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Second Target Station Project Design Development Procedure

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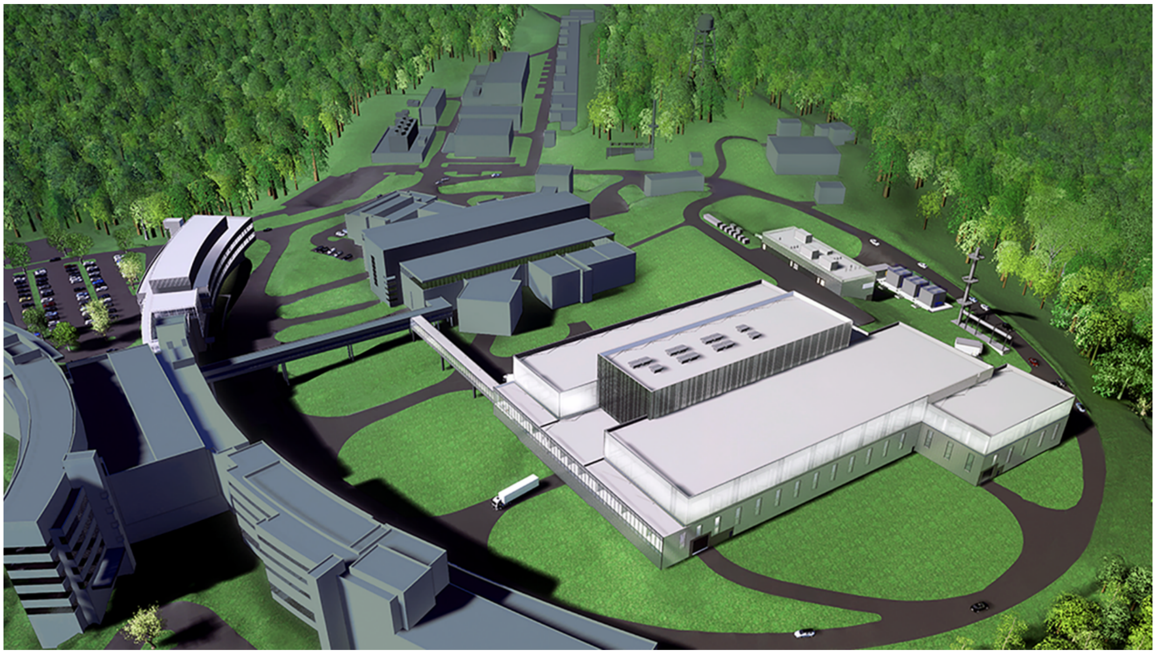
Second Target Station Project Design Development Procedure



March 2025

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S01020500-PCD10001

Second Target Station (STS) Project

Design Development Procedure

Date Published:
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Approvals

Design Development Procedure		ISSUE DATE: March 2025
PREPARED BY David C Anderson	PROJECT Second Target Station	DOCUMENT NUMBER: S01020500-PCD10001

	Signature / Date					
	Rev. 00	Date	Rev. 01	Date	Rev. 02	Date
STS Project Director	Graeme Murdoch		Graeme Murdoch	Revision 1 approvals obtained through EDRM		
	/s/ Graeme Murdoch	10/18/22				
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	/s/ Steven Hartman	9/9/22				
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Revision	Description
00	Initial Release
01	Changed “Project Change Request” (PCR) references to “Baseline Change Proposal” (BCP). Deleted 3 outdated paragraphs (about project status at the time of revision 0) from the end of section 1. Moved drawings, technical specifications and Acceptance Criteria Lists from Final Design Review deliverables to final design (pre-procurement) deliverables. Added additional clarifying text about the Accelerator Safety Review to section 3.5.3. Corrected minor typographic errors throughout.

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ACRONYMS

ACL	Acceptance Criteria List
ACGIH	American Conference of Governmental Industrial Hygienists
A/E	Architect / Engineer
ALARA	As low as reasonably achievable
ARR	Accelerator Readiness Review
ASE	Accelerator Safety Envelope
BAC	Budget at Completion
BCP	Baseline Change Proposal
CA	Configuration Authority
CAD	Computer Aided Design
CD	Critical Decision
CDR	Conceptual Design Review
CEC	Credited Engineered Control
CCM	Configuration Control Manager
CI	Configuration Item
CM	Configuration Management
CM/GC	Construction Manager/General Contractor
CM SSC	Configuration Managed System Structure or Component
COTS	commercial-off-the-shelf
DAC	Design Analysis Calculation
DDA	Designated Design Authority
EDRM	Enterprise Data and Records Management System
EMI	Electromagnetic interference
ESH&Q	Environment, Safety, Health, and Quality
FAT	Factory Acceptance Testing
FDR	Final Design Review
HA	Hazard Analysis
ICD	Interface Control Document
ICS	Integrated Control Systems
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
INCOSE	The International Council on Systems Engineering
IRR	Instrument Readiness Review
IS	Interface Sheet
ISSC	Instrument Systems Safety Committee
ISO	International Organization for Standardization
DOE	The Department of Energy
KPP	Key Performance Parameter
MIP	Manufacturing Inspection Plan
SDS	Safety Data Sheet
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
NScD	Neutron Sciences Directorate
ORNL	Oak Ridge National Laboratory

OSHA	Occupational Safety and Health Administration
PDR	Preliminary Design Review
P&ID	Piping and Instrumentation Diagram
POC	Point of Contact
PPS	Personnel Protection Systems
PtD	Prevention through Design
QA	Quality Assurance
QL	Quality Level
RF	Radio Frequency
RWP	Radiological Work Permit
SAD	Safety Assessment Document
SAM	Survey, Alignment, and Metrology
SBMS	Standards Based Management System
SEVocab	System and Software Engineering Vocabulary
SME	Subject Matter Expert
SNS	Spallation Neutron Source
STS	Second Target Station
SOW	Statement of Work
SSC	Structures, Systems, and Components
STS	Second Target Station
WBS	Work Breakdown Structure
USI	Unreviewed Safety Issue
USID	Unreviewed Safety Issue Documentation
V&V	Validation and Verification

SCOPE

The Second Target Station (STS) Project of the Oak Ridge National Laboratory (ORNL) is the technical organization tasked with the function of designing, building, and commissioning a second target station for the Spallation Neutron Source (SNS) as another world class neutron science research facility. The STS will produce long wavelength (cold) neutrons of significantly brighter intensity than those of the SNS First Target Station, to be used by a suite of new instruments with enhanced capabilities. Upon project completion and commissioning, the STS will be operated as another portion of the SNS following procedures and processes established by ORNL and the SNS.

The STS Project is the product of envisioning future scientific neutron scattering needs and development of the facilities to meet those needs. The project is managed from inception to the realization of capabilities in accordance with Department of Energy (DOE) requirements and ORNL practices. The design of the new facility and its instruments will be supported by appropriate risk or hazard analyses and reviewed in detail before being released for fabrication or procurement. Facility and equipment fabrication will be monitored to ensure critical elements of the design are achieved. The equipment will be installed and tested to ensure adequate performance prior to commissioning for use by the researchers.

In general, this procedure does not refer directly to other policies and procedures except for *S01020000-PC0001 General Policy on Engineering Practices*. *S01020000-PC0001* includes a table explicitly referencing all policies and procedures applicable to the Second Target Station project. *S01020000-PC0001* also commits the project to complying "with higher levels of authority than exist in STS such as ORNL SBMS, DOE rules and regulations and State and Federal Law." Listing all policies and procedures in only one place (*S01020000-PC0001*) minimizes the opportunity to reference a policy or procedure incorrectly or to reference a policy or procedure which has been superseded or is otherwise out of date. Instead, this document refers to other policies and procedures by citing *S01020000-PC0001* and mentioning a policy or procedure's descriptive name.

References are made throughout this procedure to "approval of the appropriate Configuration Control Manager" or CCM (see *Configuration Management Procedure for the Second Target Station Project* and *STS Design Authority Identification Document*, both listed in Table 1 of *S01020000-PC0001 General Policy on Engineering Practices*). For most STS Level 2 Systems the Level 2 WBS Manager and the Configuration Control Manager (CCM) are the same person. Per the *Configuration Management Procedure*, in cases when a Level 2 Manager is not an engineer, the Configuration Authority (CA) designates a different individual with engineering credentials (as determined by the CA) as the CCM for that system. The CCM is the highest level of *engineering* authority for each Level 2 System.

This (engineering) procedure does not intend to prevent a Level 2 Manager who is not a CCM from asserting his or her authority to prevent a design from proceeding to the next phase due to funding, schedule, or other reasons at the Level 2 Manager's discretion. In other words, when this procedure says the approval of a CCM is required, then the approval of a CCM is required, but the Level 2 Manager *always* has the authority to insert themself into the process to deny the approval of a design.

Configuration Managed Structures, Systems, and Components (CM SSCs) require the approval of the Configuration Authority. Configuration Items require approval of the associated CCM. Routine level SSCs require approvals of the CCM, or their delegate. Configuration Control Managers may delegate approvals for Routine level designs on an ad-hoc basis, or permanently by recognizing a Designated Design Authority (DDA) in the *STS Design Authority Identification Document*.

The Project's Configuration Authority (CA) may supersede the authority of the CCM, as the CA sees fit. The Technical Director and/or Project Director may similarly supersede the authority of a Level 2 Manager.

PURPOSE

The purpose of this design development procedure is to prescribe processes that ensure the facility and equipment development efforts carried out by the STS Project to: (1) use sound engineering design practices/techniques and (2) verify the resultant structures, systems, and components (SSCs – *Note: all references to SSCs in this document are assumed to include software and firmware*) meet intended performance objectives. Procurement, fabrication, installation, decommissioning, etc. of software, firmware, and Conventional Facilities can be different from characterizations in this document and interpretation may be required for these phases. For example, "installation" of Conventional Facilities would include construction of project infrastructure including buildings, utilities, and supporting systems specified in the construction documents.

This document will break down the overall design process into three (3) basic phases - *Conceptual Design, Preliminary Design,* and *Final Design.* However, the design development process must also consider the post-design phases of an overall product lifecycle, including *procurement, fabrication, pre-installation testing, installation, commissioning, operations and maintenance,* and *decommissioning.* Design *phases* end with the Final Design, but in practice, a design is not complete until the as-built condition and redlines (if any) are captured and configuration controlled. Designs are often produced during phases which occur after the Final Design phase. This document provides guidance for the entire design and development process and aligns with the Project's expectations to ensure best practices and compliance with respect to configuration management, project requirements, regulations, and laws.

This procedure includes several appendices with checklists to assist design engineers. Use of these checklists are a best practice and, in some cases, may be required by a design engineer's management or by a reviewer.

DEFINITIONS

Configuration Authority:
The highest engineering authority for the STS Project. Approval of SSCs with the highest level of safety or other characteristics important to the project require approval of the Configuration Authority. See *Configuration Management Procedure for the Second Target Station Project* for more information regarding the Configuration Authority and *STS Design Authority Identification Document* to determine the individual with this role.

