributes:	**Credited:**
Operating procedures. (AC)	
Training. (AC)	
Level detection in collection lines and pits. (EC)	
Floor liner. (DF)	
Fire Detection and Suppression System. (EC)	
Combustible control program. (AC)	
Secondary Confinement Exhaust system. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Event Number LCS2-1	
Notes: 1. When building arrangement has been finalized the LCS events will need to be updated. 2. The LCS tank is in a pit. The pipe pans, bulk shielding liner, and bunker drain to pipes with leak detection. 3. Some of these, e.g., the pipe pan drain, can be directed to the LLLW tank or to the drain tank, and those lines do not have blind flanges. There will be small sampling valves so the blinds, where they exist, do not have to be removed for sampling. The core vessel drain goes to the CV drain tank and does not have a blind. 4. The LCS collects leaks in the leak collection tank (located in a pit within the HPV), in pipes with leak detection, or in one of the pits in the HPV.	**Mitigated Frequency** **U**

Event Number
LCS3-1

Event Description:
Leakage of LCS piping or LCS collection tank.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Proton beam operating and cooling water at equilibrium activity for short lived isotopes. (IC) 2. LCS collects leaks and spills from the core vessel drain, GLS cavity drain, target drive room drain, bulk shielding drain, and area drains from the bunker. (DF) 3. Piping from the bulk shielding, pipe pans, and bunker are routed to the HPV and gravity drain but are instrumented and valved off (including a blind flange in some locations) and only opened when required to sample and drain the line. (See Note 2) (DF) 4. The core vessel drain is connected to the core vessel drain tank and is normally isolated, but during maintenance periods or during helium operation can drain the core vessel to permit continued operation. (DF) 5. Leaks from the GLS and Delay Tank locations in the HPV will drop to the HPV floor, and from there flow downslope to a tank pit, where the water will collect for disposal. (DF) 6. Leaks from the pump room go to the sloped floor, and from there to a tank pit. (DF) 7. Workers are not permitted in these areas during beam operation but could be there during shutdown.	1. Corrosion. 2. Flange gasket deterioration. 3. Operator error.	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
1. Accumulation of water in inaccessible areas.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Reduce probability or radiological consequences of cooling water leakage from the LCS system impacting WG1 .

Method of Detection:	
Level detection on drain lines, pits, or collection tank.	

Preventive Features – Attributes:	**Credited:**
Double wall piping in inaccessible areas. (DF)	

Event Number LCS3-1	
Mitigative Features – Attributes:	**Credited:**
Level instruments in collection lines and pits. (EC)	
Operating procedures. (AC)	
Training. (AC)	
Secondary Confinement Exhaust system. (EC)	
HPV floor liner. (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. When building arrangement has been finalized the LCS events will need to be updated. 2. The LCS tank is in a pit. The pipe pans, bulk shielding liner, and bunker drain to pipes with leak detection. 3. Some of these, e.g., the pipe pan drain, can be directed to the LLLW tank or to the drain tank, and those lines do not have blind flanges. There will be small sampling valves so the blinds, where they exist, do not have to be removed for sampling. The core vessel drain goes to the CV drain tank and does not have a blind. 4. The LCS collects leaks in the leak collection tank (located in a pit within the HPV), in pipes with leak detection, or in one of the pits in the HPV.	**A**

Event Number
LCS3-2

Event Description:
Plugged drain/line in LCS piping.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Proton beam operating and cooling water at equilibrium activity for short lived isotopes. (IC) 2. LCS collects leaks and spills from the core vessel drain, GLS cavity drain, target drive room drain, bulk shielding drain, and area drains from the bunker. (DF) 3. Piping from the bulk shielding, pipe pans, and bunker are routed to the HPV and gravity drain but are instrumented and valved off (including a blind flange in some locations) and only opened when required to sample and drain the line. (See Note 2) (DF) 4. The core vessel drain is connected to the core vessel drain tank and is normally isolated, but during maintenance periods or during helium operation can drain the core vessel to permit continued operation. (DF) 5. Leaks from the GLS and Delay Tank locations in the HPV will drop to the HPV floor, and from there flow downslope to a tank pit, where the water will collect for disposal. (DF) 6. Leaks from the pump room go to the sloped floor, and from there to a tank pit. (DF) 7. Workers are not permitted in these areas during beam operation but could be there during shutdown.	1. Debris plugs drain in LCS area. 2. Debris accumulation in LCS piping plugs piping. 3. Purge dam from construction not removed. 4. Other unknown plug in line.	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Accumulation of water in inaccessible areas such as bulk shielding, other secondary confinement areas served by LCS. 2. Delay of operations for cleanup.	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Reduce probability of blockage or plugging of LCS piping leading to spread of contamination and worker radiological exposure above allowable limits.

Method of Detection:
Visual observation of water accumulation.

Event Number
LCS3-2

Preventive Features – Attributes:	Credited:
Piping inspection testing post construction. (AC)	
Operating procedures. (AC)	
Training. (AC)	

Mitigative Features – Attributes:	Credited:
Strainer on all floor drains. (DF)	
Trench liner in bunker. (DF)	
GLS and delay tank cavity liner. (DF)	
Core vessel containment. (DF/EC)	
Bulk shielding liner. (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:

1. When building arrangement has been finalized the LCS events will need to be updated.
2. The LCS tank is in a pit. The pipe pans, bulk shielding liner, and bunker drain to pipes with leak detection.
3. Some of these, e.g., the pipe pan drain, can be directed to the LLLW tank or to the drain tank, and those lines do not have blind flanges. There will be small sampling valves so the blinds, where they exist, do not have to be removed for sampling. The core vessel drain goes to the CV drain tank and does not have a blind.
4. The LCS collects leaks in the leak collection tank (located in a pit within the HPV), in pipes with leak detection, or in one of the pits in the HPV.

Mitigated Frequency
A

Event Number
LCS3-3

Event Description:
LCS Collection system water prematurely pumped to Process or Sanitary waste.

Assumptions and Initial Conditions	Causes	Initiating Event Frequency
1. Proton beam operating and cooling water at equilibrium activity for short lived isotopes. (IC) 2. LCS collects leaks and spills from the core vessel drain, GLS cavity drain, target drive room drain, bulk shielding drain, and area drains from the bunker. (DF) 3. Piping from the bulk shielding, pipe pans, and bunker are routed to the HPV and gravity drain but are instrumented and valved off (including a blind flange in some locations) and only opened when required to sample and drain the line. (See Note 2) (DF) 4. The core vessel drain is connected to the core vessel drain tank and is normally isolated, but during maintenance periods or during helium operation can drain the core vessel to permit continued operation. (DF) 5. Leaks from the GLS and Delay Tank locations in the HPV will drop to the HPV floor, and from there flow downslope to a tank pit, where the water will collect for disposal. (DF) 6. Leaks from the pump room go to the sloped floor, and from there to a tank pit. (DF) 7. Discharge of LCS collection tank is hard piped to LLLW or to the cooling loops only (IC)	1. Operator error. 2. Piping design.	BEU

Unmitigated Impact on Systems	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. Discharge of activated cooling water to sanitary waste resulting in exposure of an uninvolved worker to radioactivity (requires multiple events).	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Reduce probability of LCS water being inadvertently released to the Process or Sanitary waste system.

Method of Detection:	
Sampling of wastewater.	
Activity detected in sanitary waste at the ORNL outfall.	

Event Number
LCS3-3

Preventive Features — Attributes:	Credited:
Operating procedures. (AC)	
Drain collection locations require sampling and processing before releasing to the sanitary sewer. (See Note 2) (DF/AC))	
Discharge of LCS collection tank is hard piped to LLLW or to the cooling loops only (DF)	

Mitigative Features – Attributes:	Credited:
Operator training. (AC)	
LCS water is sampled before discharging to the PW system. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:

1. When building arrangement has been finalized the LCS events will need to be updated.
2. The LCS tank is in a pit. The pipe pans, bulk shielding liner, and bunker drain to pipes with leak detection.
3. Some of these, e.g., the pipe pan drain, can be directed to the LLLW tank or to the drain tank, and those lines do not have blind flanges. There will be small sampling valves so the blinds, where they exist, do not have to be removed for sampling. The core vessel drain goes to the CV drain tank and does not have a blind.
4. The LCS collects leaks in the leak collection tank (located in a pit within the HPV), in pipes with leak detection, or in one of the pits in the HPV.

Mitigated Frequency
Prevented

Event Number
LCS 4-1

Event Description:
Direct Radiological exposure of personnel to activated cooling water in LCS collection tank, lines, pits, or HPV.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Proton beam operating and cooling water at equilibrium activity for short lived isotopes immediately before shutdown and personnel access to the area. (IC) 2. LCS collects leaks and spills from the core vessel drain, GLS cavity drain, target drive room drain, bulk shielding drain, and area drains from the bunker. (DF) 3. Piping from the bulk shielding, pipe pans, and bunker are routed to the HPV and gravity drain but are instrumented and valved off (including a blind flange in some locations) and only opened when required to sample and drain the line. (See Note 3) (DF) 4. The core vessel drain is connected to the core vessel drain tank and is normally isolated, but during maintenance periods or during helium operation can drain the core vessel to permit continued operation. (DF) 5. Leaks from the GLS and Delay Tank locations in the HPV will drop to the HPV floor, and from there flow downslope to a tank pit, where the water will collect for disposal. (DF) 6. Leaks from the pump room go to the sloped floor, and from there to a tank pit. (DF) 7. Worker location in HPV. (IC) 8. Workers are not permitted in the HPV during beam operation but could be there during shutdown. (IC/AC) 9. The LCS collection tank is located in a controlled and shielded locations the HPV. Access to the HPV requires PPS release for access. (See Note 2) (DF)	1. Procedural violation where Personnel gain access to the LCS pits prior to authorization.	**A**

Unmitigated Impact on Systems:
Excess dose to personnel.

Unmitigated Consequences

Radiological	**Chemical**	**ODH**
Public: N/A	**Public**: N/A	**Public**: N/A
WG1: Moderate	**WG1**: N/A	**WG1**: N/A
WG2: N/A	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent personnel radiological exposure above allowable levels.

Method of Detection:
Personnel surveys and dosimetry.

Event Number LCS 4-1	
Preventive Features – Attributes:	**Credited:**
Permanent or portable shielding. (DF)	
Radiation protection program. (AC)	
Controlled access to LLLW locations and Worker training. (EC/AC).	X
Mitigative Features – Attributes:	**Credited:**
Permanent or portable shielding. (DF)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	
Worker training. (AC).	
Work planning. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: N/A **WG1:** N/A **WG2:** N/A	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:	**Mitigated Frequency**
1. When building arrangement has been finalized the LCS events will need to be updated. 2. The LCS tank is in a pit. The pipe pans, bulk shielding liner, and bunker drain to pipes with leak detection. 3. Some of these, e.g., the pipe pan drain, can be directed to the LLLW tank or to the drain tank, and those lines do not have blind flanges. There will be small sampling valves so the blinds, where they exist, do not have to be removed for sampling. The core vessel drain goes to the CV drain tank and does not have a blind. 4. The LCS collects leaks in the leak collection tank (located in a pit within the HPV), in pipes with leak detection, or in one of the pits in the HPV.	Prevented

APPENDIX L. PROCESS WASTE (PW) HAZARD EVENT TABLES

APPENDIX L. PROCESS WASTE (PW) HAZARD EVENT TABLES

Event Number
PW1-1

Event Description:
Fire is initiated in the process or sanitary waste system area.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC) 2. Consequences are only associated with radiological release from the event. (IC) 3. Non-radiological hazards are considered Standard Industrial Hazards (SIH). (IC)	1. Flammable or incompatible chemicals inadvertently drained to the process waste header. 4. Process waste containing chemicals is ignited by transfer pump. 5. Leaks to sump and is ignited by sparks generated by sump pump. 6. Other unidentified ignition source.	A

Unmitigated Impact on Systems:
1. Damage to process waste equipment or to sanitary waste system equipment.
2. Damage to lift station in area; create small target building fire. (BG6-2)
3. Shutdown of operations in the affected area.
4. Radioactivity discharged to ORNL sanitary waste system.
5. Recovery time required for restoration to normal operation conditions.

Unmitigated Consequences		
Radiological	**Chemical**	**ODH**
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent a fire in the sanitary waste system area from resulting in a significant release of radiological material impacting WG1.

Method of Detection:	
Fire detection system.	
Visual.	
Audible.	
Preventive Features – Attributes:	**Credited:**
Process waste tank design and material selection. (DF)	
Chemical handling and disposal procedures. (AC)	
Pump design. (DF)	
Electrical equipment designed to code. (DF)	

Event Number

PW1-1

Mitigative Features – Attributes:	Credited:
Fire detection and suppression system. (EC)	
Building HVAC system. (EC)	
Only very low levels of radioactivity are normally present in the PW system. (AC)	
Emergency response procedures. (AC)	
Worker and experimenter procedures and training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Project Fire Hazard Analysis (PFHA).
2. Assessment of fires per NFPA 801.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:

1. SIHs, whether as part of normal operations or maintenance activities are identified as part of the design process or operational planning and appropriate codes and standards are specified or a determination that the ORNL Standards Based Management System (SBMS) provides adequate direction to address the hazard.

Mitigated Frequency
A

Event Number PW2-1				
Event Description: Chemicals inadvertently drained to process waste system create explosive mixture in the process waste system.				
Assumptions and Initial Conditions: 1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC) 2. Consequences are only associated with radiological release from the event. (IC) 3. Non-radiological hazards are considered Standard Industrial Hazards (SIH). (IC)	**Causes**: 1. Flammable or incompatible chemicals inadvertently drained to the process waste header. 2. Process waste containing chemicals is ignited by transfer pump. 3. Leaks to sump are ignited by sparks generated by sump pump. 4. Other unidentified ignition source.			**Initiating Event Frequency** **A**
Unmitigated Impact on Systems: 1. Damage to (including breach of) process waste equipment or sanitary waste system and surrounding equipment. 2. Damage to lift station in area; create small target building fire. (BG6-2) 3. Leaked process waste liquid could spread contamination to other areas of the facility. 4. Shutdown of operations in the affected area. 5. Recovery time required for restoration to normal operation conditions.	**Unmitigated Consequences**			
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Safety Function: Prevent conditions leading to an explosion and release of significant radiological material or chemicals from the process waste system impacting WG1.				

Method of Detection:	
Visual.	
Audible.	
Preventive Features – Attributes:	**Credited:**
Process waste system design and material selection. (DF)	
Sump pump design. (DF)	
Electrical equipment designed to code. (DF)	
Chemical handling and disposal procedures. (AC)	

Event Number
PW2-1

Mitigative Features – Attributes	Credited:
Building HVAC system. (EC)	
Building structure (e.g., materials of construction). (DF)	
Only very low levels of radioactivity are normally present in the PW system. (AC)	
Emergency response procedures. (AC)	
Worker training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
1. SIHs, whether as part of normal operations or maintenance activities are identified as part of the design process or operational planning and appropriate codes and standards are specified or a determination that the ORNL Standards Based Management System (SBMS) provides adequate direction to address the hazard.	**A**

Event Number
PW3-1

Event Description:
Release of radiological material due to a leak in the process waste tank.

Assumptions and Initial Conditions:
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC)
2. Consequences are only associated with radiological release from the event. (IC)
3. Non-radiological hazards are considered Standard Industrial Hazards (SIH). (IC)

Causes:
1. Failure of the process waste tank due to corrosion.
2. Tank damaged during installation or maintenance.
3. Cracking at welds as the result of long-term vibration.
4. Leak in associated piping.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Shutdown of the affected area.
2. Leaked process waste liquid could spread contamination to other areas of the facility if in the building.
3. Recovery time required for decontamination efforts or for repairs as necessary.
4. Release of process waste to groundwater from underground leak.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: Negligible	**Public**: N/A
WG1: Negligible	**WG1**: Negligible	**WG1**: N/A
WG2: Negligible	**WG2**: Negligible	**WG2**: N/A

Safety Function:
Prevent a leak from the process waste system from resulting in a significant radiological exposure to workers above allowable limits.

Method of Detection:	
Visual.	
Level probe in sump.	
Conductivity probe in sump with alarm.	

Preventive Features – Attributes:	
Process waste system design. (DF)	**Credited:**
Collection sump and pit. (DF)	
Piping design. (DF)	
Selection of material. (DF)	
Preventive maintenance program. (AC)	
Operating Procedures and Training. (AC)	

Event Number
PW3-1

Mitigative Features – Attributes:	**Credited:**
Building design includes curbs to contain leaked material. (DF)	
Building confinement capability. (DF/EC)	
Collection sump and pit. (DF)	
Contamination control procedures. (AC)	
Only very low levels of radioactivity are normally present in the PW system. (AC)	
Worker training. (AC)	
EOCs. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. SIHs, whether as part of normal operations or maintenance activities are identified as part of the design process or operational planning and appropriate codes and standards are specified or a determination that the ORNL Standards Based Management System (SBMS) provides adequate direction to address the hazard.	**A**

Event Number
PW3-2

Event Description:
Radioactive material inadvertently drained to sanitary sewer system.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC) 2. Consequences are only associated with radiological release from the event. (IC) 3. Water released from PW tanks is above discharge limits. (IC) 4. Non-radiological hazards are considered Standard Industrial Hazards (SIH). (IC)	1. High activity radioactive materials or chemicals inadvertently introduced into to the PW system and is transferred to sanitary sewer. 2. High activity radioactive materials or chemicals leaks to a sump and is transferred to the sewer. 3. Sample analysis fails to detect activity. 4. Operator error.	U

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Spread of contamination to other areas of ORNL. 2. Shutdown of operations in the affected area. 3. Inadvertent exposure to personnel. 4. Discharge of radioactive material to the environment. 5. Recovery time required for restoration to normal operation conditions.	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent release of hazardous material above allowable limits to the sanitary sewer system.

Method of Detection:	
Sampling in ORNL sanitary sewer system.	
Sampling of STS process waste prior to discharge to sanitary sewer.	
Preventive Features – Attributes:	
PW waste system design. (DF)	**Credited:**
No process waste system drainage to sanitary sewer directly. (DF)	
Sump pump design. (DF)	
Process Waste System operating procedures. (AC)	
Radioactive material handling and disposal procedures. (AC)	

Event Number
PW3-2

Mitigative Features – Attributes:	**Credited:**
Emergency response procedures. (AC)	
Worker training. (AC)	
Dilution by other water processed in the ORNL sanitary sewer system. (EC)	
Sources of PW in the facility handle only low quantities of activated material. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. SIHs, whether as part of normal operations or maintenance activities are identified as part of the design process or operational planning and appropriate codes and standards are specified or a determination that the ORNL Standards Based Management System (SBMS) provides adequate direction to address the hazard.	**A**

APPENDIX M. REMOTE HANDLING (RH) HAZARD EVENT TABLES

Component drying will occur in the Service Cell. The Service Cell event scenarios (Appendix P) address events associated with Remote Handling of equipment out of the transfer cask or storage cask as well as component handling events in the PIE Cell.

The initial evaluation of remote handling was performed assuming that a liner would be used in some of the transfer or storage casks. Based on updated design considerations, a liner is no longer required. Therefore, a number of these events have been deleted or combined.

Table M.1: General Remote Handling Conditions

Number	Description	Designation
1	When the core vessel is open to the general atmosphere, the pressure in the core vessel is maintained at a slightly negative pressure to control contamination and assure that air flow is into the core vessel. The exhaust is filtered prior to being exhausted.	EC/DF
2	When the core vessel is open to the general atmosphere, the core vessel exhaust is maintained at high enough flow to assure that the face velocity across the core vessel opening prevents contamination from leaving the core vessel. The exhaust is filtered prior to being exhausted.	EC
3	The Drive Room roof beams are not required to be removed for target removal or MRA removal.	DF
4	Crane access to core vessel components is through hatches in the Target Drive Room roof.	DF
5	Components in a transfer cask will be lifted from the Target Drive Room roof and transported to the Service Cell.	IC
6	Transport of the transfer cask with the overhead crane will maintain the cask at TBD height above the floor except when lifting from the Drive Room roof.	AC
7	The transfer cask will mate to the target drive room roof to permit crane access through the cask to reach the target segment or other component removal.	IC
8	Water (to the target segments) will not be removed prior to starting to lift items such as roof panels, supplemental shield or internal shield blocks. Water from the target segment to be removed will be blown out to the maximum extent possible and water in the other segments will remain and provide active cooling to those segments. Loop 2 cooling water flow will still be provided.	AC
9	The shield block design extends full height from above the target block up to approx. top of core vessel. Target Shield blocks are split vertically. There are two removable target shield blocks. These shield blocks are actively cooled and will have water disconnected and partially blown down prior to removal. Target segment water cooling will still be in effect while target shield block removal is ongoing.	DF/EC
10	None of our transfer casks will employ a liner. The perishable component will be removed directly from the core vessel and transfer into the cask. Only the cask will require a closure (at the bottom interface). All casks will be lifted by features on the cask. The casks may or may not use a plug lid on the top to cover the component lifting interface opening	DF
11	During target removal and other non-CMS removal/replacement operations, hydrogen can remain in the CMS.	IC

APPENDIX M. REMOTE HANDLING (RH) HAZARD EVENT EVENTS

Event Number RH3-1				
Event Description: Drop of a Drive Room roof hatch/plug by the overhead crane during facility preparation for target removal (or removal of other activated components). This event bounds an operator error causing the crane to impact the water lines cooling the target system.				
Assumptions and Initial Conditions: 1. The Drive Room roof plugs/hatches must be removed to allow overhead crane access to the core vessel. (DF) 2. The Drive Room walls are not removable. (IC) 3. Available source term from activated water in the other target segments not being removed and target central shaft remains during target removal. (IC) 4. Only one hatch will be open at a time to prevent a smaller hatch from falling through a larger hatch opening. (AC) 5. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1.	**Causes**: 1. Overhead Crane mechanical failure. 2. Lifting hook failure. 3. Failure to properly rig the plug/hatch for the lift. 4. Mechanical failure on the "hook or ring feature" on the component being lifted.			**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. Damage to the Target Drive mechanism. 2. Damage to the Target Drive shaft, target shaft, and target segments. 3. Damage to the Core Vessel lid. 4. Damage to the target system cooling lines above the core vessel lid causing a spill of activated/contaminated water. 5. Damage to the TVP above the core vessel lid. 6. Failure of the Core Vessel vacuum seal causing loss confinement for the Core Vessel. 7. Activated water in the ullage of the core vessel requiring draining and cleanup. 8. Activated water flows onto the core vessel lid, which could flow to the outside of the core vessel.	**Unmitigated Consequences** **Radiological** **Public**: Negligible **WG1**: Moderate **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A		**ODH** **Public**: **WG1**: N/A **WG2**: N/A
Safety Function: Prevent a Target Drive Room roof hatch/plug from being dropped onto the core vessel or components on the lid of the core vessel or within the Target Drive Room.				
Method of Detection:				
Visual.				
Audible.				
Preventive Features – Attributes:				**Credited:**
Target Drive Room roof hatch/plug design prevents it passing through the opening in the Target Drive Room roof. (DF)				X
Crane Design per TBD. (DF)				
Design of the component attachment point (hook, ring, etc.). (DF)				
ORNL Hoisting and Rigging Program including the STS procedures regarding rigging requirements as well as preparation and performance of the lift. (AC)				
STS surveillance and inspection program for the lift systems and components to be lifted. (AC)				

Event Number
RH3-1

Mitigative Features – Attributes:	Credited:
A slightly negative pressure in the core vessel prior to the event prevents gross release of material from the core vessel when top seal is lost (EC) (See Item 1 in Table M-1)	
The inherent shielding required for operation assures that there is substantial material between the dropped component and the activated material in the core vessel. (DF)	
Process water clean-up system limits activation and contamination of the cooling water. (EC)	
The required time to prepare for target removal and before starting removal of these components allows additional time for water activation to decay and for cleanup of contamination (e.g., tungsten and associated contaminates). (AC)	
Emergency response training. (AC)	
Core vessel exhaust flow increased to assure that contamination does not leave the core vessel. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. Verify that this hatch will not drop through the hatch or result in a release to WG1.	**Radiological** **Public**: N/A **WG1:** N/A **WG2:** N/A	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:	Mitigated Frequency:
1. This event can also be considered a direct exposure event (i.e., RH4-X event).	Prevented

Event Number
RH3-2

Event Description:
Drop of core vessel cover during facility preparation for target removal (or removal of other activated components).

Assumptions and Initial Conditions:
1. The target cooling lines to the target segment being removed have been drained and disconnected. (AC)
2. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1.
3. Target drive motor removal will be with a jib crane inside the target drive room with manual control requiring workers to be in the TDR for this operation. (IC)
4. Core vessel covers will be lifted by a jib crane inside the target drive room with manual control requiring workers to be in the TDR for this operation. (IC)
5. Target Drive Motor is not required to be removed for target segment replacement. (DF)

Causes:
1. Lifting device mechanical failure.
2. Lifting hook failure.
3. Failure to properly rig the core vessel cover for the lift.
4. Mechanical failure on the “hook or ring feature” on the component being lifted.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Damage to the Target Drive mechanism.
2. Damage to the Target Drive shaft.
3. Damage to the Core Vessel lid.
4. Damage to the TVP above the core vessel lid.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent a drop of the core vessel cover.

Method of Detection:	
Visual.	
Audible.	

Preventive Features – Attributes:	**Credited:**
Crane Design: jib crane design, or portable hoist design per TBD. (DF)	
Design of the component attachment point (hook, ring, etc.). (DF)	
ORNL Hoisting and Rigging Program including the STS procedures regarding rigging requirements as well as preparation and performance of the lift. (AC)	
STS surveillance and inspection program for the lift systems and components to be lifted. (AC)	

Event Number
RH3-2

Mitigative Features – Attributes:	Credited:
A slightly negative pressure in the core vessel prior to the event prevents gross release of material from the core vessel when top seal is lost (EC) (See Item 1 in Table M-1)	
The inherent shielding required for operation assures that there is substantial material between the dropped component and the activated material in the core vessel. (DF)	
Process water clean-up system draining limits residual activation and contamination from the cooling water lines. (EC)	
Emergency response training. (AC)	
Core vessel exhaust flow increased to assure that contamination does not leave the core vessel. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:	Mitigated Frequency: A
1. This event can also be considered a direct exposure event (i.e., RH4-X event).	

Event Number
RH3-3 (Event Deleted based on segmented target design)

Event Description:
Drop of the target support shaft during removal.
The segmented target design approach has a solid center axle. The segments are "hung" onto this center shaft by bolts at the top of the shaft. A pin at the beam elevation locates the segment during installation. Rotation is induced at the top of the segment, not at the beam elevation. Thus, the shaft "follows" along and does not drive rotation. This design makes shaft failure in-credible situation. Therefore, the fault considered in this event is not credible as the target segments must all be removed to replace the target shaft. The shaft is designed to be life of the facility and would only be replaced with no target material in the core vessel.

Event Number RH3-3a					
Event Description: Drop of the target drive motor during motor removal.					
Assumptions and Initial Conditions: 1. The target cooling lines to the are not connected See Event RH3-6 for failure to drain cooling lines. (IC) 2. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1. 3. Target drive motor removal will be with a jib crane inside the target drive room with manual control requiring workers to be in the TDR for this operation. (IC) 4. Target Drive Motor is not required to be removed for target segment replacement. (DF)	**Causes**: 1. Lifting device mechanical failure. 2. Lifting hook failure. 3. Failure to properly rig the target drive motor. 4. Mechanical failure on the "hook or ring feature" on the component being lifted.				**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. Damage to the Target Drive mechanism. 2. Damage to the Target Drive shaft. 3. Damage to the Core Vessel lid. 4. Failure of the Core Vessel vacuum seal causing loss confinement for the Core Vessel.		**Unmitigated Consequences**			
		Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible		**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Prevent a drop of the target drive motor.					
Method of Detection:					
Visual.					
Audible.					
Preventive Features – Attributes:					**Credited:**
Crane Design: jib crane design, or portable hoist design per TBD. (DF)					
Design of the component attachment point (hook, ring, etc.). (DF)					
ORNL Hoisting and Rigging Program including the STS procedures regarding rigging requirements as well as preparation and performance of the lift. (AC)					
STS surveillance and inspection program for the lift systems and components to be lifted. (AC)					

Event Number
RH3-3a

Mitigative Features – Attributes:	Credited:
Emergency response training. (AC)	
The inherent shielding required for operation assures that there is substantial material between the dropped component and the activated material in the core vessel. (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:	Mitigated Frequency:
1. This event can also be considered a direct exposure event (i.e., RH4-X event).	**A**

Event Number
RH3-4

Event Description:
Drop of a shield block by the hoist during facility preparation for target segment removal, including immediately over the target segment and onto the target segment.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. The specific assumptions and initial conditions for the removal of the target Drive Room roof plug/hatch, target drive motor, and core vessel lid are still applicable. (IC) 2. The target segment to be removed and its associated utilities (e.g., cooling water lines) has been removed. (IC) 3. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1.	1. Overhead Crane mechanical failure. 2. Lifting hook failure. 3. Failure to properly rig the shield block for the lift. 4. Mechanical failure of the shield block attachment point (e.g., ring or other appropriate attachment design).	A

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. The drop damages the target assembly. 2. The drop damages the target assembly attachment point for target removal. 3. The drop damages the target shaft. 4. The drop damages the target segment seismic restraint system.	**Public**: Negligible **WG1**: Low **WG2**: Negligible	**Public**: **WG1**: N/A **WG2**: N/A	**Public**: **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent a drop of shield block during removal from the core vessel, including a drop over the target segments. Location of personnel needs to be defined for their impact.

Method of Detection:	
Visual.	
Audible.	

Preventive Features – Attributes:	Credited:
Crane Design or portable hoist design per TBD. (DF)	
ORNL Hoisting and Rigging Program including the STS procedures regarding rigging requirements as well as preparation and performance of the lift. (AC)	
STS Surveillance and inspection program on crane and lifting hardware. (AC)	
Design of the component attachment point (hook, ring, etc.). (DF)	

Event Number
RH3-4

Mitigative Features – Attributes:	Credited:
A slightly negative pressure in the core vessel prior to the event prevents gross release of material from the core vessel when top seal is lost. (EC) (See Item 1 in Table M-1)	
Cask is in place limiting the opening at the top of the Target Drive Room roof. (AC)	
Process water clean-up system limits residual contamination after system draining. (EC)	
The required time to prepare for target removal and before starting removal of these components allows additional time for water activation to decay and for cleanup of contamination (e.g., tungsten and associated contaminates). (AC)	
Emergency response training. (AC)	
Core vessel exhaust flow increased to assure that contamination does not leave the core vessel. (EC)	
Personnel are not permitted in the Target Drive Room during this operation. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:
1. Determine the potential release from the target assembly from a drop load impact event.
2. Assure that the shield block cannot impact the target foot.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Notes:
1. Water (to the target segments) will not be removed prior to starting to lift items such as Target Drive Room roof hatch/plug or supplemental shielding. After core vessel target shield blocks are removed, then target segment water will be removed to the extent practicable, but only removed to the specific segments planned for maintenance. Main water flow will still be provided to the bulk of the segments. Loop 2 water will still be operable.
2. The shield block design extends full height from above the target block up to approximately the top of the core vessel. Target Shield blocks are split vertically. There are two removable target shield blocks in each segment. These shield blocks are actively cooled and will have water disconnected and partially blown down prior to removal. Target segment water cooling will still be in effect while target shield block removal is ongoing.
3. This event can also be considered a direct exposure event (i.e., RH4-X event).

Mitigated Frequency:
A

Event Number
RH3-5

Event Description:
Failure to adequately drain water from the target cooling system for the applicable component prior to starting the target removal process.

Assumptions and Initial Conditions:
1. This event could happen when attempting to remove the target segment. (IC)
2. This event could occur when disconnecting the water lines prior to starting a lift. (IC)
3. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1. (Exception to Table M-1 is that of having drained and dried component.)

Causes:
1. Operator error – failure to drain/blow down the segment.
2. Operator error – failure to isolate the segment from the main cooling water system.
3. Operator error – failure to blow down the component.

Initiating Event Frequency
U

Unmitigated Impact on Systems:	Unmitigated Consequences		
1. None	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Safety Function:
Assure that coolant from the target segment has been drained and blown down per target removal requirements and only residual coolant remains in the segment.

Method of Detection:	
Liquid level detection in the core vessel.	
Visual for leakage on top of the core vessel lid.	
RCT surveys.	

Preventive Features – Attributes:	**Credited:**
Conduct of operations for the draining and blowdown operations and water coolant system shutdown and isolation. (AC)	

Event Number
RH3-5

Mitigative Features – Attributes:	**Credited:**
A slightly negative pressure in the core vessel prior to the event prevents gross release of material from the core vessel. (EC) (See Item 1 in Table M-1)	
With the exception of the component and shielding removed for the operation, the inherent shielding required for operation provides a robust layer of shielding immediately over the target assembly and MRA providing a tortuous path for release. (DF)	
Process water clean-up system limits contamination in the coolant water. (EC)	
The required time to prepare for target removal and before starting removal of these components allows additional time for water activation to decay and for cleanup of contamination. (AC)	
Emergency response training. (AC)	
Potential routing of the water lines (possibly below the lid) Design TBD. (DF)	
PPE. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	
Core vessel exhaust flow increased to assure that contamination does not leave the core vessel. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:
1. Determine level of activation and contamination in the coolant water.
2. Determine the time for circulation and continued coolant water cleanup prior to staring the operation.

Mitigated Consequences:

Radiological	**Chemical**	**ODH**
Public: Negligible	**Public:** N/A	**Public**: N/A
WG1: Low	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Notes:
1. It is anticipated that the worst-case condition for this event is spilled tritiated water that will need to be cleaned up to permit continued operations.

Mitigated Frequency: **U**

Event Number
RH3-6

Event Description:
Failure to adequately drain water from the target cooling system prior to starting the target drive motor replacement removal process.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Water lines are required to be disconnected prior to target drive motor replacement. (IC) 2. Since the target segments are not being removed, the system only needs to be drained and not blown down. (IC) 3. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1. (Exception to Table M-1 is that of having drained and dried component.)	1. Operator error – failure to drain the water lines to the segments.	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. None	**Public**: Negligible **WG1**: Low **WG2**: Negligible	**Public**: N/A **WG1:** N/A **WG2:** N/A	**Public**: N/A **WG1:** N/A **WG2:** N/A

Safety Function:
Assure that coolant from the target segments has been drained per target drive motor replacement requirements and only residual coolant remains in the water lines.

Method of Detection:	
RCT surveys.	
Visual for leakage on top of the core vessel lid.	

Preventive Features – Attributes:	**Credited:**
Conduct of operations for the draining and blowdown operations and water coolant system shutdown and isolation. (AC)	

Event Number RH3-6	
Mitigative Features – Attributes:	**Credited:**
Process water clean-up system limits contamination in the coolant water. (EC)	
The required time to prepare for target removal and before starting removal of these components allows additional time for water activation to decay and for cleanup of contamination. (AC)	
Emergency response training. (AC)	
PPE. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Determine level of activation and contamination in the coolant water. 2. Determine the time for circulation and continued coolant water cleanup prior to staring the operation.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:	**Mitigated Frequency:**
1. It is anticipated that the worst-case condition for this event is spilled tritiated water that will need to be cleaned up to permit continued operations.	**A**

Event Number
RH3-7

Event Description:
Drop of the target segment assembly during removal from the core vessel.

Assumptions and Initial Conditions:
1. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1.
2. The specific assumptions and initial conditions for the removal of the target Drive Room roof hatch/plug, target drive motor, and core vessel access lid are still applicable. (IC)
3. Coolant from the target segment has been “drained” per target removal requirements and only residual coolant remains in the segment. (IC)
4. Transfer or storage cask is in place on the roof of the Target Drive Room and the lift is through the cask. (IC)
5. The shielding above the target segment has been removed from the core vessel. (IC)
6. Personnel are not permitted in the target drive room during a lift of an activated component from the core vessel. (AC/IC)
7. Personnel are permitted in the target drive room to prepare for a lift of a component from the core vessel. (C)

Causes:
1. Overhead Crane or portable hoist mechanical failure.
2. Ziplift failure.
3. Failure to properly rig the hook for the lift.
4. Mechanical failure of the target attachment point.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Impact and damage adjacent target segments or shielding.
2. Failure could cause water to leak into the core vessel.
3. Failure could impact cooling to other target segments.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent a drop of a target segment assembly during removal from the core vessel. Location of personnel needs to be defined for their impact.

Method of Detection:	
Visual.	
Audible.	

Preventive Features – Attributes:	**Credited:**
Crane Design or portable hoist design per TBD. (DF)	
ORNL Hoisting and Rigging Program including the STS procedures regarding rigging requirements as well as preparation and performance of the lift. (AC)	
STS Surveillance and inspection program on crane and lifting hardware. (AC)	
Design of the target module attachment point and Ziplift. (DF)	

Event Number RH3-7	
Mitigative Features – Attributes:	**Credited:**
A slightly negative pressure in the core vessel prior to the event prevents gross release of material from the core vessel. (EC) (See Item 1 in Table M-1)	
Process water clean-up system limits residual contamination after system draining. (EC)	
The required time to prepare for target removal and before starting removal of these components allows additional time for water activation to decay and for cleanup of contamination. (AC)	
Emergency response training. (AC)	
Cask is in place limiting the opening at the top of the Target Drive Room roof. (AC)	
Transfer or storage cask is in place on the roof of the Target Drive Room and the lift is through the cask. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	
Core vessel exhaust flow increased to assure that contamination does not leave the core vessel. (EC)	
Personnel are not permitted in the target drive room during this operation. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Determine the potential release from the target assembly from an impact event. 2. Demonstrate the robustness of the target shroud for a drop.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency:**
1. This event can also be considered a direct exposure event (i.e., RH4-X event). 2. With the initial conditions of the cask in place and personnel not permitted in the target drive room the potential exposure to WG1 is low.	**A**

Event Number RH3-8				
Event Description: Target is lifted too far and impacts/damages the transfer or storage cask.				
Assumptions and Initial Conditions: 1. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1. 2. The specific assumptions and initial conditions for the removal of the target Drive Room roof hatch/plug, target drive motor, and core vessel access lid are still applicable. (IC) 3. Coolant from the target segment to be removed has been drained and blown down to the extent practical per target removal requirements and only residual coolant remains in the segment. (IC) 4. Transfer or storage cask is in place and the lift is through the cask. (IC) 5. The of shielding above the target segment has been removed from the core vessel. (IC) 6. A portable hoist is mounted on top of the cask and used to lift the component into the cask. (IC)		**Causes**: 1. Operator error 2. Crane control error 3. Crane drive error		**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. Damage to the transfer or storage cask which prevents sealing and closing for movement. 2. If damage to lifting device occurs and leads to a drop of the target system, then the consequences are the same as Event RH3-7.	**Unmitigated Consequences**			
	Radiological **Public**: Negligible **WG1**: Moderate **WG2**: Negligible		**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Prevent the target segment from being lifted too far into the transfer cask. Location of personnel needs to be defined for their impact.				
Method of Detection:				
Visual.				
Audible.				
Crane or portable hoist sensors for lift.				
Preventive Features – Attributes:				**Credited:**
Crane Design or portable hoist design per TBD. (DF)				
Hook height monitoring device TBD. (EC)				
STS lift procedures. (AC)				
Lift Spotter communication with crane operator. (AC)				

Event Number
RH3-8

Mitigative Features – Attributes:	Credited:
A slightly negative pressure in the core vessel prior to the event prevents gross release of material from the core vessel. (EC) (See Item 1 in Table M-1)	
Process water clean-up system limits residual contamination after system draining. (EC)	
The required time to prepare for target removal and before starting removal of these components allows additional time for water activation to decay and for cleanup of contamination (e.g., tungsten). (AC)	
Emergency response training. (AC)	
Cask is in place limiting the opening at the top of the Target Drive Room roof. (AC)	
A camera will be in the target drive room that permits the operator to observe the lift. (EC)	
Use of a portable hoist with an installed load cell will alert the hoist operator that there is an issue, so that the lift can be stopped. This prevents the potential exposure to a worker to a direct shine from the component. (EC)	X
Component specific lifting procedures will be in place to direct the hoist operator if the load cell give a high reading. (AC)	X
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area and perform the operation. (AC)	
Personnel are not permitted in the target drive room during this operation. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. Determine the potential release from the target assembly from an impact event. 2. Demonstrate the robustness of the target shroud for a drop.	**Radiological** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency:
1. This event can also be considered a direct exposure event (i.e., RH4-X event).	**A**

Event Number RH3-9a				
Event Description: Failure to close the Transfer Cask Gamma Shield door (partially) with a drop of the target within the cask or partially out of the cask. Note failure to close the Transfer Cask Gamma Shield door and disconnecting the Ziplift or crane hook would have the same consequences as RH3-3, 4, 5 or 7				
Assumptions and Initial Conditions: 1. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1. 2. Coolant from the target segment has been drained and blown down per target removal requirements and only residual coolant remains in the segment. (IC). 3. Transfer or storage cask is in place and the lift is through the cask. (IC) 4. The integral Transfer Cask Gamma Shield door on the cask is open/closed manually. (DF) 5. Either a Ziplift or other attachment mechanism may be used to accomplish the lift. (AC) 6. A portable hoist is mounted on top of the cask and used to lift the component into the cask. (IC) 7. Ziplift cannot be disconnected under load. (IC).	**Causes**: 1. Operator error 2. Mechanical failure of Gamma Shield Door drive mechanism. 3. Failure to lift the component totally into the cask. 4. Gamma door sensor failure. 5. Hoisting and rigging configuration does not permit the component to be lifted fully into the cask preventing door closure. 6. Operator error in closing the Gamma Shield Door.			**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. Transfer Cask Gamma Shield door damage. 2. Inability to continue with activated component removal operation. 3. Drop could wedge into the opening and prevent remote handling to continue.	**Unmitigated Consequences**			
	Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible.	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A		**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Assure that the Transfer Cask Gamma Shield door is in place prior to disconnecting the crane hook or Ziplift or lifting the transfer cask and activated component has been pulled entirely into the transfer or storage cask.				
Method of Detection:				
Gamma Door sensor feedback				
Area Radiation Monitors (ARM) and alarms				
Rad Surveys				
Visual				
Inability to secure the cask bottom closure				

Event Number RH3-9a	
Preventive Features – Attributes:	**Credited:**
Transfer Cask Gamma Shield door design (DF)	
Gamma door manual drive system design (DF)	
Operator procedures (AC)	
Mitigative Features – Attributes:	**Credited:**
A slightly negative pressure in the core vessel prior to the event prevents gross release of material from the core vessel (EC) (See Item 1 in Table M-1)	
Cask is in place limiting the opening at the top of the Target Drive Room roof. (AC)	
Positive verification instrumentation of Gamma Shield Door position. (EC)	
A camera will be in the target drive room that permits the operator to observe condition of the Gamma door. (EC)	
Positive verification that component has been properly raised into the transfer or storage cask. (EC)	
STS Remote Handling procedures. (AC)	
The inherent shielding/confinement provided by Gamma Shield Door fixture and transfer or storage cask installed over the core vessel opening. (AC/EC)	
Emergency response training. (AC)	
Personnel are not permitted in the target drive room during this operation. (AC)	
Operator manual control of the Gamma Shield Door closure mechanism. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Event Number
RH3-9a

Planned analysis, assumption validations, and Risk/Opportunities:

1. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible **WG1**: Low **WG2**: Negligible.	**Public**: N/A **WG1:** N/A **WG2:** N/A	**Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:

1. Sensors for the gamma door closure are TBD.
2. Details of remote handling process including installation of top closure need to be defined. The steps in this process could modify the potential for this event
3. This event can also be considered a direct exposure event (i.e., RH4-X event).
4. Worker exposure to recover from this event could be significant.