Configuration Control Manager:
The highest engineering authority for a Level 2 WBS System. See *Configuration Management Procedure for the Second Target Station Project* for more information regarding the Configuration Control Managers and *STS Design Authority Identification Document* to determine which individuals have this role.

Configuration Items:
SSCs which perform safety functions or otherwise require additional rigor during the design process. See *Configuration Management Procedure for the Second Target Station Project* for more information.

Configuration Managed Structures, Systems, and Components:
SSCs which perform critical safety functions or are of extreme importance to the project. Credited Engineered Controls (CECs) are a subset of CM SSCs. See *Configuration Management Procedure for the Second Target Station Project* for more information.

Credited Controls:
"Controls determined through Safety Analysis to be essential for safe operation directly related to the protection of workers, the public, and the environment."
- DOE O 420.2D, Safety of Accelerators, Approved: 9-9-2022, attachment 2

DOE O 413.3B:
A DOE order providing direction for managing projects delivering large scale capital assets.

Verification:
Verification is the process of confirming a system, structure, or component (including software and firmware) fulfills its specified requirements.

Validation:
Validation is the process of providing objective evidence that a system, structure, or component (including software and firmware) fulfills its mission objective and achieves its intended use in its operational environment.

1. PRE-DESIGN

"*Design is the process of developing, expressing, documenting, and communicating the realization of the architecture of the system through a complete set of design characteristics described in a form suitable for implementation.*"

> *-INCOSE Systems Engineering Handbook 4e 2015 07, Section 4.5 Design Definition Process, subsection 4.5.1.2 Description.*

"…architecture and design have features, properties, and characteristics satisfying, as far as possible, the problem or opportunity expressed by a set of system requirements (traceable to mission/business and stakeholder requirements) and life cycle concepts (e.g., operational, support) and are implementable through technologies (e.g., mechanics, electronics, hydraulics, software, services, procedures)."

> *-INCOSE Systems Engineering Handbook 4e 2015 07, Section 4.4 Architecture Definition Process, subsection 4.4.1.2 Description.*

A design does not exist for itself. A design is a solution to a problem which must be addressed. Before a design can begin, the problem which it addresses must be identified and expressed as a need. The pre-design phase typically consists of identifying the problem and gathering information to understand the problem. As the problem is understood, a solution begins to form.

The need for a second target station at SNS was identified during the Spallation Neutron Source (SNS) project. This need is expressed and documented in *S01000000-PI0001 Mission Need Statement For Spallation Neutron Source Second Target Station*. The document was approved by the Department of Energy (DOE) in *LTR-DOE-SC-2009-01-07 STS CD-0 Approval* in 2009. Approval of the project's mission need marked the beginning of the Critical Decision (CD) process as the CD-0 milestone. The Project developed its conceptual design for the facility after CD-0 approval and issued *S01010000-TR0001 Spallation Neutron Source Second Target Station Conceptual Design Report* in two volumes (1) *Overview, Technical and Experimental Systems* and (2) *Conventional Facilities Conceptual Design Report* in March of 2020. The Conceptual Design Phase for the Project was formally approved in November 2020 with the approval of CD-1, at which time the project began its Preliminary Design phase.

The Critical Decision milestones for the STS Project, like all DOE O 413.3B projects, may be thought of as CD-0 *Develop Conceptual Design*, CD-1 *Develop Preliminary Design*, CD-2 *Develop Final Design*, CD-3 *Procurement and Installation*, and CD-4 *Complete Project*. At the project level, design phases exist between these milestones (see Figure 1 for an illustration of the relationship between design phases and project milestones). The design phases of an individual SSC may or may not completely align with these project phases. For the purposes of this procedure, the terms "*Conceptual Design*", "*Preliminary Design*" and "*Final Design*" refer to the design phases of the SSC, not the Project.

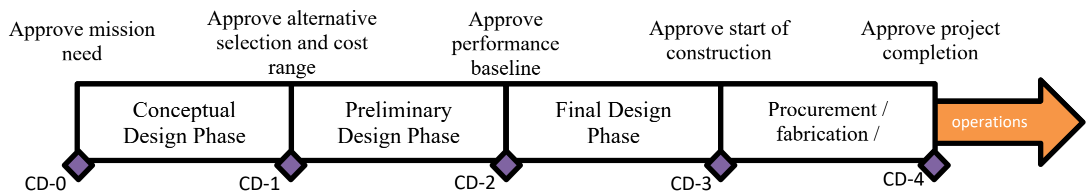

Figure 1. Critical Decision Process

It is helpful to understand the design process as a subsection of the overall product lifecycle of an engineered system (or system of systems). The well-known "Vee model", shown below in Figure 2 illustrates the concept of beginning with the end in mind.

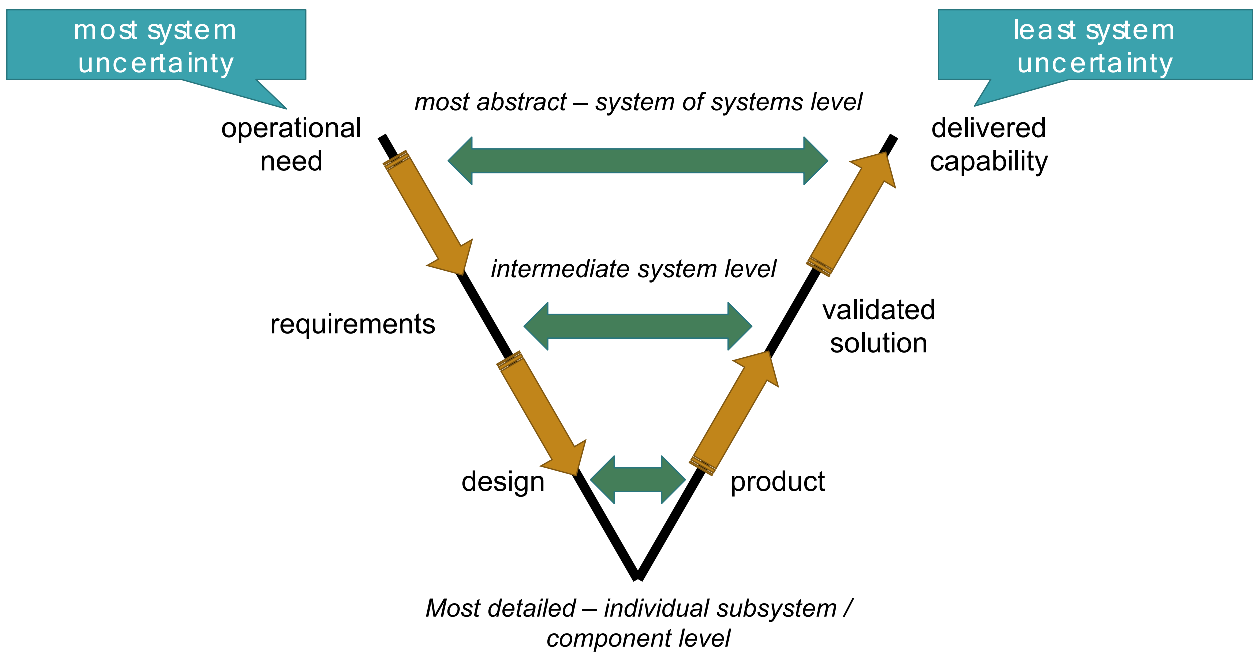

Figure 2. The "Vee model".

The top left corner of the Vee indicates the identification of an operational need, which may also be described as a mission need. The horizontal double headed arrow shows that the system design process must meet the operational need with a delivered capability. The operational need is decomposed and expressed as a set of requirements for the design of the system or system of systems. In this case the requirements must look to the other side of the Vee to a validated solution, meaning that the requirements must be expressed in such a way that they can be measurably and objectively shown to have been met before the system is delivered to the operational organization. The arrow points in both directions indicating that the validated solution must look back to the requirements and ensure they have been met. A design is produced which satisfies the requirements and is the primary subject of this procedure. The design, which has been evolved from the requirements expressed in the previous phase looks across the Vee to the product. That is, the design must be producible. The Vee model is the most abstract at the top, most detailed at the bottom, most uncertain on the left, and most certain on the right.

A full understanding of the design process is not possible without also understanding an SSC's entire lifecycle, as illustrated by another version of the Vee model shown below in Figure 3.

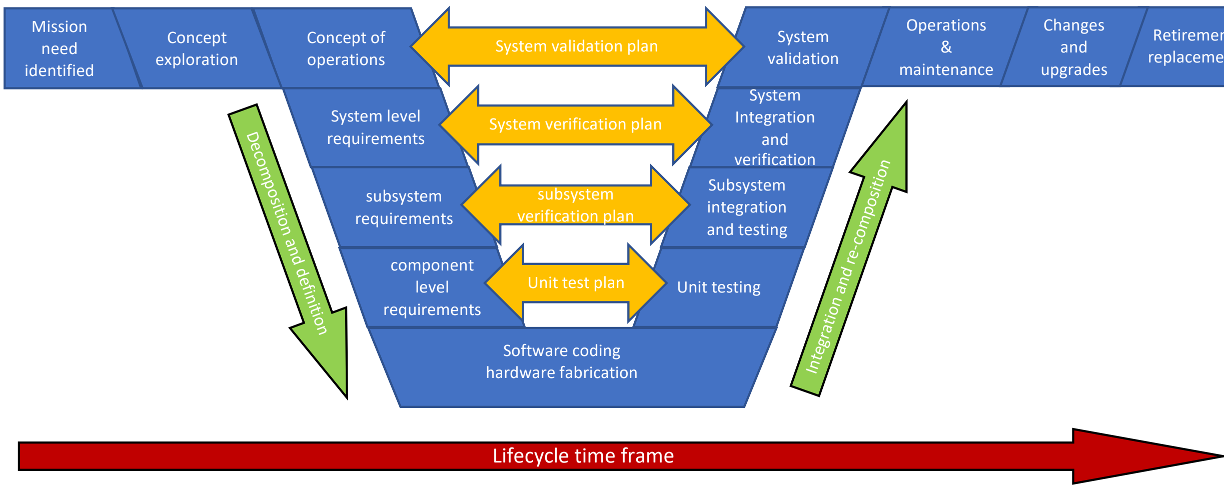

Figure 3. Detail added to the basic Vee model, adapted and modified from Systems Engineering for Intelligent Transportation Systems. January 2007. FHWA. Publication No. FHWA-HOP-07-069.

The lifecycle of an SSC begins with its "birth" as the identification of a need and "dies" when the SSC is retired or replaced. The design phase is a small section in the overall life of a product but must consider the whole. A design which ignores the needs of the remainder of an SSC's life is incomplete.

During the "pre-design" phase, a business case or mission need for a design is established, as already discussed in the context of the STS project. The "Concept of Operations" for the STS project is expressed in the First Experiments Report (*ORNL/SPR-2019/1407*) and will be confirmed at the end of the project by validation of the Key Performance Parameters (KPPs) (the *preliminary* KPPs are cited in *S01010000-PN0001 Preliminary Project Execution Plan for the Second Target Station Project* and repeated in many other documents, including the *Global Requirements Document*) for the project. The KPPs are officially established by DOE at CD-2. The preliminary KPPs are subject to change until approval of the KPPs at CD-2.

The System Level Requirements exist in the form of the STS Global Requirements Document (*S01010100-SR0001*), which have in turn been decomposed into the five (5) Level 2 Requirements Documents for Accelerator Systems (*S02010100-SR0001*), Target Systems (*S03010000-SR0001*), Instrument Systems (*S04010100-SR0001*), Conventional Facilities (*S05010100-SR0001*) and Integrated Control Systems (*S06000000-SR0002*). Level 2 Requirements Documents are decomposed to level 3 and lower requirements documents and eventually end up as designs and drawings, which are requirements documents of another kind. Engineering drawings include requirements in the form of dimensions and tolerances (and other manufacturing specifications) which are verified by inspections and inspection reports.

2. DESIGN

2.1 CONSIDERATIONS APPLICABLE TO ALL DESIGN PHASES

2.1.1 Checklists

Checklists (provided in Appendices A through F) are a list of factors which should be considered in the design of an SSC. **They are not a substitute for interaction with Subject Matter Experts** (SMEs). Checklists should be visited at the beginning of a design to understand if features need to be incorporated into a design to mitigate or eliminate a hazard, (or capitalize on an opportunity) or to alter the design to avoid a hazard altogether. Checklists are not necessarily comprehensive. Subject Matter Experts must be consulted to ensure related issues are understood to the fullest extent possible. Checklists do not provide guidance about what to do about qualifying items; direction in this regard can be provided by SMEs who can provide input to make designs safe, compliant, and better able to address system requirements.

Uncertainty on the behalf of a designer with respect to the intent of a checklist item can be clarified with a conversation with a Subject Matter Expert. Visiting checklists and consulting SMEs early in the design process is essential because alteration of a design to avoid, eliminate or mitigate a hazard is much easier at the beginning of the design process than at the end, when interfacing and interacting designs and design decisions are fixed. Revisitation of checklists and consultations with SMEs at the end of the design process ensures that a design has not changed in such a way as to negate design goals, requirements, interfaces, and safety features. Subject Matter Experts must be utilized throughout the design process to provide guidance as designs mature.

2.1.2 Prevention through Design

The National Institute for Occupational Safety and Health (NIOSH) leads a national initiative called *Prevention through Design* (PtD). Prevention through Design is the optimal method of preventing occupational illnesses, injuries, and fatalities by **designing out hazards and risks.** This approach involves the design of tools, equipment, systems, work processes, and facilities to reduce, or eliminate, hazards associated with work. The concept is simply that the safety and health of workers throughout the life cycle are considered while the product and/or process is being designed. The life cycle starts with concept development, and includes design, construction or manufacturing, operations, maintenance, and eventual disposal of whatever is being designed, which could be a facility, a material, or a piece of equipment.

Prevention through Design applies to the design of a facility, that is, to the aspects of the completed building that make a project inherently safer. Prevention through Design does not focus on how to make different methods of work safer. For example, it does not focus on how to use fall protection systems, but it does include consideration of design decisions that influence how often fall protection will be needed. Similarly, PtD does not address how to erect safe scaffolding, but it does relate to design decisions that influence the location and type of scaffolding needed to accomplish the work. Prevention through Design concepts may also be used to design temporary structures. Some design decisions improve workplace safety. For example, when the height of parapet walls is designed to be 42", the parapet acts as a guardrail and enhances safety. When designed into the permanent structure of the building and sequenced early in construction, the parapet at this height acts to enhance safety during initial construction activities and during subsequent maintenance and construction activities, such as roof repair.

Information on how to implement Prevention through Design practices may be found at https://www.cdc.gov/niosh/ptd/training-resources/.

2.1.3 Ergonomics and Human Factors

Designs must be evaluated for ergonomic concerns, particularly in the case of SSCs in enclosed or confined spaces, at increased elevation and in pits. Situations in which a worker suffering a medical emergency in a space or condition in which rescue of the individual is difficult or impossible must be addressed by design requirements. Engaging the Environment, Safety, Health, and Quality (ESH&Q) group is necessary to understand and develop requirements for designs effected by such issues.

Designers should reference *DOE-HDBK-1140-2001 Human Factors-Ergonomics Handbook for the Design for Ease of Maintenance* (archived) for guidance regarding incorporation of ergonomic safety in design.

Sufficient space around a worker must be maintained to allow for equipment to be installed, uninstalled, and must consider the routing of ancillary equipment such as cabling. This includes space for a worker to position in front of the equipment, as well as working space to each side, above, and below. Anthropometric dimensions (found in *DOE-HDBK-1140-2001 Human Factors-Ergonomics Handbook…*) should be used to determine appropriate clearances for maintenance and to provide sufficient space to accommodate tools, test equipment, procedures, and other job aids during an in-place repair.

It is common practice to design for the 5^{th} percentile for females, and to the 95^{th} percentile for males. Designing to meet the dimensions of 5^{th} percentile of the female population usually represents the smallest measurement for design in a population. Conversely, designing to meet the dimensions of 95^{th} percentile of the male population represents the largest dimension. Designing to meet the dimensions included between 5^{th} percentile and 95^{th} percentile of a population range accommodates approximately 90% of the total population. The 95^{th} percentile male weighs approximately 100 kg (220 pounds) and is approximately 1.85 meters (6 feet 1 inch) tall.

When technicians are required to work or passthrough limited spaces, appropriate clearances should be provided and each potential working position which may be required to access or perform common tasks (*DOE-HDBK-1140-2001* provides guidance in this regard) should be considered. Walking, squatting, stooping, and kneeling are often required of a worker attempting to perform maintenance tasks. Additionally, while in these positions, a worker may be expected to handle and manipulate heavy or awkward equipment during installation and removal from racks, shelves, etc.

In addition to the space required for the workers body, dimensions should reflect the size of equipment, tools, and materials that will be required to move through the space. These dimensions should be combined to account for the total space required for the worker to perform the required task.

2.1.4 Radiation Safety in Design

Prompt radiation is produced by beam operations and may include gamma and neutron radiation. Items and materials that have been activated by beam (including water, air, shielding, and target components) can also produce gamma radiation that may be hazardous to workers. The Second Target Station Project is required by law to limit the exposure of workers to radiation, and to reduce radiation in occupied areas to levels as low as reasonably achievable (ALARA). Second Target Station design, construction, and operations plans will be reviewed for compliance with the law and the ALARA principle before permission to operate will be granted by DOE.

The design goal for normally occupied areas (accessible to workers without radiation training, having no postings or access restrictions) is to limit radiation levels to less than 0.25 mrem/h. If that design goal is not met within the initial design, the first effort should be to redesign with reasonable compromises to achieve the design goal. The addition of shielding or other engineered changes should next be considered if the hazard cannot be completely eliminated through redesign.

If the design goal cannot reasonably be met through design changes or the addition of shielding, then access restrictions must be considered in the design. Radiological postings may be adequate if the radiation levels are moderate (see guidance below). Locked doors or electronic access controls must be considered for areas exceeding certain limits.

Accident conditions must be considered in addition to normal operating conditions. Accidents primarily need to be considered in areas where beams (proton and/or neutron) might be mis-steered or where beams might be enabled without required shielding/access restrictions. Materials that may be exposed to proton or neutron beams or to scattered particles that can cause activation should be selected to minimize activation. Materials in such areas should be selected to minimize radiation levels when workers will be present. Assemblies in areas with significant activation levels should be designed to minimize worker exposures during maintenance activities.

Areas with radiation levels of 2 mrem/h or higher must be posted to restrict entry to workers with appropriate radiation worker training. Restrictions are increasingly stringent as the radiation level increases, and any areas with radiation levels above 1 rem/h must have locked and/or interlocked access points.

The STS Neutronics team will help determine the expected dose rates in areas that may have elevated radiation levels. The STS Radiation Safety Officer can assist in planning access points and determining the appropriate level of restrictions. The STS ESH&Q team should be included at all stages of design planning to prevent costly modifications to designs in later stages.

2.1.5 Standards

S01020500-COR10000 Second Target Station (STS) Project Code of Record contains a list of codes and standards applicable to the STS Project.

2.1.6 Reviews

References are made throughout this procedure to "formal" reviews. Latitude may be exercised by Configuration Control Managers and reviewers in regard to the degree of formality of a review with respect to the configuration or quality levels, the complexity of the design and/or the importance of a design, but at a minimum, a formal design review requires documentation of the review in the form of design review notes, including names and roles of reviewers, captured and controlled in the Electronic Data and Records Management (EDRM) system.

An informal review may take the form of a conversation between a CCM or Designated Design Authority and an engineer in one's office or even over email. Documentation of the review is recommended but not required. *S01020000-PC0001 General Policy on Engineering Practices* provides guidance for the required formality of reviews.

2.2 CONCEPTUAL DESIGN

The overall conceptual design process is summarized in the flowchart shown at the end of this section in Figure 4.

DOE O 413.3B provides the following definition:

> *"The Conceptual Design process requires a mission need as an input. It is the exploration of concepts, specifications and designs for meeting the mission needs, and the development of alternatives that are technically viable, affordable and sustainable. The conceptual design provides sufficient detail to produce a more refined cost estimate range and to evaluate the merits of the project."*
>
> - DOE O 413.3B Program and Project Management for the Acquisition of Capital Assets, Change 7, Attachment 2

The conceptual design phase begins with a basic understanding of the problem that must be addressed by the design. Simple solutions are often addressed with simple designs, but more complex problems require complex and creative solutions. In such cases, alternatives must be considered.

The conceptual design phase for an SSC typically begins when requirements are understood at a high level only. Detailed requirements are developed during the conceptual design phase but, except for the highest levels of requirements, are usually not fully defined until the preliminary design phase and are commonly revised or appended during downstream design activities.

Interfaces are identified and developed during conceptual design and should be completely defined before design reviews begin (consult the Graded Approach Matrix in *S01020000-PC0001 General Policy on Engineering Practices* to determine if a Conceptual Design Review is required, and if so, the formality of the review). Interface Control Documents must be released before an SSC's first design review (see *Interface Control Procedure* listed in *S01020000-PC0001 General Policy on Engineering Practices)*.

A verification plan to confirm each requirement would ideally be developed in parallel with requirements, but because of time pressures and other factors is frequently deferred until a later development phase. At a minimum, requirements should be written with verification in mind. A requirement's author often finds it desirable to include one or more requirements that are unverifiable to express "design intent", but from a practical standpoint, a requirement that is unverifiable has no value. Effective requirements are SMART - **S**pecific, **M**easurable, **A**ttainable, **R**ealistic and **T**ime-bound.