Mitigated Frequency: A

Event Number
RH3-9b

Event Description:
Failure to close the Target Drive Room Gamma Shield door (partially) with a drop of the target within the cask or partially out of the cask. Note failure to close the Target Drive Room Gamma Shield door and disconnecting the Ziplift or crane hook would have the same consequences as RH3-3, 4, 5 or 7

Assumptions and Initial Conditions:
1. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1.
2. Coolant from the target segment has been drained and blown down per target removal requirements and only residual coolant remains in the segment. (IC).
3. Transfer or storage cask is in place and the lift is through the cask. (IC)
4. The integral shield door on the cask is open/closed manually. The Gamma Shield Door (that will reside at the high bay level) is motor driven. (DF)
5. Either a Ziplift or other attachment mechanism may be used to accomplish the lift. (AC)
6. A portable hoist is mounted on top of the cask and used to lift the component into the cask. (IC)
7. Ziplift cannot be disconnected under load (IC).

Causes:
1. Operator error
2. Failure of Gamma Shield Door drive mechanism.
3. Failure to lift the component totally into the cask.
4. Gamma door sensor failure.
5. Hoisting and rigging configuration does not permit the component to be lifted fully into the cask preventing door closure.
6. Operator error in closing the Gamma Shield Door.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Target Drive Room Gamma Shield door damage.
2. Inability to continue with activated component removal operation.
3. Drop could wedge into the opening and prevent remote handling to continue.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible **WG1**: Low **WG2**: Negligible.	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Assure that the Target Drive Room Gamma Shield door is in place prior to disconnecting the crane hook or Ziplift or lifting the transfer cask and activated component has been pulled entirely into the transfer or storage cask.

Method of Detection:	
Target Drive Room Gamma Shield sensor feedback	
Area Radiation Monitors (ARM) and alarms	
Rad Surveys	
Visual	
Inability to secure the cask bottom closure	

Event Number RH3-9b	
Preventive Features – Attributes:	**Credited:**
Target Drive Room Gamma Shield door design (DF)	
Target Drive Room Gamma Shield door drive system design (DF)	
Operator procedures (AC)	
Mitigative Features – Attributes:	**Credited:**
A slightly negative pressure in the core vessel prior to the event prevents gross release of material from the core vessel (EC) (See Item 1 in Table M-1)	
Cask is in place limiting the opening at the top of the Target Drive Room roof. (AC)	
Positive verification instrumentation of Gamma Shield Door position. (EC)	
A camera will be in the target drive room that permits the operator to observe condition of the Gamma door. (EC)	
Positive verification that component has been properly raised into the transfer or storage cask. (EC)	
STS Remote Handling procedures. (AC)	
The inherent shielding/confinement provided by Gamma Shield Door fixture and transfer or storage cask installed over the core vessel opening. (AC/EC)	
Emergency response training. (AC)	
Personnel are not permitted in the target drive room during this operation. (AC)	
Operator control of the Gamma Shield Door closure mechanism. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

<table>
<tr><td colspan="4">Event Number
RH3-9b</td></tr>
<tr><td rowspan="2">Planned analysis, assumption validations, and Risk/Opportunities:
1. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.</td><td colspan="3">Mitigated Consequences:</td></tr>
<tr><td>Radiological
Public: Negligible
WG1: Low
WG2: Negligible.</td><td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
<tr><td colspan="3">Notes:
1. Sensors for the Target Drive Room Gamma Shield door closure are TBD.
2. Details of remote handling process including installation of top closure need to be defined. The steps in this process could modify the potential for this event
3. This event can also be considered a direct exposure event (i.e., RH4-X event).
4. Worker exposure to recover from this event could be significant.</td><td>Mitigated Frequency:
A</td></tr>
</table>

Event Number
RH3-9c

Event Description:
Failure to close the Core Vessel Lid Gamma Shield door (partially) with a drop of the target within the cask or partially out of the cask. Note failure to close the Core Vessel Lid Gamma Shield door and disconnecting the Ziplift or crane hook would have the same consequences as RH3-3, 4, 5 or 7

Assumptions and Initial Conditions:
1. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1.
2. Coolant from the target segment has been drained and blown down per target removal requirements and only residual coolant remains in the segment. (IC).
3. Transfer or storage cask is in place and the lift is through the cask. (IC)
4. The Core Vessel Lid Gamma Shield Door is motor driven. (DF)
5. Either a Ziplift or other attachment mechanism may be used to accomplish the lift. (AC)
6. A portable hoist is mounted on top of the cask and used to lift the component into the cask. (IC)
7. Ziplift cannot be disconnected under load (IC).

Causes:
1. Operator error
2. Failure of Core Vessel Lid Gamma Shield Door drive mechanism.
3. Failure to lift the component totally out of the core vessel.
4. Core Vessel Lid Gamma Shield door sensor failure.
5. Hoisting and rigging configuration does not permit the component to be lifted fully into the cask preventing door closure.
6. Operator error in closing the Gamma Shield Door.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Core Vessel Lid Gamma Shield a door damage.
2. Inability to continue with activated component removal operation.
3. Drop could wedge into the opening and prevent remote handling to continue.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible **WG1**: Low **WG2**: Negligible.	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Assure that the Core Vessel Lid Gamma Shield door is in place prior to disconnecting the crane hook or Ziplift or lifting the transfer cask and activated component has been pulled entirely into the transfer or storage cask.

Method of Detection:	
Core Vessel Lid Gamma Shield Door sensor feedback	
Area Radiation Monitors (ARM) and alarms	
Rad Surveys	
Visual	
Inability to secure the cask bottom closure	

Event Number RH3-9c	
Preventive Features – Attributes:	**Credited:**
Core Vessel Lid Gamma Shield door design (DF)	
Core Vessel Lid Gamma Shield door drive system design (DF)	
Operator procedures (AC)	
Mitigative Features – Attributes:	**Credited:**
A slightly negative pressure in the core vessel prior to the event prevents gross release of material from the core vessel (EC) (See Item 1 in Table M-1)	
Cask is in place limiting the opening at the top of the Target Drive Room roof. (AC)	
Positive verification instrumentation of Core Vessel Lid Gamma Shield Door position. (EC)	
A camera will be in the target drive room that permits the operator to observe condition of the Core Vessel Lid Gamma Shield door. (EC)	
Positive verification that component has been properly raised into the transfer or storage cask. (EC)	
STS Remote Handling procedures. (AC)	
The inherent shielding/confinement provided by Core Vessel Lid Gamma Shield Door fixture and transfer or storage cask installed over the core vessel	
Emergency response training. (AC)	
Personnel are not permitted in the target drive room during this operation. (AC)	
Operator control of the Gamma Shield Door closure mechanism. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

<table>
<tr><td colspan="4">Event Number
RH3-9c</td></tr>
<tr><td rowspan="2">Planned analysis, assumption validations, and Risk/Opportunities:
1. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.</td><td colspan="3">Mitigated Consequences:</td></tr>
<tr><td>Radiological
Public: Negligible
WG1: Low
WG2: Negligible.</td><td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
<tr><td colspan="3">Notes:
1. Sensors for the Core Vessel Lid Gamma Shield door closure are TBD.
2. Details of remote handling process including installation of top closure need to be defined. The steps in this process could modify the potential for this event
3. This event can also be considered a direct exposure event (i.e., RH4-X event).
4. Worker exposure to recover from this event could be significant.</td><td>Mitigated Frequency:
A</td></tr>
</table>

Event Number
RH3-10

Event Description:
Failure to fully lift the target segment into the transfer or storage cask such that the Core Vessel Lid Gamma Shield, Target Drive Room Gamma Shield door, or Transfer Cask Gamma Shield door impacts the target on closure.

<table>
<tr>
<td colspan="2">Assumptions and Initial Conditions:
1. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1.
2. Coolant from the target segment has been “drained” per target removal requirements and only residual coolant remains in the segment. (IC)
3. Transfer or storage cask is in place and the lift is through the cask. (IC)
4. Transfer Cask Gamma Shield door is open/closed manually. The Core Vessel Lid Gamma Shield and Target Drive Room Gamma Shield Door are motor driven. . (DF)
5. A portable hoist is mounted on top of the cask and used to lift the component into the cask. (IC)</td>
<td colspan="2">Causes:
1. Operator error.
2. Core Vessel Lid Gamma Shield, Target Drive Room Gamma Shield door, or Transfer Cask Gamma Shield door drive mechanical failure.
3. Failure to lift the component totally into the cask.</td>
<td>Initiating Event Frequency
A</td>
</tr>
<tr>
<td rowspan="2">Unmitigated Impact on Systems:
1. Core Vessel Lid Gamma Shield, Target Drive Room Gamma Shield door, or Transfer Cask Gamma Shield Door damage
2. Inability to continue with activated component removal operation.
3. Damage to the target disk</td>
<td colspan="4">Unmitigated Consequences</td>
</tr>
<tr>
<td colspan="2">Radiological
Public: Negligible
WG1: Low
WG2: Negligible.</td>
<td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td>
<td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td>
</tr>
<tr>
<td colspan="5">Safety Function:
Assure that the target segment is lifted fully into the transfer cask before closing the Gamma door as the Gamma door could impact the target disk and open it up for release of contamination.</td>
</tr>
<tr><td colspan="4">Method of Detection:</td><td></td></tr>
<tr><td colspan="4">Area Radiation Monitors (ARM) .</td><td></td></tr>
<tr><td colspan="4">Core Vessel Lid Gamma Shield, Target Drive Room Gamma Shield door, or Transfer Cask Gamma Shield door sensor feedback.</td><td></td></tr>
<tr><td colspan="4">Operator knowledge of activity / training.</td><td></td></tr>
</table>

Event Number
RH3-10

Preventive Features – Attributes:	Credited:
Crane Design or portable hoist design per TBD. (DF)	
Hook height monitoring device TBD. (EC)	
STS lift procedures. (AC)	
Lift Spotter communication with crane operator. (AC)	
Core Vessel Lid Gamma Shield, Target Drive Room Gamma Shield door, or Transfer Cask Gamma Shield door closure system will monitor torque to detect impacts/binding of the system and cameras will be used for visual inspection. (EC)	

Mitigative Features – Attributes:	Credited:
A slightly negative pressure in the core vessel prior to the event prevents gross release of material from the core vessel (EC) (See Item 1 in Table M-1)	
Process water clean-up system limits residual contamination after system draining. (EC)	
The required time to prepare for target removal and before starting removal of these components allows additional time for water activation to decay and for cleanup of contamination. (AC)	
A camera will be in the target drive room that permits the operator to observe the lift. (EC)	
Personnel are not permitted in the target drive room during this operation. (IC)	
Emergency response training. (AC)	
Cask is in place limiting the opening at the top of the Target Drive Room roof. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Training of personnel authorized to be in the area. (AC)	
Area Radiation Monitors (ARM) and alarms (EC).	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Determine if it is possible to manually move the Core Vessel Lid Gamma Shield and Target Drive Room Gamma Shield doorr into a position if the motor is not functioning properly.
2. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible **WG1**: Low **WG2**: Negligible.	**Public**: N/A **WG1:** N/A **WG2:** N/A	**Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:

1. This event can also be considered a direct exposure event (i.e., RH4-X event).

Mitigated Frequency: A

Event Number
RH3-11

Event Description:
Failure to maintain core vessel environmental conditions during all lift operations of highly activated components from the Core Vessel.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1. 2. Core vessel pressure is monitored to alarm operator. (IC) 3. Core vessel exhaust is designed to handle maximum opening size. (DF) 4. The Core Vessel will be vented prior to any lifting operations of highly activated components from the Core Vessel. (AC)	1. Exhaust system failure. 2. Drop of component onto the core vessel lid or the gamma door mechanism.	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Safety Function:
Assure that a slightly negative pressure is maintained in the core vessel during all lift operations and adequate core vessel exhaust flow is present to prevent unwanted contamination from getting out of the core vessel. (See Table M-1 Item 1)

Method of Detection:	
Fan operability monitor.	
Core vessel pressure monitor.	

Preventive Features – Attributes:	**Credited:**
Exhaust system design for maximum opening condition. (DF)	

Event Number
RH3-11

Mitigative Features – Attributes:	Credited:
Exhaust system design for maximum opening condition. (DF)	
Emergency response training. (AC)	
Gamma door is in place for most of the operations, limiting the opening at the top of the Target Drive Room roof. (AC)	
Cask is in place limiting the opening at the top of the Target Drive Room roof. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Training of personnel authorized to be in the area. (AC)	
Personnel are not permitted in the target drive room during a lift of an activated component from the core vessel. (AC)	
Core vessel exhaust flow increased to assure that contamination does not leave the core vessel. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. Exhaust system capacity needs to be determined.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:	Mitigated Frequency: A

Event Number
RH3-12 **(Event Deleted See Event RW3-13)**

Event Description:
Failure to secure the top closure of the transfer or storage cask

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. The cask is intended to be closed completing the cask seal and the cask lifted by an attachment to the cask. 2. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1.	1. Operator error. 2.	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Possible contamination along the route of cask transport.	**Public**: Negligible **WG1**: Low **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Assure that the top closure of the transfer cask is closed prior movement from the Target Drive Room.

Method of Detection:	
Radiation monitors	
Rad Survey	

Preventive Features – Attributes:	**Credited:**
Hoisting and Rigging Procedures (AC)	
Rad Survey (AC)	
STS remote handling procedures (AC)	

Event Number RH3-12 **(Event Deleted See Event RW3-13)**			
Mitigative Features – Attributes:			**Credited:**
STS Remote Handling Procedures (AC)			
Planned analysis, assumption validations, and Risk/Opportunities: None	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A
Notes: Lifting process needs to be defined by target systems remote handling management.			**Mitigated Frequency:** **A**

Event Number RH3-13					
Event Description: Failure to secure the top closure of the target transfer case.					
Assumptions and Initial Conditions: 1. All casks to be mounted on the applicable plug/hatch opening lifted off of the Target Drive Room roof by an external attachment to the cask. (DF/AC) 2. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1.		**Causes**: 1. Operator error			**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. Possible contamination along the route of cask transport, however, none is expected.		**Unmitigated Consequences**			
		Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A		**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A
Safety Function: Assure that the top closure of the transfer cask is closed prior movement from the roof of the Target Drive Room.					
Method of Detection:					
Area Radiation Monitors (ARM)					
RCT Survey					
Preventive Features – Attributes:					**Credited:**
Hoisting and Rigging Procedures (AC)					
RCT Survey (AC)					
STS remote handling procedures (AC)					

Event Number RH3-13				
Mitigative Features – Attributes:				**Credited:**
STS Remote Handling Procedures (AC)				
Area Radiation Monitors (ARM) (EC)				
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)				
Personnel are not permitted in the target drive room during this operation. (AC)				
Planned analysis, assumption validations, and Risk/Opportunities: 1. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.	**Mitigated Consequences:**			
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A	
Notes: Detailed Lifting process needs to be defined by target systems remote handling management.				**Mitigated Frequency:** **A**

Event Number
RH3-14 (Event Deleted)

Event Description:
Failure to properly seat the bottom closure of the transfer or storage cask.

Assumptions and Initial Conditions:
1. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1.
2. The cask bottom closure is not designed to control leakage (IC)

Causes:
1. Operator Error.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Contamination of the High Bay pit used for drying.
2. Potential contamination of the High Bay along the path from the core vessel to the Service Cell. .

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
None as there is no release of hazardous material outside of confinement.

Method of Detection:	
Rad Surveys.	
Cask contamination detected.	
Drying pit monitoring.	

Preventive Features – Attributes:	**Credited:**
STS Remote Handling procedures. (AC)	

Event Number
RH3-14 (Event Deleted)

Mitigative Features – Attributes:	**Credited:**
Remote handling procedures and water removal from the target segment minimizes potential release to the environment. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes: Lifting process needs to be defined by target systems remote handling management.	**Mitigated Frequency: A**

Event Number
RH3-15

Event Description:
Failure to secure the bottom closure of the transfer or storage cask. See Event RH4-4 for evaluation of direct exposure.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. All casks to be mounted on the applicable plug/hatch opening lifted off of the Target Drive Room roof by an external attachment to the cask. (IC) 2. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1. 3. The Cask will be lowered to a minimum elevation of TBD immediately after lifting the cask off the Target Drive Room roof. (IC).	1. Operator Error. 2. Failure to follow procedures. 3. Equipment failure (cask closure by bolts).	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
1. Leakage of water onto to the floor and associated contamination and airborne release of hazardous material.	**Radiological** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Safety Function:
Assure that bottom cask plate is secured with the proper bolting and tightening processes.

Method of Detection:	
Visual.	
Audible.	

Preventive Features – Attributes:	**Credited:**
STS activated component removal procedures. (AC)	
Cask closure design. (DF)	

Event Number RH3-15			
Mitigative Features – Attributes:			**Credited:**
Most of the travel to the storage location is at limited elevation. (DF)			
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area and perform this operation. (AC)			
Planned analysis, assumption validations, and Risk/Opportunities: 1. The load path across the high bay floor needs to be evaluated to determine potential mission and safety implications of coolant spilled on the floor.	**Mitigated Consequences:** **Radiological** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A
Notes: 1. Lifting process needs to be defined by target systems remote handling management.			**Mitigated Frequency:** A

Event Number
RH3-17

Event Description:
Failure to secure the top closure of the other transfer or storage cask. Consequences for water cooled and non-water-cooled components are the same since water cooled components are flanged to isolate the water line.

Assumptions and Initial Conditions:

1. All casks to be mounted on the applicable plug/hatch opening lifted off of the Target Drive Room roof by an external attachment to the cask. (IC)
2. Any water line is drained and partially blown down in-situ to establish a water level below the connection or cutting location before lifting into the cask. (AC)
3. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1.
4. No reusable core vessel components are water cooled. (IC)

Causes:

1. Operator error.

Initiating Event Frequency
BEU

Unmitigated Impact on Systems:

1. Possible contamination along the route of cask transport.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: N/A	**Public**: N/A	**Public**: N/A
WG1: N/A	**WG1:** N/A	**WG1:** N/A
WG2: N/A	**WG2:** N/A	**WG2:** N/A

Safety Function:
Assure that the top closure of the transfer cask is closed and water-cooled components are closed to prevent leakage.

Method of Detection:	
Area Radiation Monitors (ARM).	
RCT Survey.	
Operator observation.	

Preventive Features – Attributes:	**Credited:**
Hoisting and Rigging Procedures. (AC)	
RCT Survey. (AC)	
STS remote handling procedures. (AC)	

Event Number
RH3-17

Mitigative Features – Attributes:	**Credited:**
STS Remote Handling Procedures. (AC)	
Any water line is drained and partially blown down in-situ to establish a water level below the connection or cutting location before lifting into the cask. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.	**Radiological** **Public**: N/A **WG1:** N/A **WG2:** N/A	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:	**Mitigated Frequency:**
1. Lifting process needs to be defined by target systems remote handling management.	**BEU**

Event Number
RH3-18 (Event Deleted)

Event Description:
Failure to secure the bottom closure of the other transfer or storage cask. Consequences for water cooled and non-water-cooled components are the same since water cooled components are flanged to isolate the water line. See Event RH4-4 for direct exposure evaluation.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1. 2. All casks to be mounted on the applicable plug/hatch opening lifted off of the Target Drive Room roof by an external attachment to the cask. (IC) 3. Any water line is drained and partially blown down in-situ to establish a water level below the connection or cutting location before lifting into the cask. (AC)	1. Operator Error. 2. Failure to follow procedures. 3. Equipment failure (cask closure by bolts).	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Drop of component out of the cask onto the floor or instrumentation bunkers. 2. Potential leakage of water onto to the drop area if the flanged piping fails and associated contamination and airborne release of hazardous material.	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1:** N/A **WG2:** N/A	**Public**: N/A **WG1:** N/A **WG2:** N/A

Safety Function:
Assure that bottom cask plate is secured by the proper bolting and tightening processes.

Method of Detection:	
Visual.	
Audible.	

Preventive Features – Attributes:	**Credited:**
STS activated component removal procedures. (AC)	
Cask closure design. (DF)	

Event Number
RH3-18 (Event Deleted)

Mitigative Features – Attributes:	Credited:
Most of the travel to the storage location is at limited elevation. (DF)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:	Mitigated Frequency: A
1. Lifting process needs to be defined by target systems remote handling management.	

Event Number
RH3-19

Event Description:
Drop of an Other Transfer or Storage Cask when moving from the Target Drive Room roof.

Assumptions and Initial Conditions:
1. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1.
2. All casks to be mounted on the applicable plug/hatch opening lifted off of the Target Drive Room roof by an external attachment to the cask. (IC)
3. The Cask will be lowered to a minimum elevation of TBD immediately after lifting the cask off the Target Drive Room roof. (AC)

Causes:
1. Operator Error.
2. Failure to follow hoisting and rigging procedures.
3. Equipment failure (cask attachment point, crane, crane rigging).

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Damage to one or more Instrument Bunkers if the drop is over a bunker.
2. Damage to Target Drive Room ventilation depending on drop location.
3. Damage to and loss of cooling to the target systems requiring cooling depending on drop location.
4. Delay target replacement.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Safety Function:
Prevent a drop of an Other Transfer or Storage Cask when moving from the Target Drive Room.

Method of Detection:	
Visual.	
Audible.	

Preventive Features – Attributes:	**Credited:**
Cask lifting mechanism design. (DF)	
STS Activated Component Removal Procedures. (AC)	
Hoisting and rigging program. (AC/EC)	
Crane and rigging. (DF/EC)	

Event Number
RH3-19

Mitigative Features – Attributes:	Credited:
Most of the travel to the storage location is at limited elevation. (DF)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. The load path for heavy and/or activated components across the high bay floor needs to be evaluated to determine potential mission and safety implications of a drop.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:	Mitigated Frequency:
1. Lifting process needs to be defined by target systems remote handling management.	**A**

Event Number
RH3-20

Event Description:
Drop of the target Transfer or Storage Cask with disposable activated components when moving from the Target Drive Room roof to the Service Cell.

Assumptions and Initial Conditions:
1. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1.
2. All casks to be mounted on the applicable plug/hatch opening lifted off of the Target Drive Room roof by an external attachment to the cask. (IC)
3. The Cask will be lowered to a minimum elevation of TBD immediately after lifting the cask off the Target Drive Room roof. (AC)
4. Any water line is drained and partially blown down in-situ to establish a water level below the connection or cutting location before lifting into the cask. (AC)

Causes:
1. Operator Error.
2. Failure to follow hoisting and rigging procedures.
3. Equipment failure (cask attachment point, crane, crane rigging).

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Damage to one or more Instrument Bunkers if the drop is over a bunker.
2. Damage to Target Drive Room ventilation depending on drop location.
3. Damage to and loss of cooling to the target systems requiring cooling depending on drop location.
4. Delay target replacement.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Safety Function:
Prevent a drop of the target Transfer or Storage Cask or Other Transfer or Storage Cask when moving from the Target Drive Room roof to the Service Cell or another location in the High Bay.

Method of Detection:	
Visual.	
Audible.	

Preventive Features – Attributes:	**Credited:**
Cask lifting mechanism design. (DF)	
STS Activated Component Removal Procedures. (AC)	
Hoisting and rigging program. (AC/EC)	
Crane and rigging. (EC)	

Event Number
RH3-20

Mitigative Features – Attributes:	Credited:
Most of the travel to the storage location is at limited elevation. (DF)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. The load path for heavy and/or activated components across the high bay floor needs to be evaluated to determine potential mission and safety implications of a drop.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Notes:

1. Lifting process needs to be defined by target systems remote handling management.

Mitigated Frequency: **A**

Event Number
RH3-21

Event Description:
Drop of the shield block onto the MRA and shield block cooling pipe chase.

Assumptions and Initial Conditions:
1. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1.
2. The specific assumptions and initial conditions for the removal of the target Drive Room roof hatch/plug, target drive motor, and core vessel access lid are still applicable. (IC)
3. Transfer or storage cask is in place on the roof of the Target Drive Room and the lift is through the cask. (IC)
4. The of shielding above the target segment has been removed from the core vessel. (IC)

Causes:
1. Operator Error.
2. Failure to follow hoisting and rigging procedures.
3. Equipment failure (cask attachment point, crane, crane rigging).

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Impact and damage to the lower water-cooled shielding.
2. Failure of the shield block could cause water to leak into the core vessel.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Safety Function:
None as there is no release of hazardous material.

Method of Detection:	
Visual.	
Audible.	

Preventive Features – Attributes:	**Credited:**
Cask lifting mechanism design. (DF)	
STS Activated Component Removal Procedures. (AC)	
Hoisting and rigging program. (AC/EC)	
Crane and rigging. (EC)	

Event Number RH3-21	
Mitigative Features – Attributes:	**Credited:**
A slightly negative pressure in the core vessel prior to the event prevents gross release of material from the core vessel. (EC)	
Process water clean-up system limits residual contamination after system draining. (EC)	
The required time to prepare for target removal and before starting removal of these components allows additional time for water activation to decay and for	
Emergency response training. (AC)	
Cask is in place limiting the opening at the top of the Target Drive Room roof. (AC)	
Transfer or storage cask is in place on the roof of the Target Drive Room and the lift is through the cask. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes: 1. Lifting process needs to be defined by target systems remote handling management.	**Mitigated Frequency: A**

Event Number
RH3-22

Event Description:
Drop of a shield block over MRA access area of Core Vessel.

Assumptions and Initial Conditions:
1. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1.
2. The specific assumptions and initial conditions for the removal of the target Drive Room roof hatch/plug, target drive motor, and core vessel access lid are still applicable. (IC)
3. Transfer or storage cask is in place on the roof of the Target Drive Room and the lift is through the cask. (IC)
4. The of shielding above the target segment has been removed from the core vessel. (IC)

Causes:
1. Operator Error.
2. Failure to follow hoisting and rigging procedures.
3. Equipment failure (cask attachment point, crane, crane rigging).

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Impact and damage to the lower water-cooled shielding.
2. Failure of the shield block could cause water to leak into the core vessel.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Safety Function:
None as there is no release of hazardous material.

Method of Detection:	
Visual.	
Audible.	

Preventive Features – Attributes:	**Credited:**
Cask lifting mechanism design. (DF)	
STS Activated Component Removal Procedures. (AC)	
Hoisting and rigging program. (AC/EC)	
Crane and rigging. (EC)	

Event Number
RH3-22

Mitigative Features – Attributes:	Credited:
A slightly negative pressure in the core vessel prior to the event prevents gross release of material from the core vessel. (EC)	
Process water clean-up system limits residual contamination after system draining. (EC)	
The required time to prepare for target removal and before starting removal of these components allows additional time for water activation to decay and for	
Emergency response training. (AC)	
Cask is in place limiting the opening at the top of the Target Drive Room roof. (AC)	
Transfer or storage cask is in place on the roof of the Target Drive Room and the lift is through the cask. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A
Notes:			**Mitigated Frequency: A**

Event Number RH3-23 (Event Deleted as an MRA extraction fixture is no longer required in the design)
Event Description: Drop of MRA extraction fixture when preparing to pull the MRA away from the target system

Event Number
RH3-24

Event Description:
Drop of the MRA during removal.

Assumptions and Initial Conditions:
1. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1.
2. The specific assumptions and initial conditions for the removal of the target Drive Room roof hatch/plug, target drive motor, and core vessel access lid are still applicable. (IC)
3. Transfer or storage cask is in place on the roof of the Target Drive Room and the lift is through the cask. (IC)
4. The of shielding above the target segment has been removed from the core vessel. (IC)

Causes:
1. Operator Error.
2. Failure to follow hoisting and rigging procedures.
3. Equipment failure (cask attachment point, crane, crane rigging).

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Impact and damage to the lower water-cooled shielding.
2. Likely water leak into the core vessel.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Safety Function:
Prevent a drop of the MRA during removal.

Method of Detection:	
Visual.	
Audible.	

Preventive Features – Attributes:	**Credited:**
Cask lifting mechanism design. (DF)	
STS Activated Component Removal Procedures. (AC)	
Hoisting and rigging program. (AC/EC)	
Crane and rigging. (EC)	

Event Number
RH3-24

Mitigative Features – Attributes:	Credited:
A slightly negative pressure in the core vessel prior to the event prevents gross release of material from the core vessel. (EC)	
Process water clean-up system limits residual contamination after system draining. (EC)	
The required time to prepare for target removal and before starting removal of these components allows additional time for water activation to decay and for	
Emergency response training. (AC)	
Cask is in place limiting the opening at the top of the Target Drive Room roof. (AC)	
Transfer or storage cask is in place on the roof of the Target Drive Room and the lift is through the cask. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A
Notes:			**Mitigated Frequency: A**

Event Number
RH3-25

Event Description:
Failure to drain the MRA coolant line prior to cutting the line for MRA removal.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1. 2. The specific assumptions and initial conditions for the removal of the target Drive Room roof hatch/plug, target drive motor, and core vessel access lid are still applicable. (IC) 3. Transfer or storage cask is in place on the roof of the Target Drive Room and the lift is through the cask. (IC) 4. The of shielding above the target segment has been removed from the core vessel. (IC)	1. Operator Error. 2. Failure to follow procedures.	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Water leak into the core vessel.	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1:** N/A **WG2:** N/A	**Public**: N/A **WG1:** N/A **WG2:** N/A

Safety Function:
Assure that the MRA coolant line is drained and blown down to the extent practicable prior to cutting the line for MRA removal.

Method of Detection:	
Visual.	
Audible.	

Preventive Features – Attributes:	**Credited:**
STS Activated Component Removal Procedures. (AC)	

Event Number
RH3-25

Mitigative Features – Attributes:	Credited:
A slightly negative pressure in the core vessel prior to the event prevents gross release of material from the core vessel. (EC)	
Process water clean-up system limits residual contamination after system draining. (EC)	
The required time to prepare for target removal and before starting removal of these components allows additional time for water activation to decay and for cleanup of contamination. (AC)	
Emergency response training. (AC)	
Cask is in place limiting the opening at the top of the Target Drive Room roof. (AC)	
Transfer or storage cask is in place on the roof of the Target Drive Room and the lift is through the cask. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A
Notes:			**Mitigated Frequency: A**

Event Number
RH3-26

Event Description:
Failure to drain the TVP coolant line prior to cutting the line for TVP removal.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1. 2. The specific assumptions and initial conditions for the removal of the target Drive Room roof hatch/plug, target drive motor, and core vessel access lid are still applicable. (IC) 3. Transfer or storage cask is in place on the roof of the Target Drive Room and the lift is through the cask. (IC)	1. Operator Error. 2. Failure to follow procedures.	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Water leak into the core vessel.	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1:** N/A **WG2:** N/A	**Public**: N/A **WG1:** N/A **WG2:** N/A

Safety Function:
Assure that the TVP coolant line is drained and blown down to the extent practicable prior to cutting the line for TVP removal.

Method of Detection:	
Visual.	
Audible.	

Preventive Features – Attributes:	**Credited:**
STS Activated Component Removal Procedures. (AC)	

Event Number
RH3-26

Mitigative Features – Attributes:	Credited:
A slightly negative pressure in the core vessel prior to the event prevents gross release of material from the core vessel. (EC)	
Process water clean-up system limits residual contamination after system draining. (EC)	
The required time to prepare for target removal and before starting removal of these components allows additional time for water activation to decay and for cleanup of contamination. (AC)	
Emergency response training. (AC)	
Cask is in place limiting the opening at the top of the Target Drive Room roof. (AC)	
Transfer or storage cask is in place on the roof of the Target Drive Room and the lift is through the cask. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A
Notes:			**Mitigated Frequency: A**

<table>
<tr><td colspan="6">Event Number
RH3-27</td></tr>
<tr><td colspan="6">Event Description:
Drop of TVP during removal.</td></tr>
<tr><td colspan="2">Assumptions and Initial Conditions:
1. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1.
2. Transfer or storage cask is in place on the roof of the Target Drive Room and the lift is through the cask. (IC)</td><td colspan="3">Causes:
1. Operator Error.
2. Failure to follow hoisting and rigging procedures.
3. Equipment failure (cask attachment point, crane, crane rigging).</td><td>Initiating Event Frequency
A</td></tr>
<tr><td colspan="3" rowspan="2">Unmitigated Impact on Systems:
1. Impact and damage to the equipment impacted by the drop.</td><td colspan="3">Unmitigated Consequences</td></tr>
<tr><td>Radiological
Public: Negligible
WG1: Negligible
WG2: Negligible</td><td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
<tr><td colspan="6">Safety Function:
Prevent a drop of the TVP during removal.</td></tr>
<tr><td colspan="5">Method of Detection:</td><td></td></tr>
<tr><td colspan="5">Visual.</td><td></td></tr>
<tr><td colspan="5">Audible.</td><td></td></tr>
<tr><td colspan="5"></td><td></td></tr>
<tr><td colspan="5">Preventive Features – Attributes:</td><td>Credited:</td></tr>
<tr><td colspan="5">Cask lifting mechanism design. (DF)</td><td></td></tr>
<tr><td colspan="5">STS Activated Component Removal Procedures. (AC)</td><td></td></tr>
<tr><td colspan="5">Hoisting and rigging program. (AC/EC)</td><td></td></tr>
<tr><td colspan="5">Crane and rigging. (EC)</td><td></td></tr>
</table>

Event Number RH3-27	
Mitigative Features – Attributes:	**Credited:**
A slightly negative pressure in the core vessel prior to the event prevents gross release of material from the core vessel. (EC)	
Process water clean-up system limits residual contamination after system draining. (EC)	
The required time to prepare for target removal and before starting removal of these components allows additional time for water activation to decay and for cleanup of contamination. (AC)	
Emergency response training. (AC)	
Cask is in place limiting the opening at the top of the Target Drive Room roof. (AC)	
Transfer or storage cask is in place on the roof of the Target Drive Room and the lift is through the cask. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A
Notes:			**Mitigated Frequency: A**

Event Number
RH4-1

Event Description:
Undetected "hot spot" from Be-7 when handling coolant line or MRA assembly.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1.	1. Be-7 contamination Inherent in system operation. 2. Piping configuration permits preferential plating.	A

Unmitigated Impact on Systems:
1. Potential impact on remote handling operations to provide adequate shielding for operation.
2. Component activation higher than planned could impact access to coolant system filters and resin components.

Unmitigated Consequences

Radiological	**Chemical**	**ODH**
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Safety Function:
Prevent excessive or inadvertent exposure to higher than anticipated source term when handling a coolant line or MRA assembly.

Method of Detection:	
RAD Survey.	
Personnel radiation monitors.	

Preventive Features – Attributes:	**Credited:**
RAD Surveys. (AC)	
STS component removal procedures. (AC)	
Routing of piping within the facility. (DF)	

Event Number RH4-1	
Mitigative Features – Attributes:	**Credited:**
Process water clean-up system draining limits residual activation and contamination from the cooling water lines. (EC/AC)	
Process water clean-up design to limit contamination in the process water. (EC)	
Remote handling procedures. (AC)	
Use of shielded transfer or storage casks for activated component removal. (AC/EC)	
Localized shielding over exposed piping. (DF)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Need to determine if the water lines will be drained and partially blown down prior to removal. 2. Operational monitoring warranted to determine if this is a potential hazard. Based on FTS operation, Be-7 has not been an issue.	**Radiological** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A
Notes:			**Mitigated Frequency: A**

Event Number
RH4-2

Event Description:
Undetected "hot spot" from tantalum & other material when handling coolant line coolant system component.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1. 2. The current target design eliminates the potential for Tungsten to come into contact with water caused from target clad breach or tungsten erosion. (DF)	1. Target cladding breach and tungsten erosion or corrosion products concentrate in a location in the piping or other non-target system component. 2. Activated material in the water is inherent in operation. 3. Piping configuration permits preferential plating.	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Potential impact on remote handling operations to provide adequate shielding for operation. 2. Component activation higher than planned could impact access to coolant system filters and resin components.	**Public**: Negligible **WG1**: Low **WG2**: Negligible	**Public**: N/A **WG1:** N/A **WG2:** N/A	**Public**: N/A **WG1:** N/A **WG2:** N/A

Safety Function:
TBD prevention of inadvertent exposure to higher than anticipated source term when handling coolant line coolant system component.

Method of Detection:	
RAD Survey.	
Coolant water activation level monitoring for cladding breach.	
Personnel radiation monitors.	

Preventive Features – Attributes:	**Credited:**
RAD Surveys. (AC)	
STS component removal procedures. (AC)	
Routing of piping within the facility. (DF)	

Event Number RH4-2	
Mitigative Features – Attributes:	**Credited:**
Process water clean-up system draining limits residual activation and contamination from the cooling water lines. (AC/EC)	
Process water clean-up design to limit contamination in the process water. (EC)	
Remote handling procedures. (AC)	
Use of shielded transfer or storage casks for activated component removal (AC/EC)	
Localized shielding over exposed piping. (DF)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Need to determine if the water lines will be blown down or just be drained. 2. Since operation with a cladding breach is planned monitoring of the activation level in the system is warranted to prevent higher than anticipated levels of contaminates in the water.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A
Notes:			**Mitigated Frequency: A**

Event Number RH4-3				
Event Description: Failure to install local required shielding for target or high activity component from core vessel.				
Assumptions and Initial Conditions: 1. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1. 2. Activated water lines are routed above the core vessel lid in some locations. (IC) 3. Some water lines will still be active and not drained above the core vessel lid. (IC)	**Causes**: 1. Operator error. 2. Failure to follow STS procedures. 3. Failure to perform Rad Surveys.			**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. Potential impact on remote handling operations to provide adequate shielding for operation.	**Unmitigated Consequences**			
	Radiological **Public**: Negligible **WG1**: Moderate **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A	
Safety Function: TBD prevention of inadvertent exposure to higher than anticipated source term due to failure to install local required shielding for target or high activity component from core vessel.				
Method of Detection:				
RAD Survey.				
Area Radiation Monitor (ARM) and alarms.				
Personnel radiation monitors.				
Preventive Features – Attributes:				**Credited:**
RAD Surveys. (AC)				
STS component removal procedures. (AC)				

Event Number
RH4-3

Mitigative Features – Attributes:	Credited:
STS Operating and Maintenance Procedures. (AC)	
Remote handling procedures. (AC)	
All casks to be mounted on the applicable plug/hatch opening and lifted off of the Target Drive Room roof by an external attachment to the cask. (AC)	
Transfer or storage cask is in place on the roof of the Target Drive Room and the lift is through the cask. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	X
Area Radiation Monitor (ARM) and alarms.(EC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Need to determine if the local shielding will be required for any steps during remote handling operations or maintenance operations.
2. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible **WG1**: Moderate **WG2**: Negligible	**Public**: N/A **WG1:** N/A **WG2:** N/A	**Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:

Mitigated Frequency:
A

Event Number RH4-4				
Event Description: Failure to secure the bottom closure of the transfer or storage cask. This event evaluates potential direct exposure to personnel in the area. Events RH3-15 and RH3-18 evaluate hazardous material release from this event.				
Assumptions and Initial Conditions: 1. All casks to be mounted on the applicable plug/hatch opening lifted off of the Target Drive Room roof by an external attachment to the cask. (IC) 2. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Storage Cask are contained in Table M-1. 3. The Cask will be lowered to a minimum elevation of TBD immediately after lifting the cask off the Target Drive Room roof. (AC)	**Causes**: 1. Operator Error. 2. Failure to follow procedures. 3. Equipment failure (cask closure by bolts).			**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. Potential impact on remote handling operations to recover from cask failure. 2. Depending on where the failure occurred, damage to SSCs on which the component was dropped.	**Unmitigated Consequences**			
	Radiological **Public**: Negligible **WG1**: Moderate **WG2**: Negligible		**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A
Safety Function: Prevent cask movement until the cask bottom closure is properly secured.				
Method of Detection:				
RAD Survey				
Visual				
Area Radiation Monitor (ARM) and alarms				
Personnel radiation monitors				
Preventive Features – Attributes:				**Credited:**
RAD Surveys (AC)				
STS activated component removal procedures (AC)				X
Cask closure design. (DF)				

Event Number
RH4-4

Mitigative Features – Attributes:	Credited:
STS Operating and Maintenance Procedures (AC)	
Remote handling procedures (AC)	
Most of the travel to the storage location is at limited elevation. (DF)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	
Area Radiation Monitor (ARM) and alarms (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.	**Radiological** **Public**: Negligible **WG1**: Moderate **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:	Mitigated Frequency: Prevented
1. Lifting process needs to be defined by target systems remote handling management. 2. It is assumed that if the bottom closure of the cask has not been secured, it would be detected when the crane attempted to move the cask from the target drive room roof.	

Event Number RH4-5					
Event Description: Failure to install temporary shielding or access controls in High Bay cask storage location or the High Bay.					
Assumptions and Initial Conditions: 1. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1. 2. No cask storage with highly activated replaceable components is permitted in the High Bay. (AC) 3. Temporary storage of replaceable activated components (e.g., shield blocks) is permitted in the High Bay. (IC)		**Causes**: 1. Operator error. 2. Failure to follow STS procedures.			**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1.		**Unmitigated Consequences**			
		Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible		**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A
Safety Function: Assure required temporary shielding or access controls in High Bay cask storage location or the High Bay are in place.					
Method of Detection:					
RAD Survey					
Area Radiation Monitor (ARM) and alarms					
Personnel radiation monitors					
Preventive Features – Attributes:					**Credited:**
RAD Surveys (AC)					
STS component removal procedures (AC)					
No cask storage with activated components is permitted in the High Bay. (AC)					

Event Number
RH4-5

Mitigative Features – Attributes:	Credited:
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	
Area Radiation Monitor (ARM) and alarms (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Need to determine if the local shielding will be required for any steps during remote handling operations or maintenance operations where the casks are stored.
2. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Notes:

Mitigated Frequency: Prevented

Event Number
RH4-6

Event Description:
Direct radiological exposure to facility worker during monolith shutter insert removal.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. Shutter replacement is a part of bunker maintenance procedures and not included. (IC)	1. Lack or loss of shielding (fixed or temporary). 2. Radiation streaming from defect in monolith insert transfer cask, 3. Neutron beam line component drops out of cask. 4. Improper procedures or worker error.	A

Unmitigated Impact on Systems:
1. Shutdown of maintenance operation until intact shielding for the removed monolith insert is restored.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible **WG1**: High **WG2**: Negligible	**Public:** N/A **WG1:** N/A **WG2:** N/A	**Public:** N/A **WG1:** N/A **WG2:** N/A

Safety Function:
Prevent personnel radiological exposure above allowable levels to facility worker during monolith shutter insert removal

Method of Detection:	
Area Radiation Monitor (ARM).	
Visual.	
Proper and periodic monitoring of worker personal dosimetry (self-reading pocket dosimeters during replacement).	

Preventive Features – Attributes:	Credited:
Cask material specification and design. (DF)	X
Monolith & guide insert and shutter replacement procedures. (AC)	X
Operating Procedures and Training .(AC)	X
Trained operators. (AC)	
Installed Temporary Shielding. (DF)	

Event Number
RH4-6

Mitigative Features – Attributes:	Credited:
Temporary shielding (DF)	
EOPs (AC)	
Trained operators (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Calculate maximum activity of shutter and monolith insert components and possible dose exposure.
2. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: N/A	**Public:** N/A	**Public:** N/A
WG1: N/A	**WG1:** N/A	**WG1:** N/A
WG2: N/A	**WG2:** N/A	**WG2:** N/A

Notes:
Onsite 1 consequence assume worker is inadvertently exposed to a 1000R/hr field for 5 minutes

Mitigated Frequency Prevented

Event Number RH4-7				
Event Description: Personnel receive excessive radiation exposure during target replacement.				
Assumptions and Initial Conditions: 1. Target life can be up to 20 years. (IC) 2. Segmented target. (IC) 3. Spent target in handling cask for up to 5 days. (IC) 4. Cooling water limited but component is not dry. (IC)	**Causes:** 1. Worker error. 2. Improper monitoring for radiation levels. 3. Excessive stay-time in radiation areas. 4. Required local shielding inadequate or not in place.			**Initiating Event Frequency** A
Unmitigated Impact on Systems: None.		**Unmitigated Consequences**		
		Radiological **Public**: Negligible **WG1**: High **WG2**: Negligible	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A
Safety Function: Prevent personnel radiological exposure above allowable levels during target replacement.				
Method of Detection:				
Personal dosimetry.				
Area Radiation Monitor (ARM)				
Preventive Features – Attributes:				**Credited:**
Adequate shielding above target to reduce dose and activation to acceptable levels. (DF)				X
Required temporary shielding in place. (EC)				X
Operating Procedures and Training. (AC)				X
Radiation Protection Program. (AC)				
Radiation postings. (AC)				
Trained personnel. (AC)				

Event Number
RH4-7

Mitigative Features – Attributes:	Credited:
Temporary shielding. (EC)	
Radiation Protection Program and radiation control procedures. (AC)	
Worker training. (AC)	
Area Radiation Monitor (ARM) and alarm (EC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Analysis of radiation dose and shielding requirements during replacement operation.
2. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: N/A **WG1:** N/A **WG2:** N/A	**Public:** N/A **WG1:** N/A **WG2:** N/A	**Public:** N/A **WG1:** N/A **WG2:** N/A

Notes:

Mitigated Frequency Prevented

Event Number
RH4-8

Event Description:
Personnel receives excessive radiation exposure during moderator/ reflector assembly replacement

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. Replacing moderator/reflector assembly at the end of its design life. (IC) 2. Components are intact. (IC) 3. Shield blocks above MRA removed. (IC) 4. Cooling water limited but component is not dry. (IC)	1. Worker error. 2. Improper monitoring for radiation levels. 3. Excessive stay-time in radiation areas. 4. Required local shielding inadequate or not in place.	A

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
None	**Public**: Negligible **WG1**: High **WG2**: Negligible	**Public:** N/A **WG1:** N/A **WG2:** N/A	**Public:** N/A **WG1:** N/A **WG2:** N/A

Safety Function:
Prevent personnel radiological exposure above allowable levels during moderator/ reflector assembly replacement.

Method of Detection:	
Personal dosimetry.	
Area Radiation Monitor (ARM).	

Preventive Features – Attributes:	**Credited:**
Shielding design. (DF)	X
Required temporary shielding in place. (EC)	X
Operating Procedures and Training. (AC)	X
Radiation Protection Program. (AC)	
Radiation postings. (AC)	
Trained personnel. (AC)	

Event Number RH4-8	
Mitigative Features – Attributes:	**Credited:**
Temporary shielding (AC)	
Radiation Protection Program and radiation control procedures (AC)	
Worker training (AC)	
Area Radiation Monitor (ARM).and alarm (EC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Analysis of radiation dose and shielding requirements during replacement operation. 2. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.	**Radiological** **Public:** N/A **WG1:** N/A **WG2:** N/A	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A

Notes:	**Mitigated Frequency Prevented**

Event Number RH4-9					
Event Description: Personnel receive excessive radiation exposure during replacement of target drive unit.					
Assumptions and Initial Conditions: 1. Personnel are required to be in the target drive region during target drive replacement. (IC) 2. Cooldown period established before access allowed after operation. (AC) 3. Cooling water limited but component is not dry. (IC) 4. Target drive is above the core vessel lid. (DF) 5. Target Drive Motor replacement is performed with a manually operated Jib crane in the TDR. (IC) 6. Exposure to workers for this operation will be negligible at the time of motor replacement. (IC)		**Causes:** 1. Worker error. 2. Improper monitoring for radiation levels. 3. Excessive stay-time in radiation areas. 4. Required local shielding inadequate or not in place.			**Initiating Event Frequency** A
Unmitigated Impact on Systems: None			**Unmitigated Consequences**		
			Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A
Safety Function: Prevent excessive personnel radiation exposure above allowable levels during replacement of target drive unit.					
Method of Detection:					
Personal dosimetry.					
Area Radiation Monitor (ARM).					
Preventive Features – Attributes:					**Credited:**
Adequate shielding above target to reduce dose and activation to acceptable levels. (DF)					
Trained personnel. (AC)					
Operating Procedures and Training. (AC)					
Radiation Protection Program. (AC)					
Radiation postings. (AC)					
Required temporary shielding in place. (EC)					

Event Number
RH4-9

Mitigative Features – Attributes:	Credited:
Temporary shielding. (EC)	
Radiation Protection Program and radiation control procedures. (AC)	
Worker training. (AC)	
Area Radiation Monitor (ARM).	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Analysis of radiation dose and shielding requirements during replacement operation.
2. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.
3. Analysis and verification that the assumed exposure to workers for this operation will be negligible at the time of motor replacement.
4. Determine the activation level of the water at the time of this operation.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible **WG1**: Low **WG2**: Negligible	**Public:** N/A **WG1:** N/A **WG2:** N/A	**Public:** N/A **WG1:** N/A **WG2:** N/A

Notes:

Mitigated Frequency
A

Event Number RH4-9a					
Event Description: Failure to drain the water from the coolant lines prior to initiating target removal cause personnel to receive excessive radiation exposure both from the water lines and from water leakage during replacement of target drive unit.					
Assumptions and Initial Conditions: 1. Personnel are required to be in the target drive region during target drive replacement. (IC) 2. Cooldown period established before access allowed after operation. (AC) 3. Cooling water limited but component is not dry. (IC) 4. Target drive is above the core vessel lid. (DF) 5. Target Drive Motor replacement is performed with a manually operated Jib crane in the TDR. (IC) 6. Exposure to workers for this operation will be negligible at the time of motor replacement. (IC)		**Causes:** 1. Worker error. 2. Improper monitoring for radiation levels. 3. Excessive stay-time in radiation areas. 4. Required local shielding inadequate or not in place.			**Initiating Event Frequency** A
Unmitigated Impact on Systems: None		**Unmitigated Consequences**			
		Radiological **Public**: Negligible **WG1**: Moderate **WG2**: Negligible	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A		**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A
Safety Function: Assure that coolant is removed prior to initiating target removal to prevent excessive personnel radiation exposure above allowable levels during replacement of target drive unit.					
Method of Detection:					
Personal dosimetry.					
Area Radiation Monitor (ARM).					
Visual					
Preventive Features – Attributes:					**Credited:**
Adequate shielding above target to reduce dose and activation to acceptable levels. (DF)					
Trained personnel. (AC)					
Operating Procedures and Training. (AC)					
Radiation Protection Program. (AC)					
Radiation postings. (AC)					
Required temporary shielding in place. (EC)					

Event Number RH4-9a	
Mitigative Features – Attributes:	**Credited:**
Temporary shielding. (EC)	
Radiation Protection Program and radiation control procedures. (AC)	
Worker training. (AC)	
Area Radiation Monitor (ARM).	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	X

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Analysis of radiation dose and shielding requirements during replacement operation. 2. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval. 3. Determine the activation level of the water at the time of this operation.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A
Notes:			**Mitigated Frequency** **A**

Event Number RH4-10				
Event Description: Personnel receive excessive Radiation Exposure during replacement Proton Beam Window (PBW) or Target Viewing Periscope (TVP).				
Assumptions and Initial Conditions: 1. No access to target drive region during the physical lift of the PBW or TVP. (AC) 2. Personnel are permitted in the TDR during preparation for PBW or TVP removal. (IC) 3. Cooldown period established before access allowed after operation. (AC) 4. Cooling water limited but component is not dry. (IC)	**Causes** 1. Worker error. 2. Improper monitoring for radiation levels. 3. Excessive stay-time in radiation areas. 4. Required local shielding inadequate or not in place.			**Initiating Event Frequency** A
Unmitigated Impact on Systems: None	**Unmitigated Consequences**			
	Radiological **Public**: Negligible **WG1**: High **WG2**: Negligible	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A		**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A
Safety Function: Prevent personnel exposure above allowable levels during replacement Proton Beam Window (PBW) or Target Viewing Periscope (TVP)..				

Method of Detection:	
Personal dosimetry.	
Area radiation detection device.	

Preventive Features – Attributes:	**Credited:**
Adequate shielding above components to reduce dose and activation to acceptable levels. (EC)	X
Required temporary shielding in place. (EC)	X
Operating Procedures and Training. (AC)	X
Radiation Protection Program. (AC)	
Radiation postings. (AC)	

Event Number RH4-10			
Mitigative Features – Attributes:			**Credited:**
Temporary shielding. (AC)			
Radiation Protection Program and radiation control procedures. (AC)			
Worker training. (AC)			
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)			
Planned analysis, assumption validations, and Risk/Opportunities: 1. Analysis of radiation dose and shielding requirements during replacement operation.	**Mitigated Consequences:** **Radiological** **Public:** N/A **WG1:** N/A **WG2:** N/A	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A
Notes:			**Mitigated Frequency Prevented**

Event Number RH4-11					
Event Description: Drop of the target Transfer or Storage Cask or Other Transfer or Storage Cask when moving from the Target Drive Room roof to the Service Cell leading to direct exposure of workers in the area to high radiation exposure.					
Assumptions and Initial Conditions: 1. Additional Assumptions and Initial Conditions for Target Removal from the Core Vessel and into the Transfer or Storage Cask are contained in Table M-1. 2. All casks to be mounted on the applicable plug/hatch opening lifted off of the Target Drive Room roof by an external attachment to the cask. (IC) 3. The Cask will be lowered to a minimum elevation of TBD immediately after lifting the cask off the Target Drive Room roof. (AC) 4. Any water line is drained and partially blown down in-situ to establish a water level below the connection or cutting location before lifting into the cask. (AC) 5. The Transfer or Storage Cask is not designed or certified to not fail if dropped. (IC)		**Causes**: 1. Operator Error. 2. Failure to follow hoisting and rigging procedures. 3. Equipment failure (cask attachment point, crane, crane rigging).			**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. Damage to one or more Instrument Bunkers if the drop is over a bunker. 2. Damage to Target Drive Room ventilation depending on drop location. 3. Damage to and loss of cooling to the target systems requiring cooling depending on drop location. 4. Delay target replacement.			**Unmitigated Consequences**		
			Radiological **Public**: Negligible **WG1**: High **WG2**: Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A
Safety Function: Prevent a drop of the target Transfer or Storage Cask or Other Transfer or Storage Cask when moving from the Target Drive Room roof to the Service Cell or another location in the High Bay.					
Method of Detection:					
Visual.					
Audible.					
Preventive Features – Attributes:					**Credited:**
Cask lifting mechanism design. (DF)					
STS Activated Component Removal Procedures. (AC)					X
Hoisting and rigging program. (AC/EC)					X
Critical Lift Program (AC)					X
Crane and rigging design. (EC)					X

Event Number	
RH4-11	
Mitigative Features – Attributes:	**Credited:**
Most of the travel to the storage location is at limited elevation. (DF)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: N/A **WG1**: N/A **WG2**: N/A	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1:** N/A **WG2:** N/A

Notes:	**Mitigated Frequency: Prevented**
1. Lifting process needs to be defined by target systems remote handling management. 2. In addition to the specific safety function identified to prevent a drop, the high bay crane should be designed to prevent failures that would leave a component suspended in the high bay, partially removed from the core vessel, or partially lowered into the service cell. Additionally, these requirements would include speed limiters and travel distance limiters. Robustness of the design is also provided by the seismic design to prevent the crane or the track from falling and impacting personnel egress.	

APPENDIX N. CONTACT AND REMOTE WASTE HANDLING AND DECONTAMINATION AREA (RW) HAZARD EVENT TABLES

Once the detailed Target Building layout is completed and the location for contact and remote handled waste is identified, these events must be reevaluated.

APPENDIX N. CONTACT AND REMOTE WASTE HANDLING AND DECONTAMINATION AREA (RW) HAZARD EVENT TABLES

Event Number
RW1-1

Event Description:
During Contact Waste Handling, release of radiological material due to localized fire in the Contact Handled (CH) Waste Handling Area.

Assumptions and Initial Conditions:
1. Solid contact handled waste stored and/or packaged according to ORNL waste management procedures, contains bounding equilibrium nuclides from the material in the container (See Note 1). (IC)
2. Waste originates from the HPV, high bay, PIE Cell, or Service Cell systems. (IC)
3. This event is assumed to occur in an area that is likely to have surface contamination and may involve equipment that contains significant quantities of radioactive material. (IC)
4. Decontamination activities are to be completed in the Service or PIE Cell. (IC)
5. Contact handled waste could be in containers within various parts of the Target Building but would be low activity waste as high activity will be handled in the Service or PIE Cell. (IC)
6. Vehicle caused fires are addressed in TG1-3. (IC)
7. Remote handling of activated components from the core vessel (e.g., target segment) is addressed in the RH event tables. (IC)

Causes:
1. Electrical short.
2. Thermal energy from electrical equipment.
3. Friction from bearings, gears, motors, and power tools.
4. Hydraulic fluid leaks from forklift and is ignited.
5. Human error.
6. Combustibles in facility.
7. Other ignition source.
8. Cleaning agents contact other materials and produce flammable fumes.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Shutdown of the affected area due to damage and contamination.
2. Potential for damage to surrounding operating areas or equipment.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2:** N/A	**WG2**: N/A

Safety Function:
Reduce probability of fire occurrence leading to a release of radiological material from contact handled waste above allowable limits.

Method of Detection:	
Fire detection system.	
Visual.	

Event Number
RW1-1

Preventive Features – Attributes:	Credited:
Forklift design. (DF)	
NFPA standards. (DF)	
Preventive maintenance program (forklift maintenance). (AC)	
Electrical equipment design code. (DF)	
Prohibition of EVs and Hybrid vehicles (including forklifts) from entering the target building. (AC)	

Mitigative Features – Attributes:	Credited:
Building ventilation system. (EC)	
Fire detection and suppression system. (EC)	
Building design (i.e., materials of construction). (DF)	
Most Contact Handled waste has low activity. (AC)	
Combustible material control program. (AC)	
Emergency Operating Procedures. (AC)	
Radiation and contamination control procedures. (AC)	
Operating Procedures and Training. (AC)	
NFPA requirements. (EC/AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. Once the Target Building layout is completed and the location for contact and remote handled waste is identified, these events must be reevaluated. 2. A Project Fire Hazard Analysis will be performed in support of CD-2 and inform the fire events in the PHAR. 3. Assessment of fires per NFPA 801.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
1. Radionuclide inventories are based on the component or system. For example, target segments are assumed to have a 10-year life and more permanent components such as the target drive shaft is assumed to have a 40-year life. Evaluations are based on the worst-case radionuclide inventory anticipated for the activity. Event scenarios are evaluated based on the worst inventory for activities that could be present.	**A**

Event Number
RW1-2

Event Description:
Release of radiological material as the result of a fire involving the liquid waste shipping truck during loading of waste.

Assumptions and Initial Conditions:
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC)
2. Water released to LLLW tanks initially goes through the leak collection tanks or is pumped from the cooling loops, thus preventing short-cooled water from entering the LLLW system. (i.e., Nothing goes to the LLLW automatically.) (DF)
3. This event assumes that the fire is confined to the immediate area of the truck loading area and releases only the material that is being loaded onto the truck. (IC)
4. The truck could be located either in the building or outside. (IC)
5. Vehicle caused fires are addressed in TG1-3. (IC)
6. Remote handling of activated components from the core vessel (e.g., target segment) is addressed in the RH event tables. (IC)
7. Waste originates from the HPV, high bay, PIE Cell, or Service Cell systems. (IC)

Causes:
1. Electrical short.
2. Batteries in the truck generate hydrogen gas.
3. Flammables (e.g., truck fuel).
4. Other unidentified ignition sources.
5. Miscellaneous combustibles in area.
6. Worker error.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Shutdown of the affected area.
2. Potential for damage to surrounding operating areas or equipment.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2:** N/A	**WG2**: N/A

Safety Function:
Reduce probability of fire occurrence from the liquid waste shipping truck during loading of waste that could result in release of radiological material above allowable limits.

Method of Detection:
Visual.
Fire detection system.

Event Number
RW1-2

Preventive Features – Attributes:	Credited:
Electrical equipment design code. (DF)	
ORNL approved Truck for handling waste. (AC)	
Operating Procedures and Training. (AC)	
Trained personnel. (AC)	
NFPA standards. (EC/DF)	
Prohibition of EVs and Hybrid vehicles from entering the target building. (AC)	

Mitigative Features – Attributes:	Credited:
Fire detection and suppression system. (EC)	
Building ventilation system. (EC)	
Curbs to confine released water. (DF)	
Combustible material control program. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	
Emergency response procedures. (AC)	
NFPA requirements. (EC/DF)	
Building design (i.e., materials of construction). (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Define the process for bringing a truck into the facility for performing waste removal.
2. Once the Target Building layout is completed and the location for contact and remote handled waste is identified, these events must be reevaluated.
3. A Project Fire Hazard Analysis will be performed in support of CD-2 and inform the fire events in the PHAR.
4. Assessment of fires per NFPA 801.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2:** N/A	**WG2**: N/A

Notes:

Mitigated Frequency
A

Event Number
RW1-3

Event Description:
Activated gaseous release to high bay due to fire around waste cask/container during Remote Handled (RH) waste handling.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Solid contact handled waste stored and/or packaged according to ORNL waste management procedures, contains bounding equilibrium nuclides from the material in the container (See Note 1). (IC) 2. Waste originates from the HPV, high bay, PIE Cell, or Service Cell systems. (IC) 3. Release of radioactive gases to SCE ventilation system. (IC) 4. Gases are circulated throughout high bay by recirculating ventilation system. (IC)	1. Combustible loading in area. 2. Electrical short. 3. Thermal energy from electrical equipment. 4. Friction from bearings, gears, motors, and power tools. 5. Hydraulic fluid leaks from forklift and is ignited. 6. Human error. 7. Combustibles in facility. 8. Other ignition source. 9. Cask/Container has inadequate/no gas sealing.	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Contamination of a large portion of the building. 2. Shutdown of the affected area. 3. Recovery time required for decontamination efforts or for repairs as necessary.	**Public**: Negligible **WG1**: Moderate **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Reduce probability of fire occurrence during Remote Handled (RH) waste handling resulting in a release of radiological material above allowable limits.

Method of Detection:	
Visual.	
Fire detection system.	

Preventive Features – Attributes:	**Credited:**
Crane or Hoist design. (DF)	
ORNL Hoisting and Rigging Program including the STS procedures regarding preparation and performance of the lift. (AC)	
Electrical equipment design code. (DF)	
NFPA standards. (DF/EC)	
Preventive maintenance program (forklift maintenance). (AC)	
Operating Procedures and Training. (AC)	

Event Number
RW1-3

Mitigative Features – Attributes:	**Credited:**
Building design (i.e., materials of construction). (DF)	
Secondary Confinement Exhaust ventilation system. (EC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	
Radiation and contamination control procedures. (AC)	
Emergency Operating Procedures. (AC)	
Combustible material control program. (AC)	
NFPA requirements. (EC/AC)	
Fire detection and suppression system. (EC)	
Spent waste cask/container design including Confinement features. (DF)	X

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Determine the potential release consequences and decay heat. 2. Once the Target Building layout is completed and the location for contact and remote handled waste is identified, these events must be reevaluated. 3. A Project Fire Hazard Analysis will be performed in support of CD-2 and inform the fire events in the PHAR. 4. Assessment of fires per NFPA 801.	**Radiological** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. Radionuclide inventories are based on the component or system. For example, target segments are assumed to have a 10-year life and more permanent components such as the target drive shaft is assumed to have a 40-year life. Evaluations are based on the worst-case radionuclide inventory anticipated for the activity. Event scenarios are evaluated based on the worst inventory for activities that could be present.	**A**

Event Number
RW1-4

Event Description:
Fire is initiated in the HPV or one of the drain tanks, leak collection, resin storage tank, or LLLW tank pits.

Assumptions and Initial Conditions	Causes	Initiating Event Frequency
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC) 2. All collection tanks and the resin storage tank in the HPV are in covered pits that are not easily accessed. (DF) 3. Workers could be in the HPV for maintenance or surveillance operations. (IC) 4. Workers are not permitted in the HPV during beam operations. (AC/IC)	1. Flammable or incompatible chemicals inadvertently introduced to the LLLW system. 2. LLLW containing chemicals is ignited by transfer pump 3.	A

Unmitigated Impact on Systems	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. Potential for damage to LLLW tanks and associated equipment. 2. Shutdown of operations in the affected area due to contamination. 3. Recovery time required for restoration to normal operation conditions.	**Public**: Negligible **WG1**: Low **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Reduce probability of fire in the HPV or one of the drain tanks, leak collection, resin storage tank, or LLLW tank pits resulting in a release of radiological material above allowable limits.

Method of Detection:	
Fire detection system.	
Visual.	

Preventive Features – Attributes:	Credited:
Chemical handling and disposal procedures. (AC)	
Electrical equipment designed to code. (DF)	
NFPA requirements. (EC/AC)	

Event Number
RW1-4

Mitigative Features – Attributes:	Credited:
Fire detection and suppression system. (EC)	
Building Secondary Confinement Exhaust system. (EC)	
Limited access for discharges to LLLW system. (DF)	
Emergency response procedures. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	
STS/ORNL radiation protection program. (AC)	
NFPA requirements. (EC/DF)	
LLLW tank design and material selection. (DF)	
All collection tanks and the resin storage tank in the HPV are in covered pits that are not easily accessed. (DF)	
PPS access control to the HPV during beam operations. (EC)	
Workers are not permitted in the HPV until access is granted following an appropriate cooldown time and RCT survey. (AC)	
Piping from the IX Column to the resin storage tank and from the resin storage tank to the wall are hard piped. (DF)	
Pits will have a hard cover. (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. A Project Fire Hazard Analysis will be performed in support of CD-2 and inform the fire events in the PHAR. 2. Assessment of fires per NFPA 801.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Notes:			**Mitigated Frequency** **A**

Event Number
RW2-1

Event Description:
Release of radiological material due to explosion in the Contact Handled Waste Handling Area.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Solid CH waste stored and/or packaged according to ORNL waste management procedures contains bounding equilibrium nuclides from the material in the container (See Note 1). (AC/IC) 2. Waste originates from HPV, high bay, or service cell systems. (IC) 3. This event is assumed to occur in an area that is likely to also have surface contamination and may involve equipment that contains significant quantities of radioactive material. (IC) 4. Decontamination activities are to be completed in the Service Cell or PIE Cell. (AC/IC) 5. Remote handling of activated components from the core vessel (e.g., target segment) is addressed in the RH event tables. (IC)	1. Hydrogen from forklift battery is ignited. 2. Cleaning agents contact other materials and produce explosive fumes. 3. Ignition sources could include spark from electrical short. 4. Thermal energy from electrical equipment. 5. Friction from bearings, gears, motors, and power tools. 6. Other unidentified ignition source.	U

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Shutdown of the affected area due to contamination and equipment damage. 2. Potential for significant damage to surrounding operating areas or equipment.	**Public**: Negligible **WG1**: Low **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Reduce probability of explosion in the Contact Handled Waste Handling Area that could result in a release of radiological material above allowable limits.

Method of Detection:	
Visual.	
Audible.	

Preventive Features – Attributes:	**Credited:**
Forklift/hoist design with battery compartment vents. (DF)	
Operating Procedures and Training for handling waste materials and for decontamination practices. (AC)	
Battery charging and maintenance program. (AC)	
Forklift/hoist maintenance. (AC)	
Chemical control program could minimize use of reactive chemicals for cleaning or decontamination. (AC)	
Preventive maintenance program (forklift maintenance). (AC)	
NFPA standards. (EC/DF)	

Event Number
RW2-1

Mitigative Features – Attributes:	Credited:
Fire detection and suppression system. (EC)	
Building ventilation system. (EC)	
Building structure/design (i.e., materials of construction). (DF)	
Most Contact Handled waste has low activity. (DF)	
Combustible material control program. (AC)	
Radiation and contamination control procedures. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	
Emergency Operating Procedures. (AC)	
Operating Procedures and Training. (AC)	
NFPA requirements. (EC/DF)	
Pits will have a hard cover. (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:
1. Once the Target Building layout is completed and the location for contact and remote handled waste is identified, these events must be reevaluated.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:
1. Radionuclide inventories are based on the component or system. For example, target segments are assumed to have a 10-year life and more permanent components such as the target drive shaft is assumed to have a 40-year life. Evaluations are based on the worst-case radionuclide inventory anticipated for the activity. Event scenarios are evaluated based on the worst inventory for activities that could be present.

Mitigated Frequency
U

Event Number RW2-2		
Event Description: Release of radiological material due to explosion or fire involving ion exchange resin in the HPV or Service Cell.		
Assumptions and Initial Conditions: 1. Solid contact handled waste stored and/or packaged according to ORNL waste management procedures, contains bounding equilibrium nuclides from the material in the container, (IC) 2. Waste stored and/or packaged according to ORNL waste management procedures. (IC) 3. Contains bounding equilibrium nuclides from the material in the container (See Note 1). (IC) 4. Waste originates from cooling water system. 5. IX resin could be in the IX column or resin storage tank in the HPV or waste container cask/container in the Service cell. (IC) 6. Resin could react with a strong oxidizer. (IC) 7. Cleaning agents (e.g., strong oxidizer) are permitted in either the HPV or Service Cell only after evaluation of specific use and potential for interaction with resin (AC/IC) 8. Ion exchange resin is not required to be maintained wet to prevent autoignition of the resin. The radionuclide inventory is not high enough for this to occur. (DF/IC) 9. Two IX Columns are used in operation and when one column is spent, it is allowed to decay for nominally 6 months prior to sluicing from that column to the resin storage tank where it is allowed to decay further. (AC/IC) 10. The spent IX Column is drained to the Resin Storage Tank in a Pit to allow further decay time before shipment. (IC/AC)	**Causes**: 1. Other ignition source.	**Initiating Event Frequency** BEU

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
1. Shutdown of the affected area due to contamination and equipment damage. 2. Potential for significant damage to surrounding operating areas or equipment	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Reduce probability of explosion or fire involving ion exchange resin in the HPV or Service Cell resulting in a release of radiological material above allowable limits.

Method of Detection:	
Visual.	
Differential pressure alarms associated with ventilation system.	
Audible.	

Event Number
RW2-2

Preventive Features – Attributes:	Credited:
Low thermal loading of resin and resin storage tank design precludes drying in short time periods. Ion exchange resin is not required to be maintained wet to prevent autoignition of the resin. The radionuclide inventory is not high enough for this to occur. (DF)	X
Cleaning agents (e.g., strong oxidizer) are permitted in either the HPV or Service Cell only after evaluation of specific use and potential for interaction with resin. (AC)	X
Operating Procedures and Training for handling waste materials including ion exchange resin (AC)	

Mitigative Features – Attributes:	Credited:
Worker training. (AC)	
Building structure/design (i.e., materials of construction) .(DF)	
Resin storage tank is located in a covered pit within the HPV. (DF)	
Service Cell design to control contamination, including ventilation. (DF)	
All piping connections to the IX Column are hard piped within the HPV (DF)	
Piping connections from the IX Column to the resin storage tank and from the resin storage tanks to the wall are hard piped within the HPV (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: N/A **WG1**: N/A **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency Prevented
1. Radionuclide inventories are based on the component or system. For example, target segments are assumed to have a 10-year life and more permanent components such as the target drive shaft is assumed to have a 40-year life. Evaluations are based on the worst-case radionuclide inventory anticipated for the activity. Event scenarios are evaluated based on the worst inventory for activities that could be present.	

Event Number
RW2-3

Event Description:
Chemicals inadvertently drained to LLLW system create explosive mixture.

Assumptions and Initial Conditions:
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC)
2. Water released to LLLW tanks initially drains to the leak collection tanks or is pumped from the cooling loops, thus preventing short-cooled water in the LLLW. (i.e., Nothing goes to the LLLW automatically.) (DF)
3. The LCS collection tanks and the resin storage tank are located in covered pits within the HPV. Access to these pits requires a special operation to lift the pit cover and enter this confined space.. (DF)

Causes:
1. Flammable or incompatible chemicals inadvertently introduced into to the LLLW system.
2. Waste containing chemicals is ignited by transfer pump.
3. Other unidentified ignition source and explodes.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Potential for damage to (including breach of) LLLW tank and associated equipment or sump pump and surrounding equipment.
2. Shutdown of operations in the affected area.
3. Recovery time required for restoration to normal operation conditions.

Unmitigated Consequences

Radiological	**Chemical**	**ODH**
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: Low	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Reduce probability of Chemicals inadvertently being drained to LLLW system and creating an explosive mixture; reduce probability if ignition; prevent release of activity caused by explosion.

Method of Detection:	
Visual.	
Audible.	

Preventive Features – Attributes:	**Credited:**
NFPA standards. (DF/EC)	
Electrical equipment designed to code. (DF)	
Chemical handling and disposal procedures. (AC)	
Operating Procedures and Training for handling waste materials including ion exchange resin (AC)	

Event Number RW2-3	
Mitigative Features – Attributes:	**Credited:**
Secondary Confinement Exhaust ventilation system. (EC)	
Fire detection and suppression system. (EC)	
Limited access for discharges to LLLW system. (DF)	
Building structure. (DF)	
LLLW waste tank design and material selection. (DF)	
Emergency response procedures. (AC)	
Radiation and contamination control procedures. (AC)	
Combustible material control program. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	
NFPA requirements. (EC/DF)	
All collection tanks and the resin storage tank in the HPV are in covered pits that are not easily accessed. (DF)	
PPS access control to the HPV during beam operations. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: Low **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Notes:			**Mitigated Frequency** **A**

Event Number RW3-1					
Event Description: Release of radiological material due to loss of confinement from Contact Handled Waste Handling.					
Assumptions and Initial Conditions: 1. Solid contact handled waste stored and/or packaged according to ORNL waste management procedures, contains bounding equilibrium nuclides from the material in the container. (IC) 2. Solid CH waste stored and/or packaged according to ORNL waste management procedures. (IC) 3. Contains bounding equilibrium nuclides from the material in the container (See Note 1). (IC) 4. Waste originates from HPV, high bay, PIE Cell, and Service Cell. (IC) 5. This event assumes surface contamination is present. (IC) 6. Decontamination activities are to be completed in the Service Cell or PIE Cell. (IC)		**Causes**: 1. Impact by forklift or other damage to waste packaging. 2. Worker error – improper handling of waste material. 3. Failure of SCE system from localized power failure or mechanical failure of exhaust fans. 4. Plugged HEPA filters block exhaust flow path and cause airflow reversal.			**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. Shutdown of the affected area due to contamination. 2. Recovery time required for decontamination efforts.			**Unmitigated Consequences**		
			Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Reduce probability of or consequences from a loss of confinement from Contact Handled Waste Handling operations with release of radiological material above allowable limits.					
Method of Detection:					
Ventilation system alarms.					
Air activity monitor in the stack.					
Radiation monitoring of personnel if potential contamination.					
RCT routine monitoring for contamination.					
Preventive Features – Attributes:					**Credited:**
Differential pressure instrumentation and fan interlocks to start standby fan if the primary fan fails or if exhaust vacuum is low. (EC)					
Standby power source. (EC)					
Redundant exhaust fans. (DF)					
Electrical equipment design code. (DF)					
Operating Procedures and Training. (AC)					

Event Number
RW3-1

Mitigative Features – Attributes:	Credited:
HEPA filter status monitoring instrumentation. (EC)	
Redundant banks of HEPA filters - additional filters can be brought on line if any HEPA filters begin to plug. (DF/AC)	
Building design and confinement capability. (DF)	
Radiation and contamination control procedures. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	
HEPA filter testing and replacement program. (AC)	
Emergency response procedures. (AC)	
Preventive maintenance program for exhaust fans. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
1. Radionuclide inventories are based on the component or system. For example, target segments are assumed to have a 10-year life and more permanent components such as the target drive shaft is assumed to have a 40-year life. Evaluations are based on the worst-case radionuclide inventory anticipated for the activity. Event scenarios are evaluated based on the worst inventory for activities that could be present.	**A**

Event Number
RW3-3

Event Description:
Release of radiological material due to loss of confinement through flooding in the HPV (water line leaks and floods HPV confinement area).

Assumptions and Initial Conditions:

1. Solid contact handled waste stored and/or packaged according to ORNL waste management procedures, contains bounding equilibrium nuclides from the material in the container. (IC)
2. Solid CH waste stored and/or packaged according to ORNL waste management procedures. (IC)
3. Contains bounding equilibrium nuclides from the material in the container (See Note 1). (IC)
4. Waste originates from HPV and high bay systems. (IC)
5. This event assumes surface contamination is present. (IC)

Causes:
Water supply piping to solid waste handling and/or decontamination areas ruptures as the result of:

- Corrosion,
- Cracking at welds as the result of long-term vibration,
- Piping damaged during installation or maintenance,
- Worker error,
- Valve failure.

Initiating Event Frequency
A

Unmitigated Impact on Systems:

1. Shutdown of the affected area due to contamination.
2. Recovery time required for decontamination efforts or for repairs as necessary.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Reduce probability of or consequences above allowable limits from a loss of confinement with release of radiological material from water line leaks and floods HPV confinement area .

Method of Detection:	
Sump alarms.	
Visual.	
HPV drain tank or pit level alarm.	

Preventive Features – Attributes:	**Credited:**
Water piping design. (DF)	
Operating Procedures and Training. (AC)	

Event Number
RW3-3

Mitigative Features – Attributes:	Credited:
Secondary Confinement Exhaust ventilation system. (EC)	
Waste handling room design includes curbs or berms to contain leaked material in LCS or HPV. (DF)	
Sumps in waste handling areas or sloped floors to collect liquids. (DF)	
Building confinement capability. (DF/EC)	
Contamination control procedures. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	
HPV design to control leaks. (See Note 1) (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
1. Radionuclide inventories are based on the component or system. For example, target segments are assumed to have a 10-year life and more permanent components such as the target drive shaft is assumed to have a 40-year life. Evaluations are based on the worst-case radionuclide inventory anticipated for the activity. Event scenarios are evaluated based on the worst inventory for activities that could be present.	**A**

Event Number
RW3-4

Event Description:
Personnel exposure to activated gaseous release from Contact Handled Waste Handling operations.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Tungsten target after 20 year irradiation at 700 kW. (IC) 2. Release of radioactive gases to SCE ventilation system. (IC) 3. Gases are circulated throughout high bay by recirculating ventilation system. (IC)	1. Undetected breach or breach during handling releases confined gases. 2. Waste handling cask/container has inadequate or no gas sealing.	**EU**

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Contamination of a portion of the building. 2. Shutdown of the affected area. 3. Recovery time required for decontamination efforts or for repairs as necessary.	**Public**: Negligible **WG1**: Low **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Reduce probability of gaseous release of radiological material during Contact Handled Waste Handling operations.