Design requirements are developed during the Conceptual Design phase by decomposing requirements from higher level systems, laws and regulations, safety, failure scenarios, handling needs, performance requirements, interface definition and the need to meet the SSC's use case and/or customer requirements. See the *Systems Engineering and Management Plan* for additional direction regarding the generation of requirements.

The SSC should be "graded" as early as possible in the design process. An SSC will have both a quality grade, which is determined using the *Quality Level Determination Procedure,* and a Configuration Level from the *Configuration Management Procedure for the Second Target Station Project*, both indicated in *S01020000-PC0001 General Policy on Engineering Practices*. Delay in grading an SSC may result in avoidable design rework. The Quality Level and Configuration level are typically the same, but in cases when they differ, the highest of the two determines which design reviews and approvals are required by the Graded Approach Matrix in *S01020000-PC0001 General Policy on Engineering Practices.* The Grade is assigned by the SSC's Configuration Control Manager (CCM) and/or the Project's Configuration Authority (CA) per the *Configuration Management Procedure.* The *Quality Level Determination Procedure* also provides guidance with respect to the need for *Acceptance Criteria Listing* and *Manufacturing Inspection Plan* documents.

Design checklists, included in the appendices of this procedure, should be utilized to assist with the development of the design. *Caution – review section 2.1.1 for direction regarding the use of checklists.*

Feasibility of a design, in terms of its manufacturability, install-ability, reliability, maintainability etc. is developed during the conceptual design phase to a level of reasonable confidence that concerns can be overcome during later design phases. It is inappropriate to include high levels of detail such as fillets, chamfers, countersinks and counterbores, etc. except in cases where such detail is required to answer feasibility issues. Use cases, schematics, sketches, flow diagrams, etc. are developed to understand a design's "big picture" before adding unnecessary detail.

2.2.1 Conceptual Design Reviews

Determination of whether a Conceptual Design Review is required is accomplished by understanding a design's quality level (see Quality Level Determination Procedure) and configuration level (see Configuration Management Procedure for the Second Target Station Project), then referencing the Graded Approach Matrix in *S01020000-PC0001 General Policy on Engineering Practices.* The Configuration Control Manager for the respective Level 2 WBS area, the Level 2 Manager, the Configuration Authority, and the ESH&Q manager may require a higher level of review than indicated by the Graded Approach Matrix at their discretion. Reviews should include reviewers from interfacing systems. In the case of systems which interface with systems external to the project, for example, First Target Station systems, the importance of including reviewers responsible for interfacing systems is increased.

Conceptual Design Reviews shall:

- Review functional and performance requirements of subsystem hardware
- Review hardware engineering specifications and conceptual design
- Review ESH&Q (including ergonomics and human factors)

2.2.2 Approval

Approval authority for a conceptual design is indicated in the Graded Approach Matrix in the *General Policy on Engineering Practices*. In general, the CCM decides if a design may proceed to the Preliminary Design Phase except in cases when they delegate the decision or when superseded by the Configuration Authority.

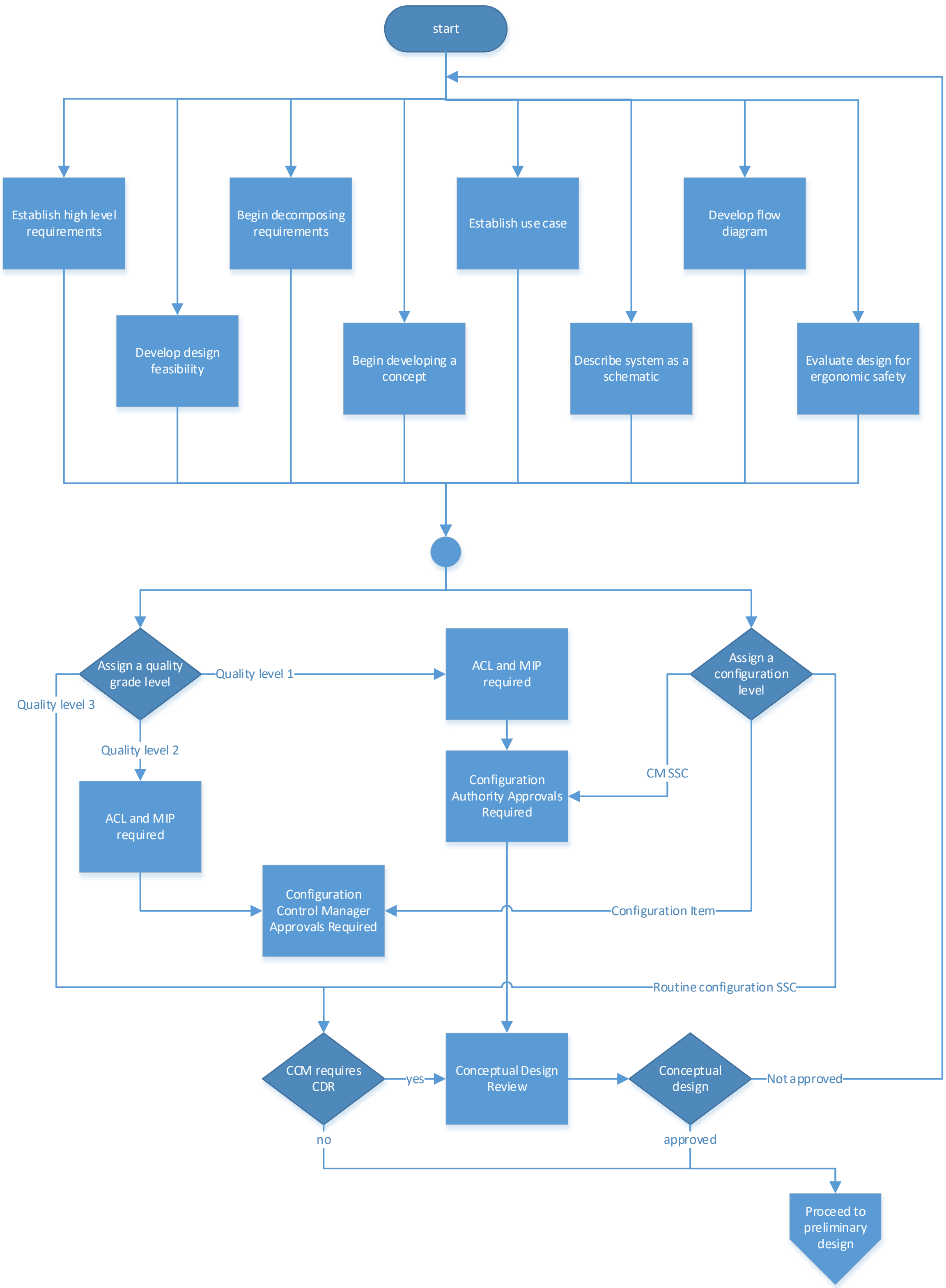

Figure 4. Conceptual Design Flowchart

2.3 PRELIMINARY DESIGN

The overall preliminary design process is summarized in the flowchart shown at the end of this section on Figure 5.

DOE O 413.3B defines Preliminary Design as:

> *"… the design that is prepared following CD-1 approval. Preliminary design initiates the process of converting concepts to a design appropriate for procurement or construction. All KPPs* [Key Performance Parameters] *and project scope are sufficiently defined to prepare a budget estimate. This stage of the design is complete when it provides sufficient information to support development of the PB* [Performance Baseline]*."*
>
> - DOE O 413.3B Program and Project Management for the Acquisition of Capital Assets, Change 7, Attachment 2

The preliminary design phase builds upon the conceptual design to reduce risk and increase confidence that the design is sufficiently viable as to proceed to final design. Because the baselines for DOE O 413.3B projects are established at CD-2, design must be sufficiently mature to justify confidence that the project as a whole will not exceed its cost and schedule contingency, which is typically 20% to 40% at this stage of the project. Extrapolating to the component level, a design has to be sufficiently mature as to estimate its cost and schedule to a similar confidence level. This means that the design of a relatively simple system, or a system that is similar to one familiar to its designer need not be as mature as one for a sophisticated or first-of-a-kind system at the end of the preliminary design phase. The primary objective of the preliminary design phase is to reduce the project's risk of exceeding the baseline cost and schedule estimates plus contingency.

The Quality and Configuration Grades identified during the Conceptual Design Phase should be reevaluated in the Preliminary Design phase.

The design checklists, included in the appendices of this procedure, should be revisited to ensure changes in the design during its development have not altered fundamental design assumptions. *Caution – review section 2.1.1 for direction regarding the use of checklists.*

Requirements and interfaces are defined early in the preliminary design phase. The *Systems Engineering and Management Plan*, as identified in *S01020000-PC0001 General Policy on Engineering Practices,* provides an overview of the requirements management process for the STS. In addition to approvals required by the *Configuration Management Procedure* and *Quality Level Determination Document*, all requirements documents must be signed according to the Subject Matter Expert (SME) Points of Contact (POC) matrix (Table 1) in *NUPO00000-MOU10000 Memorandum of Understanding Between Oak Ridge National Laboratory's Neutron Upgrades Project Office and Neutron Sciences Directorate.* Requirements are reviewed during Preliminary Design Reviews to determine if they are appropriate, complete and if the design meets them.

Upon definition of design requirements, the engineer makes a determination as to whether a commercial-off-the-shelf (COTS) solution exists. Even in cases when a COTS system is available, in some cases it may still be preferable to design a new one in house, if it can be done at a lower cost (including the labor cost of the engineer[s] and designer[s] performing the work), higher performance, better reliability, improved maintainability, etc.

Interface Sheets, detailing each interface an SSC has with other SSCs, must be complete before a Preliminary Design Review. The *Interface Control Procedure*, listed in *S01020000-PC0001 General Policy on Engineering Practices,* details the process for identifying and controlling interfaces to other systems within and outside of the project.

At the conclusion of preliminary design, all key design decisions have been made, key design features have been identified, and trade studies are complete and documented. Preliminary design analysis calculations (DACs) (neutronics, fluid flow, thermal, mechanical, etc.) must be sufficiently complete to support the design.

2.3.1 ES&H Deliverables and Their Relationship to Preliminary Design

The STS Project is committed to providing the following ES&H deliverables for CD-2:

1. Preliminary Safety Assessment Document (SAD) for the Second Target neutron facilities (target building and instrument halls)
2. Updated Hazard Analysis (HA) report for second target
3. Unreviewed Safety Issue Documentation (USID) and supporting analyses for modifications to existing SNS proton facilities

The significance of these deliverables with respect to the development of preliminary designs at the system and subsystem level is that requirements related to addressing ES&H issues must be understood at a level of confidence that the project can establish a reasonable baseline. This means that the development of designs and their effect on the environment and on the safety and health of operational personnel, the scientific user community and the public must be developed in parallel with design features needed to address these factors during the preliminary design phase. This occurs in an iterative, back and forth manner and requires careful communication and attention on the part of both ES&H staff and design staff to ensure that by the end of the preliminary design phase there are no gaps between ES&H requirements and the ability of the design to meet them.