Method of Detection:	
Radiological surveys.	

Preventive Features – Attributes:	**Credited:**
Waste/transfer cask/container design (DF)	
Operating Procedures and Training (AC)	

Event Number
RW3-4

Mitigative Features – Attributes:	Credited:
Secondary Confinement Exhaust ventilation system. (EC)	
Area radiation monitors (ARM). (EC)	
Confinement features in the waste handling cask/container. (DF)	
Building design. (DF)	
Radiation alarms. (EC)	
Radiation postings. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	
Emergency response procedures. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. Determine the potential release consequences and decay heat. 2. Verify that based on the “Lasagna Segmented Target Design” the gases are not likely to get into the coolant loop.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
1. The waste handling cask/container is assumed to have a “well” or depression in the bottom lid to contain any free liquids that could collect. 2. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.	**A**

Event Number RW3-5					
Event Description: Release of radiological material due to a leak or overflow in the LLLW tanks.					
Assumptions and Initial Conditions: 1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC) 2. Water released to LLLW tanks initially drains through the leak collection tanks or is pumped from the cooling loops, thus preventing short-cooled water in the LLLW. (i.e., Nothing goes to the LLLW automatically.) (DF)		**Causes**: 1. Failure of the collection tank due to corrosion. 2. Tank damaged during installation or maintenance. 3. Cracking at welds as the result of long-term vibration. 4. Overfilling of tank from level indicator failure. 5. Operator inattention.			**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. Shutdown of the affected area. 2. Recovery time required for decontamination efforts or for repairs as necessary.			**Unmitigated Consequences**		
			Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Reduce probability of or consequences from a LLLW tank overflow resulting in a release of radiological material above allowable limits.					
Method of Detection:					
Visual.					
Conductivity probe in sump with alarm.					
Preventive Features – Attributes:					**Credited:**
Collection tank design. (DF)					
Overflow line to adjacent LLLW tank. (DF)					
Selection of material. (DF)					
Level instrument tied to fill valve. (EC)					
Operating Procedures and Training. (AC)					
Preventive maintenance program. (AC)					

Event Number	
RW3-5	
Mitigative Features – Attributes:	**Credited:**
Secondary Confinement Exhaust ventilation system. (EC)	
Waste handling area of HPV design includes floor liner and curbs to contain leaked material. (DF)	
Slopped floor contains leakage and pits prevent migration. (DF)	
Building confinement capability. (DF/EC)	
Contamination control procedures. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	
All collection tanks and the resin storage tank in the HPV are in covered pits that are not easily accessed. (DF)	
PPS access control to the HPV during beam operations. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Notes:			**Mitigated Frequency** **A**

Event Number RW3-6 (Event Deleted as the evaporator in the LLLW system has been deleted.)
Event Description: LLLW Evaporator overflow or boil over.

Event Number
RW3-7

Event Description:
During manual disconnect of resin transfer connection at one of the locations in the Service Cell from the High Integrity Container (HIC) (resin shipping container) or at the wall, pipe still contains activated material resulting in loss of confinement and contamination to WG1. This could be from either line to the HIC. (MAR < 20 gallons)

Assumptions and Initial Conditions:
1. Personnel are permitted in the Service Cell for this operation. (IC/(AC)
2. Other activated component handling operations in the Service Cell are not permitted at the same time personnel are performing resin sluicing operations. (IC/AC).
3. Infrequent operation: resin transfer to the HIC is not required on a regular basis based on size.
4. Two IX Columns are used in operation and when one column is spent, it is allowed to decay for nominally 6 months prior to sluicing from that column to the resin storage tank where it is allowed to decay further. (IC)
5. The spent IX Column is drained to the Resin Storage Tank in a Pit to allow further decay time before shipment. (IC/AC)

Causes:
1. Operator error.
2. Failure to follow procedure or other error.
3. Equipment fault preventing complete drainage of the system.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Contamination of the Service Cell and the High Integrity Container leads to loss of production due to cleanup of the Service Cell.
2. Contamination could affect the ability to allow personnel access and perform hands-on activities.
3. Personnel contamination/exposure event

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
During manual disconnect of resin transfer connection at one of the locations in the Service Cell from the HIC, prevent a contamination/exposure event to WG1 above allowable limits.

Method of Detection:	
Visual detection by WG1.	
Leak detection into the service cell or pit (detection and alarm).	

Preventive Features – Attributes:	**Credited:**
Sluicing Pipe Sight Glass Verification – to ensure that sluicing has been completed. (AC)	
Pipe Disconnect and Verification Procedure – Verification that pipe drained of water and/or resin prior to disconnect. (AC)	

Event Number
RW3-7

Mitigative Features – Attributes:	Credited:
Radiation Safety Program: • Ensures required PPE and personnel training. (AC) • Radiological Work Permit (RWP) – to establish requirements for the identified task. (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	
Operator Training and Procedures – for sluicing operations. (AC)	
Operator Training and Procedures – Operators will be following appropriate Waste Acceptance Criteria (WAC) procedures for removal of resin and shipment to offsite disposal. (AC)	
Service Cell HVAC – Service Cell ventilation is set for personnel access. (AC) (EC)	
Service Cell and HIC cask/container/pit – provides for controlling any spillage. (EC)	
Environmental Safety and Health Program (ESH) – assesses the need for specific PPE to be worn during operation. (AC)	
The spent resin is transferred from the Resin Storage Tank where it has allowed the resin to decay before transferring to the HIC in the Service Cell. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. Upon completion of the Service Cell and HPV floor layout determine the maximum quantity of material that could be spilled for this event.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
1. MAR based on size of the transfer line capacity.	A

Event Number RW3-8					
Event Description: During resin sluicing from the Ion Exchange Column (IXC) to the resin storage tank or from the resin storage tank to the HIC, resin slurry is discharged to wrong location. The event results in release of activated water and resin to HPV or to HOG. (MAR < 400 Gallons)					
Assumptions and Initial Conditions: 1. Personnel may be permitted in the HPV or service cell during sluicing operations transferring material. (IC) 2. The transfer pipe is hard piped from the IXC to the resin storage tank and from the resin storage tank to the HPV wall. (IC) 3. The transfer pipe is composed of both hard pipe and hoses in the service cell. (IC) 4. The HPV is on the Target Facility Secondary Confinement HVAC system. (DF) 5. Two IX Columns are used in operation and when one column is spent, it is decayed for nominally 6 months prior to transfer from that column to the resin storage tank where it is allowed to decay further. (IC) 6. The spent IX Column is drained to the Resin Storage Tank in a Pit to allow further decay time before shipment. (IC/AC) 7. The service cell is on the Target Facility Secondary Confinement HVAC system but includes HEPA filteration in the Service Cell prior to connecting to the Secondary Confinement System (See Note 7) (DF)	**Causes**: 1. Component failure. 2. Resin storage tank overflow. 3. HIC overflow. 4. Vacuum pump discharges resin slurry to HOG. 5. Valve sequence error.			**Initiating Event Frequency** U	
Unmitigated Impact on Systems: 1. Resin change-out may not be able to be performed (depending on the failure) until this condition has been repaired. 2. Recovery time required for decontamination efforts or for repairs as necessary. 3. Significant exposure to cleanup personnel (WG1) possible.	**Unmitigated Consequences**				
	Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A		
Safety Function: To prevent transfer of resin slurry to the wrong place, and to prevent a significant leak or pipe break.					
Method of Detection:					
Flow, Pressure, and Level Monitors (resin storage tank, HIC, vacuum pump surge tank, HOG)					
Leak Detection and alarms/control room notification.					
Preventive Features – Attributes:				**Credited:**	
Maintenance/surveillance Procedures – to ensure the integrity of all components of the piping. (AC)					
Vessel designed to ASME BPVC. (DF)					
Piping designed to ASME B31.3. (DF)					
Resin storage tank sized for multiple transfers. (DF)					
HIC sized for one resin storage tank volume of resin. (DF)					
Operating procedure. (AC)					

Event Number
RW3-8

Mitigative Features – Attributes:	Credited:
HPV Floor Design – to passively control leaks and prevent spread to other areas of the Target Facility. (DF)	
Target Building HVAC – Secondary Confinement Air Exhaust (SCE) operating. (EC)	
Leak Detection and Alarm Notification- To detect a pipe break. (EC)	
Operator Training and Procedure – to respond to leak detection. (AC)	
Building Access Control - limits access to HPV areas during active sluicing operations. (AC)	
Resin storage tank level indications (visual and liquid level). (EC)	
Alarmed drainage collection in HOG line from HPV. (EC)	
Alarmed liquid collection location (e.g., tank) in vacuum line from the resin storage tank and HIC. (EC)	
All collection tanks and the resin storage tank in the HPV are in covered pits that are not easily accessed. (DF)	
All piping connections to the IX Column are hard piped within the HPV. (DF)	
Piping connections from the IX Column to the resin storage tank and from the resin storage tanks to the wall are hard piped within the HPV. (DF)	
The spent resin is transferred from the Resin Storage Tank where it has allowed the resin to decay before transferring to the HIC in the Service Cell. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. A procedure will be developed to control sluicing to manage the transfer of resign and the flow of water/resign. .

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:

1. This event is based on the IXC being in the HPV.
2. The HPV is designed to capture and hold spills of contaminated liquid.
3. Operator response is credited to prevent spread of contamination from this event to other areas of the facility.
4. MAR based on capacity of the HIC. This bounds the potential release from the IXC.
5. Personnel access to the sluicing operations will be based on activation of the resin and potential dose for workers.
6. Since all of the piping in the HPV is hard piped, the likelihood of a leak during this process is unlikely.
7. The Target Facility Secondary Confinement HVAC system for the Service Cell includes a local system with filters in the Service Cell and fans discharging to the main Secondary Confinement System.

Mitigated Frequency
U

Event Number
RW3-9

Event Description:
During resin sluicing from resin storage tank to HIC, a leak occurs in the HPV in the piping (either line) between the Resin Storage Tank and the HIC. A leak in the HPV is postulated to occur during pumping from the resin storage container to the HIC. The event results in release of activated water and resin. (MAR < 400 gallons)

Assumptions and Initial Conditions:
1. Personnel may be in the HPV and in the Service Cell during sluicing operations transferring material. (IC)
2. The transfer pipe is hard piped from the resin storage tank to the service cell wall. (IC)
3. The transfer pipe from the wall in the service cell to the HIC includes both hard pipe and flexible pipe. (IC)
4. The HPV is on the Target Facility Secondary Confinement HVAC system. (DF)
5. Two IX Columns are used in operation and when one column is spent, it is allowed to decay for nominally 6 months prior to sluicing from that column to the resin storage tank where it is allowed to decay further. (IC)
6. The spent IX Column is drained to the Resin Storage Tank in a Pit to allow further decay time before shipment. (IC/AC)

Causes:
1. Component failure.
2. Sluicing Pipe failure (connecting lines).
3. Operator error.
4. Failure to follow procedure or other error.
5. Valve sequence error.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Resin change-out may not be able to be performed (depending on the failure) until this condition has been repaired.
2. Recovery time required for decontamination efforts or for repairs as necessary.
3. Significant exposure to cleanup personnel (WG1) possible.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
To prevent a piping leak/break during resin transfer to the HIC in either the Service Cell or the HPV.

Method of Detection:	
Flow, Pressure, and Level Monitors.	
Leak Detection and alarms/control room notification.	

Preventive Features – Attributes:	**Credited:**
Maintenance/surveillance Procedures – to ensure the integrity of all components of the piping loop. (AC)	
Vessel designed to ASME BPVC. (DF)	
Piping designed to ASME B31.3. (DF)	
Operating procedure. (AC)	

Event Number	
RW3-9	

Mitigative Features – Attributes:	**Credited:**
HPV Floor Design – to passively control leaks and prevent spread to other areas of the Target Facility. (DF)	
Target Building HVAC – Secondary Confinement Air Exhaust (SCE) operating. (EC)	
Leak Detection and Alarm Notification- To detect a pipe break. (EC)	
Operator Training and Procedure – to respond to leak detection. (AC)	
Building Access Control - limits access to HPV areas during active sluicing operations. (AC)	
All piping connections to the IX Column are hard piped within the HPV. (DF)	
Piping connections from the IX Column to the resin storage tank and from the resin storage tanks to the wall are hard piped within the HPV. (DF)	
Resin storage tank is located in a covered pit within the HPV. (DF)	
The spent resin is transferred from the Resin Storage Tank where it has allowed the resin to decay before transferring to the HIC in the Service Cell. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Determine the airborne release and consequences from a spill in this room.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. The HPV is designed to capture and hold spills of contaminated liquid. 2. Operator response is credited to prevent spread of contamination from this event to other areas of the facility. 3. MAR based on capacity of the resin storage tank. 4. Personnel access to the sluicing operations will be based on activation of the resin and potential dose for workers. 5. Based on flexible piping being used in the Service Cell, the event frequency of a leak is anticipated.	A

Event Number
RW3-10

Event Description:
During resin sluicing, a leak occurs in the Service Cell in the flexible piping (either line) between the resin storage tank and the HIC. A leak in the service cell is postulated to occur during pumping from the resin storage container to the HIC. The event results in release of activated water and resin. (MAR < 400 gallons)

Assumptions and Initial Conditions:
1. Personnel may be in the service cell during sluicing operations when transferring material. (IC)
2. The transfer pipe is composed of both hard pipe and hoses from the wall in the service cell to the HIC. (IC)
3. The service cell is on the Target Facility Secondary Confinement HVAC system but includes HEPA filteration in the Service Cell prior to connecting to the Secondary Confinement System (See Note 5) (DF)
4. Infrequent operation: Resin transfer to the HIC is not required on a regular basis based on size. (IC)
5. Other activated component handling operations in the Service Cell are not permitted when to personnel are performing sluicing operation. (IC).
6. Two IX Columns are used in operation and when one column is spent, it is allowed to decay for nominally 6 months prior to sluicing from that column to the resin storage tank where it is allowed to decay further. (IC)
7. The spent IX Column is drained to the Resin Storage Tank in a Pit to allow further decay time before shipment. (IC/AC)

Causes:
1. Component failure.
2. Operator error.
3. Failure to follow procedure or other error.
4. Improper connection to the High Integrity Shipping Container.
5. Valve sequence error.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Contamination of the Service Cell and the High Integrity Container leads to loss of production due to cleanup of the Service Cell.
2. Contamination could affect the ability to allow personnel access and perform hands-on activities.
3. Significant exposure to cleanup personnel (WG1) possible.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
To prevent a leak/break during resin transfer to the HIC in the Service Cell.

Method of Detection:	
Flow, Pressure, and Level Monitors.	
Leak Detection and alarms/control room notification.	

Preventive Features – Attributes:	**Credited:**
Maintenance/operating Procedures – to ensure the integrity of all components of the piping loop. (AC)	**X**

Event Number
RW3-10

Mitigative Features – Attributes:	Credited:
Operator Training and Procedures – Operators will be following appropriate Waste Acceptance Criteria (WAC) procedures for packaging of resin and shipment to offsite disposal. (AC)	
Target Building HVAC – Secondary Confinement Air Exhaust (SCE) operating. (EC)	
Leak Detection and Alarm Notification- To detect a pipe break. (EC)	
Operator Training and Procedure – to respond to leak detection. (AC)	
Building Access Control - limits access to service cell during active sluicing operations. (AC)	
Operator Training and Procedures for sluicing operations. (AC)	
Service Cell HVAC – Service Cell ventilation is set for personnel access. (AC) (EC)	
Service Cell and HIC cask/container/pit – provides for controlling any spillage. (DFR)	
The spent resin is transferred from the Resin Storage Tank where it has allowed the resin to decay before transferring to the HIC in the Service Cell. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Determine the airborne release and consequences from a spill in this room.
2. Upon completion of the Service Cell and HPV floor layout determine the maximum quantity of material that could be spilled for this event.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:

1. This event is based on the resin storage vessel being in the HPV and the high integrity shipping container being in the service cell.
2. MAR based on size of the storage container (368 gallons)
3. Personnel access to the sluicing operations will be based on activation of the resin and potential dose for workers.
4. Based on flexible piping being used in the Service Cell, the event frequency of a leak is anticipated.
5. The Target Facility Secondary Confinement HVAC system for the Service Cell includes a local system with filters in the Service Cell and fans discharging to the main Secondary Confinement System.

Mitigated Frequency
A

Event Number
RW3-11

Event Description:
During manual disconnect the connection of the flexible line breaks at one of the locations in the Service Cell from the High Integrity Container (shipping container) or at the wall, spraying water/resin over the service cell and the flexible pipe siphons water/resin from HIC resulting in loss of confinement and contamination to WG1. The open line allows water/resin to drain into the service cell in addition to the liquid that would be remaining in the flexible pipe. This could be from either line to the HIC. (MAR < 400 gallons)

Assumptions and Initial Conditions:
1. Personnel are permitted in the Service Cell for this operation. (IC)
2. Other activated component handling operations in the Service Cell are not permitted due to personnel performing sluicing operation. (IC).
3. Infrequent operation: Resin transfer to the HIC is not required on a regular basis based on size. (IC)
4. Water/resin is initially drained from the IX Column in the HPV to a Resin Storage Tank in a covered pit and allowed to decay before transfer to the HIC in the Service Cell. (IC)
5. At disconnect, resin initially in the line becomes the source of exposure. (IC)
6. Two IX Columns are used in operation and when one column is spent, it is allowed to decay for nominally 6 months prior to sluicing from that column to the resin storage tank where it is allowed to decay further. (IC)

Causes:
1. Operator error: failure to follow procedure or other error.
2. Valve fault preventing complete isolation.
3. Failure of resin/water separation in the HIC.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Contamination of the Service Cell and the High Integrity Container leads to loss of production due to cleanup of the Service Cell.
2. Contamination could affect the ability to allow personnel access and perform hands-on activities.
3. Significant exposure to cleanup personnel (WG1) possible.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
To prevent a contamination/exposure above allowable limits during manual disconnect the connection of the flexible line breaks at one of the locations in the Service Cell from the High Integrity Container (shipping container) or at the wall to WG1. .

Method of Detection:	
Visual detection by WG1.	
Area Radiation Monitors.	
Leak monitoring in the service cell or pit (detection and alarm).	

Preventive Features – Attributes:	**Credited:**
Sluicing Pipe Sight Glass Verification – to ensure that sluicing has been completed. (AC)	
Pipe Disconnect and Verification Procedure – Verification that pipe drained of water and/or resin prior to disconnect. (AC)	

Event Number
RW3-11

Mitigative Features – Attributes:	**Credited:**
Radiation Safety Program: • Ensures required PPE and personnel training. (AC) • Radiological Work Permit (RWP) – to establish requirements for the identified task. (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	
Operator Training and Procedures for sluicing operations. (AC)	
Service Cell HVAC – Service Cell ventilation is set for personnel access. (AC) (EC)	
Service Cell and HIC cask/container/pit – provides for controlling any spillage. (EC)	
Operator Training and Procedures – Operators will be following appropriate Waste Acceptance Criteria (WAC) procedures for removal of resin and shipment to offsite disposal. (AC)	
Environmental Safety and Health Program (ESH) – assesses the need for specific PPE to be worn during operation. (AC)	
Water/resin is initially drained from the IX Column in the HPV to a Resin Storage Tank in a covered pit and allowed to decay before transfer to the HIC in the Service Cell. (AC)	
The spent resin is transferred from the Resin Storage Tank where it has allowed the resin to decay before transferring to the HIC in the Service Cell. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Upon completion of the Service Cell and HPV floor layout determine the maximum quantity of material that could be spilled for this event.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. MAR based on size of the storage container (368 gallons)	A

Event Number RW3-12				
Event Description: During resin transfer either into or out of the resin storage tank, a leak occurs in the gas vent line to the HOG. The event results in potentially activated particulates and tritiated water in the gases released to the HPV.				
Assumptions and Initial Conditions: 1. Personnel may be in the HPV or Service Cell during sluicing operations. (IC) 2. There should be no radioactive gases in this material except for tritiated water. (IC) 3. Two IX Columns are used in operation and when one column is spent, it is allowed to decay for nominally 6 months prior to sluicing from that column to the resin storage tank where it is allowed to decay further. (IC) 4. The spent IX Column is drained to the Resin Storage Tank in a Pit to allow further decay time before shipment. (IC/AC)	**Causes**: 1. Component failure. 2. Pipe leak.			**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. HPV contamination and associated cleanup.	**Unmitigated Consequences**			
	Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible		**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: To control the consequences of a gaseous leak to below allowable limits during resin transfer either into or out of the resin storage tank in the gas vent line to the HOG.				
Method of Detection:				
Area radiation alarms (ARM)/control room notification.				
Preventive Features – Attributes:				**Credited:**
None identified.				

Event Number
RW3-12

Mitigative Features – Attributes:	Credited:
PPS limits access to the HPV and Service Cell during sluicing operations if conditions warran.t (AC)	
Target Building HVAC - Secondary Confinement. (EC)	
Operator Training and Procedure – to respond to fault. (AC)	
All piping connections to the IX Column are hard piped within the HPV. (DF)	
The spent resin is transferred from the Resin Storage Tank where it has allowed the resin to decay before transferring to the HIC in the Service Cell. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:
1. Determine the potential exposure to personnel from airborne releases during resin transfer events.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible **WG1**: Low **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:
1. This event is based on the resin storage tank being in the HPV.
2. Personnel access to the sluicing operations will be based on activation of the resin and potential dose for workers.
3. The initial installation location for ARMs and IRMs will be identified during design and be verified or altered during commissioning and fault testing. The Radiation Safety Officer will make the final determination for their location and present this information to the Radiation Safety Committee for approval.

Mitigated Frequency
A

Event Number
RW3-13

Event Description:
During resin sampling in the HPV, a leak is postulated to occur. The event results in release of activated water and resin. (MAR < 400 gallons)

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. Personnel are performing the sampling in the in the HPV as a hands-on operation. (IC) 2. Resin is transferred from the resin storage tank in a covered pit in the HPV to the Service Cell. (DF) 3. Two IX Columns are used in operation and when one column is spent, it is allowed to decay for nominally 6 months prior to sluicing from that column to the resin storage tank where it is allowed to decay further. (IC) 4. The spent IX Column is drained to the Resin Storage Tank in a Pit to allow further decay time before shipment. (IC/AC)	1. Component failure. 2. Operator error.	A

Unmitigated Impact on Systems:	Unmitigated Consequences		
1. Contamination in the room could limit operations until it is cleaned up.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
To prevent or control the consequences of a leak/break occurring during resin sampling.

Method of Detection:	
Visual.	
Leak Detection and alarms/control room notification.	

Preventive Features – Attributes:	Credited:
Automatic Resin Sampling System – provides an enclosed integrated sample system that significantly reduces the likelihood of mechanical or operator error causing a leak during the sampling process. (EC) (See Note 3)	
Maintenance Procedures – to ensure the integrity of all components of the piping loop. (AC)	

Event Number
RW3-13

Mitigative Features – Attributes:	Credited:
Automatic Resin Sampling System – provides an enclosed integrated sample system that provides a secondary confinement of the sample system to assure that any leaks are contained within the system. (EC) (See Note 3)	
HPV Room Design – to collect leaks. (EC)	
Target Building Leak Sensors – to detect the leak. (EC)	
Target Building HVAC – Secondary Confinement ventilation assures that any material is filtered before it reaches the public by either filtering or providing isolation of the room. (EC)	
Building Access Control - limits access to HPV. (AC)	
Environmental Safety and Health Program (ESH) – assesses the need for specific PPE to be worn during operation. (AC)	
Radiation Safety Program: • Ensures required PPE and personnel training (AC). • Radiological Work Permit (RWP) - to establish requirements for the identified task. (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	
Operator Training and Procedure – to use the automatic resin sampling system. (AC)	
The spent resin is transferred from the Resin Storage Tank where it has allowed the resin to decay before transferring to the HIC in the Service Cell. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible **WG1**: Low **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:

1. Design based on Sentry Isolok Automatic Sampler system design (or similar) with integrated containment. This design provides both a significant reduction in frequency of failure and due to the secondary confinement system, mitigation.
2. MAR based on size of the storage container (368 gallons).
3. Use of the Automatic Resin Sampling System prevents workers from having to access the IX column in the HPV except to connect and disconnect the resin sample container. Sampling operations are performed remotely.

Mitigated Frequency
A

Event Number
RW4-1

Event Description:
Personnel receive inadvertent external exposure to radiation in the vicinity of Contact Handled waste.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Solid CH waste stored and/or packaged according to ORNL waste management procedures. (AC) 2. Contains bounding equilibrium nuclides from the material in the container (See Note 1). Waste is from cooling water, HV, GW, service cell and LLLW systems. (IC) 3. This event assumes surface contamination is present. (IC) 4. All high-level activated waste is handled in the Service Cell. Only low-level contaminated waste would be stored in areas outside the Service Cell. (AC)	1. Inadequate shielding. 2. Worker error. 3. Improper monitoring for radiation levels. 4. Personnel enter areas of high radiation. 5. Shielding (ion exchange column) fails allowing pathway for direct radiological exposure. 6. Resin inadvertently pumped to the open room floor.	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
None	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent personnel exposure above allowable levels in the vicinity of Contact Handled waste

Method of Detection:	
Radiation Survey (AC)	

Preventive Features – Attributes:	**Credited:**
Shielding design (if required). (DF)	
Operating Procedures and Training. (AC)	
Radiation Protection program. (AC)	
Radiation postings. (AC)	
Personnel training reduce likelihood of personnel entering high radiation areas. (AC)	

Event Number
RW4-1

Mitigative Features – Attributes:	Credited:
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	
Radiation control procedures. (AC)	
Emergency response procedures. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
1. Radionuclide inventories are based on the component or system. For example, target segments are assumed to have a 10-year life and more permanent components such as the target drive shaft is assumed to have a 40-year life. Evaluations are based on the worst-case radionuclide inventory anticipated for the activity. Event scenarios are evaluated based on the worst inventory for activities that could be present. 2. Decontamination operations are performed in the Service Cell or PIE Cell.	**A**

Event Number
RW4-2

Event Description:
Facility worker receives inadvertent direct radiological exposure in the vicinity of LLLW, leak collection, or resin storage tanks.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Accelerator operating at full power. (IC) 2. Short lived isotopes are at equilibrium. (IC) 3. Water released to LLLW tanks initially drains through the leak collection tanks or is pumped from the cooling loops, thus preventing short-cooled water in the LLLW. (i.e., Nothing goes to the LLLW automatically.) (DF) 4. LLLW tanks are located in pits with covers in the HPV to prevent normal access and potential exposure. (DF) 5. Two IX Columns are used in operation and when one column is spent, it is allowed to decay for nominally 6 months prior to sluicing from that column to the resin storage tank where it is allowed to decay further. (IC) 6. The spent IX Column is drained to the Resin Storage Tank in a Pit to allow further decay time before shipment. (IC/AC)	1. Improper monitoring for radiation levels. 2. Personnel enter areas of high radiation. 3. Source term higher than design basis. 4. Inadequate shielding.	BEU (Note 1)

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
None.	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent personnel exposure above allowable levels in the vicinity of LLLW, leak collection, or resin storage tanks.

Method of Detection:	
Radiological survey.	

Preventive Features – Attributes:	**Credited:**
Location of LLLW tanks in covered pits in the HPV without normal access. (DF)	**X**
Radiation postings and personnel training reduce likelihood of personnel entering high radiation areas. (AC)	
PPS reduces likelihood of personnel accessing HPV. (EC)	
Operating Procedures and Training. (AC)	
Radiation Protection program. (AC)	
RCT surveys. (AC)	

Event Number RW4-2				
Mitigative Features – Attributes:				**Credited:**
Radiation Safety Program: • Ensures required personnel training. (AC) • RCT survey. (AC) • Radiological Work Permit (RWP) – Establishes requirement for radiological safety associated with maintenance or other work in the HPV. (AC) • Required delay on entry to the HPV. (AC)				
Emergency Response Procedures. (AC)				
Personnel wear either TDSs or alarming radiation monitors. (AC)				
The spent resin is transferred from the Resin Storage Tank where it has allowed the resin to decay before transferring to the HIC in the Service Cell. (AC)				
Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**			
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Notes: 1. Tanks are located in pits within the HPV. The cover on these pits makes inadvertent access to these pits BEU. The DF includes a pit cover that is not removable by a single individual and labeling on the pit that this is a confined space. The PPS access controls noted above for the HPV limits entry until RCT survey and delay on entry have been completed. These add an additional layer of protection.				**Mitigated Frequency** **BEU**

Event Number
RW4-3

Event Description:
Inadvertent entrance into radiation-controlled area in the HPV results in direct exposure (from piping, collection tanks, or resin storage tank).

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Design of HPV precludes normal physical access during beam operation. (IC) 2. LLLW tanks, resin storage tank, and drain tanks are located in pits with covers design to preclude normal access. (DF) 3. IX columns are in the HPV and shielded to minimize exposure. (DF) 4. Two IX Columns are used in operation and when one column is spent, it is allowed to decay for nominally 6 months prior to sluicing from that column to the resin storage tank where it is allowed to decay further. (IC) 5. The spent IX Column is drained to the Resin Storage Tank in a Pit to allow further decay time before shipment. (IC/AC)	1. Operator error.	U (Note 1)

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
None.	**Radiological** **Public**: N/A **WG1**: Low **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent radiological exposure above allowable limits to workers in the HPV from Inadvertent entrance into radiation-controlled area in the HPV.

Method of Detection:	
Radiological survey.	
Personal wear TLDs.	

Preventive Features – Attributes:	**Credited:**
Location of LLLW tanks in pits with without normal access. (DF) (See Note 1)	**X**
IX columns are in a shielded area of the HPV and the resin storage tank is in a covered pit in the HPV. (DF) (See Note 1)	
Radiation control procedures. (AC)	
Personnel are not permitted in the HPV during beam operation by the PPS (EC)	

Event Number
RW4-3

Mitigative Features – Attributes:	Credited:
Radiation Safety Program: • Ensures required personnel training. (AC) • RCT survey.(AC) • Radiological Work Permit (RWP) – Establishes requirement for radiological safety associated with maintenance or other work in the HPV. (AC) • Required delay on entry to the HPV. (AC)	
Environmental Safety and Health Management System Program (ESHMS) – to assess the risks and establish requirements for specific tasks. (AC)	
Personnel wear TLDs or alarming radiation monitors. (AC)	
The spent resin is transferred from the Resin Storage Tank where it has allowed the resin to decay before transferring to the HIC in the Service Cell. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Determine the dose potential of the various components for a direct exposure (piping, cooling tanks, exchange columns, etc.)

Mitigated Consequences:

Radiological	Chemical	ODH
Public: N/A	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: N/A	**WG2**: N/A	**WG2**: N/A

Notes:

1. All tanks are located in pits within the HPV. The cover on these pits makes inadvertent access to these pits BEU. The DF includes a pit cover that is not removable by a single individual and labeling on the pit that this is a confined space. The PPS access controls noted above for the HPV initial entry with RCT survey and delay on entry adds a layer of protection on potential exposure to workers.

Mitigated Frequency
U

Event Number
RW4-4

Event Description:
Inadvertent entrance into radiation-controlled area in the HPV results in direct exposure (from piping, components, or IX Column).

Assumptions and Initial Conditions:
1. Design of HPV precludes normal physical access during beam operation. (IC)
2. IX columns are in the HPV and shielded to minimize exposure. (DF)
3. Two IX Columns are used in operation and when one column is spent, it is allowed to decay for nominally 6 months prior to sluicing from that column to the resin storage tank where it is allowed to decay further. (IC)
4. The spent IX Column is drained to the Resin Storage Tank in a Pit to allow further decay time before shipment. (IC/AC)
5. Resign sampling will be performed from the Resin Storage Tank and not form the IX Columns. (DF/AC)

Causes:
1. Operator error.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
None.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: N/A	**Public**: N/A	**Public**: N/A
WG1: Moderate	**WG1**: N/A	**WG1**: N/A
WG2: N/A	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent radiological exposure above allowable limits to workers in the HPV from Inadvertent entrance into radiation-controlled area in the HPV.

Method of Detection:	
Radiological survey.	
Personal wear TLDs.	

Preventive Features – Attributes:	**Credited:**
IX columns are in a shielded area of the HPV and the resin storage tank is in a covered pit in the HPV. (DF)	**X**
Radiation control procedures. (AC)	
Personnel are not permitted in the HPV during beam operation by the PPS (EC)	

Event Number
RW4-4

Mitigative Features – Attributes:	Credited:
Radiation Safety Program: • Ensures required personnel training. (AC) • RCT survey. (AC) • Radiological Work Permit (RWP) – Establishes requirement for radiological safety associated with maintenance or other work in the HPV. (AC) • Required delay on entry to the HPV. (AC)	X
Environmental Safety and Health Management System Program (ESHMS) – to assess the risks and establish requirements for specific tasks. (AC)	
Personnel wear TLDs or alarming radiation monitors. (AC)	
Access to the resin storage tank is only required to connect and disconnect a resin sampling container. (AC)	
IX Column is behind a shielded barrier.	
The spent resin is transferred from the Resin Storage Tank where it has allowed the resin to decay before transferring to the HIC in the Service Cell. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Determine the dose potential of the various components for a direct exposure (piping and exchange columns.)	**Radiological** **Public**: N/A **WG1**: Low **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. The PPS access controls noted above for the HPV initial entry with RCT survey and delay on entry adds a layer of protection on potential exposure to workers.	A

APPENDIX O. STORAGE PAD (SP) HAZARD EVENT TABLES

Currently no storage pad is planned for use in storing spent target or other activated components from the core vessel. All of these items are planned to be housed in the Service Cell or in appropriate casks within the Target Building. Components originating in the Core Vessel will be housed in the Service Cell and will not be housed in the High Bay. Items will remain in those locations until declared as waste and scheduled for shipment off site as waste. The events in Appendix O are retained in this issue of the STS Hazard Analysis as a place holder should a later project decision is made to include a storage pad in the project scope.

APPENDIX O. STORAGE PAD (SP) HAZARD EVENT TABLES

Event Number
SP1-1

Event Description:
Fire at storage pad around spent target storage cask or other container of stored solid waste allows material to overheat from loss of heat sink resulting in breach of cask or container.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. A spent target is placed in storage after drying is completed and significant radiological decay has occurred. (IC) 2. A half-hour fire develops around cask or other storage container. (IC) 3. No cover is over the storage pad. (IC)	1. Brush or debris fire at storage pad. 2. Truck accident releasing fuel with follow on fire.	A

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. No impact on system but Delay in shipping waste off site.	**Public:** Negligible **WG1:** Moderate **WG2:** Low	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent a significant fire near the waste containers on the storage pad leading to a release of radiological material.

Method of Detection:	
Visual.	
Nasal.	

Preventive Features – Attributes:	Credited:
Truck access barriers. (EC)	

Event Number
SP1-1

Mitigative Features – Attributes:	Credited:
Internal shielding is designed to avoid lead melting and reducing shielding without external signs. (DF)	
Storage Pad designed for drainage away from casks. (DF)	
Radiation Safety Program. (AC)	
Containers other than target cask have much lower radioactive material inventory. (AC/DF)	
Combustible Control Program for storage pad. (AC)	
Fire Department response procedures and training. (AC)	
Worker training. (AC)	
Waste containers including storage casks designed to withstand 49 CFR design basis fire. (DF)	X

Planned analysis, assumption validations, and Risk/Opportunities:

1. Accident analysis—the ability of various storage casks to withstand credible unmitigated fire events will need to be analyzed.
2.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:

1. Event is a place holder should a storage pad be added to the project baseline.

Mitigated Frequency
A

Event Number
SP4-1

Event Description:
Mobile crane drops spent target storage cask or other container while loading/unloading from truck.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. A spent target is placed in storage after drying is completed and significant radiological decay has occurred. (IC) 2. No cover is over the storage pad. (IC) 3. Containers other than target cask have much lower radioactive material inventory. (IC)	1. Crane failure. 2. Worker error. 3. Lifting hardware failure.	A

Unmitigated Impact on Systems:
1. Delay in shipping waste off site.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Moderate	**WG1**: N/A	**WG1**: N/A
WG2: Low	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent a load drop from resulting in loss of shielding of spent target and significant radiological exposure to workers.

Method of Detection:	
Visual.	

Preventive Features – Attributes:	**Credited:**
Crane design. (DF)	
Rigging design. (AC)	
Critical lift program. (AC)	X
• Hoisting and rigging program (AC)	X
Crane maintenance. (AC)	
Worker training. (AC)	

Event Number SP4-1	
Mitigative Features – Attributes:	**Credited:**
Target storage cask and other containers designed similarly to 49CFR transportation regulations or equivalent for a crane drop. (EC)	
EOPs. (AC)	
Containers other than target cask have much lower radioactive material inventory. (DF)	
Worker training. (AC)	
Radiation Safety Program. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Potential effect of credible unmitigated load drop event on various storage and/or transport containers needs to be evaluated/analyzed. 2. Worker radiation exposure will need to be evaluated based on the unmitigated load drop resulting in a loss of shielding or dispersal of contents.	**Radiological** **Public:** Negligible **WG1:** Low **WG2:** Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes: 1. Event is a place holder should a storage pad be added to the project baseline.	**Mitigated Frequency** **A**

Event Number SP7-1				
Event Description: NDC-2 level Tornado or High Winds at Storage Pad damages Spent Target Storage Cask and releases contamination from spent rotating target or other stored container of solid waste.				
Assumptions and Initial Conditions: 1. A spent target is placed in storage following drying of water from the waste adequate to meet shipping requirements, including significant radiological decay has occurred. (IC) 2. High winds or missile generated by tornado impact the storage cask. (IC) 3. Could include transport of relatively light container (i.e., drum) out of storage pad area. (IC) 4. Inventories of other containers have much lower radioactive than target. (IC/AC)	**Causes**: 1. NDC-2 level Tornado or high straight winds. 2. Missiles generated by tornados or high straight winds.			**Initiating Event Frequency** U
Unmitigated Impact on Systems: 1. Delay in shipping waste off site.	**Unmitigated Consequences**			
	Radiological **Public:** Negligible **WG1:** Low **WG2:** Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A		**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Minimize the consequences of a tornado missile strike or high winds causing significant damage to a waste storage cask.				
Method of Detection:				
Visual.				
Severe weather warnings.				
Preventive Features – Attributes:				**Credited:**
None.				

Event Number
SP7-1

Mitigative Features – Attributes:	Credited:
Casks and containers designed to 49CFR transportation regulations or equivalent for a missile impact. (DF)	
Radiation Safety Program. (AC)	
Inventories of other containers have much lower radioactive than target. (DF)	
Emergency response procedures. (AC)	
ORNL Planning Facility Protection for Severe Conditions Program requirements within SBMS for operational practices for severe weather. (AC)	
Personnel training. (AC)	
Waste is dry (meeting shipping requirements) before being placed in storage container. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Design criteria development for cask and cask restraints.
2. Potential effect of wind missile on storage cask for high level material needs to be assessed.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:

1. Event is a place holder should a storage pad be added to the project baseline

Mitigated Frequency
U

Event Number
SP7-2

Event Description:
NDC-2 level Rain event at storage pad allows spent target storage cask or other container of stored solid waste to leak material from cask or container.

Assumptions and Initial Conditions:
1. A spent target is placed in storage following drying of water from the waste adequate to meet shipping requirements, including significant radiological decay has occurred. (IC)
2. High winds associated with a thunderstorm impact the storage cask allowing rain to spread contamination. (IC)
3. Could include transport of relatively light container (I.e., drum) out of storage pad area. (IC)
4. Storage cask design would not facilitate leakage of water into the waste due only to a rain event. (IC)
5. Containers other than target cask have much lower radioactive material inventory. (IC)

Causes:
1. NDC-2 level rain event (Natural phenomena).

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Delay in shipping waste off site.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Minimize the likelihood of a storm event damaging waste containers resulting in a release of radiological material.

Method of Detection:

Visual.

Radiation survey.

Preventive Features – Attributes: | **Credited:**

None.

Event Number SP7-2	
Mitigative Features – Attributes:	**Credited:**
Other containers designed similarly to 49CFR transportation regulations or equivalent for rain event. (DF)	
Radiation Safety Program. (AC)	
Storage Pad not sited in a potential flood zone. (DF)	
Containers other than target cask have much lower radioactive material inventory. (DF)	
Casks are designed to not allow water intrusion during rain. (DF)	
Storage Pad designed for drainage away from casks. (DF)	
Worker training. (AC)	
ORNL Planning Facility Protection for Severe Conditions Program requirements within SBMS for operational practices for severe weather. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1.	**Radiological** **Public:** Negligible **WG1:** Low **WG2:** Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. Event is a place holder should a storage pad be added to the project baseline	**A**

APPENDIX P. SERVICE CELL (SS) AND PIE CELL (SSP) HAZARD EVENT TABLES

This appendix has been divided into two sections: SS events covering the Service Cell and SSP event covering the PIE Cell. Also see the events in the RH tables for transport of activated components into and out of the Service Cell and PIE Cell.

APPENDIX P. SERVICE CELL (SS) AND PIE CELL (SSP) HAZARD EVENT TABLES

Event Number
SS1-1

Event Description:
Localized fire in Service cell.

Assumptions and Initial Conditions:

1. Assume spent target is stored in the service cell; contains 10 y equilibrium nuclides from tungsten target. (IC)
2. Fire is assumed to breach target shroud and exit service cell to surrounding areas. (IC)
3. In addition to the spent target segments, spent/disposable items from the core vessel as well as spent IX Resin. (IC)
4. Only one component or IX Resin transfer operation will occur in the Service Cell at a time. (AC)
5. Spent/disposable components or IX Resin (other than the operation noted in Item 4 above) are contained in covered pits within the Service Cell.(AC/DF)

Causes:

1. Excess combustible inventory.
2. Cleaning or decontamination agents contact other materials and produce flammable fumes.
3. Electrical equipment short.
4. Thermal energy from electrical equipment.
5. Friction from bearings, gears, motors, and power tools.
6. Human error.
7. Other ignition source.

Initiating Event Frequency
U

Unmitigated Impact on Systems:

1. Shutdown of the affected area.
2. Potential for damage to surrounding operating areas or equipment.
3. Release of Ta/W, off-gases and/or contamination.
4. Plugging of primary filters from smoke.
5. Contamination of surrounding areas.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Moderate	**WG1**: N/A	**WG1**: N/A
WG2: Low	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent a fire in the Service Cell from releasing significant quantities of radiological material to WG1 above allowable limits.

Method of Detection:	
Fire detection system.	
Visual.	
Loss of instrument signals.	

Event Number	
SS1-1	
Preventive Features – Attributes:	**Credited:**
Electrical equipment design code. (DF)	
NFPA standards. (DC)	
Mechanical design codes and standards. (DF)	
Combustible material control program. (AC)	
Trained personnel. (AC)	
Operating Procedures and Training. (AC)	
Preventive maintenance program. (AC)	
Mitigative Features – Attributes:	**Credited:**
Service Cell design minimizes the potential for spreading the fire. (DF)	X
Component design (shell material and construction) minimizes the potential for spreading the fire and release of material. (DF)	X
Service cell liner and materials of construction minimizes the potential for spreading the fire. (DF)	
Activated components are stored in closed pits within the Service Cell. (DF/AC)	
Fire detection and suppression system. (EC)	
SCE ventilation system. (EC)	
Air activity monitoring (RCT as needed). (AC)	
Fire Protection Program. (AC)	
Emergency Operating Procedures. (AC)	
Radiation and contamination control procedures. (AC)	
Worker training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Project Fire Hazard Analysis (PFHA). 2. Assessment of fires per NFPA 801. 3. Analysis to determine the maximum fire size that could exist in the Service Cell to permit an evaluation of the potential for release of significant quantities of radiological material or breach target stainless steel shell.	**Radiological** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes: 1.	**Mitigated Frequency** **U**

Event Number
SS2-1

Event Description:
Explosion in service cell.

Assumptions and Initial Conditions:
1. Assume spent target is stored in the service cell; contains 10 y equilibrium nuclides from tungsten target. (IC)
2. Explosion breaches target shroud and ignites combustibles in service cell. (IC)
3. Follow on small fire (SS1-1) that breaches service cell. (IC)
4. In addition to the spent target segments, spent/disposable items from the core vessel as well as spent IX Resin. (IC)
5. Only one component or IX Resin transfer operation will occur in the Service Cell at a time. (AC)
6. Spent/disposable components or IX Resin (other than the operation noted in Item 4 above) are contained in covered pits within the Service Cell.(AC/DF)

Causes:
1. Cleaning or decontamination agents contact other materials and produce explosive fumes.
2. Ignition sources could include spark from electrical short.
3. Thermal energy from electrical equipment.
4. Friction from bearings, gears, motors, and power tools.
5. Other unidentified ignition source.

Initiating Event Frequency
EU

Unmitigated Impact on Systems:
1. Potential for damage to in cell equipment.
2. Release of Ta/W, off-gases and/or contamination to surrounding area.
3. Plugging of primary filters from smoke.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Moderate	**WG1**: N/A	**WG1**: N/A
WG2: Low	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent an explosion in the service cell that leads to a release of radiological material above allowable limits.

Method of Detection:	
Visual.	
Audible.	
Differential pressure alarms associated with ventilation system.	

Preventive Features – Attributes:	**Credited:**
Lack of explosive materials. (AC/DF)	X
NFPA standards. (DC)	
Trained personnel. (AC)	
Operating Procedures and Training. (AC)	
Preventive maintenance program. (AC)	
Electrical equipment design code. (DF)	

Event Number
SS2-1

Mitigative Features – Attributes:	Credited:
Service Cell structure minimizes the potential for spreading the fire. (DF)	
SCE ventilation system. (DF)	
Air activity monitoring (RCT as needed). (AC)	
Fire Protection Program. (AC)	
Emergency Operating Procedures	
Radiation and contamination control procedures. (AC)	
Worker training. (AC)	
Activated components are stored in closed pits within the Service Cell. (DF/AC)	
Component design (shell material and construction) minimizes the potential for spreading the fire and release of material. (DF)	
Service cell liner and materials of construction minimizes the potential for spreading the fire. (DF)	
Fire detection and suppression system. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Evaluate the need for credited fire barriers.
2. Analysis to determine the potential for a detonation in the Service Cell to permit an evaluation of the potential for release of significant quantities of radiological material or breach target stainless steel shell.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: N/A	**Public**: N/A	**Public**: N/A
WG1: N/A	**WG1**: N/A	**WG1**: N/A
WG2: N/A	**WG2**: N/A	**WG2**: N/A

Notes:

Mitigated Frequency Prevented

Event Number

SS2-2

Event Description:
Breach of hydrogen transfer piping to cryogenic moderator system allows hydrogen to escape to the High Bay and into Service Cell and PIE Cell.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Hydrogen cloud is drawn into the service cell SCE via inlet air ductwork, is ignited in the service cell and explodes. (IC) 2. Assume spent target is stored in the service cell; contains 10 y equilibrium nuclides from tungsten target. (IC)	1. Impact by 50T high bay crane load as the result of crane failure or operator error. 2. Failure of the hydrogen piping due to corrosion. 3. Piping damaged during installation or maintenance. 4. Cracking at welds as the result of long- term vibration.	BEU

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Damage to Service Cell components and confinement. 2. Release of Ta/W, off-gases and/or contamination. 3. Plugging of primary filters from smoke.	**Public**: Low **WG1**: Moderate **WG2**: Low	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent a hydrogen transfer piping to cryogenic moderator system breach that allows hydrogen to escape to the High Bay and into Service Cell and PIE Cell.

Method of Detection:	
Hydrogen monitoring instrumentation.	
Loss of hydrogen system pressure detected by instrumentation.	

Event Number
SS2-2

Preventive Features – Attributes:	Credited:
Cryo system and piping design. (DF)	
Dilution occurs as the gas travels through to the high bay and service cell area (See Note 1). (DF)	
Crane inspection and certification program. (AC)	
Hoisting and rigging program. (AC)	
Personnel training. (AC	
Restrictions on crane travel in vicinity of hydrogen piping and HUR. (AC)	
Maintenance procedures. (AC)	
SOPs. (AC)	

Mitigative Features – Attributes:	Credited:
Service Cell structure. (DF)	
SCE confinement system with exhaust HEPA filters (See Note 1). (DF)	
Emergency response procedures. (AC)	
Worker training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Evaluate potential hydrogen release quantities and service cell concentrations.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Low	**Public**: N/A	**Public**: N/A
WG1: Moderate	**WG1**: N/A	**WG1**: N/A
WG2: Low	**WG2**: N/A	**WG2**: N/A

Notes:

1. The location of the Service Cell relative to the hydrogen piping and HUR as well as the inherent nature of hydrogen supports dilution occurring as the gas travels through to the high bay and to the service cell area making this event BEU.

Mitigated Frequency
BEU

Event Number SS2-3					
Event Description: Explosive (natural) gas from leak is drawn into target building through air supply system intakes and is deposited into High Bay, Service Cell, and PIE Cell.					
Assumptions and Initial Conditions: 1. Explosive gas cloud is drawn into the service cell via ventilation system inlet air ductwork, is ignited in the service cell. (IC) 2. Assume spent target is stored in the service cell; contains 10 y equilibrium nuclides from tungsten target. (IC) Note: this event assumes the natural gas line is located such that its breach cannot affect the target facility, and that no natural gas is piped into the target facility.	**Causes**: 1. Operator error. 2. Piping failure due to impact, corrosion, material defect, improper maintenance. 3. Ignition source: spark, thermal source, unidentified ignition source.				**Initiating Event Frequency** BEU
Unmitigated Impact on Systems: 1. Damage to Service Cell components and confinement. 2. Release of Ta/W, off gases, and/or contamination. 3. Plugging of primary filters from smoke.		**Unmitigated Consequences**			
		Radiological **Public**: N/A **WG1**: N/A **WG2**: N/A		**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Assure that the natural gas is not routed into or near the Target Building.					
Method of Detection:					
Odor of gas.					
Audible.					
Explosion visible.					

Event Number SS2-3			
Preventive Features – Attributes:			**Credited:**
Natural gas supply line piping design/ selection of material. (DF)			
Physical impact barriers or remote location of pipe (well off the road .or underground). (DF)			
Maintenance procedures. (AC)			
SOPs. (AC)			
Vehicle speed limits. (AC)			
Restrictions prohibiting vehicles carrying explosive gases (with the exception of hydrogen in approved bottles and transported under ORNL and STS procedures) within the vicinity of the target building. (AC)			
Mitigative Features – Attributes:			**Credited:**
Service Cell structure. (DF)			
An SCE confinement HVAC system with exhaust HEPA filters. (DF)			
Emergency response procedures. (AC)			
Worker training. (AC)			
Fire department response. (AC)			
Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: N/A **WG1**: N/A **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Notes:			**Mitigated Frequency** **BEU**

Event Number

SS3-1

Event Description:

Loss of confinement from service cell due to inadequate ventilation during a target transfer or manipulation in the service cell.

Assumptions and Initial Conditions:

1. Assume spent target is stored in the service cell; contains 10 y equilibrium nuclides from tungsten target. (IC)
2. In addition to the spent target segments, spent/disposable items from the core vessel as well as spent IX Resin. (IC)
3. Only one component or IX Resin transfer operation will occur in the Service Cell at a time. (AC)
4. Spent/disposable components or IX Resin (other than the operation noted in Item 2 above) are contained in covered pits within the Service Cell.(AC/DF)

Causes:

1. Loss of local SCE.
2. Inadequate service cell/maintenance.
3. Open area too large for SCE to adequately contain.
4. Leakage of airborne radiological material through improperly sealed or degraded concrete penetrations in the
   a. Service Cell walls.
   b. SCE and offgas ducting.
   c. Remote manipulator seals.
   d. Shielded window seals.
   e. Cell access plugs.
   f. Doors to Service Cell.

Initiating Event Frequency

A

Unmitigated Impact on Systems:

1. Allows leakage of radiological material to occupied areas.
2. Release of contamination outside the Service Cell into occupied areas.
3. Decontamination and cleanup effort required.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:

Assure that Service Cell confinement is maintained to limit contamination spread out of the Service Cell.

Method of Detection:	
Service cell negative pressure sensors.	
SCE instrumentation.	
Contamination surveys and periodic air activity surveys in areas adjacent to Service Cell.	

Event Number SS3-1				
Preventive Features – Attributes:				**Credited:**
Properly designed and sealed concrete penetrations and HVAC ducting. (DF)				
SCE has redundant fans and standby power supply. (DF)				
Periodic penetration/seal inspection. (AC)				
Periodic inspection for concrete shrinkage and settlement crack propagation. (AC)				
Mitigative Features – Attributes:				**Credited:**
Target building SCE system maintains negative pressure in the Service Cell. (DF)				
Differential pressure detection / alarm on loss of negative pressure between TC and adjacent areas. (EC)				
Radiation protection program. (AC)				
Contamination control program. (AC)				
EOPs. (AC)				
Worker training. (AC)				
SOPs requiring evacuation of adjacent areas on loss of negative pressure alarm. (AC)				
Planned analysis, assumption validations, and Risk/Opportunities: 1. Evaluate potential loss of confinement scenarios.	**Mitigated Consequences:**			
	Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Notes:				**Mitigated Frequency** **A**

Event Number				
SS3-2				
Event Description: The in cell target lifting device (either the Service Cell Crane or a portable hoist drops the target segment when lowering into a service cell pit.				
Assumptions and Initial Conditions: 1. The lifting device or rigging fails and drops the segment. (IC) 2. Breach of spent target shroud. (IC) 3. Assume spent target contains 10 y equilibrium nuclides from tungsten target. (IC) 4. Component is transferred into and out of the pit via a cask. (AC) 5. Personnel are in the cell during this activity. (IC) 6. The SCE and HOG systems are assumed to be operational during this operation. (IC)	**Causes**: 1. Speed control electric short. 2. Hoist failure. 3. Rigging failure. 4. Operator error.			**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. Release of target material, confined gases, and/or contamination. 2. Damage to in-cell components (service cell crane or other equipment). 3. Difficult and expensive recovery required. 4. Direct radiation exposure during recovery efforts.	**Unmitigated Consequences**			
	Radiological **Public**: Negligible **WG1**: Moderate **WG2**: Negligible		**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Prevent a target segment drop that results in release of radiological material above allowable limits when handling in the service cell.				
Method of Detection:				
Erratic operation of drive motor in operating gallery.				
Impact vibration.				
In-cell cameras.				
Visual.				
Audible.				

Event Number SS3-2			
Preventive Features – Attributes:			**Credited:**
Correct drive motor sizing motor. (DF)			
Overspeed trip. (DF)			
Fail safe brake on motor or winch (DF)			
Operating procedures. (AC)			
Motor preventive maintenance. (AC)			
Critical lift program (including hoisting and rigging). (AC)			
Trained operators. (AC)			
Mitigative Features – Attributes:			**Credited:**
SCE in the service cell and the HOG confinement in pit design (See Note 1). (DF)			X
Thick service cell walls provide confinement and shielding. (DF)			
Emergency operating procedures. (AC)			
Worker training. (AC)			
Procedure for evacuation of adjacent areas on loss of negative pressure/flow. (AC)			
Planned analysis, assumption validations, and Risk/Opportunities: 1. Consequence evaluation.	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Notes: 1. The SCE and HOG systems must be operational during this operation.			**Mitigated Frequency** **A**

Event Number

SS3-3

Event Description:
Target inadequate initial dewatering prior to target removal and transport to service cell.

Assumptions and Initial Conditions:
1. Assume spent target is stored in the service cell; contains 10 y equilibrium nuclides from tungsten target. (IC)
2. SCE System operates as designed. (IC)
3. Corrosion of stored target occurs from breaches in Inconel cladding. (IC)
4. Water level in component is above cutting level of component. (IC)

Causes:
1. Breaches caused by mechanical failure or flow-induced vibration during target service life.
2. Ineffective dewatering of target.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Contamination of service cell.
2. See remote handling events for impacts during movement to the service cell.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Assure that Target initial dewatering is complete prior to target removal and transport to service cell.

Method of Detection:	
Periodic radiation surveys.	

Preventive Features – Attributes:	**Credited:**
Use of deionized water-cooling minimized corrosion. (EC)	
Filters and ion exchange system removes dissolved ions and particulates. (EC)	
Operating procedures. (AC)	
Rad Con checks on cooling system. (AC)	
Access control to cooling system. (AC)	

Event Number	
SS3-3	
Mitigative Features – Attributes:	**Credited:**
Coolant system shielding. (AC)	
Radiation Control Procedures. (AC)	
Trained personnel. (AC)	
ALARA Program. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Notes:			**Mitigated Frequency** **A**

Event Number SS3-4				
Event Description: Vacuum pump connection line leaks gas to the service cell during spent target, PBW, MRA, or TVP drying operations.				
Assumptions and Initial Conditions: 1. Assume spent target, PBW, MRA, or TVP is stored in the service cell; contains bounding equilibrium nuclides for that component from operating the tungsten target. (See Note 2) (IC) 2. Vacuum pumping and processing is performed in the HPV. (DF) 3. Flexible connections will be provided in the Service Cell to connect to the equipment for drying. (DF) 4. Personnel are permitted in the Service Cell during component drying operations. (AC) 5. Connections in the Service Cell are all in vacuum during drying operation. (DF)	**Causes**: 1. Discharge line leakage or disconnected. 2. Operator error.			**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. Airborne activity with exposure to operating staff. 2. Contamination of surrounding operating areas or equipment. 3. Release of off-gas and tritium oxides to service cell and SCE. 4. Contamination of surrounding areas.	**Unmitigated Consequences**			
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A		**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Prevent a release of significant quantities of radiological material above allowable limits to the Service Cell during component drying.				
Method of Detection:				
Audible.				
Visual				
Radiation monitoring of personnel if potential contamination.				
RCT routine monitoring for contamination.				

Event Number

SS3-4

Preventive Features – Attributes:	Credited:
Mechanical design codes and standards. (DF)	
Trained personnel. (AC)	
Operating Procedures and Training. (AC)	
Only vacuum piping in the Service Cell. (DF)	

Mitigative Features – Attributes:	Credited:
HOG ventilation in service pits (DF)	
Activated components are stored in closed pits within the Service Cell. (DF/AC)	
Air activity monitoring (RCT if needed). (EC)	
Emergency Operating Procedures. (AC)	
Radiation and contamination control procedures. (AC)	
Worker training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:

1. The process for drying components has not been finalized, but the event is not expected to significantly change.
2. Radionuclide inventories are based on the component or system. For example, target segments are assumed to have a 10-year life and more permanent components such as the target drive shaft is assumed to have a 40-year life. Evaluations are based on the worst-case radionuclide inventory anticipated for the activity. Event scenarios are evaluated based on the worst inventory for activities that could be present.

Mitigated Frequency
A

Event Number
SS3-5

Event Description:
Shear jams when shearing spent target piping or TVP components during size reduction for waste disposal purposes.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Assume spent target, PBW, MRA, or TVP is stored in the service cell; contains bounding equilibrium nuclides for that component from operating the tungsten target. (See Note 2) (IC)	1. Wear on mechanism. 2. Operator error. 3. Low hydraulic pressure/ leak of hydraulic fluid. 4. Misalignment of shear to workpiece.	U

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Airborne activity with exposure to operating staff. 2. Exposure to personnel during recovery operations.	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent a release of significant quantities of radiological material to the Service Cell during shearing or other size reduction operations.

Method of Detection:	
Air activity monitor in the stack.	
Radiation monitoring of personnel if potential contamination.	
RCT routine monitoring for radiation dose rates and contamination.	

Event Number
SS3-5

Preventive Features – Attributes:	Credited:
Mechanical design codes and standards. (DF)	
Trained personnel. (AC)	
Operating Procedures and Training. (AC)	
Preventive maintenance program. (AC)	

Mitigative Features – Attributes:	Credited:
SCE ventilation system. (EC)	
Activated components are stored in closed pits within the Service Cell. (DF/AC)	
Air activity monitoring (RCT if needed). (EC)	
Radiation and contamination control procedures. (AC)	
Worker training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. Evaluate Equipment design with recovery capability.	**Radiological** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
1. The process for handling these components has not been finalized, but the event is not expected to significantly change. 2. Radionuclide inventories are based on the component or system. For example, target segments are assumed to have a 10-year life and more permanent components such as the target drive shaft is assumed to have a 40-year life. Evaluations are based on the worst-case radionuclide inventory anticipated for the activity. Event scenarios are evaluated based on the worst inventory for activities that could be present.	U

Event Number

SS4-1

Event Description:
Roof access hatch/plug to the service cell is opened while a source is present and unshielded in the service cell and radiation controls are not implemented for personnel in the High Bay.

Assumptions and Initial Conditions:

1. Assume spent target is stored in the service cell; contains 10 y equilibrium nuclides from tungsten target.

Causes:

1. Worker error.
2. Failure to follow procedures.

Initiating Event Frequency
A

Unmitigated Impact on Systems:

1. Event has no impact on systems but has significant potential consequences to personnel.
2. Excessive worker exposure to radiation from the service cell.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: High	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent worker exposure above allowable limits from components within the service cell with the roof hatch/pug open.

Method of Detection:	
Visual.	
Audible.	
High radiation alarm in the area.	

Event Number

SS4-1

Preventive Features – Attributes:	**Credited:**
Procedures and RCT Holds to ensure the access hatch/plug remains shut when a source is present within the service cell and not secured in a pit with the pit lid in place or a transfer cask is in place, or other radiological controls are in place to provide adequate shielding. (AC)	X
Operating procedures. (AC)	
Trained personnel. (AC)	
Shielding or access limitations on personnel when the crane removes the access hatch/plug. (AC)	X

Mitigative Features – Attributes:	**Credited:**
Transfer cask and/or temporary shielding when hatch/plug is removed. (AC)	
Trained operators. (AC)	
Access check of service cell prior to removing crane access hatch/plug. (AC)	
Access control to service cell. (AC)	
Radiation Control procedures. (AC)	
ALARA program. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Shielding calculations for sources within service cell. 2. Consequence evaluations.	**Radiological** **Public**: N/A **WG1**: N/A **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. The service cell room hatches/plugs are for equipment access only and not for personnel access. Administrative controls are required to secure the area before the hatch is opened either to place a transfer cask in the opening or to remove equipment.	Prevented

Event Number					
SS4-2					
Event Description: Load drops into service cell from: 1) high bay crane or 2) in-cell crane.					
Assumptions and Initial Conditions: 1. Load is dropped into the service cell while lowering the transfer cask. (IC) 2. Load is dropped from in-cell crane. (IC) 3. Assume spent target is stored in the service cell; contains 10 y equilibrium nuclides from tungsten target. (IC)		**Causes**: 1. Operator error. 2. Crane mechanical or electronic control failure. 3. Hoisting or rigging fault.			**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. High radiation in the high bay. 2. Damage to transfer cask, pits, waste cask, waste liner or other components. 3. Potential increased radiation in the adjacent areas. 4. Service Cell and PIE Cell operations prevented until repairs are completed. 5. Potential for release of target material, remaining cooling water, and/or contamination. 6. High exposure during recovery operations.		**Unmitigated Consequences**			
		Radiological **Public**: Negligible **WG1**: High **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A		**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Prevent a load drop or suspended load into or inside the service cell.					
Method of Detection:					
Visual.					
Audible.					
High radiation alarm in High Bay.					

Event Number

SS4-2

Preventive Features – Attributes:	**Credited:**
Crane travel limits. (EC/DF)	
Crane speed limits/governor. (EC/DF)	
SOPs. (AC)	
Trained crane operators. (AD)	
Critical Lift Procedures (AC)	X
Crane design, certification, and preventive maintenance. (DF/AC)	X
Hoisting and rigging program (AC)	X

Mitigative Features – Attributes:	**Credited:**
Transfer Cask shielding. (DF)	
Procedures to ensure the transfer cask and any required radiation controls (e.g., temporary shieling) is in place before starting crane operations with the source. (AC)	
EOPs. (AC)	
Trained personnel. (AC)	
Evacuation of affected area. (AC)	
High bay Area Radiation Monitor (ARM) alarm (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Consequence evaluations
2. Shielding calculations for sources within service cell.

Mitigated Consequences:

Radiological	**Chemical**	**ODH**
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:

Mitigated Frequency
A

Event Number
SS4-3

Event Description:
Service Cell personnel access door is opened inadvertently while a source is present and unshielded in the service cell.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. Assume spent target is stored in the service cell; contains 10 y equilibrium nuclides from tungsten target. (IC)	1. Worker error.	A

Unmitigated Impact on Systems:
1. Event has no impact on systems but has a potentially significant consequences to personnel.
2. Excessive worker exposure to radiation from the service cell.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: High	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent a worker from entering the service cell and receiving exposure from components above allowable limits within the service cell.

Method of Detection:	
Visual.	
Audible.	
PPS Service Cell Door interlock system prevents door operation when a source is present.	
High Area Radiation Monitor (ARM) alarm.	

Event Number
SS4-3

Preventive Features – Attributes:	Credited:
PPS Service Cell Door interlock system prevents door operation when a source is present (See Note 2). (EC)	X
Operating procedures. (AC)	
Trained personnel. (AC)	

Mitigative Features – Attributes:	Credited:
Access check in service cell prior to opening personnel access door. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	X
ALARA program. (AC)	
Area Radiation Monitors (ARM). (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:
1. Shielding calculations for sources within service cell.
2. Consequence evaluations.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: N/A	**Public**: N/A	**Public**: N/A
WG1: N/A	**WG1**: N/A	**WG1**: N/A
WG2: N/A	**WG2**: N/A	**WG2**: N/A

Notes:
1. Based on the number of potential conditions in the Service Cell, both visual (camera) and radiation monitoring are required to guide Control Room authorization for entry into the service cell.
2. PPS Service Cell Door interlock system is designated as the Service Cell Interlock System.

Mitigated Frequency
Prevented

Event Number

SS4-4

Event Description:
Cannot retrieve piping section, target foot, or stored spent PBW, TVP or MRA from storage pit.

Assumptions and Initial Conditions:
1. Assume spent target, PBW, MRA, or TVP is stored in the service cell; contains bounding equilibrium nuclides for that component from operating the tungsten target. (See Note 2) (IC)

Causes:
1. Damage to lifting hardware or in-cell crane.
2. Piping or component lands outside of disposal liner.
3. Piping or component too long for disposal liner.
4. Operator error.

Initiating Event Frequency
U

Unmitigated Impact on Systems:
1. Exposure to personnel during recovery operations.
2. Operational impact on Service Cell operations.
3. Potential damage to service cell liner.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent a component from being trapped in a Service Cell pit in a condition that precludes its removal using normal operational practices.

Method of Detection:

Visual

Event Number

SS4-4

Preventive Features – Attributes:	Credited:
Operating Procedures and Training. (AC)	
Preventive maintenance program. (AC)	
Mechanical design codes and standards. (DF)	
Trained personnel. (AC)	

Mitigative Features – Attributes:	Credited:
SCE ventilation system. (EC)	
Radiation and contamination control procedures. (AC)	
Worker training. (AC)	
Detailed activated component handling procedures. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:

1. The process for handling these components has not been finalized, but the event is not expected to significantly change.
2. Radionuclide inventories are based on the component or system. For example, target segments are assumed to have a 10-year life and more permanent components such as the target drive shaft is assumed to have a 40-year life. Evaluations are based on the worst-case radionuclide inventory anticipated for the activity. Event scenarios are evaluated based on the worst inventory for activities that could be present.

Mitigated Frequency
U

Event Number

SS4-6

Event Description:
Excess exposure during target, PBW, TVP, or MRA handling in service cell.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Assume spent target, PBW, MRA, or TVP is stored in the service cell; contains bounding equilibrium nuclides for that component from operating the tungsten target. (See Note 2) (IC) 2. Normal handling of components in the Service Cell and personnel are in the Service Cell. (IC)	1. Inadvertent crane operation. 2. Operator error. 3. Personnel are in the service cell when they are not permitted. 4. Inadequate procedures	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Exposure to personnel during operations.	**Public**: Negligible **WG1**: Moderate **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent an exposure to personnel above allowable limits in the Service Cell during target, PBW, TVP, or MRA handling.

Method of Detection:	
High radiation alarm in the area.	
Worker worn dosemeters.	

Event Number

SS4-6

Preventive Features – Attributes:	**Credited:**
Mechanical design codes and standards. (DF)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	X
Operating Procedures and Training. (AC)	
Control Room notification prior to Service Cell personnel entries. (EC)	
Service cell radiation monitors (EC)	X

Mitigative Features – Attributes:	**Credited:**
Activated components are stored in closed pits within the Service Cell. (DF/AC)	
SCE ventilation system. (EC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	
Radiation and contamination control procedures. (AC)	
Worker training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: N/A **WG1**: N/A **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency Prevented**
1. The process for handling these components has not been finalized, but the event is not expected to significantly change. 2. Radionuclide inventories are based on the component or system. For example, target segments are assumed to have a 10-year life and more permanent components such as the target drive shaft is assumed to have a 40-year life. Evaluations are based on the worst-case radionuclide inventory anticipated for the activity. Event scenarios are evaluated based on the worst inventory for activities that could be present.	

Event Number
SS4-7

Event Description:
Inadequate dewatering of IX resin prior to shipment offsite.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Assume spent target, PBW, MRA, or TVP is stored in the service cell; contains bounding equilibrium nuclides for that component from operating the tungsten target. (See Note 2) (IC)	1. Shipping package malfunctions causing package to not drain. 2. Inadequate vacuum. 3. Operator error.	A

Unmitigated Impact on Systems:
1. Violation of DOE/DOT regulations impacting future waste handling operations.
2. Possible worker exposure during recovery.

Unmitigated Consequences		
Radiological	**Chemical**	**ODH**
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Ensure that IX resin shipping packages meets shipping requirements prior to shipment offsite.

Method of Detection:

Shipping inspection.

Event Number

SS4-7

Preventive Features – Attributes:	Credited:
Trained personnel. (AC)	
Operating Procedures and Training. (AC)	
Shipping package inspection and verification. (AC)	
ORNL Waste Management oversight (AC)	

Mitigative Features – Attributes:	Credited:
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	
Radiation and contamination control procedures. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:

1. The process for handling these components has not been finalized, but the event is not expected to significantly change.
2. Radionuclide inventories are based on the component or system. For example, target segments are assumed to have a 10-year life and more permanent components such as the target drive shaft is assumed to have a 40-year life. Evaluations are based on the worst-case radionuclide inventory anticipated for the activity. Event scenarios are evaluated based on the worst inventory for activities that could be present.

Mitigated Frequency

A

Event Number

SS4-8

Event Description:
During transport of the cask with a target segment a fault causes the cask to remain in the high bay and suspended from the high bay crane for an extended time.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. The transfer cask while suspended from the high bay crane becomes "stuck" between the Target Drive Room and the Service Cell. (IC) 2. Assume spent target segment contains 10 y equilibrium nuclides from operation at design conditions. (IC)	1. Operator error. 2. Crane mechanical or electronic control failure. 3. Hoisting or rigging fault.	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. High radiation in the high bay. 2. Potential increased radiation in the adjacent areas. 3. Excess exposure during recovery operations.	**Public**: Negligible **WG1**: Low **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Mitigate the radiologival consequences of a suspended load becoming "stuck" in the high bay.

Method of Detection:	
Visual.	
Audible.	
Area Radiation Monitors (ARM) in High Bay.	

Event Number SS4-8	
Preventive Features – Attributes:	**Credited:**
Crane travel limits. (EC)	
Crane speed limits/governor. (DF)	
SOPs. (AC)	
Trained crane operators. (AD)	
Crane certification and preventive maintenance. (AC)	

Mitigative Features – Attributes:	**Credited:**
Transfer Cask shielding. (DF)	
Hoisting and rigging program.	
Procedures to ensure the transfer cask and any required radiation controls (e.g., temporary shieling) is in place before starting crane operations with the source. (AC)	
EOPs. (AC)	
Trained personnel. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Consequence evaluations 2. Shielding calculations for sources within service cell.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Notes:			**Mitigated Frequency** **A**

Event Number

SS5-1

Event Description:

Localized fire in Service Cell. (See SS1-1 for radiological exposure evaluation)

Assumptions and Initial Conditions:

1. Assume spent target is stored in the service cell; contains 10 y equilibrium nuclides from tungsten target. (IC)
2. Fire is assumed to breach target shroud and exit service cell to surrounding areas. (IC)
3. In addition to the spent target segments, spent/disposable items from the core vessel as well as spent IX Resin. (IC)
4. Only one component or IX Resin transfer operation will occur in the Service Cell at a time. (AC)
5. Spent/disposable components or IX Resin (other than the operation noted in Item 4 above) are contained in covered pits within the Service Cell.(AC/DF)

Causes:

1. Excess combustible inventory.
2. Cleaning or decontamination agents contact other materials and produce flammable fumes.
3. Electrical equipment short.
4. Thermal energy from electrical equipment.
5. Friction from bearings, gears, motors, and power tools.
6. Human error.
7. Other ignition source.

Initiating Event Frequency

U

Unmitigated Impact on Systems:

1. Shutdown of the affected area.
2. Potential for damage to surrounding operating areas or equipment.
3. Release of activated component material and/or contamination.
4. Contamination of surrounding areas.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Moderate	**WG1**: N/A	**WG1**: Low
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:

Prevent a fire in the Service Cell from releasing significant quantities of radiological material to WG1 above allowable limits.

Method of Detection:	
Fire detection system.	
Visual.	
Loss of instrument signals.	

Event Number	
SS5-1	

Preventive Features – Attributes:	**Credited:**
Electrical equipment design code. (DF)	
NFPA standards. (DC)	
Mechanical design codes and standards. (DF)	
Combustible material control program. (AC)	
Trained personnel. (AC)	
Operating Procedures and Training. (AC)	
Worker training (AC)	
Preventive maintenance program. (AC)	

Mitigative Features – Attributes:	**Credited:**
Service cell design minimizes the potential for spreading the fire. (DF)	X
Component design (shell material and construction) minimizes the potential for spreading the fire and release of material. (DF)	X
Activated components are stored in closed pits within the Service Cell. (DF/AC)	
Fire detection and suppression system. (EC)	
SCE ventilation system. (EC)	
Air activity monitoring (RCT as needed). (AC)	
Fire Protection Program. (AC)	
Emergency Operating Procedures. (AC)	
Radiation and contamination control procedures. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Consequence evaluations.
2. Project Fire Hazard Analysis (PFHA).
3. Assessment of fires per NFPA 801. .
4. Analysis to determine the maximum fire size that could exist in the Service Cell to permit an evaluation of the potential for release of significant quantities of radiological material or breach target stainless steel shell.

Mitigated Consequences:

Radiological	**Chemical**	**ODH**
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: Low
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:

Mitigated Frequency
U

Event Number SSP1-1				
Event Description: Localized fire in PIE Cell.				
Assumptions and Initial Conditions: 1. Assume one spent target component in the PIE Cell; contains 10 y equilibrium nuclides from tungsten target. (IC) 2. Fire is assumed to breach target shroud and exit PIE Cell to surrounding areas. (IC) 3. Personnel are assumed to be in the Service Cell while PIE Cell operations occur. (IC) 4. Fire detection system detects fire in service cell and actuates water mist system while personnel are in the service cell (ODH consideration only for IC – See Event SSP5-1 for ODH evaluation). 5. It is assumed that the only spent component to be handled in the PIE Cell is the target segment. (AC)	**Causes**: 1. Excess combustible inventory. 2. Cleaning or decontamination agents contact other materials and produce flammable fumes. 3. Electrical equipment short. 4. Thermal energy from electrical equipment. 5. Friction from bearings, gears, motors, and power tools. 6. Human error. 7. Other ignition source.			**Initiating Event Frequency** U
Unmitigated Impact on Systems: 1. Shutdown of the affected area. 2. Potential for damage to surrounding operating areas or equipment. 3. Release of activated component material and/or contamination. 4. Plugging of in-cell filters from smoke. 5. Contamination of surrounding areas.	**Unmitigated Consequences**			
	Radiological **Public**: Negligible **WG1**: Moderate **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: Low **WG2**: N/A	
Safety Function: Prevent a fire in the PIE Cell from releasing significant quantities of radiological material.				
Method of Detection:				
Fire detection system.				
Visual.				
Loss of instrument signals.				

Event Number	
SSP1-1	
Preventive Features – Attributes:	**Credited:**
Electrical equipment design code. (DF)	
NFPA standards. (DC)	
Mechanical design codes and standards. (DF)	
Combustible material control program. (AC)	
Trained personnel. (AC)	
Operating Procedures and Training. (AC)	
Preventive maintenance program. (AC)	
Mitigative Features – Attributes:	**Credited:**
PIE and service cell design minimizes the potential for spreading the fire. (DF)	X
Component design (shell material and construction) minimizes the potential for spreading the fire and release of material. (DF)	X
Activated components are stored in closed pits within the Service Cell. (DF/AC)	
Fire detection system detects fire in service cell and actuates water mist system while personnel are in the service cell (IC). (EC)	
SCE ventilation system. (EC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	
Fire Protection Program. (AC)	
Emergency Operating Procedures. (AC)	
Radiation and contamination control procedures. (AC)	

Event Number			
SSP1-1			
Planned analysis, assumption validations, and Risk/Opportunities: 1. Perform consequence evaluations. 2. Project Fire Hazard Analysis (PFHA). 3. Assessment of fires per NFPA 801. 4. Analysis to determine the maximum fire size that could exist in the PIE Cell to permit an evaluation of the potential for release of significant quantities of radiological material or breach target stainless steel shell.	**Mitigated Consequences:** **Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	 **Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	 **ODH** **Public**: N/A **WG1**: Low **WG2**: N/A
Notes:			**Mitigated Frequency** **U**

Event Number

SSP2-1

Event Description:
Explosion in PIE Cell.

Assumptions and Initial Conditions:

1. Assume spent target component in the PIE Cell; contains 10 y equilibrium nuclides from tungsten target. (IC)
2. Explosion breaches target shroud and ignites combustibles in PIE Cell. (IC)
3. Follow on small fire (SS1-1) that breaches PIE Cell. (IC)
4. Personnel are assumed to be in the Service Cell while PIE Cell operations occur. (IC)

Causes:

1. Hydrogen buildup from radiolysis of coolant left in target.
2. Cleaning or decontamination agents contact other materials and produce explosive fumes.
3. Ignition sources could include spark from electrical short.
4. Thermal energy from lighting or electrical equipment.
5. Friction from bearings, gears, motors, and power tools.
6. Other unidentified ignition source.

Initiating Event Frequency
EU

Unmitigated Impact on Systems:

1. Potential for damage to in cell equipment.
2. Release of activated component material and/or contamination to surrounding area.
3. Actuation of water mist system introduces ODH in service cell.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Moderate	**WG1**: N/A	**WG1**: Low
WG2: Low	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent an explosion in the PIE Cell from releasing significant quantities of radiological material above allowable limits.

Method of Detection:	
Visual.	
Audible.	
Differential pressure alarms associated with ventilation system.	

Preventive Features – Attributes:	**Credited:**
Lack of explosive materials; Combustible control program. (DF/AC)	X
Trained personnel. (AC)	
Operating Procedures and Training. (AC)	
Preventive maintenance program. (AC)	

Event Number
SSP2-1

Mitigative Features – Attributes:	Credited:
Building structure minimizes the potential for spreading the fire. (DF)	
SCE ventilation system. (DF)	
Air activity monitoring (RCT as needed). (AC)	
PIE Cell design provides an inherent fire barrier. (DF)	
Emergency Operating Procedures. (AC)	
Radiation and contamination control procedures. (AC)	
Worker training. (AC)	
Activated components are stored in closed pits within the Service Cell. (DF/AC)	
Component design (shell material and construction) minimizes the potential for spreading the fire and release of material. (DF)	
PIE cell liner and materials of construction minimizes the potential for spreading the fire. (DF)	
Fire detection and suppression system. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Perform accident analysis.
2. Project Fire Hazard Analysis (PFHA).
3. Assessment of fires per NFPA 801. .
4. Analysis to determine the maximum fire size that could exist in the PIE Cell to permit an evaluation of the potential for release of significant quantities of radiological material or breach target stainless steel shell.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: N/A	**Public**: N/A	**Public**: N/A
WG1: N/A	**WG1**: N/A	**WG1**: N/A
WG2: N/A	**WG2**: N/A	**WG2**: N/A

Notes:

Mitigated Frequency
Prevented

Event Number SSP3-1				
Event Description: Loss of confinement from PIE Cell.				
Assumptions and Initial Conditions: 1. Assume spent target component in the PIE Cell; contains 10 y equilibrium nuclides from tungsten target. (IC) 2. Assessment includes contamination only. (IC) 3. No operations in the PIE Cell will create airborne particulate from grinding and cutting. (IC/AC) 4. Workers are permitted in the Service Cell during PIE operations. (IC)	**Causes**: 1. Loss of SCE. 2. Inadequate PIE Cell/maintenance. 3. Leakage of airborne radiological material through improperly sealed or degraded concrete penetrations in the a. PIE Cell walls. b. PCE and offgas ducting. c. Remote manipulator seals. d. Shielded window seals. e. Cell access plugs. f. .Small equipment pass-through			**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. Uncontrolled release of radiological material to occupied areas. 2. Release of contamination outside the PIE Cell into occupied areas. 3. Decontamination and cleanup effort required.	**Unmitigated Consequences**			
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Safety Function: Assure that PIE Cell confinement is maintained to limit contamination spread out of the PIE Cell.				
Method of Detection:				
PIE Cell negative pressure sensors.				
PCE instrumentation.				
Contamination surveys and periodic air activity surveys in areas adjacent to PIE Cell.				