The following section outlines the STS process to ensure successful parallel development of ES&H requirements and system, structure, and component design.

2.3.2 ES&H Review

A formal ES&H Review is required for each major subsystem (defined below in section 2.3.2.2). See section 2.1.6 for direction with respect to the definition of formal.

2.3.2.1 Review Timing

The ES&H review is required before preliminary design reviews. Best practice dictates that this review is held as early as possible and could be held as early as during the conceptual design phase. The design of the SSC must be sufficiently mature and understood as to justify confidence that the design will not change in such a way that ES&H hazards will be significantly different or worse before the preliminary design review is held. In cases when hazards change, another review should be held.

ES&H issues will be again reviewed during the Preliminary Design Review. Review with ES&H should be performed early enough in the design so that these issues can be properly addressed before a Preliminary Design Review but must also be held late enough in the design that the hazards can be understood, and that they do not experience significant change before the more important Preliminary Design Review.

2.3.2.2 System Level of the Review

ES&H review of STS Systems must be at a level in which integration occurs, and low enough that ES&H reviewers have sufficient visibility to see that a hazard may or may not exist. In other words, the reviewer should at least have the ability to know that a concern may exist, and follow up on lower level concerns during the period between the formal ES&H review and the preliminary design review.

2.3.2.2.1 Accelerator Systems

ES&H review of Accelerator Systems shall be at level 2. That is, all Accelerator Systems are reviewed during one review.

2.3.2.2.2 Target Systems

Target Systems are reviewed at level 3.

2.3.2.2.3 Instrument Systems

Instrument Systems are reviewed at level 3.

2.3.2.2.4 Conventional Facilities

Conventional Facilities are reviewed by building.

2.3.2.2.5 Integrated Control Systems (ICS)

- Personnel Protection Systems shall have a dedicated review.
- Target Protection Systems shall have a dedicated review.
- The remainder of Integrated Control Systems are reviewed during a third ICS review.

2.3.2.3 Content of the review

The first session of each ES&H Review will be a comprehensive overview of the system. The overview section is not necessarily ES&H focused, but instead is presented in such a way and with enough detail that ES&H reviewers understand the subsystems and components which make up the system.

The second part of the review addresses specific ES&H issues with which the engineer is already aware.

2.3.2.3.1 Required review elements

At a minimum, the ES&H and Radiological checklists provided in APPENDIX C and APPENDIX D shall be addressed during the review.

The ES&H Review shall specifically address:

- Hazards to people
  - Workers
  - Users
  - The general public
- Pressure system safety
- Vacuum safety
- Systems capable of storing energy
  - Pressure
  - Capacitance
  - Springs
  - other
- Oxygen deficiency hazards (ODH)
- Ventilation systems (for example, truck exhaust)
- Radiological safety
- Hazardous waste resulting from fabrication, installation, and operation
- Hazardous waste resulting from decommissioning
- Ergonomics and Human Factors (see section 2.1.1)
  - Personnel rescue during medical emergencies
  - Confined space hazards
  - Fall hazards and protection
  - Elevated work hazards
- Toxic materials
  - Lead
  - Cadmium
  - Beryllium
- Use of materials susceptible to high activation
  - Copper
- Fire Protection, Prevention, and Control
  - Materials with a high combustible load potential
    - Wood
    - Plastics (i.e., polyethylene)
    - Flammable and combustible solids, liquids and gases
    - Interior finishes

- Life Safety
  - Means of egress
    - Head height
    - Stair, ramp, handrail and guardrail details
    - Door and door hardware details
    - Exit signs and emergency lighting
  - Travel distance to an exit
  - Common path of travel
  - Occupant load
- Fire barrier locations
- Fire sprinkler design intent
- Fire alarm (detection and notification) design intent
- Fire protection for specific locations
  - Clean rooms
  - Computer rooms
  - Electrical installations in hazardous locations
  - Hazardous materials in enclosures/hoods
  - HEPA filter systems
  - Laboratory areas
  - Ovens, furnaces, and environmental chambers
  - Portable structures

2.3.2.4 Tracking and follow up

Concerns and action items are generated from the review and tracked. The ES&H team will follow up with the engineering team after the review to gain a better understanding of issues incompletely pursued during the review and add concerns and action items as appropriate.

The ES&H concerns and action items shall be specifically reviewed during the Preliminary Design Review and shown to have been fully addressed and resolved by the design at the Final Design Review. In addition to covering the specific known concerns and action items, ES&H shall be reviewed at a more general level during the Preliminary Design Review and Final Design Review to ensure the maturation of the design has not introduced new ES&H hazards.

2.3.3 Preliminary Design Review

A Preliminary Design Review is:
"A review conducted to evaluate the progress, technical adequacy, and risk resolution of the selected design approach for one or more ... items; to determine each design's compatibility with the requirements for the ... item; to evaluate the degree of definition and assess the technical risk associated with the selected manufacturing methods and processes; to establish the existence and compatibility of the physical and functional interfaces among the ... items and other items of equipment, facilities, software and personnel; and, as applicable, to evaluate the preliminary operational and support documents."

-ISO/IEC/IEEE. 2009. *Systems and Software Engineering - System and Software Engineering Vocabulary (SEVocab)*. Geneva, Switzerland: International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC)/ Institute of Electrical and Electronics Engineers (IEEE). ISO/IEC/IEEE 24765:2009.

Like the Conceptual Design Review, guidance regarding whether a Preliminary Design Review is required is determined by the Graded Approach Matrix in *S01020000-PC0001 General Policy on Engineering Practices.* The Configuration Control Manager for the respective Level 2 WBS area, the Level 2 Manager, the Configuration Authority, and the ESH&Q manager each have the authority to require a higher level of review than what is indicated by the Graded Approach Matrix.

As a best practice, Preliminary Design Reviews should include an NScD Subject Matter Expert (see POC SME matrix [Table 1] in *S01010000-MO0001 Memorandum of Understanding between Oak Ridge National Laboratory's Neutron Sciences Directorate and Second Target Station Project)* or individual responsible for the operation of a similar SSC as a reviewer. The appropriate CCM or CA may require an NScD reviewer at their discretion. Reviewers of STS internal and external interfacing systems should be included in the review.

Preliminary verification of a design must be performed at a level appropriate that it can be completed with within baseline confidence boundaries and that the resultant design product will be capable of meeting its requirements. More specific direction regarding preliminary design verification is provided in *S01020500-PIN10000 Preliminary Design Definition Document* and by the appropriate CCM and/or CA.

Preliminary Design Reviews shall:

- Review design and compliance to requirements
- Confirm and review deliverables
- Review related items on risk registry
- Review of recommendations and action items from previous reviews
- Review associated items from the STS Tracking System
- Review fabrication of test articles
- Review plans for long-lead procurement items
- Review ESH&Q
    - Review action items from formal ES&H Review

Deliverables for a Preliminary Design Review include:

- Interface Control Documents (ICDs)/Interface Sheets
- CM/GC ICD Review and Comments (for Conventional Facilities)
- Systems Requirements Document
- Design Description Document
- Verification, by analysis, R&D efforts, or prototypes, of key requirements
- Configuration Level Determination
- Configuration and Quality Level Determination Form
- System Safety Classification
- Design Analysis Calculations
- Safety Basis Document
- Acquisition Strategy
- Manufacturing/Fabrication Strategy
- Installation Plan
- System Verification Plan
- CM/GC 50% Constructability Review and Comments (for Conventional Facilities)
- CM/GC 90% Constructability Review and Comments (for Conventional Facilities)
- CM/GC 50% Preliminary Design Review Comments (for Conventional Facilities)
- CM/GC 90% Preliminary Design Review Comments (for Conventional Facilities)

The above deliverables list is representative of *S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix* and *S01020500-PIN10000 Preliminary Design Definition Document,* which includes additional detail at the subsystem level.

2.3.4 Approval

Authority to proceed to the Final Design Phase is determined by the respective Configuration Control Manager unless their authority has been delegated to a designee or is superseded by the Configuration Authority.

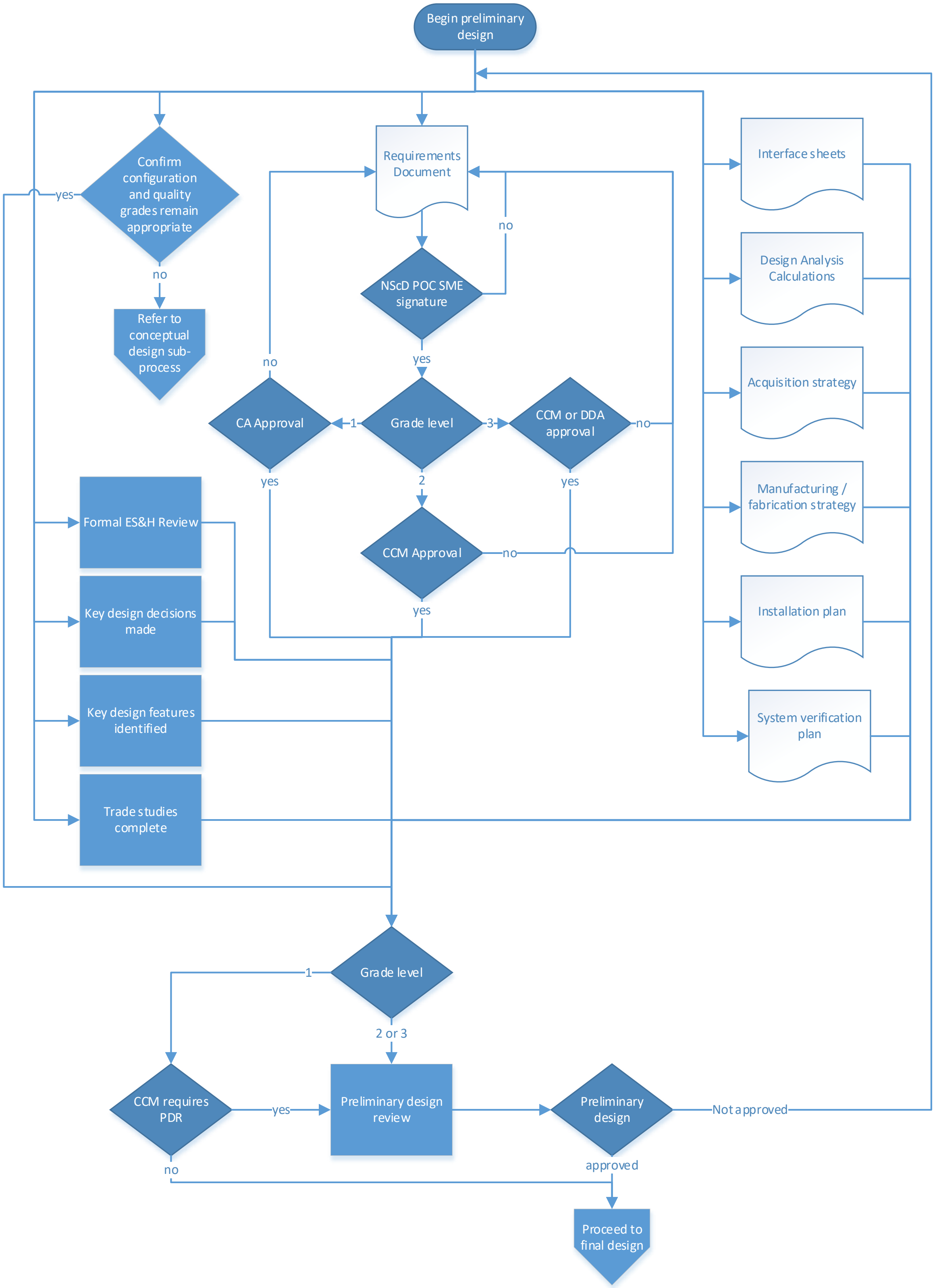

Figure 5. Preliminary Design Flowchart

2.4 FINAL DESIGN

The overall final design process is summarized in the flowchart shown at the end of this section in Figure 6.

DOE O 413.3B defines Final Design as:

> *"Completion of the design effort and production of all the approved design documentation necessary to permit procurement, construction, testing, checkout and turnover to proceed."*
>
> - DOE O 413.3B Program and Project Management for the Acquisition of Capital Assets, Change 7, Attachment 2

During the Final Design Phase all design ambiguity must be fully resolved. All risk must be resolved or mitigated to an acceptable level (as determined by the design's approver). Design Analysis Calculations (DACs), drawings, and any associated technical specifications which are required to procure, manufacture, install, and construct the SSC must be completed.

The Quality and Configuration Grades identified during the Conceptual Design Phase should be revisited to determine if they remain appropriate.

The design checklists, included in the appendices of this procedure, should be revisited to ensure changes in the design during its development have not altered fundamental design assumptions. *Caution – review section 2.1.1 for direction regarding the use of checklists.*

The following accomplishments are achieved during the Final Design phase:

- Completion of final detailed geometry definition
- Finalization of supporting analysis consistent with final geometry
- Translation of established requirements and designs into detailed drawings and technical specifications
- Conveyance of all design deliverables
- Resolution of all ESH&Q related issues, including radiation safety (see section 2.1.4), and Human Factors and Ergonomics (see section 2.1.3)
- Satisfaction of all requirements
- A full understanding of the manufacturing and procurement process, with no remaining feasibility concerns
- Communication of the acquisition process and associated challenges to the procurement and/or manufacturing engineering group(s)
- A plan for verification and validation of component and system requirements
- Agreement with the appropriate installation SME regarding the installation sequence and process
- A full understanding of the capabilities and limitations of deliverables by the NScD operational recipient(s) (the customer) of the SSC
- An alignment strategy, understood and agreed upon by the Survey, Alignment, and Metrology Group, if applicable

- CM/GC constructability review with no remaining feasibility concerns (for Conventional Facilities)

Although not performed during the Final Design phase, **a design is not complete until as-built drawings are issued** before project completion. See the STS's *Policy on As-Built and Redline Drawings*, identified in *S01020000-PC0001 General Policy on Engineering Practices* for direction in this regard. *Note – Drawings for designs which are not changed do not require revision, but field approved changes, like any other kind of change, must be captured to maintain configuration control.*

2.4.1 Project Change

Designs naturally evolve over the course of the development process. After the project has been baselined at CD-2, changes to a design which affect the ability of the project to complete within its baselined cost and schedule plus contingency must be formally captured. Detailed guidance for Baseline Change Proposals (BCPs) may be found in *S01020000-PR0003 Second Target Station Project Change Control Procedure*.

Summarized at a high level, a BCP is required for:

- Additions or deletions of scope to the WBS
- Change to the Budget at Completion (BAC)
- Use of Management Reserve or contingency, or transfer of Management Reserve or Contingency from one WBS element to another
- Any change or delay to a Level 3 or higher milestone > 3 months

When a Lead Engineer and/or their management believes a BCP may be warranted, *S01020000-PR0003 Second Target Station Project Change Control Procedure* shall be referenced and followed.

2.4.2 Final Design Review

All SSCs require a Final Design Review before proceeding to procurement, fabrication, installation, etc. Credited Engineered Controls and other Configuration Managed SSCs, Configuration Items, and Quality Level 1 and 2 SSCs require formal Final Design Reviews.

- Level 1 – Serious
    - Review by individuals or groups independent from those who created the design
    - The review committee panel shall include representatives from interfacing SSCs, ESH&Q, and Systems Engineering
- Level 2 – Important
    - Review by individuals or groups other than those who created the design but could be supervised or managed by the same person
    - The committee panel shall also include representatives from interfacing SSCs

- ESH&Q and Systems Engineering reviewer are optional, at the discretion of the Level 2 Manager, CCM, ESH&Q Manager, and Systems Engineering and Integration Lead

Routine level design requires an informal design review, except in cases when the Level 2 Manager, CCM, ESH&Q Manager or Configuration Authority requests a formal review. Some independent review is recommended as a best practice.

Whenever possible, reviewers from NScD should be included as reviewers for STS systems. Structures, systems, and components with an interface to an FTS SSC *must* have a reviewer for the interfacing FTS system included in the Final Design Review. At the discretion of the appropriate CCM or CA, an NScD SME may be required as a drawing approver.

Reviews of CM SSCs and Configuration Items (See Configuration Management procedure) must include a Subject Matter Expert and/or an individual responsible for the operation of a similar NScD SSC as a reviewer. As a best practice, reviews for all SSCs should include an NScD SME or individual responsible for the operation of a similar SSC as a reviewer.

The appropriate CCM or CA may require an NScD reviewer at their discretion.

The Final Design Review shall, at a minimum:

- Demonstrate that all requirements have been met by the design
- Review the verification and validation plan
- Review the final design, cost, and schedule
- Review related items on risk registry
- Review associated items from the STS Tracking System
- Review ESH&Q
    - o Review action items from formal ES&H Review (held during preliminary design phase)
    - o Radiation safety (see APPENDIX D and section 2.1.4)
    - o Human Factors and Ergonomics (see section 2.1.3)
- Review of recommendations and action items from previous reviews
- Ensure design conforms to all interfaces
- Review drawing status
- Review CM/GC Constructability (Conventional Facilities)

Deliverables for a Final Design Review include:

- Interface Control Documents and all Interface Sheets (complete and released in EDRM)
- Systems Requirements Document (complete and released in EDRM)
- Design Description Document (complete and released in EDRM)
- Configuration Level Determination
- QA Level Determination Form
- System Safety Classification
- Design Analysis Calculations (final and approved or near final and approved)

- Safety Basis Document (for Credited PPS Engineering Controls [CECs]) complete and released in EDRM
- Acquisition Strategy (formal report or a section in review power point, per CCM discretion)
- Manufacturing/Fabrication Strategy (formal report or a section in review power point, per CCM discretion)
- Installation Plan (formal report or a section in review power point, per CCM discretion)
- System Verification Plan
- Piping and Instrumentation Diagrams (P&IDs)

The above deliverables list is representative of *S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix*. Level 2 Managers, CCMs, the ESH&Q Manager and Configuration Authority may require additional deliverables on a case-by-case basis.

Following the Final Design Review, the review committee will provide recommendations in a report that is sent to the responsible Lead Engineer. The Lead Engineer and CCM may decide to modify documents, reports, models, and drawings. Modified deliverables must be re-approved. The final set of approved deliverable items, along with a report that provides responses to the review committee's recommendations, will be submitted to the appropriate CCM for approval of the completion of the design phase. Design Review Notes are documented and stored for Record Copy in the Electronic Data and Records Management (EDRM) system.

2.4.3 Approval

Credited Engineered Controls (CECs) or other Configuration Managed Structures, Systems, or Components (CM SSCs) require approval of the STS Configuration Authority. Approval of Configuration Items require approval of the appropriate Configuration Control Manager (CCM). Approval of "Level 3 - Routine" SSCs require CCM approval unless delegated to a Designated Design Authority. See *Configuration Management Procedure for the Second Target Station Project* for additional detail regarding approvals.

Approval of Configuration Items and normally configured SSCs *may* also require approval from the Level 2 WBS manager, as determined by the Level 2 WBS Manager.

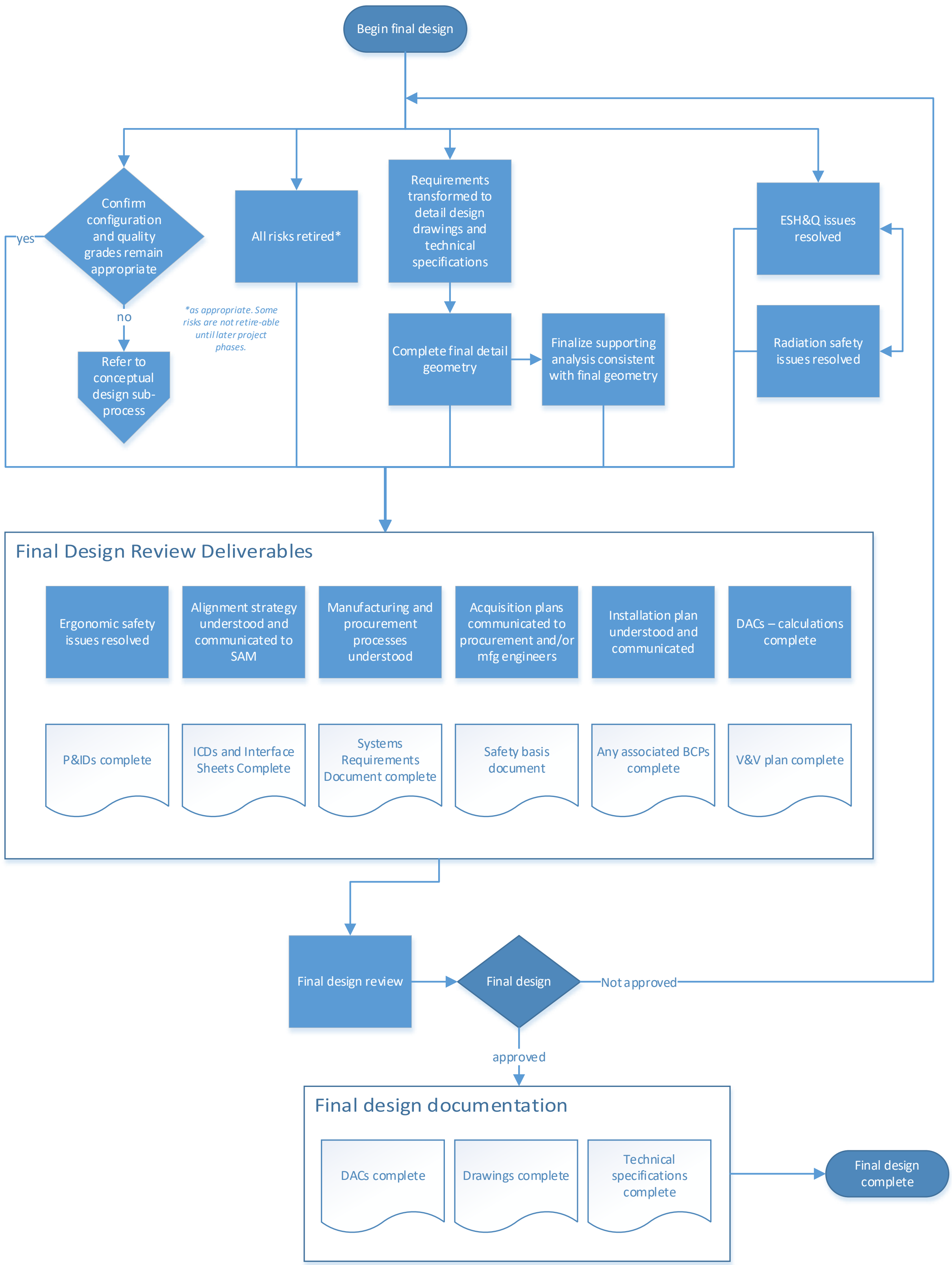

Figure 6. Final Design Flowchart

3. POST DESIGN

As previously mentioned, the procurement, fabrication, installation, and decommissioning phases (etc.) for software, firmware, and Conventional Facilities can be different from characterizations in this document and interpretation may be required.