Event Number
SSP3-1

Preventive Features – Attributes:	Credited:
Properly designed and sealed concrete penetrations and SCE ducting. (DF)	
SCE has redundant fans and standby power supply. (DF)	
Periodic penetration/seal inspection. (AC)	
Periodic inspection for concrete shrinkage and settlement crack propagation. (AC)	

Mitigative Features – Attributes:	Credited:
Target building SCE system maintains negative pressure in the PIE Cell. (EC)	
Differential pressure detection / alarm on loss of negative pressure between PIE Cell and adjacent areas. (EC)	
Radiation protection program. (AC)	
Contamination control program. (AC)	
EOPs. (AC)	
Worker training. (AC)	
SOPs requiring evacuation of adjacent areas on loss of negative pressure alarm. (AC)	
The PIE Cell includes in cell HEPA filters for the ventilation exhaust. (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Consequence evaluations	**Radiological** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency** **A**

Event Number

SSP3-3

Event Description:
Target drying not complete prior to target transport to PIE Cell. Leakage into PIE cell from inadequately drained target.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Assume spent target component in the PIE Cell; contains 10 y equilibrium nuclides from tungsten target. (IC) 2. No personnel are permitted in the PIE Cell (IC)	1. Operator Error. 2. Ineffective drying of target. 3. Shear of piping releasing inadequately drained water.	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
1. Water based contamination of area including PCE. 2. Contamination of PIE Cell..	**Radiological** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent an activated component being brought into the PIE Cell until component drying has been completed.

Method of Detection:	
Periodic radiation surveys.	

Preventive Features – Attributes:	**Credited:**
Inspection of target prior to transport (EC)	
Operating procedures. (AC)	

Event Number			
SSP3-3			
Mitigative Features – Attributes:			**Credited:**
Activated Component handling procedures. (AC)			
Radiation Control Procedures. (AC)			
Trained personnel. (AC)			
ALARA Program. (AC)			
Use of deionized water-cooling minimized corrosion. (EC)			
Filters and ion exchange system removes dissolved ions and particulates. (DF)			
Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Notes:			**Mitigated Frequency** **A**

Event Number					
SSP4-1					
Event Description: Access hatch to the PIE Cell is opened inadvertently prior to verification that activation and contamination levels permit opening or entry.					
Assumptions and Initial Conditions: 1. Assume spent components in the PIE Cell; contains bounding equilibrium nuclides from the material (See Note 1). (IC)		**Causes**: 1. Worker error.			**Initiating Event Frequency** A
Unmitigated Impact on Systems: 1. Event has no impact on systems but has significant consequences to personnel. 2. Excessive worker exposure to radiation from the PIE Cell.			**Unmitigated Consequences**		
			Radiological **Public**: Negligible **WG1**: High **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Prevent personnel exposure from opening PIE Cell access hatch prior to verification that activation and contamination levels permit opening or entry.					
Method of Detection:					
Visual.					
Audible.					
Service cell radiation monitor					

Event Number

SSP4-1

Preventive Features – Attributes:	Credited:
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	X
Operating procedures. (AC)	
RCT Hold prior to PIE Cell access hatch opening. (AC)	X
Lock on PIE cell hatch lifting device	

Mitigative Features – Attributes:	Credited:
Trained operators. (AC)	
Access check in PIE Cell prior to opening access hatch. (AC)	
Radiation Control procedures. (AC)	
ALARA program. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. Shielding calculations for sources within PIE Cell 2. Consequence evaluations.	**Radiological** **Public**: N/A **WG1**: N/A **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
1. Radionuclide inventories are based on the component or system. For example, target segments are assumed to have a 10-year life and more permanent components such as the target drive shaft is assumed to have a 40-year life. Evaluations are based on the worst-case radionuclide inventory anticipated for the activity. Event scenarios are evaluated based on the worst inventory for activities that could be present.	Prevented

Event Number

SSP4-2

Event Description:
Load suspended from PIE Cell crane swings during sudden lateral movement of crane trolley.

Assumptions and Initial Conditions:
1. Load swings into shielded viewing window, partially or fully shattering the window. (IC)
2. Assume spent target component in the PIE Cell; contains 10 y equilibrium nuclides from tungsten target. (IC)

Causes:
1. Operator error.
2. Crane mechanical or electronic control failure.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. High radiation in Service Cell operating gallery.
2. Potential increased radiation in the adjacent areas.
3. Shield window replacement required.
4. This event has significant consequences to personnel in the operating gallery if they cannot immediately evacuate excessive worker exposure to radiation.
5. Potential for release of target component material and/or contamination.
6. Personnel are permitted in the Service Cell during PIE Cell operations. (IC)

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: High	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent a Load suspended from the PIE Cell crane from impacting a viewing window.

Method of Detection:	
Visual.	
Audible.	
High radiation alarm in operating gallery.	

Event Number	
SSP4-2	

Preventive Features – Attributes:	**Credited:**
Crane lateral travel limits. (EC/DF)	X
Crane speed limits/governor. (EC/DF)	X
SOPs. (AC)	
Trained crane operators. (AC)	
Crane certification and preventive maintenance. (DF/AC)	

Mitigative Features – Attributes:	**Credited:**
Thick tempered cover glass in window. (DF)	
Multiple glass pane layers in shielded window generally do not fall out when shattered provided by concrete PIE Cell walls. (DF)	
Shielding between windows. (DF)	
EOPs. (AC)	
Trained personnel. (AC)	
Evacuation of affected area. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Consequence evaluation 2. Shielding calculations for sources within PIE Cell.	**Radiological** **Public**: N/A **WG1**: N/A **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. Material handling within the PIE cell has not been defined. Preventive controls need to be revisited when the design is completed.	Prevented

Event Number SSP4-3					
Event Description: Excess exposure during inspection/leak testing of target foot.					
Assumptions and Initial Conditions: 1. Assume spent target contains 10 y equilibrium nuclides from tungsten target. (IC) 2. Personnel are in the Service Cell and not in the PIE cell during this operation. (IC)		**Causes**: 1. Backup of leak test fluid. 2. Target foot jams in exposed location. 3. Inadequate shielding. 4. Operator error.			**Initiating Event Frequency** U
Unmitigated Impact on Systems: 1. Service Cell contamination impacting operations in this area. 2. Exposure to personnel during operations. 3. Exposure to personnel during recovery operations. 4. Contamination release to operator gallery.		**Unmitigated Consequences**			
		Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible		**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Prevent a radiological exposure above allowable limits to personnel in the Service Cell during inspection/leak testing of the target foot.					
Method of Detection:					
Visual.					
Audible.					
High radiation alarm in the area.					

Event Number
SSP4-3

Preventive Features – Attributes:	Credited:
Mechanical design codes and standards. (DF)	
Trained personnel. (AC)	
Operating Procedures and Training. (AC)	
Preventive maintenance program. (AC)	

Mitigative Features – Attributes:	Credited:
Testing equipment design. (DF)	
SCE ventilation system. (EC)	
Radiation and contamination control procedures. (AC)	
Worker training. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
1. The process for handling these components has not been finalized, but the event is not expected to significantly change. 2. Radionuclide inventories are based on the component or system. For example, target segments are assumed to have a 10-year life and more permanent components such as the target drive shaft is assumed to have a 40-year life. Evaluations are based on the worst-case radionuclide inventory anticipated for the activity. Event scenarios are evaluated based on the worst inventory for activities that could be present.	U

Event Number

SSP5-1

Event Description:
Localized fire in PIE Cell. (See SSP1-1 for radiological exposure evaluation)

Assumptions and Initial Conditions:
1. Assume one spent target component in the PIE Cell; contains 10 y equilibrium nuclides from tungsten target. (IC)
2. Fire is assumed to breach target shroud and exit PIE Cell to surrounding areas. (IC)
3. Personnel are assumed to be in the Service Cell while PIE Cell operations occur. (IC)
4. Fire detection system detects fire in service cell and actuates water mist system while personnel are in the service cell (IC)

Causes:
1. Excess combustible inventory.
2. Cleaning or decontamination agents contact other materials and produce flammable fumes.
3. Electrical equipment short.
4. Thermal energy from electrical equipment.
5. Friction from bearings, gears, motors, and power tools.
6. Human error.
7. Other ignition source.

Initiating Event Frequency
U

Unmitigated Impact on Systems:
1. Shutdown of the affected area.
2. Potential for damage to surrounding operating areas or equipment.
3. Release of activated component material and/or contamination.
4. Plugging of in-cell filters from smoke.
5. Contamination of surrounding areas.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Moderate	**WG1**: N/A	**WG1**: Low
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent a fire in the PIE Cell from releasing significant quantities of radiological material with water mist system causing an ODH hazard.

Method of Detection:	
Fire detection system.	
Visual.	
Loss of instrument signals.	

Event Number SSP5-1	
Preventive Features – Attributes:	**Credited:**
Electrical equipment design code. (DF)	
NFPA standards. (DC)	
Mechanical design codes and standards. (DF)	
Combustible material control program. (AC)	
Trained personnel. (AC)	
Operating Procedures and Training. (AC)	
Worker training (AC)	
Preventive maintenance program. (AC)	
Mitigative Features – Attributes:	**Credited:**
PIE and service cell design minimizes the potential for spreading the fire. (DF)	X
Component design (shell material and construction) minimizes the potential for spreading the fire and release of material. (DF)	X
Activated components are stored in closed pits within the Service Cell. (DF/AC)	
Fire detection and suppression system. (EC)	
SCE ventilation system. (EC)	
Air activity monitoring (RCT as needed). (AC)	
Fire Protection Program. (AC)	
Emergency Operating Procedures. (AC)	
Radiation and contamination control procedures. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Consequence evaluations. 2. Project Fire Hazard Analysis (PFHA). 3. Assessment of fires per NFPA 801. . 4. Analysis to determine fire size that could breach target stainless steel shell.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: Low **WG2**: N/A
Notes:			**Mitigated Frequency** **U**

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APPENDIX Q. TRUCK BAY (TB) HAZARD EVENT TABLES

APPENDIX Q. TRUCK BAY (TB) HAZARD EVENT TABLES

<table>
<tr><td colspan="6">Event Number
TB1-1</td></tr>
<tr><td colspan="6">Event Description:
Release of radiological material due to localized fire in the Truck Bay.</td></tr>
<tr><td colspan="2">Assumptions and Initial Conditions:
1. Radioactive material in this area is assumed to be limited to surface contamination or radioactive material in approved packaging. (IC)
2. Potential for release of low levels of radiological material to the high bay or environment. (IC)
3. The fire is confined to the truck bay. (IC)</td><td colspan="3">Causes:
1. Electrical short generates spark.
2. Thermal energy from such equipment as heaters or welding equipment.
3. Friction from such equipment as motors and power tools.
4. Hydraulic fluid leaks from forklift and is ignited.
5. Worker error.
6. Combustibles in area.
7. Truck fuel spills and is ignited.
8. Other unidentified ignition source.
9. Cleaning or decontamination agents contact other materials and produce flammable fumes.
10. Vehicle fire (including electric vehicles is addressed in TB1-2 and TB1-3).</td><td>Initiating Event Frequency
A</td></tr>
<tr><td colspan="3" rowspan="2">Unmitigated Impact on Systems:
1. Shutdown of the affected area.
2. Potential for damage or contamination of surrounding operating areas or equipment, including the corridor STS111 (adjacent to the mockup test stand and manipulator gallery) to the high bay STS310, and to the south instrument floor.
3. An electric vehicle fire or hybrid vehicle fire could lead to an extended outage due to the intensity of the fire.</td><td colspan="3">Unmitigated Consequences</td></tr>
<tr><td>Radiological
Public: Negligible
WG1: Low
WG2: Negligible</td><td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
<tr><td colspan="6">Safety Function:
Prevent a localized fire in the truck bay from causing a release of radiological material above allowable limits.</td></tr>
<tr><td colspan="5">Method of Detection:</td><td></td></tr>
<tr><td colspan="5">Fire detection system.</td><td></td></tr>
<tr><td colspan="5">Visual</td><td></td></tr>
<tr><td colspan="5">Preventive Features – Attributes:</td><td>Credited:</td></tr>
<tr><td colspan="5">Electrical equipment design code. (DF)</td><td></td></tr>
<tr><td colspan="5">NFPA standards. (DF/EC)</td><td></td></tr>
<tr><td colspan="5">Prohibition of EVs and Hybrid vehicles with lithium-ion batteries from entering the target building. (AC)</td><td></td></tr>
<tr><td colspan="5">Preventive maintenance program (Forklift maintenance). (AC)</td><td></td></tr>
<tr><td colspan="5">Operating Procedures and Training. (AC)</td><td></td></tr>
</table>

Event Number	
TB1-1	
Mitigative Features – Attributes:	**Credited:**
Building design. (DF)	
Emergency Operating Procedures. (AC)	
Fire detection and suppression system. (EC)	
Radiation and contamination control procedures. (AC)	
Worker training. (AC)	
Fire Department response. (AC)	
Combustible material control program. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Evaluate consequences of STS not having airlock doors between truck bay and high bay. 2. Evaluate consequences of a fuel spill in the truck bay. 3. Determine where fuel would drain to in the event of a fuel spill. 4. Project Fire Hazard Analysis (PFHA). 5. Assessment of fires per NFPA 801.	**Radiological** **Public:** Negligible **WG1:** Low **WG2:** Negligible	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. A fuel spill in the truck bay could be more significant that assessed here if the fuel could enter more contaminated regions such as the Service Cell or PIE Cell. 2. A truck fire leading to a full facility fire is addressed in BG1-1. 3. A truck fire spreading to adjacent rooms is addressed in TB1-3.	A

Event Number
TB1-2

Event Description:
Release of radiological material due to localized vehicle fire in the Truck Bay.

Assumptions and Initial Conditions:	**Causes:**	**Initiating Event Frequency**
1. This event assumes that the fire is confined to the immediate area of the vehicle. (IC) 2. The release is assumed to involve surface contamination or radioactivity contained in approved packaging only. (IC) 3. Depending on the quantity of combustibles in the area, the fire could spread to areas adjacent to the truck bay and could involve release of additional radioactive material. (See Event TB1-3) (IC)	1. Electrical short. 2. Batteries in the truck generate hydrogen gas. 3. Flammables (e.g., truck fuel - gasoline or diesel fuel). 4. Other unidentified ignition sources. 5. Miscellaneous combustibles in area. 6. Worker error.	**A**

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Shutdown of the affected area. 2. Potential for damage or contamination of surrounding operating areas or equipment, including the corridor STS111 (adjacent to the mockup test stand and manipulator gallery) to the high bay STS310, and to the south instrument floor.	**Public:** Negligible **WG1**: Low **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent a localized vehicle fire from causing a release of radiological material above allowable limits.

Method of Detection:	
Visual.	
Fire detection system.	

Preventive Features – Attributes:	Credited:
Electrical equipment design code. (DF)	
Trained personnel. (AC)	
NFPA standards. (DF/EC)	
Operating Procedures and Training. (AC)	
Prior to trucks entering the target building they are required to all time for brakes to cool and an inspection of the truck for potential fuel leaks and hot spots. (AC). (See Note 2) (AC)	

Event Number TB1-2	
Mitigative Features – Attributes:	**Credited:**
Fire detection and suppression system. (EC)	
Emergency response procedures. (AC)	
Worker training. (AC)	
Combustible material control program. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Evaluate consequences of STS not having airlock doors between truck bay and high bay. 2. Evaluate consequences of a fuel spill in the truck bay. 3. Determine where fuel would drain to in the event of a fuel spill. 4. Project Fire Hazard Analysis (PFHA). 5. Assessment of fires per NFPA 801.	**Radiological** **Public:** Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency** **A**
1. A fuel spill in the truck bay could be more significant than assessed here if the fuel could enter more contaminated regions such as adjacent operational areas of the building. 2. The most likely cause of a vehicle fire (exclusive of EVs) is overheated brakes on a truck. Therefore, prior to entry into the Target Building, the truck must be staged outside to permit brakes to cool, and a general inspection of the wheels performed.	

Event Number
TB1-3

Event Description:
Release of radiological material due to localized fire in the Truck Bay that spreads to an adjacent room with higher levels of radionuclides.

Assumptions and Initial Conditions:
1. Radioactive material in this area is assumed to include surface contamination or radioactive material in approved packaging. (IC)
2. Radioactive material in this area is assumed to include radioactive material in adjacent rooms. (IC)

Causes:
1. Electrical short generates spark.
2. Thermal energy from such equipment as heaters or welding equipment.
3. Friction from such equipment as motors and power tools.
4. Hydraulic fluid leaks from forklift and is ignited.
5. Worker error.
6. Combustibles in area.
7. Truck fuel spills and is ignited.
8. other unidentified ignition source.
9. Cleaning or decontamination agents contact other materials and produce flammable fumes.
10. Vehicle fire (including electric vehicles).

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Shutdown of the affected area.
2. Potential for damage to surrounding operating areas or equipment, including in the corridor STS111 (adjacent to the mockup test stand and manipulator gallery) to the high bay STS310, and to the south instrument floor.
3. An electric vehicle fire or hybrid vehicle fire could lead to an extended outage due to the intensity of the fire.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Moderate	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent a localized fire from spreading to adjacent areas and/or causing a release of radiological material above allowable limits.

Method of Detection:	
Fire detection system.	
Visual.	

Preventive Features – Attributes:	**Credited:**
Electrical equipment design code. (DF)	
Prohibition of EVs and Hybrid vehicles with lithium-ion batteries from entering the target building. (AC)	X
Prior to trucks entering the target building they are required to all time for breaks to cool and an inspection of the truck for potential fuel leaks and hot spots. (AC)	X
NFPA standards. (DF/EC)	
Preventive maintenance program (Forklift maintenance). (AC)	
Operating Procedures and Training. (AC)	

Event Number
TB1-3

Mitigative Features – Attributes:	Credited:
Building design. (DF)	
Shield walls between the truck bay and vaults/rooms with increased levels of radiological material. (DF)	X
Emergency Operating Procedures. (AC)	
Fire detection and suppression system. (EC)	
Radiation and contamination control procedures. (AC)	
Worker training. (AC)	
Fire Department response. (AC)	
Combustible material control program. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Evaluate consequences of STS not having airlock doors between truck bay and high bay.
2. Evaluate consequences of a fuel spill in the truck bay.
3. Determine where fuel would drain to in the event of a fuel spill.
4. Project Fire Hazard Analysis (PFHA).
5. Assessment of fires per NFPA 801.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: N/A	**Public:** N/A	**Public**: N/A
WG1: N/A	**WG1:** N/A	**WG1**: N/A
WG2: N/A	**WG2:** N/A	**WG2**: N/A

Notes:

1. A fuel spill in the truck bay could be more significant that assessed here if the fuel could enter the Service Cell or PIE Cell.
2. A truck fire leading to a full facility fire is addressed in BG1-1.
3. The most likely cause of a vehicle fire (exclusive of EVs) is overheated brakes on a truck. Therefore, prior to entry into the Target Building, the truck must be staged outside to permit brakes to cool, and a general inspection of the wheels performed.
4. Due to the inability to fight (extinguish) a lithium fire in an EV or hybrid vehicle they are excluded from the Target Building.
5. The fire initiated by the vehicle (EV, hybrid, or truck) requires both preventive controls (EV and Hybrid) as well as the mitigative for fires initiated by the other causes above.

Mitigated Frequency
Prevented

Event Number
TB2-1

Event Description:
Release of radiological material as the result of an explosion involving the liquid waste shipping truck during loading of waste.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. System operating so that radionuclides in it are at equilibrium for 700 kW operation and at maximum activity anticipated. (IC) 2. Potential for release of radiological material to the environment. (IC) 3. Facility is operating at normal beam on target conditions. (IC)	1. Electrical short. 2. Spark generated by electrical equipment in the area. 3. Other unidentified ignition sources. 4. Batteries in the truck generate hydrogen gas. 5. Flammables (e.g., truck fuel). 6. Worker error. 7. Overheated truck (e.g., brakes).	**U**

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. Shutdown of the affected area. 2. Potential for significant damage to surrounding operating areas or equipment, including the corridor STS111 (adjacent to the mockup test stand and manipulator gallery) to the high bay STS310, and to the south instrument floor.	**Public**: Negligible **WG1**: Low **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent a liquid waste shipping truck from resulting in an explosion and releasing radiological material. .

Method of Detection:	
Visual.	
Audible.	

Preventive Features – Attributes:	Credited:
Electrical equipment design code. (DF)	
Trained personnel. (AC)	
NFPA standards. (DF/EC)	
Operating Procedures and Training. (AC)	

Event Number
TB2-1

Mitigative Features – Attributes:	Credited:
Building structure. (DF)	
Emergency Operating Procedures. (AC)	
Building ventilation system. (EC)	
Radiation and contamination control procedures. (AC)	
Worker training. (AC)	
Waste handling procedures (IC)	
Waste transport containers/casks. (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency U

Event Number
TB2-2

Event Description:
Release of radiological material due to explosion in the Truck Bay.

Assumptions and Initial Conditions:	**Causes:**	**Initiating Event Frequency**
1. Radioactive material in this area is assumed to be limited to surface contamination or radioactive materials in approved packaging. (IC) 2. Potential for release of radiological material to the high bay or environment. (IC)	1. Hydrogen from forklift battery or battery charging is ignited. 2. Cleaning or decontamination agents contact other materials and produce explosive fumes. 3. Ignition sources could include spark from electrical short. 4. Thermal energy from such equipment as heaters or welding equipment. 5. Friction from such equipment as motors and power tools. 6. Other unidentified ignition source.	**U**

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Shutdown of the affected area 2. Potential for significant damage to surrounding operating areas or equipment, including the corridor STS111 (adjacent to the mockup test stand and manipulator gallery) to the high bay STS310, and to the south instrument floor	**Public:** Negligible **WG1:** Low **WG2:** Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent a non-truck-initiated explosion from resulting in a release of radiological material above allowable limits.

Method of Detection:	
Visual.	
Audible.	

Preventive Features – Attributes:	Credited:
Forklift design with battery compartment vents. (DF)	
Operating Procedures and Training. (AC)	
Battery charging and maintenance program. (AC)	
Forklift maintenance. (AC)	
Appropriate design standards (NFPA, IEEE, etc.). (DF)	

Event Number TB2-2				
Mitigative Features – Attributes:				**Credited:**
Building structure. (DF)				
Emergency Operating Procedures. (AC)				
Chemical control program could minimize use of reactive chemicals for cleaning or decontamination. (AC)				
Radiation and contamination control procedures. (AC)				
Worker training. (AC)				
Appropriate design standards (NFPA, IEEE, etc.). (DF)				
Planned analysis, assumption validations, and Risk/Opportunities: 1. Evaluate consequences of STS not having airlock doors between truck bay and high bay	**Mitigated Consequences:**			
	Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Notes:				**Mitigated Frequency** **U**

Event Number TB3-1				
Event Description: Release of radiological material due to loss of confinement from the Truck Bay.				
Assumptions and Initial Conditions: 1. Surface contamination. (IC) 2. Radioactive material in approved packaging. (AC) 3. Radiological material from LLLW tanks or IX resin in casks present. (IC) 4. Potential for release of radiological material to the environment. (IC)	**Causes:** 1. HVAC system upset or failure causes loss of airflow. 2. Breach of packaging. 3. Leak of LLLW during transfer. 4. Worker error – improper monitoring for contamination.			**Initiating Event Frequency** **A**
Unmitigated Impact on Systems: 1. Shutdown of the affected area. 2. Contamination of area including the corridor STS111 (adjacent to the mockup test stand and manipulator gallery) to the high bay STS310, and to the south instrument floor. 3. Recovery time required for decontamination efforts.	**Unmitigated Consequences**			
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A		**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Minimize the consequences from a loss of confinement in the Truck Bay.				

Method of Detection:	
Ventilation system failure alarms.	
Stack Air activity monitors.	

Preventive Features – Attributes:	**Credited:**
HVAC system design. (DF)	
Operating Procedures and Training. (AC)	
Standby power source. (DF/AC)	
HVAC system monitoring instrumentation. (EC)	
Redundant HEPA filters and exhaust fans. (DF)	
Preventive maintenance program for exhaust fans. (AC)	
HEPA filter testing and replacement program. (AC)	

<table>
<tr><td colspan="4">Event Number
TB3-1</td></tr>
<tr><td colspan="3">Mitigative Features – Attributes:</td><td>Credited:</td></tr>
<tr><td colspan="3">Building design and confinement capability. (DF/EC)</td><td></td></tr>
<tr><td colspan="3">Emergency response procedures. (AC)</td><td></td></tr>
<tr><td colspan="3">RCT contamination surveys. (AC)</td><td></td></tr>
<tr><td colspan="3">Radiation and contamination control procedures. (AC)</td><td></td></tr>
<tr><td colspan="3">Radiation Safety Program –
• Radiological Work Permit (RWP) (AC)
• Radiation Survey (AC)
• Training of personnel authorized to be in the area. (AC)</td><td></td></tr>
<tr><td colspan="3"></td><td></td></tr>
<tr><td colspan="3"></td><td></td></tr>
<tr><td colspan="3"></td><td></td></tr>
<tr><td colspan="3"></td><td></td></tr>
<tr><td rowspan="2">Planned analysis, assumption validations, and Risk/Opportunities:
1. Evaluate consequences of STS not having airlock doors between truck bay and high bay</td><td colspan="3">Mitigated Consequences:</td></tr>
<tr><td>Radiological
Public: Negligible
WG1: Negligible
WG2: Negligible</td><td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
<tr><td colspan="3">Notes:
1. This event is only an assumed loss of the HVAC and thus only limited activity can be released.</td><td>Mitigated Frequency
A</td></tr>
</table>

Event Number
TB4-1

Event Description:
Personnel receive inadvertent external exposure to radiation in truck bay.

Assumptions and Initial Conditions:	**Causes:**	**Initiating Event Frequency**
1. Surface contamination and radioactive material in approved packaging. (IC) 2. The radiation exposure rate in the Truck Bay or local general access area is anticipated to be low. (IC) 3. Personal dosimetry would likely be required throughout the Target Building. (IC)	1. Inadequate shielding. 2. Worker error - improper monitoring for radiation levels. 3. Personnel enter areas of high radiation.	**A**

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
None.	**Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent inadvertent radiological exposure to personnel above allowable limits.

Method of Detection	
Personal dosimetry.	
Radiological survey.	

Preventive Features – Attributes:	**Credited:**
Shielding of equipment or packages containing significant quantities of radioactive material. (DF)	
Operating Procedures and Training. (AC)	
Radiation postings. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	

Event Number TB4-1				
Mitigative Features – Attributes:				**Credited:**
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)				
Radiological control procedures. (AC)				
Worker training. (AC)				
Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**			
	Radiological **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Notes:				**Mitigated Frequency** **A**

APPENDIX R. TARGET, DRIVE, AND SUPPORT SYSTEMS (TS) HAZARD EVENT TABLES

The initial evaluation of target systems was based on a solid monolithic target. Since that evaluation, the target design has evolved to a segmented solid target. The segmented target design is included in the events in this appendix. The analyses to date have determined that the potential consequences from postulated event scenarios would be less than that for the solid monolithic target. Additionally, target and MRA replacement will be much simpler with this design, thus minimizing the potential for certain types of events. The bounding accident evaluations have maintained the initial solid monolithic target consequences to permit alternate target designs (including alternate segmented target configurations) that may have consequences higher than the current design.

APPENDIX R. TARGET, DRIVE, AND SUPPORT SYSTEMS (TS) HAZARD EVENT TABLES

<table>
<tr><td colspan="5">Event Number
TS3-2</td></tr>
<tr><td colspan="5">Event Description:
Rotating target locked rotor</td></tr>
<tr><td colspan="2">Assumptions and Initial Conditions:
1. Rotation stops within 1 second. (IC)
2. Cooling flow continues initially until cooling boundary fails. (IC)
3. Beam stays on. (IC)
4. Core vessel operating in inert helium near atmospheric pressure or in vacuum. (IC)
5. Without rotation, the high heat flux damages the target cooling boundary and causes a loss of cooling. (IC)
6. After loss of cooling with beam trip decay heat cannot raise target temperature to 800 C threshold for tungsten/steam reaction. (DF)
7. Core vessel ullage, burst disk designed with a rating of less than +7.35 PSIG and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. (DF)
8. Neutron beam windows remain intact throughout event. (IC)
9. Two segments of tungsten assumed vaporized. (IC)</td><td colspan="2">Causes:
1. Bearing failure.
2. Motor failure.
3. Support failure shifts shielding and target disk together.
4. Foreign object between target disk and shielding.
5. Loss of power to the drive system.
6. Control system inadvertently turns off drive.
7. Operator error.</td><td>Initiating Event Frequency
A</td></tr>
<tr><td rowspan="2">Unmitigated Impact on Systems:
1. Possible moderator vessel failure and hydrogen release after local target block collapses/fails.
2. Hydrogen and water vapor vents through core vessel burst disk and hydrogen safe vent.
3. Possible Loop 1 pressure vent through burst disk.
4. Bulk of water released from target retained in ullage, Core Vessel Drain Line, and drain tank.
5. Extended loss of STS use.</td><td colspan="4">Unmitigated Consequences</td></tr>
<tr><td colspan="2">Radiological
Public: Low
WG1: Moderate
WG2: Low</td><td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
<tr><td colspan="5">Safety Function:
Prevent target rotation failure from leading to a target failure and release of radiological material above allowable limits.</td></tr>
<tr><td colspan="4">Method of Detection:</td><td></td></tr>
<tr><td colspan="4">Rotation sensor.</td><td></td></tr>
<tr><td colspan="4">Drive motor sensor.</td><td></td></tr>
<tr><td colspan="4">Loop 1 out of range flow, temperature, or pressure..</td><td></td></tr>
</table>

Event Number TS3-2	
Method of Detection (continued):	
Liquid level in Loop 1 GLS tank.	
CMS pressure detection.	
Core vessel liquid detection probe.	
TVP -Target viewing periscope.	
Core vessel burst disk actuation.	
RGA on core vessel off-gas.	
Preventive Features – Attributes:	**Credited:**
Robust mechanical design with low bearing loads. (DF)	
Operating Procedures and Training. (AC)	
Surveillance and Maintenance. (AC)	
Mitigative Features – Attributes:	**Credited:**
TPS beam trip if permissive rotation signal is lost. (EC)	
TPS beam trip if target rotation stops or slows beyond limits. (EC)	X
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	X
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
Collection of Water by the Core Vessel (DF); Confinement by Core Vessel, Core Vessel Drain Line, and neutron beam windows. (DF)	
Core Vessel Drain Line Liquid Detection Probe. (EC) • Alarm in Control Room on detection of a leak. (EC) • MPS trip on High Level in the Core Vessel Drain Line. (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line. (EC)	
MPS beam trip for Target cooling Loop 1 GLS tank level out of limits. (EC)	
MPS beam trip for Target cooling Loop 1 return flow out of limits. (EC)	
MPS beam trip for Target cooling Loop 1 return temperature out of limits. (EC)	
Activation detected by monitoring in the STS Stack. (EC)	
Passive decay heat removal to fixed monolith shielding in mitigated case after beam trip .(DF)	
MPS beam trip for Target cooling Loop 1 pump exit pressure out of limits. (Note 1) (EC)	
Moderator Reflector Assembly design (Hydrogen moderator is insulated by a vacuum layer and there is also a water layer between the hydrogen vessel and target wheel). (DF)	
Core vessel Pressure relief system causes an alarm in the control room. (EC)	

Event Number
TS3-2

Mitigative Features (Continued) – Attributes:	**Credited:**
Exhaust from burst disks have designated keep away regions to protect workers that may be in these areas. (EC)	
Burst disk in CMS (reduces hydrogen inventory). (EC)	
Emergency response procedures. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Evaluate design concept for fail safe rotation sensor.
2. Accident (consequence) analysis for stationary target for unmitigated case with beam causing a loss of cooling event.
3. Document the time to target failure with cooling and no target rotation.

Mitigated Consequences:

Radiological	**Chemical**	**ODH**
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:

1. Delay built into the MPS trip to provide recovery time prior to the required trip. Delay time TBD.
2. The time to target failure without rotation has been initially determined to be less than 4 seconds.
3. Consequences for this event have not been calculated for the collocated worker. However, since the core vessel is inerted and the release is only through the vents, the releases should be no more than moderate. Since the core vessel leak detection is defined as a credited control for other events, it has also been identified here as a second level of control per the Control Selection Policy.
4. Proton beam window will not fail for nominally an hour so that it is not impacted by this event and does not provide a passive beam trip.
5. The burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures.
6. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.

Mitigated Frequency
A

Event Number
TS3-3

Event Description:
Rotating target separation of one or two segments from segment seismic restraint module.

Assumptions and Initial Conditions:
1. Rotation stops within 1 second. (IC)
2. Cooling flow bypasses target and goes to core vessel. (IC)
3. Beam stays on. (IC)
4. Core vessel operating in inert helium near atmospheric pressure or in vacuum. (IC)
5. After loss of cooling with beam trip decay heat cannot raise target temperature to 800 C threshold for tungsten/steam reaction. (DF)
6. Core vessel ullage, burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. (DF)
7. Neutron beam windows remain intact throughout event. (IC)
8. Two segments of tungsten assumed vaporized. (IC)
9. Segmented Target design. (DF) (See Note 1)

Causes:
1. Failed connection due to material defect or radiation damage or corrosion.

Initiating Event Frequency
EU

Unmitigated Impact on Systems:
1. Possible moderator vessel failure and hydrogen release after local target block collapses.
2. Possible damage to shielding if impacted by segment.
3. Bulk of water released from target retained in ullage, Core Vessel Drain Line, and drain tank.
4. Extended loss of STS use.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Low	**Public**: N/A	**Public**: N/A
WG1: Moderate	**WG1**: N/A	**WG1**: N/A
WG2: Low	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent target segment seismic restraint module failure leading to a release of radiological material above allowable limits.

Method of Detection:	
Loop 1 out of range flow, temperature, or pressure.	
Drive motor sensor.	
TVP -Target viewing periscope.	
Core vessel liquid detection probe.	
Core vessel burst disk actuation notification in the control room.	

Event Number
TS3-3

Preventive Features – Attributes:	Credited:
RGA on core vessel off-gas. (EC)	
CMS pressure detection. (EC)	
Target segment attachment points designed to withstand an SDC-2 seismic event with a design margin of TBD. (DF)	
Design margin rotational features and attachments. (DF)	
Material selected to be resistant to corrosion and radiation damage. (DF)	
Low rotational speed reduces the probability of a failure. (DF)	
Maximum transmitted motor torque much less than required to shear target shaft or connection to the segment seismic restraint module. (DF)	
QA program. (AC)	
Operating Procedures and Training .(AC)	
Surveillance and Maintenance. (AC)	

Mitigative Features – Attributes:	Credited:
Core Vessel Drain Line Liquid Detection Probe. (EC) • Alarm in Control Room on detection of a leak. (EC) • MPS trip on High Level in the Core Vessel Drain Line. (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line. (EC)	X
TPS beam trip if target rotation stops or slows beyond limits. (EC)	X
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	X
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
Vent the CMS in parallel with a beam trip to mitigate this event. (AC)	
Collection of Water by the Core Vessel; Confinement by Core Vessel and Core Vessel Drain Line. (DF)	
TPS beam trip for out-of-range Loop 1 return flow. (EC)	
Core vessel burst disk rupture causes an alarm in the control room. (EC)	
Target cooling Loop 1 GLS tank level. (EC)	
MPS beam trip for out-of-range Loop 1 return flow. (EC)	
Core vessel pressure relief system. (EC)	
Passive decay heat removal to fixed monolith shielding in mitigated case after beam trip. (DF)	
Emergency response procedures. (AC)	
Activation detected by monitoring in the STS Stack. (EC)	

Event Number
TS3-3

Mitigative Features – Attributes (Continued):	Credited:
Exhaust from burst disks have designated keep away regions to protect workers that may be in these areas. (EC)	
Segmented Target Design. (DF) (See Note 1)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Accident (consequence) analysis for stationary target for unmitigated case with beam and mitigated case.
2. Analysis to determine structural integrity for one second stopped rotor with cooling water flow present.
3. Document the time to target failure with cooling and no target rotation.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:

1. The segmented target design approach has the segments “hung” onto the target drive shaft by bolts at the bottom of the drive shaft and above the target shaft. The seismic restrain module near the beam elevation locates the segment during installation. Rotation is induced from the target drive shaft at the top of the segment, not at the beam elevation or by the target shaft. Thus, the target shaft “follows” along and does not drive rotation. This design makes shaft failure not credible. Therefore, the fault considered in this event is one or two segments become disconnected at the segment seismic restraint module location making only a single segment credible. The scenario (extremely unlikely) would be segment becoming entangled in shielding due to deflection. This would likely stop the crown from rotating and be detected by the crown rotation control. The motor would stall or “slip” before a segment shears it’s bolted connection.
2. The time to target failure without rotation has been initially determined to be less than 4 seconds.
3. Consequences for this event have not been calculated for the collocated worker. However, since the core vessel in inerted and the release is only through the vents, the releases should be no more than moderate. Since the core vessel leak detection is defined as a credited control for other events, it has also been identified here as a second level of control per the Control Selection Policy.
4. The design margin for the segment attachment points to survive an SDC-2 seismic event with a design margin of TBD reduces the likelihood of this event to EU.
5. Proton beam window will not fail for nominally an hour so that it is not impacted by this event and does not provide a passive beam trip.
6. The burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures.
7. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.

Mitigated Frequency
EU

Event Number
TS3-4

Event Description:
Loss of cooling flow leading to a release of activated Cooling Water into Core Vessel.

Assumptions and Initial Conditions:
1. Target rotation continues (IC)
2. Core vessel operating in helium near atmospheric pressure or in vacuum (IC)
3. Core vessel ullage, burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. (DF)
4. Target rotation continues so whole target heats from beam until loss of target block strength at elevated temperatures causes disk to collapse onto steel shielding and stops rotation (IC)
5. Half of tungsten assumed vaporized (See Note 5) (IC)
6. Event assumes that the cooling channels for the target segments are on the outside of the target block and not in the immediate vicinity of the tungsten. (DF)

Causes:
1. Loss of material integrity caused by manufacturing error, high coolant pressure, material fatigue caused by thermal cycles or corrosion.
2. Loss of Pump electrical power.
3. Sudden pump failure; damage to coupling; sudden bearing failure.
4. Worn or failing pump or motor components results. in efficiency reduction
5. Motor speed controller failure.
6. Operator error

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Possible moderator vessel failure and hydrogen release after target block collapses.
2. Hydrogen and water vapor vents through core vessel burst disk and hydrogen safe vent.
3. Bulk of water released from target retained in ullage, Core Vessel Drain Line, and drain tank.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Low	**Public**: N/A	**Public**: N/A
WG1: Moderate	**WG1**: N/A	**WG1**: N/A
WG2: Low	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent activity release above allowable limits from target damaged by overheating from a loss of cooling water flow.

Method of Detection:	
Loop 1 GLS tank level change	
Core vessel burst disk actuation notification in the control room.	
Loop 1 flow change	
RGA on core vessel off-gas	
Activation detected by monitoring in the STS Stack	
Core Vessel leak detection probe	
Core vessel pressure change when in vacuum mode	

Event Number
TS3-4

Preventive Features – Attributes:	Credited:
Use of appropriate National Codes or Standards on Target cooling systems (DF)	
Operating Procedures and Training (AC)	
Surveillance & Maintenance (AC)	

Mitigative Features – Attributes:	Credited:
Collection of Water by the Core Vessel (DF)	
Confinement by Core Vessel and neutron beam windows (DF)	
Target cooling loop level, flow, temperature, or pressure monitors (EC)	
Moderator Reflector Assembly design (Hydrogen moderator is insulated by a vacuum layer and there is also a water layer between the hydrogen vessel and target wheel) (DF)	
TPS beam trip on out-of-range Loop 1 return flow (EC)	X
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	X
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
Core Vessel Drain Line Liquid Detection Probe (EC) • Alarm in Control Room on detection of a leak (EC) • MPS trip on High Level in the Core Vessel Drain Line (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line (EC)	
Exhaust from burst disks have designated keep away regions to protect workers that may be in these areas (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Leak level detection requirement to be developed.
2. Tolerable leak level to permit continued operation to be developed.
3. Document the time to failure for a rotating target with no cooling and beam on.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Event Number
TS3-4

Notes:
1. As target overheats, slumping target could cause a release of hydrogen into the inert core vessel atmosphere.
2. Initial analysis shows that the target will not reach failure for nominally 5 minutes with continued rotation, no cooling, and the beam on.
3. Loss of cooling or partial loss of cooling to a single segment is addressed in Event TS3-12.
4. Proton beam window will not fail for nominally an hour so that it is not impacted by this event and does not provide a passive beam trip.
5. The Inconel shell and cooling channels may not lose enough strength unit after exceeding 800 C to cause failure. Therefore, assuming half of the tungsten as a source term is likely conservative but does not impact the assumed unmitigated consequences.
6. With the target reaching temperatures of nominally 800 C before failure, any water in the target would be boiled off or drained off (depending on the event) and only a potential steam environment in the core vessel is credible. Note that much of the water/steam in the core vessel would be cooled by the surrounding shielding and core vessel components. Once the target stops rotating it is assumed that target segments not in the beam path will quickly cool below 800 C limiting any potential participation in any steam tungsten reaction.
7. The burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures.
8. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.

Mitigated Frequency
A

Event Number
TS3-5

Event Description:
Loss of Heat Sink resulting in a release of activated Cooling Water into the core vessel due to overheating of Target

Assumptions and Initial Conditions:
1. Failure in tower cooling loop causes primary loop temperatures to increase until boiling and loss of target cooling occurs (IC)
2. Target block temperature increases until structural failure of target block (primarily the Inconel) occurs (IC)
3. Target rotation continues so whole target heats from beam until loss of target block strength at elevated temperatures causes disk to collapse onto steel shielding and stops rotation (IC)
4. With beam remaining on, 50% of tungsten assumed vaporized. (See Note 4) (IC)
5. Core vessel operating in inert helium near atmospheric pressure or in vacuum (IC)
6. After loss of cooling with beam trip decay heat cannot raise target temperature to 800 C threshold for tungsten/steam reaction (DF)
7. Core vessel ullage, burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. (DF)
8. Neutron beam windows remain intact throughout event. (See Note 4) (IC)
9. Failure in tower cooling loop causes primary loop temperatures to increase until boiling and loss of target cooling occurs (IC)
10. Loop 1 heat exchanger is a double plate heat exchanger requiring a failure of both plates to allow leakage between Loop 1 primary cooling water and the tower cooling water. (DF)
11. Event assumes that the cooling channels for the target segments are on the outside of the target block and not in the immediate vicinity of the tungsten. (DF)

Causes:
1. Loss of power to tower cooling pumps.
2. Tower cooling pump failure.
3. Loss of cooling tower or cooling tower water supply.
4. Partial Loss of Flow in the tower cooling water loop.
5. Leak or break in the tower cooling water loop (LOCA in the tower cooling water loop).
6. Loss of material integrity.
7. Flow blockage by loose material or debris in the loop.
8. Foreign material left during maintenance.
9. Maintenance error.
10. Damage to tower water loop piping.
11. Operator error.

Initiating Event Frequency
U

Unmitigated Impact on Systems:
1. Possible moderator vessel failure and hydrogen release after target block collapses.
2. Hydrogen and water vapor vents through core vessel burst disk and hydrogen safe vent. Bulk of water released from target retained in ullage, Core Vessel Drain Line, and drain tank.
3. Hydrogen and water increase core vessel pressure until burst disk relieves.
4. Air in leakage may cause deflagration with hydrogen with additional low-pressure powder discharges.
5. Bounding case is 50% of target material is vaporized and released by low pressure powder discharges.

Unmitigated Consequences

Radiological	**Chemical**	**ODH**
Public: Low	**Public**: N/A	**Public**: N/A
WG1: Moderate	**WG1**: N/A	**WG1**: N/A
WG2: Low	**WG2**: N/A	**WG2**: N/A

Event Number
TS3-5

Safety Function:
Prevent activity release above allowable limits from target damaged by overheating from a loss of heat sink.

Method of Detection:	
Secondary and tower loop instrumentation (pump power, pressure, temperature, flow)	
Target cooling loop gas liquid separator tank water level	
Core Vessel leak detection probe	
Target cooling loop return flow and temperature	
Leak detection on interstitial space between plates in the double plate heat exchanger.	
Preventive Features – Attributes:	**Credited:**
Electrical codes and standards (DF)	
Mechanical design codes and standards (DF)	
Double plate heat exchanger eliminates secondary loop failures. (DF)	
Surveillance & Maintenance (AC)	
Mitigative Features – Attributes:	**Credited:**
Core Vessel Drain Line Liquid Detection Probe (EC) • Alarm in Control Room on detection of a leak (EC) • MPS trip on High Level in the Core Vessel Drain Line (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line (EC)	
Double plate heat exchanger design (DF)	
Core vessel burst disk rupture causes an alarm in the control room (EC)	
TPS Beam trip upon detection of high Loop 1 return temperature (EC)	X
Inert core vessel atmosphere (EC)	
Core vessel pressure relief system – burst disk and hydrogen safe vent (EC)	
Exhaust from burst disks have designated keep away regions to protect workers that may be in these areas (EC)	
MPS beam trip upon detection of high Loop 1 cooling loop return temperature (EC)	
MPS beam trip on Target cooling Loop 1 GLS tank level (EC)	
MPS beam trip on high core vessel helium or vacuum pressure during operation (EC)	
MPS beam trip on loss of moderator system vacuum (EC)	

Event Number
TS3-5

Mitigative Features – Attributes: (continued)	Credited:
Passive decay heat removal to fixed monolith shielding in mitigated case after beam trip (DF)	
Collection of Water by the Core Vessel and core vessel drain Line (DF)	
Confinement by Core Vessel, Core vessel drain Line, and neutron beam windows (DF)	
Activation detected by monitoring in the STS Stack .(EC)	
Emergency Operating Procedures and Training (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Set point analysis for TPS and MPS beam trips.
2. Document the time to failure for loss of cooling with target rotation and beam on.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible **WG1**: Low **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:

1. Delay built into the MPS trip to provide recovery time prior to the required trip. Delay time TBD.
2. Initial analysis shows that the target will not reach failure for nominally 5 minutes with continued rotation, no cooling, and the beam on.
3. Loss of cooling or partial loss of cooling to a single segment is addressed in Event TS3-12.
4. Proton beam window will not fail for nominally an hour so that it is not impacted by this event and does not provide a passive beam trip.
5. The Inconel shell and cooling channels may not lose enough strength unit after exceeding 800 C to cause failure. Therefore, assuming half of the tungsten as a source term is likely conservative but does not impact the assumed unmitigated consequences.
6. With the target reaching temperatures of nominally 800 C before failure, any water in the target would be boiled off or drained off (depending on the event) and only a potential steam environment in the core vessel is credible. Note that much of the water/steam in the core vessel would be cooled by the surrounding shielding and core vessel components. Once the target stops rotating it is assumed that target segments not in the beam path will quickly cool below 800 C limiting any potential participation in any steam tungsten reaction.
7. The burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures.
8. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.

Mitigated Frequency
U

Event Number
TS3-6

Event Description:
Loss of target segment cooling due to internal bypass of flow or cooling channel blockage to one or more segments

Assumptions and Initial Conditions:

1. Core vessel operating in inert helium near atmospheric pressure or in vacuum (IC)
2. After loss of cooling with beam trip decay heat cannot raise target temperature to 800 C threshold for tungsten/steam reaction (DF)
3. Core vessel ullage, burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. (DF)
4. Segmented target design with tungsten cooling channels on the outside of the segment. (See Note 1)
5. With segmented target design, internal bypass flow within a segment is not credible. Plugging of several flow channels is assumed in this event. (DF)

Causes:

1 Manufacturing error
2 Debris from maintenance operation blocks supply holes restricting inlet flow.
3 Internal weld failure to allow excessive supply to return flow within a segment.
4 Excessive bypass flow within drive system.
5 Dislodged object blocks flow path to a section of a front target window or plugs the feed lines.

Initiating Event Frequency
A

Unmitigated Impact on Systems:

1. Target loss of lifetime due to increased operating temperatures.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Negligible	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent radioactivity release above allowable limits from damaged target

Method of Detection:	
TVP target viewing periscope	

Preventive Features – Attributes:	**Credited:**
Design techniques- Appropriate National Codes or Standards on Target materials will be used (DF)	
Inlet screen in Loop 1 header to target segment (DF)	X
Surveillance & Maintenance Procedures (AC)	
Periodic target replacement (AC)	

Event Number TS3-6	
Mitigative Features – Attributes:	**Credited:**
Passive decay heat removal to fixed monolith shielding in mitigated case after beam trip (DF)	
Inlet screen in Loop 1 header to target segment (DF)	
Segmented target cooling design with multiple independent cooling channels (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Document loss of cooling flow to 3 cooling channels in a segment. 2. QA/QC testing of each target segment to verify that the pressure drop in the individual segment is within specification/tolerance prior to installation.	**Radiological** **Public**: Negligible **WG1**: Negligible **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency**
1. See TS3-12 for loss of cooling to a single target segment. 2. Initial analysis shows that the target segment only reaches approximately 293 C with 3 adjacent channels blocked in a segment.	**A**

Event Number
TS3-7

Event Description:
Release of activated Target cooling water into Core Vessel due to catastrophic failure of target cooling line/channels.

Assumptions and Initial Conditions:

1. Target rotation continues so whole target heats from beam until loss of target block strength at elevated temperatures causes disk to collapse onto steel shielding and stops rotation. (IC)
2. Beam operation is assumed to continue. (IC)
3. Half of tungsten assumed vaporized. (See Note 5) (IC)
4. Core vessel operating in inert helium near atmospheric pressure or in vacuum (IC)
5. Core vessel ullage, burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. (DF)
6. Neutron beam windows remain intact throughout event (See Note 4) (IC)
7. Loss of cooling could lead to a failure of the hydrogen moderator system. (IC)
8. Event assumes that the cooling channels for the target segments are on the outside of the target block and not in the immediate vicinity of the tungsten. (DF)

Causes:
Loss of material integrity:

1. Manufacturing error.
2. High Coolant pressure.
3. Material fatigue caused by thermal cycles.
4. Weld failure.
5. Radiation damage to material.

Initiating Event Frequency
U

Unmitigated Impact on Systems:

1. Possible moderator vessel failure and hydrogen release after target block collapses
2. Hydrogen and water vapor vents through core vessel burst disk and hydrogen safe vent.
3. Bulk of water released from target retained in ullage, Core Vessel Drain Line, and drain tank.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Low	**Public**: N/A	**Public**: N/A
WG1: Moderate	**WG1**: N/A	**WG1**: N/A
WG2: Low	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent radiological material release above allowable limits from target cooling line/channel failure

Method of Detection:	
Core Vessel leak detection probe	
Target cooling loop gas liquid separator tank water level	
Target cooling loop return flow and temperature	
Core vessel pressure change	
RGA on core vessel off-gas	

Event Number TS3-7	
Preventive Features – Attributes:	**Credited:**
Appropriate National Codes or Standards (AC)	
Operating Procedures and Training (AC)	
Surveillance & Maintenance (AC)	
Periodic target replacement (AC)	
Mitigative Features – Attributes:	**Credited:**
Core Vessel Drain Line Liquid Detection Probe (EC) • Alarm in Control Room on detection of a leak (EC) • MPS trip on High Level in the Core Vessel Drain Line (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line (EC)	X
Core vessel burst disk rupture causes an alarm in the control room (EC)	
Access to core vessel vent exhaust is limited (EC)	
Inert core vessel atmosphere (DF)	
Core vessel pressure relief system – burst disk and hydrogen safe vent (EC)	
Exhaust from burst disks have designated keep away regions to protect workers that may be in these areas (EC)	
MPS beam trip on Target cooling Loop 1 GLS tank level, return flow, return temperature, or pump exit pressure monitors out of limits (See Note 2) (EC)	
MPS beam trip on high core vessel helium or vacuum pressure during operation (EC)	
MPS beam trip on loss of moderator system vacuum (EC)	
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
Activation detected by monitoring in the STS Stack. (EC)	
Passive decay heat removal to fixed monolith shielding in mitigated case after beam trip (DF)	
Collection of Water by the Core Vessel and Core Vessel drain Line (DF)	
Confinement by Core Vessel, Core vessel drain Line, and neutron beam windows (DF)	
TPS beam trip for out of range Loop 1 flow (EC)	

Event Number
TS3-7

Planned analysis, assumption validations, and Risk/Opportunities:

1. Accident (consequence) analysis including on site and off-site dose estimates.
2. Set point analysis for beam trip system.
3. Core vessel pressure response for rapid water boundary failure with following moderator boundary failure.
4. Document the time to failure for a rotating target with no cooling and beam on.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:

1. As target overheats, slumping target could cause a release of hydrogen into the inert core vessel atmosphere.
2. Initial analysis shows that the target will not reach failure for nominally 5 minutes with continued rotation, no cooling, and the beam on.
3. Loss of cooling or partial loss of cooling to a single segment is addressed in Event TS3-12.
4. Proton beam window will not fail for nominally an hour so that it is not impacted by this event and does not provide a passive beam trip.
5. The Inconel shell and cooling channels may not lose enough strength unit after exceeding 800 C to cause failure. Therefore, assuming half of the tungsten as a source term is likely conservative but does not impact the assumed unmitigated consequences.
6. With the target reaching temperatures of nominally 800 C before failure, any water in the target would be boiled off or drained off (depending on the event) and only a potential steam environment in the core vessel is credible. Note that much of the water/steam in the core vessel would be cooled by the surrounding shielding and core vessel components. Once the target stops rotating it is assumed that target segments not in the beam path will quickly cool below 800 C limiting any potential participation in any steam tungsten reaction.
7. The burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures.
8. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.

Mitigated Frequency
U

Event Number TS3-8				
Event Description: Accelerator switching system fails and delivers more than 15 pulses per second to STS.				
Assumptions and Initial Conditions: 1 Pulsed Dipole magnet power supply will not allow all ring pulses into the RTST. (DF) 2 Loop 1 provides cooling water for the Target. (DF) 3 Loop 2 provides cooling water for the Proton Beam Window, Collimator, TVP, CMS/MRA, and water-cooled shielding. (DF) 4 Target rotation continues and cooling continues to the target. (IC) 5 Core vessel operating in inert helium near atmospheric pressure or in vacuum. (IC) 6 Proton beam window will not fail for nominally an hour (with or without cooling at normal beam power conditions) so that it is not likely to be impacted by this event. (DF) 7 Proton beam remains on. (IC) 8 Core vessel ullage, burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. (DF)	**Causes**: 1. Accelerator Switching system failure		**Initiating Event Frequency** **EU**	
Unmitigated Impact on Systems: 1. Possible moderator vessel damage and hydrogen release. 2. Hydrogen and water vapor vents through core vessel burst disk and hydrogen safe vent.	**Unmitigated Consequences**			
	Radiological **Public**: Low **WG1**: Low **WG2**: Low	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A	
Safety Function: Prevent beam power above design from causing a radioactivity release from damaged target. Prevent inadvertent personnel exposure above allowable limits to excessive radiation.				
Method of Detection:				
Beam on Target viewing periscope.				
Harp and Halo monitoring thermocouples.				
MPS beam current monitors.				
Core vessel liquid detection probe.				

Event Number
TS3-8

Preventive Features – Attributes:	Credited:
Design of switching system limits the beam to 15 pulses per second. (EC)	
Circuit that will prevent the pulsed dipole power supplies from being triggered at a frequency > 15 Hz (EC)	
PPS – Repetition Limiting System (RLS) Pulsed Dipole switching frequency. (EC)	

Mitigative Features – Attributes:	Credited:
Core Vessel Drain Line Liquid Detection Probe (EC) • Alarm in Control Room on detection of a leak (EC) • MPS trip on High Level in the Core Vessel Drain Line (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line (EC)	
Core vessel burst disk rupture causes an alarm in the control room (EC)	
Inert core vessel atmosphere (DF)	
MPS Beam trip on beam diagnostics out of limits (power, harp, halo thermocouples) (EC)	
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
Core vessel pressure relief system – burst disk and hydrogen safe vent (EC)	
Exhaust from burst disks have designated keep away regions to protect workers that may be in these areas (EC)	
Pulsed Dipole magnet power supply will not allow all ring pulses into the RTST (DF)	
Design of switching system to limit the beam to not significantly exceed 15 pulses per second (EC)	
MPS beam current monitors and trips on excessive current (EC)	
MPS beam trip for abnormal Loop 1 return flow or temperature. (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Radiation (consequence) analysis showing the consequences of delivering over 15 pulses per second proton beam to STS.
2. Determine if the target boundary can see temperatures high enough for a loss of integrity for the maximum credible beam with the cooling system operating as designed.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Low	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Low	**WG2**: N/A	**WG2**: N/A

Event Number TS3-8	
Notes: 1. Delay built into the MPS trip to provide recovery time prior to the required trip. Delay time TBD. 2. Should a credited control be needed, consideration is underway for an Engineering Control that will prevent the Pulsed Dipole switching frequency from significantly exceeding 15 Hz, thereby limiting the beam power on the STS to nominally 15 pulses/sec. 3. Initial analysis shows that the target will not reach failure for nominally 5 minutes with continued rotation, no cooling, and the beam on. 4. Proton beam window will not fail for nominally an hour so that it is not impacted by this event and does not provide a passive beam trip. 5. Evaluation is of the target and moderator failures and the CMS, TS, and AS events are addressed in the applicable appendices. 6. The burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. 7. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.	**Mitigated Frequency EU**

Event Number
TS3-9

Event Description:
Beam Misalignment (Focused Beam): Release of radioactive cooling water from Target and window cooling systems due to overheating caused by a partially expanded beam or a focused beam. Release of cooling water into the Core Vessel

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Target rotation continues (IC). 2. Core vessel operating in inert helium near atmospheric pressure or in vacuum (IC) 3. Neutron beam windows remain intact throughout event (See Note 2) (IC) 4. Achieving a beam more focused than the design basis would require changes in magnet and operational configuration. The target and the proton beam window are designed to accept the design basis beam. (DF)	1. Malfunction in Beam Expander mechanism.	**BEU**

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Possible moderator vessel failure and hydrogen release after target block collapses 2. Bulk of water released from target retained in ullage, Core Vessel Drain Line, and drain tank. 3. Contamination of Core Vessel and Core Vessel Vacuum or He System	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**:

Safety Function:
Prevent a focused beam from causing a Target or Proton Beam Window failure.

Method of Detection:	
Beam Diagnostic System:	

Preventive Features – Attributes:	**Credited:**
MPS beam trip by Magnetic Diagnostic System (EC)	
Beam Expander System Design (Interlock and diverse system) (EC)	
Operating Procedures and Training (AC)	
Magnet diagnostic to detect beam focusing (EC)	

Mitigative Features – Attributes:	**Credited:**
Inert core vessel atmosphere (EC)	

Event Number
TS3-9

Planned analysis, assumption validations, and Risk/Opportunities:
1.

Mitigated Consequences:

Radiological	**Chemical**	**ODH**
Public: N/A	**Public**: N/A	**Public**: N/A
WG1: N/A	**WG1**: N/A	**WG1**: N/A
WG2: N/A	**WG2**: N/A	**WG2**: N/A

Notes:
1. See Event AIC3-1 for failure of proton beam window without target failure.
2. Proton beam window will not fail for nominally an hour so that it is not impacted by this event and does not provide a passive beam trip.
3. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.

Mitigated Frequency
BEU

Event Number
TS3-10

Event Description:
Small leak of cooling water in Loop 1 cooling that collects in core vessel.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Pump continues operating. (IC) 2. Core vessel fills with water to the level of the proton beam or above. (IC) 3. Neutron beam windows remain intact throughout event. (See Note 3) (IC) 4. Beam is terminated preventing target loss (target events with beam continuing to operate are addressed in TS event tables). (IC) 5. Core vessel rupture disk ruptures releasing activated water vapor and tritium. (IC) 6. It is assumed that Loop 1 cooling water systems be able to fill the core vessel up to the level of the proton beam. (IC)	1. Piping material defect 2. Corrosion 3. Fatigue from vibration 4. Internal erosion 5. Irradiation damage.	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Eventual loss of Loop 1 cooling system. 2. Covering of target and moderators with water. 3. Draining of core vessel may be required. 4. Could impact neutron beam windows	**Public**: Negligible **WG1**: Low **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Reduce probability of small leak of cooling water from resulting in a release of radiological material above allowable limits.

Method of Detection:	
Pressure increases in core vessel monitored by core vessel helium or vacuum system	
Core Vessel Liquid Detection	
Neutron Scattering Instruments loss of performance.	
Out of range level or pressure in Loop 1 cooling system	

Preventive Features – Attributes:	**Credited:**
Loop1 mechanical and material design (DF)	
Mounting and bracing inside the reflector (DF)	

Event Number
TS3-10

Mitigative Features – Attributes:	Credited:
TPS beam trip for out of range Loop 1 return flow (EC)	
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
Core vessel ullage, Core Vessel Drain Line, and drain tank designed to potentially keep maximum water level below neutron beam and proton beam windows for worst case accident (DF)	
MPS beam trip on Target cooling Loop 1 return flow, return temperature, or pump exit pressure monitors out of limits (See Note 1) (EC)	
MPS Beam trip on out of range GLS level (EC)	
Emergency operating procedures (AC)	
Core Vessel Drain Line Liquid Detection Probe (EC) • Alarm in Control Room on detection of a leak (EC) • MPS trip on High Level in the Core Vessel Drain Line (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line (EC)	
Trained operators (AC).	
Core vessel burst disk actuation (EC)	
Exhaust from burst disks have designated keep away regions to protect workers that may be in these areas (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Loop 1 evaluation of maximum water leak to core vessel	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Event Number TS3-10	
Notes: 1. Delay built into the MPS trip to provide recovery time prior to the required trip. Delay time TBD. 2. In the helium mode drain is possible without shutting down. Shutdown required for vacuum mode. 3. Proton beam window will not fail for nominally an hour so that it is not impacted by this event and does not provide a passive beam trip. 4. It is assumed that a small leak would be detected and terminated by the operator. However, operations may determine that continued operation was acceptable with a small leak. If the leak was small enough, the leak could "get lost in the shielding" or evaporated due to operation in the vacuum. 5. The burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. 6. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.	**Mitigated Frequency** **A**

Event Number
TS3-11 (Event moved to CW3-1d)

Event Number
TS3-12

Event Description:
Failure in the Loop 1 cooling water system results in a loss of cooling to a single target segment (Loss of flow to the proton beam window is addressed in AIC3-3).

Assumptions and Initial Conditions:
1. Core vessel ullage, burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. (DF)
2. Core vessel operating in inert helium near atmospheric pressure or in vacuum. (IC)
3. Proton beam remains on. (IC)
4. Segmented target design with tungsten cooling channels on the outside of the segment. (See Note 2)
5. With segmented target design, internal bypass flow within a segment is not credible. (See Event TS3-6). (DF)
6. TPS or MPS trips on Loop 1 flow or temperature would not have the accuracy or repeatability to detect this event. (IC)

Causes:
1. Valve misalignment.
2. Operator Error.
3. Equipment fault.
4. Debris from maintenance operation blocks supply restricting inlet flow.
5. Excessive bypass flow within drive system.
6. Dislodged object blocks flow path to a section of a front target window or plugs the feed lines.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Bulk of water released from coolant system into the core vessel retained in core vessel ullage, Core Vessel Drain Line, and drain tank.
2. Contamination of Core Vessel, Core Vessel Vacuum or He System, and RTST Line.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Moderate	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Limit the impact of a Loop 1 cooling water failure in a single target segment.

Method of Detection:	
Loop 1 parameters out of bounds	
Core vessel leak detection in the drain line.	

Preventive Features – Attributes:	**Credited:**
Operator training and procedures. (AC)	
Target design interface with the target support system requires the target segment to be fully inserted and in the right position for the operator to insert the locking screw to attach the target. (DF)	X
Inlet screen in Loop 1 header to target segment (DF)	X
Valve alignment checklist. (AC)	

Event Number
TS3-12

Mitigative Features – Attributes:	Credited:
Core Vessel Drain Line Liquid Detection Probe (EC) • Alarm in Control Room on detection of a leak (EC) • MPS trip on High Level in the Core Vessel Drain Line (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line (EC)	X
Inert core vessel atmosphere (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. Accident analysis to determine consequences of Loop 1 release. 2. Document loss of cooling flow to a segment. 3. QA/QC testing of each target segment to verify that the pressure drop in the individual segment is within specification/tolerance prior to installation.	**Radiological** **Public**: N/A **WG1**: N/A **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency Prevented
1. Delay built into the MPS trip to provide recovery time prior to the required trip. Delay time TBD 2. Initial analysis shows that the target segment only reaches approximately 293 C with 3 adjacent channels blocked in a segment. 3. The cascading protection for the target segment provides appropriate protection for the cooling of the segment. The screen in the main line limits the size of material that can reach the target segment. The screen prevents debris large enough to block 3 channel segments from reaching the target segment. Thus, the combination of the screen and the valve monitoring system prevents the loss of cooling to a single segment. 4. The burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. 5. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.	

Event Number
TS3-13

Event Description:
Target Building only loss of electric power leading to loss of cooling for target, with the beam remaining on. Event only evaluates impact on Loop 1 cooled systems (target cooling). Impact of this event on the PBW, TVP, MRA, reflector, and all Loop 2 water-cooled shielding is addressed in the Appendix A AIC events.

Assumptions and Initial Conditions:
1. All power is lost in target building. (IC)
2. Accelerator operation continues. (IC)
3. Target rotation stops within 1 second. (IC)
4. Loop 2 cools the PBW, TVP, MRA, reflector, and all Loop 2 water-cooled shielding. (DF)
5. Loop 1 cools the target segments (DF)
6. Proton beam window will not fail (melt) for nominally an hour without cooling so that it is not immediately impacted by this event and does not provide a timely passive beam trip. (DF)
10. Core vessel operating in inert helium near atmospheric pressure or in vacuum. (DF/IC)
11. Without rotation, the high heat flux damages the target cooling boundary and causes a loss of target segment cooling for the segment(s) with beam impact. (IC)
12. After loss of cooling with beam trip decay heat cannot raise target temperature to 800 C threshold for tungsten/steam reaction. (DF)
13. Core vessel ullage, burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. (DF)

Causes
1. Fault in feeder substation.
2. Fault in power line to target building.
3. Switching error.
4. Software error.
5. Overload.
6. Another electrical outage**.**

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Loop 1 Cooling water released to core vessel.
2. Target cooling stops. (IC)

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Moderate	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Assure loss of power to the Target Building does not cause the target segments to overheat and fail.

Method of Detection:	
Visual.	
UPS safety lighting.	
Multiple MPS signals and trips.	
Multiple TPS signals and trips.	

Event Number TS3-13	
Preventive Features – Attributes:	**Credited:**
Electrical system design. (DF)	
Worker training and procedures. (AC)	
Mitigative Features – Attributes:	**Credited:**
TPS beam trip due to TPS fail safe design providing a trip on loss of signal or loss of power to the TPS panel (EC)	X
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	X
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
MPS beam trip due to MPS fail safe design providing a trip on loss of signal or loss of power to the MPS panel. (EC)	
Standby and UPS power for critical systems & CEC systems. (EC)	
EOPs. (AC)	
Worker training. (AC)	
TPS beam trip on out-of-range Loop 1 return flow (EC)	
TPS beam trip if target rotation stops or slows beyond limits. (EC)	
Collection of Water by the Core Vessel; Confinement by Core Vessel, RTST, and neutron beam windows. (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Accident analysis to determine consequences of Loop 1 release.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Event Number TS3-13	
Notes: 1. This event addresses failure of the target segment cooling. Events impacting the PBW, TVP, MRA, reflector, and all Loop 2 water-cooled shielding are addressed in the AIC events. 2. Target Building only loss of electric power would likely impact the Loop 1 and Loop 2 cooling systems as well as the multiple target system support systems as well as the Target Drive. Loos of Loop 2 is addressed separately in Appendix A to assure that the proper mitigation is provided in both cases. 3. The burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. 4. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.	**Mitigated Frequency** **A**

Event Number
TS3-14

Event Description:
Target Drive Overspeed

Assumptions and Initial Conditions:

1. Target drive increases speed above allowable. (IC)
2. Loop 1 Cooling flow continues. (IC)
3. Beam stays on. (IC)
4. Core vessel operating in inert helium near atmospheric pressure or in vacuum. (DF/IC)
5. At maximum target drive speed, the target segments are driven outward and could contact shielding. (IC)
6. At increased speed the hydraulic pressures impact target cooling flow in the segments causing flow stagnation in the target segment. (IC)
7. Target segment flow stagnation causes overheating and steam blockage of flow. (IC)
8. Beam impacts target segments and gaps between segments due to the lack of sequencing between target speed and beam pulses. (IC)
9. Core vessel ullage, burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. (DF)

Causes:

1. Motor control failure.
2. Control system inadvertently increases drive speed.
3. Operator error.

Initiating Event Frequency
A

Unmitigated Impact on Systems:

1. Possible moderator vessel failure and hydrogen release after local target block fails.
2. Hydrogen and water vapor vents through core vessel burst disk and hydrogen safe vent.
3. Loop 1 pressure spike on steam formation in the target block, resulting in venting through the burst disk.
4. Bulk of water released from target retained in ullage, Core Vessel Drain Line, and drain tank.
5. Extended loss of STS use.
6. On target block failure and impact on shielding, the rotor stops and this event is equivalent to TS3-2 above.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Low	**Public**: N/A	**Public**: N/A
WG1: Moderate	**WG1**: N/A	**WG1**: N/A
WG2: Low	**WG2**: N/A	**WG2**: N/A

Safety Function:
Prevent target rotation increase from leading to a target failure and release of radiological material above allowable limits.

Method of Detection:	
Rotation sensor.	
Drive motor sensor.	
Loop 1 out of range flow, temperature, or pressure.	

Event Number TS3-14	
Method of Detection (continued):	
Liquid level in Loop 1 GLS tank.	
CMS pressure detection.	
Core vessel liquid detection probe.	
Core vessel burst disk actuation notification in the control room.	
RGA on core vessel off-gas.	
Preventive Features – Attributes:	**Credited:**
Drive motor controller design. (DF)	
Operating Procedures and Training. (AC)	
Surveillance and Maintenance. (AC)	
Mitigative Features – Attributes:	**Credited:**
TPS beam trip if drive motor speed increases beyond limits. (EC)	
TPS beam trip if target rotation increases beyond limits. (EC)	X
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	X
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
Collection of Water by the Core Vessel (DF); Confinement by Core Vessel, Core Vessel Drain Line, and neutron beam windows. (DF)	
Core Vessel Drain Line Liquid Detection Probe. (EC) • Alarm in Control Room on detection of a leak. (EC) • MPS trip on High Level in the Core Vessel Drain Line. (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line. (EC)	
MPS beam trip for Target cooling Loop 1 GLS tank level out of limits. (EC)	
MPS beam trip for Target cooling Loop 1 return flow out of limits. (EC)	
MPS beam trip for Target cooling Loop 1 return temperature out of limits. (EC)	
Activation detected by monitoring in the STS Stack. (EC)	
Passive decay heat removal to fixed monolith shielding in mitigated case after beam trip. (DF)	
MPS beam trip for Target cooling Loop 1 pump exit pressure out of limits. (Note 1) (EC)	
Moderator Reflector Assembly design (Hydrogen moderator is insulated by a vacuum layer and there is also a water layer between the hydrogen vessel and target wheel). (DF)	
Core vessel Pressure relief system causes an alarm in the control room. (EC)	

Event Number
TS3-14

Mitigative Features (Continued) – Attributes:	Credited:
Exhaust from burst disks have designated keep away regions to protect workers that may be in these areas. (EC)	
Burst disk in CMS (reduces hydrogen inventory). (EC)	
Emergency response procedures. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Determine if Target segment flow stagnation can cause overheating and steam blockage of flow in a segment.
2. Evaluate the design concept for fail safe rotation sensor.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:

1. Delay built into the MPS trip to provide recovery time prior to the required trip. Delay time TBD.
2. Consequences for this event have not been calculated for the collocated worker. However, since the core vessel is inert and the release is only through the vents, the releases should be no more than moderate. Since the core vessel leak detection is defined as a credited control for other events, it has also been identified here as a second level of control per the Control Selection Policy.
3. Proton beam window will not fail for nominally an hour so that it is not impacted by this event and does not provide a passive beam trip.
4. The burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures.
5. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.

Mitigated Frequency
A

Event Number TS3-15				
Event Description: Commissioning – Low Beam Power on Target with no Rotation and Beam Power increases above ASE commissioning limits.				
Assumptions and Initial Conditions: 1. Target rotation is not required during certain commissioning activities with beam on target. (IC) 2. Loop 1 Cooling flow is provided to the target segments. (IC) 3. Low power beam is initially on target. (IC) 4. Core vessel operating in inert helium near atmospheric pressure or in vacuum. (IC) 5. TPS allows administrative bypass of stopped rotor and beam on permissive during commissioning activities. (EC/IC) 6. Control system fails and inadvertently delivers "High" Beam Power. (IC) 7. Without rotation, the "High" Beam Power heat flux damages the target cooling boundary and causes a loss of cooling and target segment overheating and failure. (IC) 8. After loss of cooling with beam trip decay heat cannot raise target temperature to 800 C threshold for tungsten/steam reaction. (DF) 9. Core vessel ullage, burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. (DF) 10. Neutron beam windows remain intact throughout event. (IC) 11. One segment of tungsten assumed vaporized. (IC)		**Causes**: 1. Control system fails and inadvertently delivers High Beam Power. 2. Operator error.		**Initiating Event Frequency** **A**
Unmitigated Impact on Systems: 1. Possible moderator vessel failure and hydrogen release after local target shroud collapses/fails. 2. Hydrogen and water vapor vents through core vessel burst disk and hydrogen safe vent. 3. Loop 1 pressure vent through the burst disk. 4. Bulk of water released from target retained in ullage, Core Vessel Drain Line, and drain tank. 5. Extended loss of STS use.	**Unmitigated Consequences**			
	Radiological **Public**: Low **WG1**: Moderate **WG2**: Low		**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Prevent excessive beam power being delivered to the target during commissioning leading to target segment failure and release of radiological material above allowable limits.				
Method of Detection:				
Beam power instrumentation.				
Loop 1 out of range flow, temperature, or pressure.				

Event Number TS3-15	
Method of Detection (continued):	
Liquid level in Loop 1 GLS tank.	
CMS pressure detection.	
Core vessel liquid detection probe.	
Core vessel burst disk actuation notification in the control room.	
RGA on core vessel off-gas.	
Preventive Features – Attributes:	**Credited:**
Robust TPS design. (DF)	
Robust beam power control system design. (DF)	
Operating Procedures and Training. (AC)	
Surveillance and Maintenance. (AC)	
Mitigative Features – Attributes:	**Credited:**
MPS beam trip if low beam power limits exceeded. (EC)	
TPS beam trip if low beam power limits exceeded. (EC)	X
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	X
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
Collection of Water by the Core Vessel (DF); Confinement by Core Vessel, Core Vessel Drain Line, and neutron beam windows. (DF)	
Core Vessel Drain Line Liquid Detection Probe. (EC) • Alarm in Control Room on detection of a leak. (EC) • MPS trip on High Level in the Core Vessel Drain Line. (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line. (EC)	
MPS beam trip for Target cooling Loop 1 GLS tank level out of limits. (EC)	
MPS beam trip for Target cooling Loop 1 return flow out of limits. (EC)	
MPS beam trip for Target cooling Loop 1 return temperature out of limits. (EC)	
Activation detected by monitoring in the STS Stack. (EC)	
Passive decay heat removal to fixed monolith shielding in mitigated case after beam trip. (DF)	
Moderator Reflector Assembly design (Hydrogen moderator is insulated by a vacuum layer and there is also a water layer between the hydrogen vessel and target wheel). (DF)	
Core vessel Pressure relief system causes an alarm in the control room. (EC)	

Event Number
TS3-15

Mitigative Features (Continued) – Attributes:	**Credited:**
Exhaust from burst disks have designated keep away regions to protect workers that may be in these areas. (EC)	
Burst disk in CMS (reduces hydrogen inventory). (EC)	
Emergency response procedures. (AC)	
Commissioning procedures including beam power limits. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Determine commissioning procedures and beam power conditions.
2. Accident (consequence) analysis for stationary target for unmitigated case with beam causing a loss of cooling event.
3. Document the time to target failure with cooling and no target rotation.

Mitigated Consequences:

Radiological	**Chemical**	**ODH**
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Notes:

1. Delay built into the MPS trip to provide recovery time prior to the required trip. Delay time TBD.
2. The time to target failure without rotation has been initially determined to be less than 4 seconds.
3. Consequences for this event have not been calculated for the collocated worker. However, since the core vessel is inert and the release is only through the vents, the releases should be no more than moderate. Since the core vessel leak detection is defined as a credited control for other events, it has also been identified here as a second level of control per the Control Selection Policy.
4. Proton beam window will not fail for nominally an hour so that it is not impacted by this event and does not provide a passive beam trip.
5. The burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures.
6. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.

Mitigated Frequency
A

Event Number
TS3-16

Event Description:
Rotor stopped and beam travels though the gap between two target segments and impacts the target shaft and cooling water. (See Note 3)

Assumptions and Initial Conditions:
1. Target rotation stops within 1 second. (IC)
2. Cooling flow continues initially until cooling boundary fails. (IC)
3. Beam stays on. (IC)
4. Core vessel operating in inert helium near atmospheric pressure or in vacuum. (DF/IC)
5. Without rotation, the high heat flux damages the target shaft and increases cooling water activity. (IC)
6. Without rotation, the high heat flux damages the cooling water boundary and causes a loss of cooling to all the target segments. (IC)
7. After loss of cooling with beam trip decay heat cannot raise target temperature to 800 C threshold for tungsten/steam reaction. (DF)
8. Core vessel ullage, burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures. (DF)
9. Neutron beam windows remain intact throughout event. (IC)

Causes:
1. Bearing failure.
2. Motor failure.
3. Support failure shifts shielding and target disk together.
4. Foreign object between target disk and shielding.
5. Loss of power to the drive system.
6. Control system inadvertently turns off drive.
7. Operator error.

Initiating Event Frequency
U

Unmitigated Impact on Systems:
1. Damage and failure of target shaft.
2. Increase activity in loop 1 cooling system.
3. Loop 1 pressure vents through the burst disk.
4. Bulk of water released from cooling system retained in ullage, Core Vessel Drain Line, and drain tank.
5. Extended loss of STS use.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Low	**Public**: N/A	**Public**: N/A
WG1: Moderate	**WG1**: N/A	**WG1**: N/A
WG2: Low	**WG2**: N/A	**WG2**: N/A

Safety Function:
Mitigate the consequences of a target rotation failure with the beam impacting the target shaft and subsequent faults.

Method of Detection:	
Rotation sensor.	
Drive motor sensor.	
Loop 1 activity.	
Loop 1 out of range flow, temperature, or pressure.	
Liquid level in Loop 1 GLS tank.	