Engineering Change

Once a part or assembly has been promoted to Initial Release status, changes to its form, fit or function require a change to its part number, otherwise the part(s) retain their part number(s) and step to the next revision number. The *S01020000-PR0003 Second Target Station Project Change Control Procedure* and *Policy on Drawing Preparation* (identified in *S01020000-PC0001 General Policy on Engineering Practice*) provide direction regarding the required degree of formality and approvals.

As previously mentioned in the section on Final Design, any change made during any post design phase up to and including transition to operations must be captured per STS's *Policy on As-Built and Redline Drawings* or the *Policy on Nonconformances and Deviations* (as appropriate) and must be captured before CD-4.

3.1 PROCUREMENT

After the design is complete, the SSC is either made in-house or purchased. Components are purchased through the manufacturing engineering group (at the time this procedure is written, the STS manufacturing engineering group does not yet exist; until the group is formed, SNS manufacturing engineering is used) or the STS Procurement team. Detail regarding the procurement process is beyond the scope of this document, but at a high level, lower cost, locally fabricated equipment is handled by the manufacturing engineering group while more complex, higher cost, nationally and internationally sourced purchases are managed by the Procurement group. *Significant exceptions and variations to the just described generalized procurement process exist. The depiction is provided for direction, not prescription.*

The following are required before procurement may begin:

- Drawings (final and approved)
- Technical Specifications (final and approved)
- Piping and Instrumentation Diagrams (P&IDs)
- Acceptance Criteria Lists (if quality level 1 or 2)

Procurements may not be made against draft drawings or technical specifications. Drawings, technical specifications or any documentation or other instruction required to manufacture an SSC must be in an approved, released, certified for construction status before a procurement can be awarded. In special circumstances, a procurement may begin as a request for quotes against preliminary drawings or technical specifications if they are prominently marked as "DRAFT – NOT FOR MANUFACTURE" but must be in a released state before the procurement is awarded. In such a situation, drawings or specifications that are updated in a way that the cost or time to manufacture changes more than 10%, the request for bids must be re-started.

For either option, the Lead Engineer provides a Statement of Work (SOW). The complexity of the SOW scales to the complexity of the procurement. It may be as simple as an email to a fabrication engineer with instructions to build according to drawings attached to the email with parts needed by XX/XX/XXXX, or may be a lengthy document which could include requirements for manufacturer deliverables such as:

- Supplier deliverable expectations
- Payment milestones
- Project management plans
- Quality plans
- Material mill test reports
- Material certifications
- Review of manufacturing drawings
- Prototype tests and reports
- First article inspection
- Factory acceptance testing (FAT)
- Packaging requirements
- Transportation requirements
- Site acceptance testing
- etc.

If important, it should be included in the Statement of Work.

In addition to a Statement of Work, a Technical Specification may be required or desired in cases when all manufacturing (or other) information or requirements are not included on drawings.

Quoting the Systems Engineering Management Plan:
"*A Statement of Work is written for designs or design/build work performed by entities outside of the STS organization for the project. Statements of Work describe work. Statements of Work only include actions to be performed, typically by a subcontractor. An example, a Statement of Work could be as simple as "Build 2 widgets per technical specification XYZ."*

"Technical Specifications include ONLY two things: (1) technical requirements for the hardware, software or firmware; and (2) the verification tests required to confirm that the technical requirements are satisfied."

The Lead Engineer must follow the procurement to ensure:

- Deadlines are communicated
- Qualified suppliers are included in the request for bids
- The procurement is completed in a timely manner
- The criteria for awarding the procurement are communicated to and agreed upon with manufacturing engineering or the procurement group

- The procurement award is made to the best proposal

Deliverables to be provided by the design organization during the procurement phase include:
- Updated Systems Requirements Documents
- Updated Design Description Documents
- Updated Interface Control Documents
- Updated Interface Sheets
- Updated System Verification Plan
- Revisions to Drawings and Technical Specifications made to clarify or correct requirements
- Updated Risk Assessment

3.2 FABRICATION

After the procurement is awarded, the fabrication phase begins. It is the responsibility of the Lead Engineer to provide oversight of the procurement to ensure that the SSC is delivered as expected, and to protect the interests of the STS and ORNL. More complex or important fabrications require more from the engineer in the way of oversight, but no matter the scale supplier visits are a best practice. An engineer may want to drop by once a week for a simple, local procurement, or more formal visits may be warranted for non-local, more complex, or important fabrications. Expectations in this regard should be detailed in the Statement of Work, and could include kickoff meetings, interim status meetings, review of manufacturing drawings (or design drawings in the case of a design-build procurement), authorization to purchase raw material, authorization to begin fabrication, interim surveillance visits, functional testing, and acceptance. When testing is required, a test plan and acceptance criteria are also required. In the case of Quality Level 1 or 2 procurements, an Acceptance Criteria Listing (ACL) and Manufacturing Inspection Plan (MIP) are required. Tests are documented by test reports which are transmitted to EDRM for Record Copy.

Deliverables provided during the Fabrication Phase include:
- Deviation Requests
- Non-Conformance Reports
- Updated Systems Requirements Documents
- Updated Design Description Documents
- Updated Interface Control Documents
- Updated Interface Sheets
- Updated System Verification Plan
- Revisions to Drawings and Technical Specifications to as-built status
- Updated Risk Assessment
- Updated Quality Level Determination Forms
- Updated Acceptance Criteria Listing Documents
- Updated Manufacturing Inspection Plans
- Updated Safety Basis Documentation
- Completed Manufacturing Verification Reports

3.3 PRE-INSTALLATION TESTING AND ACCEPTANCE

Larger procurements typically warrant Factory Acceptance Testing, in which the fabricator performs functional testing (as specified in the procurement's statement of work and/or technical specification). Successful testing and acceptance is followed by an authorization to ship to ORNL. Depending on the equipment, site acceptance testing, with or without the attendance of the manufacturer, is performed before the equipment is installed. As with factory acceptance testing, site acceptance tests are documented by test reports and transmitted to EDRM.

3.4 INSTALLATION

The Lead Engineer works with an installation supervisor to plan the installation. Installation plans should be completed before or during the manufacturing phase to ensure the installation team understands and is prepared for the installation. The engineer and installation supervisor work together to determine the formality and complexity of the installation plan. Many installations can only take place during major maintenance periods which may only occur once or twice a year or may require an extended outage which occurs even more infrequently. In these cases, the installation planning must be performed well in advance of the installation to ensure the proper resources are in place when they are needed. The installation supervisor will typically plan and schedule craft to perform the installation, but coordination of more technical resources, such as Survey, Alignment, and Metrology or the vacuum group, require direct involvement of the Lead Engineer.

3.5 TESTING AND COMMISSIONING

After installation, testing of SSCs is frequently required. The Lead Engineer must ensure all resources are available to perform testing and that communication is accomplished with sufficient lead time for resource management to sufficiently plan for testing. The installation supervisor can often be utilized to assist with testing. Test plans must be written before testing can begin, and test reports must be stored for record copy in the EDRM system.

3.5.1 System Testing

The following list of items are typically required for completion of the System Testing Phase:

- Updated Systems Requirements Documents
- Updated Design Description Documents
- Updated Interface Control Documents
- Updated Interface Sheets
- As-Verified CAD models, drawings, P&IDs, etc. for all structures, systems, and components
- Updated Risk Assessment
- Updated (As-Verified) System Analysis Reports
- Updated Manufacturing Process Specification to an As-Verified status
- System Verification Reports
- System Operation and Maintenance Manuals

3.5.2 Integrated Systems Testing

The following list of items are typically required for completion of the Integrated Systems Testing Phase:

- Updated Systems Requirements Documents
- Updated Design Description Documents
- Updated Interface Control Documents
- Updated Interface Sheets
- Updated Manufacturing Process Specification to an As-Validated status
- As-Validated CAD models, drawings, P&IDs, etc. for all structures, systems, and components
- Updated Risk Assessment
- Updated (As-Validated) System Analysis Reports
- Updated (As-Validated) System Verification Reports
- Updated (As-Validated) System Operation and Maintenance Manuals

3.5.3 Safety of Accelerators

Prior to the start of commissioning activities and the start of routine operations, the Second Target Station (STS) must receive approval from the Department of Energy (DOE) Field Element Manager. DOE approval is contingent upon the following accelerator safety program elements being established: 1) a Safety Assessment Document (SAD); 2) a DOE approved Accelerator Safety Envelope (ASE); 3) a DOE approved Unreviewed Safety Issue (USI) Process; and 4) an Accelerator Readiness Review (ARR) Process.

The **Safety Assessment Document** (SAD) contains the results of a Safety Analysis for an accelerator or accelerator facility pertinent to understanding the risks to workers, the public, and the environment. The SAD encompasses the documented process wherein hazards of a given operation have been analyzed. This analysis includes a description and analyses of the adequacy of measures taken to eliminate, control, or mitigate the respective hazards and risks of normal operation. The analysis also includes identification and analyses of potential accidents and their associated risks. Thus, the purpose of the SAD is to provide an accurate description of the facility, an analysis of accelerator specific safety hazards, and necessary controls to eliminate or mitigate those hazards such that associated risks are understood. All hazards at an accelerator facility fall within two categories: 1) hazards which are addressed by other DOE approved applicable safety and health programs and/or processes, or 2) accelerator-specific hazards. The SAD is focused on those accelerator-specific hazards which are analyzed and addressed by the SAD and provisions of the Accelerator Safety Envelope.