Event Number TS3-16	
Method of Detection (continued):	
Activation detected by monitoring of helium exhaust or vacuum system.	
Core vessel pressure change when in vacuum mode.	
Core vessel leak detection probe.	
RGA on core vessel off-gas.	
Preventive Features – Attributes:	**Credited:**
Use of appropriate National Codes or Standards on Target cooling systems. (DF)	
Robust target shaft mechanical design with low bearing loads. (DF)	
Operating Procedures and Training. (AC)	
Surveillance and Maintenance. (AC)	
Mitigative Features – Attributes:	**Credited:**
TPS beam trip if permissive rotation signal lost. (EC)	
TPS beam trip if target rotation stops or slows beyond limits. (EC)	X
TPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	X
MPS beam trip for differential Loop 1 bulk flow across the target out of range. (EC)	
Collection of Water by the Core Vessel (DF); Confinement by Core Vessel, Core Vessel Drain Line, and neutron beam windows. (DF)	
Core Vessel Drain Line Liquid Detection Probe. (EC) • Alarm in Control Room on detection of a leak. (EC) • MPS trip on High Level in the Core Vessel Drain Line. (EC) • TPS beam trip on high-high level in the Core Vessel Drain Line. (EC)	
MPS beam trip for Target cooling Loop 1 GLS tank level out of limits. (EC)	
MPS beam trip for Target cooling Loop 1 return flow out of limits. (EC)	
MPS beam trip for Target cooling Loop 1 return temperature out of limits. (EC)	
Activation detected by monitoring in the STS Stack. (EC)	
Passive decay heat removal to fixed monolith shielding in mitigated case after beam trip. (DF)	
MPS beam trip for Target cooling Loop 1 pump exit pressure out of limits. (Note 1) (EC)	
Moderator Reflector Assembly design (Hydrogen moderator is insulated by vacuum layer and there is also a water layer between the hydrogen vessel and target wheel). (DF)	
Core vessel Pressure relief system causes an alarm in the control room. (EC)	
Exhaust from burst disks have designated keep away regions to protect workers that may be in these areas. (EC)	

Event Number
TS3-16

Mitigative Features (Continued) – Attributes:	Credited:
Burst disk in CMS (reduces hydrogen inventory). (EC)	
Emergency response procedures. (AC)	

<table>
<tr><td rowspan="2">Planned analysis, assumption validations, and Risk/Opportunities:
1. Accident (consequence) analysis for stationary target/shaft for unmitigated case with beam causing a loss of cooling event.</td><td colspan="3">Mitigated Consequences:</td></tr>
<tr><td>Radiological
Public: Negligible
WG1: Low
WG2: Negligible</td><td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
</table>

Notes:

1. Delay built into the MPS trip to provide recovery time prior to the required trip. Delay time TBD.
2. Consequences for this event have not been calculated for the collocated worker. However, since the core vessel is inert and the release is only through the vents, the releases should be no more than moderate. Since the core vessel leak detection is defined as a credited control for other events, it has also been identified here as a second level of control per the Control Selection Policy.
3. This event is the same as event TS3-2 with the beam not impacting a target segment.
4. The burst disk designed *with a rating of less than +7.35 PSIG* and vent system designed to limit peak core vessel pressure to below 15 psig even with rapid water loss from the target and/or credible hydrogen moderator failures.
5. The leak detection instrumentation is not in the core vessel, but in a drain from the core vessel to the Core Vessel Drain Tank. The Core Vessel Drain Tank is isolated from the Core Vessel and drain line by a valve. The Core Vessel Drain provides three levels of action. Low level detection on initial leak and alarm in the control room; MPS trip on high level; and TPS trip on high-high level. The drain line is closed during vacuum operation downstream of the leak detection. During helium operation it is possible to continue operation with a small leak in the water systems using applicable procedures to permit this off normal condition.

Mitigated Frequency
U

Event Number
TS4-1

Event Description:
Inadvertent actuation (or routing) of beam to the Target monolith when the PBW, Target, or other shielding has been withdrawn from the Core Vessel for maintenance or retargeting.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. Beam is actuated for normal beam on mode operations or for tuning purposes during STS retargeting or core vessel maintenance.	1. Failure of pulsed and transport dipole magnet controls. 2. Failure of TPS bypass mode controls. 3. Failure to install component prior to switching to beam on mode. 4. Operator Error.	EU

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. Damage to Core Vessel due to overheating.	**Public**: N/A **WG1**: High **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent inadvertent personnel exposure from an inadvertent actuation (or routing) of beam to the Target monolith when the PBW, Target, or other shielding has been withdrawn from the Core Vessel for maintenance or retargeting.

Method of Detection:	
Beam Diagnostic System	
Interlocked Radiation Monitors (IRM)	

Preventive Features – Attributes:	Credited:
TPS beam permit system (EC)	X
PPS to prevent beam operations if any target segment, the PBW, or core vessel component is not in place. (EC)	X
RS hold to prevent beam operations if any target segment, the PBW, or core vessel component is not in place by locking out critical devices. (AC)	X
Operating Procedures and Training (AC)	
Surveillance and Maintenance (AC)	
PPS to disable critical devices (Pulsed and transport dipole magnets) in the RTBT/RTST transfer lines (EC/AC)	
TPS to monitor critical devices (Pulsed and transport dipole magnets) in the RTBT/RTST (EC/AC)	

Event Number
TS4-1

Mitigative Features – Attributes:	Credited:
Closed vacuum Valve during Target or PBW Maintenance and retargeting (AC/EC)	
Target or PBW Handling Cask or Temporary shielding block over core vessel opening except between transfer operations (AC/EC)	
Access control to high bay (AC)	
Operating Procedures and Training (AC)	
Surveillance and Maintenance (AC)	
PPS beam trip upon detecting the status of the critical magnets (Pulsed and transport dipole magnets) in the RTBT/RTST (EC)	
PPS beam trip on Interlocked Radiation Monitor (IRM) in the RTST tunnel (EC/AC)	
Radiation Safety Officer (RSO) shall inspect core vessel shielding before beam allowed in the RTST tunnels (AC)	
TPS beam trip on critical magnets (Pulsed and transport dipole magnets) feedback signal (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:
1. Determine High Bay dose rate for accidental beam operation with only temporary shielding
2. Evaluate dose levels from accidental beam on target in bunker or within instrument hutches if they are being accessed during maintenance even with shielding still in place

Mitigated Consequences:

Radiological	Chemical	ODH
Public: N/A	**Public**: N/A	**Public**: N/A
WG1: N/A	**WG1**: N/A	**WG1**: N/A
WG2: N/A	**WG2**: N/A	**WG2**: N/A

Notes:
1. The TPS must be in Beam Permit mode to allow beam to be sent to the rotating target regardless of operation in a beam tuning or production beam mode.
2. The PPS (RTST and Target segments) must be in Beam Permit mode to allow beam to be sent to the rotating target regardless of operation in a beam tuning or production beam mode.

Mitigated Frequency Prevented

Event Number TS4-2					
Event Description: Inadvertent actuation (or routing) of beam to the Target monolith when the target systems are not ready to receive beam.					
Assumptions and Initial Conditions: 1. Beam is operating to First Target Station during STS retargeting or core vessel maintenance. 2. PBW, Target, or other shielding may have been withdrawn from the Core Vessel for maintenance or retargeting.		**Causes**: 1. Failure of Pulsed and transport dipole magnet controls 2. Failure of TPS bypass mode controls 3. Operator Error			**Initiating Event Frequency** **BEU** **(Note 1)**
Unmitigated Impact on Systems: 1. Damage to RTST equipment.		**Unmitigated Consequences**			
		Radiological **Public**: N/A **WG1**: High **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A		**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A
Safety Function: Prevent inadvertent personnel exposure from inadvertent actuation (or routing) of beam to the Target monolith when the target systems are not ready to receive beam.					
Method of Detection:					
Beam Diagnostic System					
Interlocked Radiation Monitor (IRM)					
Preventive Features – Attributes:					**Credited:**
TPS beam permit system (EC)					
PPS to prevent beam operations if any target segment, the PBW, or core vessel component is not in place. (EC)					
Operating Procedures and Training (AC)					
Surveillance and Maintenance (AC)					
PPS to disable critical devices (Pulsed and transport dipole magnets) in the RTBT/RTST transfer lines (EC/AC)					
TPS to monitor critical devices (Pulsed and transport dipole magnets) in the RTBT/RTST (EC/AC)					

Event Number
TS4-2

Mitigative Features – Attributes:	Credited:
Closed vacuum Valve during Target or PBW Maintenance and retargeting (AC/EC)	
Operating Procedures and Training (AC)	
Surveillance and Maintenance (AC)	
PPS beam trip upon detecting the status of the critical magnets in the RTBT/RTST (EC)	
PPS beam trip on Interlocked Radiation Monitor (IRM) in the RTST tunnel (EC/AC)	
TPS beam trip on critical magnet (Pulsed and transport dipole magnets) feedback signal (EC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. Determine the controls covering interactions between the FTS and STS for beam operations.	**Radiological** **Public**: N/A **WG1**: N/A **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
1. It is not credible for the beam to get to the target systems in this mode of operations. An unsafe failure of the pulsed and dipole magnets can however, lead to the beam entering the RTST and create a hazard for workers in the RTST tunnel. This event is addressed in AS4-16.	BEU

Event Number
TS4-3

Event Description:
Inadvertent beam operation to the Target monolith when a target segment was inadvertently not installed during retargeting.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. All other conditions are ready for beam operations and the system is placed in Beam Permit mode.	1. Operator Error	U

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. Damage to target due to overheating or target being unbalanced.	**Public**: N/A **WG1**: Moderate **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent inadvertent beam operations when target systems are not ready to receive beam (e.g., when a target segment was inadvertently not installed during retargeting).

Method of Detection:	
Target monitoring systems including motor.	
Interlocked Radiation Monitor (IRM)	

Preventive Features – Attributes:	Credited:
Target design interface with the target support system requires the target segment to be fully inserted and in the right position for the operator to insert the locking screw to attach the target. (DF)	X
RSO performs independent visual verification that all target segments have been properly installed prior to operation. (AC)	X
Operating Procedures and Training (AC)	
Surveillance and Maintenance (AC)	
Operator verification that all flow has been established for all target segments.	
Radiation Safety Officer (RSO) shall inspect that all target segments are installed before beam operations	

Event Number
TS4-3

Mitigative Features – Attributes:	Credited:
PPS access control to the target drive room during beam operations (AC)	
Operating Procedures and Training (AC)	
Surveillance and Maintenance (AC)	
PPS beam trip on Interlocked Radiation Monitor (IRM) in the RTST tunnel (EC/AC)	

Planned analysis, assumption validations, and Risk/Opportunities:
1. QA/QC testing of each target segment to verify that the pressure drop in the individual segment is within specification/tolerance prior to installation.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:
1. The PPS will not allow the target segment to reach Beam Permit mode unless all target segments are in position.
2. The PPS will not allow the RTST segment to reach Beam Permit mode unless the target segment is in Beam Permit mode.
3. The target system physical barrier that ensures proper orientation of the target cooling water vales is TBD.

Mitigated Frequency Prevented

Event Number
TS4-4

Event Description:
Inadvertent beam operation to the Target monolith when cooling to a target segment was not initiated following retargeting.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. All other conditions are ready for beam operations and the system is placed in Beam Permit mode.	1. Operator Error	**U**

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Damage to target due to overheating.	**Public**: N/A **WG1**: Moderate **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Prevent inadvertent beam operations when cooling is not operating at normal conditions for all segments.

Method of Detection:	
Target monitoring systems including motor.	
Interlocked Radiation Monitor (IRM)	

Preventive Features – Attributes:	**Credited:**
Target design interface with the target support system requires the target segment to be fully inserted and in the right position for the operator to insert the locking screw to attach the target. (DF)	X
Target cooling system includes a physical barrier that ensures the proper orientation of the target cooling water valves prior to operation. (DF)	X
RSO performs independent visual verification that all target cooling water vales are in the correct orientation and that the physical barrier (that ensures valve alignment) is properly installed prior to operation. (AC)	X
Operating Procedures and Training (AC)	
Surveillance and Maintenance (AC)	
Operator verification that all flow has been established for all target segments.	
Radiation Safety Officer (RSO) shall inspect that all target segments are installed before beam operations	

Event Number
TS4-4

Mitigative Features – Attributes:	Credited:
PPS access control to the target drive room during beam operations (AC)	
Operating Procedures and Training (AC)	
Surveillance and Maintenance (AC)	
PPS beam trip on Interlocked Radiation Monitor (IRM) in the RTST tunnel (EC/AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: N/A **WG1**: N/A **WG2**: N/A	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	**Mitigated Frequency Prevented**
1. The PPS will not allow the target segment to reach Beam Permit mode unless all target segments are in position. 2. The PPS will not allow the RTST segment to reach Beam Permit mode unless the target segment is in Beam Permit mode 3. The target system physical barrier that ensures proper orientation of the target cooling water vales is TBD.	

Event Number
TS4-5

Event Description:
Personnel remain in the TDR when the beam is started and receives significant exposure from normal beam operations.

Assumptions and Initial Conditions:
1. The radiation exposure rate in the TDR is expected to be low, except during beam operation. (IC)
2. Personal dosimetry is anticipated to be required throughout the facility. (IC)
3. Only WG1 is impacted by this event. (IC)

Causes:
1. Worker error – remaining in secured area.
2. Failure to follow RTST and Target Systems startup procedures and search and evict protocols prior to starting the beam.
3. Search and evict system failures.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
None

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: High	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
To assure that no personnel are in the TDR during beam operation.

Method of Detection:

Preventive Features – Attributes:	Credited:
Personnel Protection System (PPS) • Audible and visible alarm of impending beam operation (EC)	X
Sweep and Evict Procedure - Proper procedures and training for the TDR sweep and evict protocols prior to beam operations. (AC)	X
Verbal PA announcement of beginning sweep and evict prior to beam operation. (AC)	
Operating Procedures. (AC)	
Training. (AC)	

Event Number
TS4-5

Mitigative Features – Attributes:	Credited:
None	

<table>
<tr><td rowspan="2">Planned analysis, assumption validations, and Risk/Opportunities:</td><td colspan="3">Unmitigated Consequences</td></tr>
<tr><td>Radiological
Public: N/A
WG1: N/A
WG2: N/A</td><td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
<tr><td colspan="3">Notes</td><td>Mitigated Frequency
Prevented</td></tr>
</table>

Event Number
TS4-6

Event Description:
Worker inadvertently enters the TDR prior to required RCT controls.

Assumptions and Initial Conditions:
1. Following beam shut down, but prior to required RCT entry protocols. (IC)
2. The radiation exposure rate in the TDR is expected to initially be high until the activated water in lines running through the TDR decay. After 8-hours of decay, the radiation exposure rate in the TDR is expected to be <2mrem/hr.
3. The PPS provides protection for the TDR access during beam operation and assures a beam trip if the TDR door is opened. (IC)
4. Personal dosimetry is anticipated to be required throughout the facility. (IC)
5. Only WG1 is impacted by this event. (IC)

Causes:
1. Worker error.
2. Failure to follow procedures.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. None.

Unmitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: High	**WG1:** N/A	**WG1**: N/A
WG2: Negligible	**WG2:** N/A	**WG2**: N/A

Safety Function:
To prevent a direct exposure of WG1 to higher than allowed sources in the TDR by entering the TDR prior to RCT permitting entry.

Method of Detection:	
Personal radiation monitors.	
Visual in control room or RCT entry.	

Preventive Features - Attributes:	**Credited:**
Radiation Safety Program – • Radiological Work Permit (RWP). (AC) • RCT Survey. (AC) • Training of personnel authorized to be in the area. (AC)	X
PPS prevention of TDR access when in power permit or in a higher mode. (EC)	
PPS beam status light located in CCR and directly outside the TDR access door. (EC)	

Event Number
TS4-6

Mitigative Features - Attributes:	Credited:
Radiation Safety Program – • Radiological Work Permit (RWP). (AC) • RCT Survey. (AC) • Training of personnel authorized to be in the area. (AC)	X
PPS Access Control to the Target Drive Room – • Provide a lock on the access door preventing entry until authorized by mode change from the control room. (EC) • Limits access to authorized personnel during controlled access mode. (EC)	X
Area Radiation Monitors are located in the High Bay to alarm locally and provide TPPS trip for the beam if elevated radiation levels are detected. (EC)	
TDR Design – provides shielding based on normal operation to the personnel outside the TDR. (EC)	
Personal dosimetry. (AC)	
Personnel training and procedures. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
None.	**Radiological** **Public:** Negligible **WG1:** Low **WG2:** Negligible	**Chemical** **Public**: N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Notes:	Mitigated Frequency
1. PPS beam status has visible beam status light and display with mode indicated in each access door. 2. Access to the TDR is through a single-entry point during normal operations. During target segment removal/installation activities, the TDR hatches will be removed allowing broader means of access. 3. In the event of an ACL-1 spillage inside the TDR, the credited controls identified above provide adequate means to limit personnel exposure to radioactive gases and/or tritium.	A

APPENDIX S. CORE VESSEL GENERAL AREA (VS) HAZARD EVENT TABLES

APPENDIX S. CORE VESSEL GENERAL AREA (VS) HAZARD EVENT TABLES

Event Number VS1-1					
Event Description: Fire in Core Vessel.					
Assumptions and Initial Conditions: 1. Inert core vessel atmosphere with helium or vacuum mode of core vessel operation. (IC) 2. Event occurs during operation or when the Core Vessel is ready to receive beam. (IC) 3. Inherent combustible inventory of core vessel is very low. (See Note 2) (DF)		**Causes:** 1. Maintenance or operator error. 2. Flammable/combustible liquid inadvertently drained into vessel. 3. Welding during maintenance. 4. Hydrogen gas accumulation.			**Initiating Event Frequency** **BEU**
Unmitigated Impact on Systems: 1. Damage to core vessel components.			**Unmitigated Consequences**		
			Radiological **Public:** N/A **WG1:** N/A **WG2:** N/A	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A
Safety Function: Assure that the Core Vessel is inerted prior to accepting beam.					
Method of Detection:					
Core vessel instrumentation (pressure/temperature).					
Core vessel rupture disk.					
Loss of vacuum.					
Preventive Features – Attributes:					**Credited:**
Inert atmosphere or vacuum in the Core Vessel. (EC)					X
Operating procedures. (AC)					
Maintenance procedures. (AC)					
Training. (AC)					

Event Number
VS1- 1

Mitigative Features – Attributes:	Credited:
Inherent combustible inventory of core vessel is very low. (See Note 2) (DF)	
EOPs. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
1. Project Fire Hazard Analysis (PFHA). 2. Assessment of fires per NFPA 801.	**Radiological** **Public:** N/A **WG1:** N/A **WG2:** N/A	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A

Notes:	Mitigated Frequency
1. This event is prevented due to the inerting of the core vessel with helium or vacuum. 2. Events associated with the hydrogen in the CMS/MRA are addressed separately.	Prevented

Event Number
VS1-2

Event Description:
Fire in Core Vessel during remote handling operations when the Core Vessel is not inerted.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. Core vessel atmosphere is not inerted with the core vessel opened for remote handling operations. (IC) 2. Event occurs during operations with the core vessel open to the atmosphere. (IC) 3. Inherent combustible inventory of core vessel is very low. (See Note 1) (DF) 4. Release limited to contamination that may be present in the core vessel. (IC)	1. Maintenance or operator error. 2. Flammable/combustible liquid inadvertently drained into vessel. 3. Welding during maintenance. 4. Hydrogen gas accumulation.	U

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
1. Damage to core vessel components.	**Public:** Negligible **WG1:** Low **WG2:** Negligible	**Public:** N/A **WG1:** N/A **WG2:** N/A	**Public:** N/A **WG1:** N/A **WG2:** N/A

Safety Function:
Prevent or mitigate release of radiological material from a fire in the Core Vessel when the core vessel is open for remote handling operations.

Method of Detection:	
Core vessel instrumentation (pressure/temperature).	
Fire detection in the High Bay.	

Preventive Features – Attributes:	Credited:
Operating procedures. (AC)	
Maintenance procedures. (AC)	
Training. (AC)	

Event Number
VS1-2

Mitigative Features – Attributes:	**Credited:**
Inherent combustible inventory of core vessel is very low. (See Note 1) (DF)	
EOPs. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Project Fire Hazard Analysis (PFHA). 2. Assessment of fires per NFPA 801.	**Radiological** **Public:** Negligible **WG1:** Low **WG2:** Negligible	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A

Notes:	**Mitigated Frequency**
1. Events associated with the hydrogen in the CMS/MRA are addressed separately.	U

Event Number
VS2-1a

Event Description:
Explosion in Core Vessel with the Core Vessel configured for normal operation.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. Inert core vessel atmosphere with helium or vacuum mode of core vessel operation. (IC) 2. Event occurs during operation or when the Core Vessel is ready to receive beam. (IC) 3. Combustible inventory of core vessel is inherently very low with the exception of the hydrogen in the CMS/MRA. (DF)	1. Maintenance or operator error. 2. Flammable/combustible liquid inadvertently drained into vessel during maintenance. 3. Welding during maintenance. 4. Hydrogen gas accumulation. 5. Undefined ignition source.	**BEU**

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
Core vessel breach and release of a fraction of the activated target mass and activated cooling water.	**Public:** N/A **WG1:** N/A **WG2:** N/A	**Public:** N/A **WG1:** N/A **WG2:** N/A	**Public:** N/A **WG1:** N/A **WG2:** N/A

Safety Function:
Assure that the Core Vessel is inerted prior to accepting beam.

Method of Detection:	
Core vessel instrumentation (pressure/temperature).	
Core vessel rupture disk.	
Loss of vacuum.	

Preventive Features – Attributes:	Credited:
Inert atmosphere or vacuum. (EC)	X
Operating procedures. (AC)	
Maintenance procedures. (AC)	
Training. (AC)	

<table>
<tr><td colspan="4">Event Number
VS2-1a</td></tr>
<tr><td colspan="3">Mitigative Features – Attributes:</td><td>Credited:</td></tr>
<tr><td colspan="3">Combustible inventory of core vessel is inherently very low with the exception of the hydrogen in the CMS/MRA. (DF)</td><td></td></tr>
<tr><td colspan="3">EOPs. (AC)</td><td></td></tr>
<tr><td rowspan="2">Planned analysis, assumption validations, and Risk/Opportunities:</td><td colspan="3">Mitigated Consequences:</td></tr>
<tr><td>Radiological
Public: N/A
WG1: N/A
WG2: N/A</td><td>Chemical
Public: N/A
WG1: N/A
WG2: N/A</td><td>ODH
Public: N/A
WG1: N/A
WG2: N/A</td></tr>
<tr><td colspan="3">Notes:
1. Event is BEU based on IC of inerted Core Vessel either with vacuum or helium.</td><td>Mitigated Frequency
Prevented</td></tr>
</table>

Event Number
VS2-1b

Event Description:
Explosion in Core Vessel during remote handling operations when the Core Vessel is not inerted.

Assumptions and Initial Conditions:
1. Core vessel atmosphere is not inerted with the core vessel opened for remote handling operations. (IC)
2. Event occurs during operations with the core vessel open to the atmosphere. (IC)
3. Inherent combustible inventory of core vessel is very low. (See Note 1) (DF)
4. Release limited to contamination that may be present in the core vessel. (IC)
5. Hydrogen in the CMS/MRA have been removed for this operation. (See Note 1) (IC)
6. With the hydrogen removed from the Core Vessel there is not a source of combustibles that reach LEL conditions. (DF/AC)

Causes:
1. Maintenance or operator error.
2. Flammable/combustible liquid inadvertently drained into vessel during maintenance.
3. Welding during maintenance.
4. Hydrogen gas accumulation.
5. Undefined ignition source.

Initiating Event Frequency
U

Unmitigated Impact on Systems:
1. Core vessel damage and damage to components in the core vessel.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public:** N/A	**Public:** N/A
WG1: Moderate	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Safety Function:
Prevent or mitigate release of radiological material from a detonation in the Core Vessel when the core vessel is open for remote handling operations.

Method of Detection:	
Core vessel instrumentation (pressure/temperature).	
Core vessel exhaust system vent system monitoring.	
Fire detection in the High Bay.	

Preventive Features – Attributes:	**Credited:**
Operating procedures. (AC)	
Maintenance procedures. (AC)	
Training. (AC)	

Event Number
VS2-1b

Mitigative Features – Attributes:	Credited:
Combustible inventory of core vessel is very low. (DF)	
EOPs. (AC)	
Hydrogen in the CMS/MRA have been removed for this operation. (See Note 1)	X

Planned analysis, assumption validations, and Risk/Opportunities:	Mitigated Consequences:		
	Radiological **Public:** Negligible **WG1:** Low **WG2:** Negligible	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A

Notes:	Mitigated Frequency
1. Events associated with the hydrogen in the CMS/MRA are addressed separately in the CMS/MRA events. This event associated with hydrogen remaining in the CMS is addressed in CMS2-2c.	BEU

Event Number
VS2-2

Event Description:
Hydrogen collects in core vessel drain tank in the HPV.

Assumptions and Initial Conditions:
1. Hydrogen released to the core vessel flows to core vessel drain tank and explodes. (IC)
2. Personnel access to the HPV is restricted when the beam is on and before required dose level decay has occurred. (IC)
3. Core vessel operating with inert core vessel atmosphere in either helium or vacuum mode of core vessel operation. (IC)
4. The core vessel drain tank will be located in a covered pit in the HPV. (DF)
5. See Note 1 for facility configuration and event progression considerations. (DF/IC)

Causes:
1. Failure of the moderator assembly or the hydrogen piping due to:
   a. material fatigue (e.g., vibration),
   b. damage to the moderator vessel during construction or maintenance,
   c. radiation damage to moderator vessel.
2. Entrained hydrogen and radiolysis of water in the tank collects.
3. Design, fabrication errors.
4. Other TS or CM event that releases hydrogen to core vessel.

Initiating Event Frequency
EU

Unmitigated Impact on Systems:
1. Release of unreacted hydrogen to HPV.
2. Damage to systems located in the HPV.
3. Damage to target as in TS or CM events. but no release from target.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public**: N/A	**Public**: N/A
WG1: Low	**WG1**: N/A	**WG1**: N/A
WG2: Negligible	**WG2**: N/A	**WG2**: N/A

Safety Function:
Reduce potential for an explosion in the core vessel drain tank resulting in release of radioactive coolant and WG1 exposure above allowable limits.

Method of Detection:	
Core Vessel downcomer level instrumentation.	
Loss of hydrogen pressure in cryogenic moderator system.	
Pressure monitoring in core vessel environment.	
Breach of moderator vessel could be indicated by monitors in cryo vacuum system.	
Drain tank level detection.	
Pressure monitoring in core vessel drain tank.	

Event Number VS2-2	
Preventive Features – Attributes:	**Credited:**
Electrical equipment, connections and cabling designed per NFPA codes. (DF)	
Core Vessel drain valve operation. (See Note 1) (AC)	
Preventive maintenance program. (AC)	
Operating Procedures and Training. (AC)	
Mitigative Features – Attributes:	**Credited:**
Pressure monitoring system to detect a leak of hydrogen into core vessel. (EC)	
MPS Beam trip response to hydrogen moderator parameters out of range. (EC)	
Core Vessel Drain Downcomer Liquid Detection Probe. (EC) • Alarm in Control Room on detection of a leak. (EC)) • MPS trip on High Level in the Core Vessel Drain Downcomer. (EC) • TPS beam trip on high-high level in the Core Vessel Drain Downcomer. (EC)	
The core vessel drain tank will be located in a covered pit in the HPV. (DF)	
Personnel access to the HPV is restricted when the beam is on and before required dose level decay has occurred. (AC)	
Inert gas filling of core vessel drain tank during operation. (EC)	
EOPs and worker training. (AC)	
Operating procedures for draining the core vessel. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1. Core vessel vacuum and helium systems potential for hydrogen deflagration/detonation. 2. Hydrogen venting analysis.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A **WG2**: N/A

Event Number VS2-2	
Notes: 1. Operation of the core vessel drain to the core vessel drain tank during operation will be dependent on the core vessel inerting and the leak size. The drain line to the drain tank includes a P-Trap that will prevent gas from migrating to the drain tank (unless there is a pressure excursion in the core vessel that is significant enough to push water in the P-Trap out). The valve in the drain line will normally be closed and opened temporarily to drain water from the core vessel. Note that if the water level reaches the MPS or TPS trip levels, this will trip the beam. During vacuum mode operations, small leaks are not likely to be noticed as the vacuum operation will evaporate any water in the core vessel. If the leak is substantial, then the MPS and TPS trip levels would likely be reached. During helium mode operation, leaks could accumulate in the core vessel downcomer and would alert the operator. In this condition, the valve could be either cycled to drain the water from the core vessel or the valve could remain open with the P-Trap providing isolation between the two locations. These decisions would be based on operational considerations such as leak size, mode of operation, and time to the next outage.	**Mitigated Frequency** **U**

Event Number
VS3-1

Event Description:
Breach in core vessel with release of radioactive gases and/or liquid.

Assumptions and Initial Conditions:	**Causes:**	**Initiating Event Frequency**
1. Inert core vessel atmosphere, operating in helium mode of core vessel operation. (See Note 2) (IC) 2. Event occurs during operation or when the Core Vessel is ready to receive beam. (IC) 3. Helium mode of operation is conducted at a slightly negative pressure below atmospheric pressure.	1. Vessel failure due to material defect. 2. Corrosion. 3. Over-pressurization. 4. Failure of target rotating shaft seal, proton window seal, neutron window seal, or any of the equipment or instrumentation seals. 5. Failure to adequately seal vessel after maintenance.	U

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Depending on the location, a breach in the core vessel could allow activated gases to leak from the core vessel to either controlled spaces or occupied areas depending on the location of the leak. 2. Impact on operations until the breach is repaired.	**Public:** Negligible **WG1:** Low **WG2:** Negligible	**Public:** N/A **WG1:** N/A **WG2:** N/A	**Public:** N/A **WG1:** N/A **WG2:** N/A

Safety Function:
Reduce probability of core vessel breach and mitigate release of activity to below allowable limits from core vessel breach.

Method of Detection:	
Inability to maintain helium blanket or vacuum pressure in core vessel.	
Stack monitoring.	

Preventive Features – Attributes:	**Credited:**
Vessel penetration design and sealing. (DF/EC)	
Target shaft seal design. (DF)	
Vessel material selection and design. (DF)	
Proton and neutron beam window design. (DF)	
Trained operators. (AC)	
Operating Procedures and Training. (AC)	

Event Number
VS3-1

Mitigative Features – Attributes:	Credited:
Vacuum system capability to remove activated gases from the core vessel. (EC)	
SCE Ventilation system removes radioactive airborne particulates released into the target drive room or other SCE ventilated locations. (EC)	
Use of helium as blanket in the core vessel minimizes activated gases. (EC)	
Bulk shield liner and core vessel drain tank designed contain and drain large spills to basement utility vault. (DF) (See Note 1)	
Monolith design. (DF)	
Trained operators. (AC)	
EOPs. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:

1. Design features for bulk shield liner liquid containment to be developed.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public:** N/A	**Public:** N/A
WG1: Low	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Notes:

1. The core vessel drain tank is not normally open to the core vessel, but water can be drained from the core vessel drain downcomer to the core vessel drain tank based on operator action. (See drain discussion in event VS2-2.
2. Note that if the core vessel was in vacuum mode, then leaks would be into the core vessel.

Mitigated Frequency
U

Event Number
VS3-2

Event Description:
Failure of Monolith Insert neutron beam windows releasing activated gases.

Assumptions and Initial Conditions:
1. Inert core vessel atmosphere operation with helium in the core vessel. (IC)
2. Event occurs during operation or when the Core Vessel is ready to receive beam. (IC)
3. Monolith Insert design with inner and outer windows. (DF)
4. Operation with leaking outer window followed by unrelated failure of inner window or the inner window seal. (IC)
5. Helium mode of operation is conducted at a slightly negative pressure below atmospheric pressure. (IC)

Causes:
1. Neutron beam window failure caused by:
   a. Material defect
   b. Overheating
   c. Irradiation damage
   d. Corrosion
   e. Over-pressurization of core vessel
   f. Improper installation

Initiating Event Frequency
U

Unmitigated Impact on Systems:
1. Failure of both neutron beam windows on core vessel overpressure could allow activated core vessel gases to leak to the beam lines in the Neutron Beam Bunker and potentially through the beamline vacuum system to the instrument hall atmosphere.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public:** N/A	**Public:** N/A
WG1: Low	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Safety Function:
Reduce probability of neutron beam window seal failure; prevent activity release above allowable limits from neutron beam window failure.

Method of Detection:	
Inability to maintain helium blanket pressure in core vessel or inability to maintain a vacuum in core vessel	
Excessive helium usage.	
Neutron beam widow seal monitor.	
Loss of neutron signal to neutron instrument affected.	

Preventive Features – Attributes	**Credited:**
Core vessel vent path with rupture disk to prevent over-pressurization. (EC)	
Neutron beam window material selection and design. (DF)	
Neutron beam window seal selection and design. (DF)	
Neutron beam window pressure rating above core vessel rupture disk setpoint. (DF)	
Neutron beamline vacuum system discharges to SCE. (DF)	
Operating Procedures and Training. (AC)	
Trained operators. (AC)	

Event Number
VS3-2

Mitigative Features – Attributes:	Credited:
Use of helium in inerting blanket or vacuum in core vessel minimizes activation of gases. (EC)	
Monolith Insert outer neutron beam windows prevent release of internal gases to beamline in bunker if intact. (EC)	
Neutron Beam Bunker SCE ventilation is separated from instrument hall to prevent activated gases being released into the instrument hall. (EC)	
EOPs. (AC)	
Trained operators. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:
1. Evaluate neutron beam window and seal lifetime to meet the design goal of life of the facility.

Mitigated Consequences:

Radiological	Chemical	ODH
Public: Negligible	**Public:** N/A	**Public:** N/A
WG1: Low	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Notes:

Mitigated Frequency
U

Event Number
VS3-3

Event Description:
Personnel exposure to spent target activated gas release in the core vessel during target replacement.

Assumptions and Initial Conditions:	Causes:	Initiating Event Frequency
1. Target life can be up to 20 years. (IC) 2. Core Vessel vacuum System is intended to maintain core vessel at a slightly negative pressure from atmospheric during target removal. (IC/DF)	1. High target temperatures due to decay heat and early removal 2. Inadequate ventilation 3. Leaking transfer cask 4. Improper monitoring 5. Failed target shell leaks noble gases and tritium, and evaporating cooling water	U

Unmitigated Impact on Systems:	Unmitigated Consequences		
	Radiological	**Chemical**	**ODH**
None.	**Public:** Negligible **WG1:** Low **WG2:** Negligible	**Public:** N/A **WG1:** N/A **WG2:** N/A	**Public:** N/A **WG1:** N/A **WG2:** N/A

Safety Function:
Prevent personnel exposure above allowable levels; prevent activity release from target replacement.

Method of Detection:	
Dosimetry on worker.	
Stack monitor.	
RCT Survey.	

Preventive Features – Attributes:	Credited:
Cask design to allow ventilation through core vessel during handling. (EC)	
Core vessel maintained at slight negative pressure during target replacement. (EC)	
Transfer cask closed before moving from the target drive room. (AC)	

Event Number VS3-3	
Mitigative Features – Attributes:	**Credited:**
Cask design for decay heat removal and connections to Hot Off Gas system if required. (DF)	
SCE ventilation system. (EC)	
Target to be partially dewatered to prevent water spillage or evaporation during removal (Target drying will occur in the Service Cell. (AC)	
Operating procedures and training. (AC)	
Trained operators. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public:** Negligible **WG1:** Low **WG2:** Negligible	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A
Notes:			**Mitigated Frequency** **A**

Event Number
VS3-4

Event Description:
Breach of the VS boundary during beam operations exposing the CV atmosphere to the environment. See Event AIC3-11 for AIC vacuum system breach.

Assumptions and Initial Conditions:	**Causes**:	**Initiating Event Frequency**
1. Core vessel operating in inert helium near atmospheric pressure or in vacuum. (IC) 2. Proton beam remains on. (IC) 3. Personnel could be in the TVP equipment room or high bay during beam operation. (IC) 4. The seal failure could be in any of numerous seals for VS penetrations. (IC) 5. TVP window remains intact. (IC)	1. Mechanical failure of a seal. 2. Failure of TVP Bellows 3. Other event causing a pressure increase in the core vessel leading to a seal failure.	A

Unmitigated Impact on Systems:	**Unmitigated Consequences**		
	Radiological	**Chemical**	**ODH**
1. Air is pulled into the core vessel in either vacuum mode or helium mode operation for failure of a seal.	**Public**: Negligible **WG1**: Low **WG2**: Negligible	**Public**: N/A **WG1**: N/A **WG2**: N/A	**Public**: N/A **WG1**: N/A **WG2**: N/A

Safety Function:
Limit the potential exposure to workers above allowable limits in the TVP equipment room or high bay from a core vessel seal failure.

Method of Detection:	
Core vessel pressure monitoring.	

Preventive Features – Attributes:	**Credited:**
Mechanical design codes and standards. (DF)	
TVP system design (e.g. tubing, gaskets, window, mirrors). (DF)	

Event Number
VS3-4

Mitigative Features – Attributes:	**Credited:**
MPS trip on high core vessel helium or vacuum pressure during operation. (EC)	
Inert core vessel atmosphere. (EC)	
Core vessel pressure relief system – burst disk and hydrogen safe vent. (EC)	
Emergency Operating Procedures and Training. (AC)	
TVP window remains intact during minor pressure excursion. (DF)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
1.	**Radiological** **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public**: N/A **WG1**: N/A **WG2**: N/A	**ODH** **Public**: N/A **WG1**: N/A

Notes:	**Mitigated Frequency**
1. A failure of the TVP window (bellows remain intact & before burst disc actuates) would allow the CV atmosphere to travel through a tortuous path to the end of the TVP system in the TVP Room. The TVP system is enclosed with gasketed connections to keep air particles, debris, and light from entering and interfering with the system cleanliness (e.g. tubing walls, mirrors, window, etc.). It would require a secondary failure of the TVP system boundary to fully expose the TVP environment to the CV atmosphere.	**A**

Event Number
VS4-1

Event Description:
Voids/cracks in concrete shielding result in abnormally high radiation levels in occupied areas of the target building.

Assumptions and Initial Conditions:
1. WG 1 consequence of moderate assumes worker in instrument hall is exposed to un-surveyed high radiation field. (IC)
2. Beam on target. (IC)

Causes:
1. Improper concrete mixture or improper pouring and consolidation of shielding concrete during building construction causing lower attenuation or undetected voids.
2. Inadequate repair of cracks in shielding concrete that occurred after curing due to concrete shrinkage, temperature changes or building settlement.
3. Undetected streaming pathways.
4. Inadequate shielding design.
5. Inaccurate, incomplete or lack of area radiation survey.
6. Undocumented or unauthorized shielding configuration change.

Initiating Event Frequency
A

Unmitigated Impact on Systems:
1. Shutdown of operations until shielding is repaired, replaced, or augmented.

Unmitigated Consequences

Radiological	Chemical	ODH
Public: Negligible	**Public:** N/A	**Public:** N/A
WG1: High	**WG1:** N/A	**WG1:** N/A
WG2: Negligible	**WG2:** N/A	**WG2:** N/A

Safety Function:
Prevent personnel exposure above allowable levels in occupied areas of the target building.

Method of Detection:	
Visible concrete voids following removal of concrete formwork.	
RCT radiation surveys detect unexpectedly high radiation levels in occupied areas during operation.	
Proper and periodic monitoring of operator personal dosimetry (self-reading pocket dosimeters) during operations.	

Event Number
VS4-1

Preventive Features – Attributes:	Credited:
Properly designed and specified shielding (e.g., concrete mixture and placement). (DF)	
Inspection and supervision of workers during shielding concrete pouring and placement. (AC)	
Vibration of concrete prior to setting. (AC)	
Establishing proper concrete curing environment. (AC)	
Use of approved (i.e., V&V'd) design codes. (DF)	
Configuration management program. (AC)	

Mitigative Features – Attributes:	**Credited:**
Steel shielding within and outside the core vessel but within the concrete shell designed to reduce streaming paths and external dose. (DF)	X
Addition of replacement or temporary shielding in areas affected by voids or cracks. (EC)	
Shielding radiation surveys during operation. (AC)	
Radiation Safety Program – • Radiological Work Permit (RWP) (AC) • Radiation Survey (AC) • Training of personnel authorized to be in the area. (AC)	X
Initial power ramp-up planning with RCT surveys. (AC)	X
Operating procedures. (AC);	
Trained Operators. (AC)	

Planned analysis, assumption validations, and Risk/Opportunities:	**Mitigated Consequences:**		
	Radiological **Public**: Negligible **WG1**: Low **WG2**: Negligible	**Chemical** **Public:** N/A **WG1:** N/A **WG2:** N/A	**ODH** **Public:** N/A **WG1:** N/A **WG2:** N/A

Notes:	**Mitigated Frequency** **A**