The **Accelerator Safety Envelope** (ASE) is comprised of a documented set of verifiable physical and administrative requirements, bounding conditions, and credited controls that address accelerator specific hazards and risks and that ensure safe operation of the accelerator facility. The DOE Field Element Manager approves the ASE.

The **Unreviewed Safety Issue** (USI) Process is an activity or discovered condition with accelerator specific hazards that have yet to be evaluated to determine if the respective activity or condition introduces accelerator specific hazards that are not adequately addressed by the current SAD and approved ASE.

Accelerator Readiness Reviews (ARRs) are required prior to DOE approval for commissioning and/or routine operation. They are a structured review process wherein hardware, personnel, and procedures associated with commissioning or routine operation are evaluated and found ready to permit the activity to be undertaken safely.

The ARR team is made up of accelerator experts, each with experience in some aspect of the efficient and safe operation of a DOE accelerator. The team will develop initial lines of inquiry based on the SAD and ASE. ARR team members will examine the STS design, construction, quality assurance practices, proposed conduct of operations, commissioning, experience and training of personnel, operating procedures, and especially the level of safety incorporated into each of those aspects of the facility evolution. STS management, operations, and safety personnel will fully support the ARR reviewers through presentations, formal and informal discussions, and providing support documentation as needed for this comprehensive and in-depth review of the respective accelerator safety program. Following a successful ARR and successful closure of any pre-start actions, the DOE Program Element Manager approves the start of commissioning or routine operations.

Once an accelerator facility has been approved for routine operation, situations may arise that warrant review to ensure safety is maintained. In general, major additions to or modifications of the accelerator may justify an ARR. However, contractor focused reviews may be more appropriate to support minor facility modifications, equipment or instrumentation upgrades. One example is the use of Instrument Readiness Reviews (IRRs). IRR programs have been appropriately reviewed by ARRs, and IRRs may be used to ensure that accelerator safety requirements are reviewed and applied as appropriate. IRRs are typically conducted by the NScD Instrument Systems Safety Committee (ISSC). The IRR is a review of the safety of the instrument before the instrument shutter may be opened.

Required deliverables for ARRs and IRRs include:

- Finalized Interface Control Documents and Interface Sheets
- Finalized Systems Requirements Documents
- Finalized Design Description Documents
- Finalized Design Analysis Calculations
- Finalized Safety Analysis Documentation
- Finalized Drawings, including incorporation of all as-builts
- Manufacturing Verification Reports
- System Verification Reports
- System Operation and Maintenance Manuals
- A final report from the Radiation Safety Committee
- Commissioning Plan

- Safety Assessment Document
- Accelerator Safety Envelope

ES&H team members, each an expert in some aspect of accelerator safety, are available to consult with designers as plans develop. The safety team can provide input on DOE, ORNL, and specific industry safety standards which must be met in the final design. In addition, most of the safety team members have experience at SNS and can help ensure the STS design will be compatible with existing SNS safety practices. Safety team members can also assist with required ORNL reviews and approvals, including mandatory radiation shielding/safety reviews and approvals by an STS-selected Radiation Safety Committee. These internal safety approvals must be obtained before the ARR meets and of course before STS operation will be approved by DOE.

3.5.4 Commissioning

Commissioning periods vary from system to system but are longer activities than testing. Commissioning involves operating a system for an extended period in order to better understand the operation of the system, develop rigorous operations procedures manuals and to tune the system for optimal performance. Commissioning does not always (directly) involve engineering, for example in the case of an instrument, but requires engineering support. Depending on the nature of the system and the particular nature of its commissioning, engineering works with the operating organization to develop plans, commissioning procedures and to provide required technical support, up to and including component and system level redesign. To ensure proper configuration management, all design changes must be documented to reflect their as-built condition before the project or activity is closed.

All deliverables for the ARR and IRR shall be evaluated to determine if they require update as a result of changes made during the commissioning period. Updated documents are formally revised, approved and transmitted to the EDRM system for Record Copy.

Completion of the Commissioning phase indicates that the SSC is ready for acceptance by the NScD operations organization and customer.

NOTE: Instrument Commissioning is performed by NScD after CD-4.

3.6 ACCEPTANCE AND CLOSEOUT

Acceptance and closeout expectations are documented in the STS Transition to Operations Plan. At the time this document is being written, this plan does not yet exist, but will be written and released as preliminary before CD-2, revised at CD-3, and finalized before CD-4.

Instruments require an additional Instrument Readiness Review before entering the user program. Engineering staff (except for members of the Instrument Systems Safety Committee) do not typically participate in these reviews but provide support as necessary.

The STS Project is validated as a System of Systems per the verification and validation plan by the Systems Engineering and Integration Lead. Validation of the project provides objective evidence that the project has met its Key Performance Parameters and is confirmed by DOE with approval of the CD-4 Project Closeout Milestone.

By definition, all support from project personnel must be complete before CD-4. Project charge numbers cease to exist when CD-4 is complete and all support going forward is provided by the NScD operating organization.

3.7 OPERATIONS AND MAINTENANCE

The operations and maintenance phase, including system upgrades and other kinds of changes or reconfiguration occurs after the STS project is complete. The operations and maintenance phase is by far the longest phase of an SSC's lifecycle, so it is critical that this phase is understood as well as possible by the design engineering staff and that the NScD operating organization is engaged during design phases to ensure the operations and maintenance phase is considered. Proper control of the configuration is critical during operations and maintenance, which in turn requires the configuration of the SSC during the design phase to be understood and captured as accurately as possible. As changes occur during the operations and maintenance phase, the understanding of its configuration always decreases. It is the responsibility of the design organization to ensure the quality of configuration documentation is complete and correct at project closeout.

3.8 DECOMMISSIONING

The STS Global Requirements Document requires all SSCs to be designed with decommissioning in mind. Many components will be radioactive or otherwise present harm to the environment or to the personnel responsible for removing them. These factors must be taken into account in design. Features should be present to accommodate removal, materials should be chosen for low activation potential, low environmental toxicity, and good industrial hygiene. Space allocation boundaries must be observed to ensure the possibility of upgrades and replacement. Agreements between two neighboring SSCs to cross one another's allocated borders may work during the initial operations and maintenance phase of the facility but have the potential to cause unnecessary problems later in the lifecycle of the facility when upgrades and replacements are required.

APPENDIX A. Design Checklist

	Yes	No	N/A
Credited Engineered Control (CEC)			
Configuration Managed System, Structure or Component (CM SSC)			
Configuration Item (CI)			
Routine Design			
Special Grade (expedited, documentation only, test hardware)			
Quality Level 1			
Quality Level 2			
Quality Level 3			
Acceptance Criteria Listing (ACL)			
Manufacturing Inspection Plan (MIP)			
Flow Diagram			
System Schematic or Block Diagram			
Design Analysis Calculation (DAC)			
Conceptual Design Review Required			
Preliminary Design Review Required			
Final Design Review Required, formal			
Manufacturability Analysis and plan			
Install-ability Analysis and plan			
Ergonomics Analysis			
Radiation Safety Analysis			
Neutronics Analysis			
ES&H Evaluation			
Requirements Document			
Verification and Validation Plan			
Listed in Interface Control Document?			
Interface Sheet			
Equipment Specification			
Procurement Plan required			
Factory Acceptance Testing (FAT) required?			
Site Acceptance Testing Required?			
Commissioning Plan			
Test Plan			
High Energy Pressure System?			
System capable of storing electrical energy			
Controls and Data Acquisition			
Human Interfaces			
Lifting features			
Weight below crane capacity?			
Will it fit on a truck?			
Will it get through the door?			

APPENDIX B. Utilities Checklist

	Yes	No	N/A
Compressed Air			
Vacuum			
House Nitrogen, gaseous			
Hydrogen, gaseous			
Hydrogen, liquid			
Helium, gaseous			
Helium, liquid			
Argon, gaseous			
Electrical Power			
Electrical Power with generator backup			
Electrical Power with UPS backup			
any specific or unique electrical grounding requirements			
Hot Off Gas (HOG)			
Secondary Confinement Exhaust (SCE)			
Vacuum pump local exhaust			
Laboratory hood local exhaust			
Building HVAC and exhaust			
Potable Water			
Fire protection water			
Sensible Chilled Water			
Tower Cooling Water			
Activated Cooling Water Loop			
Deionized Water (for building systems)			
Secondary Deionized Water Cooling			
Activated Cooling Water Leak Collection			
Low Level Liquid Waste			
Floor Drains			
Process Waste			
Sanitary Sewer			
Solid Waste collection			
Radioactive Solid Waste collection			
Hazardous Non-radioactive Solid Waste collection			
Mixed (Hazardous & Radioactive) Solid Waste collection			

APPENDIX C. ES&H Checklist

Select applicable ES&H hazards which may be introduced or have the potential for significant increases to existing hazards and indicate the controls required to be incorporated into design.

Environmental Hazards
Does the design:

- Introduce portable oil storage equipment?
- Introduce ozone depleting substances?
- Initiate a permanent discharge of water or bio-hazards to waste streams?
- Introduce the storage of hazardous materials?
- Other:

Safety and Health Hazards
Does the design:

- Introduce machinery with mechanical motion that employees may work on or near?
  - If so, is machine guarding provided?
- Introduce a system that stores energy (e.g., pressurized components, vacuum systems, springs, batteries, capacitors, hydraulic accumulators, etc.)?
  - Are lockout/tagout features and procedures required?
- Introduce a potential oxygen deficiency hazard (inert gas, cryogenic material)?
- Introduce equipment pinch points or sharp edges that employees may work on or near ("near" = distance where an individual or tool could contact the piece of equip.)?
- Create a work area that will be posted as a high noise (greater than 85 dBA) area?
  - The American Conference of Governmental Industrial Hygienists (ACGIH) recommends an 85dB(A) for an 8-hour time-weighted average, with the stipulation that a 3dB exchange rate be used to calculate time-varying noise exposures. Thus, a worker can be exposed to 85dB(A) for 8 hours, but to no more than 88dB(A) for 4 hours or 91dB(A) for 2 hours.
- Introduce overhead obstructions?
- Create tripping hazards or an area with an unstable surface for personnel to stand or walk on?
- Introduce compressed gas cylinders?
- Create an extreme temperature environment or expose workers to conditions that prevent the body from maintaining proper body temperature?
- Introduce potential for contacting a high temperature surface (>50°C)?
- Introduce ergonomic hazards (e.g., repetitive motion, excessive manual force, heavy lifting, awkward postures, vibration)?
- Adversely affect facility HVAC or local exhaust system flow paths or velocities used to control exposures to hazardous substances?
- Permanently obstruct access to a facility? Obstruct exits and accessways?
- Disable or degrade safety equipment (e.g., eyewashes, emergency showers, etc.)?

- Block/obstruct aisle, entrance, exit, or access to safety/emergency response equip.?
- Create narrow alley of less than OSHA allowable? Create access and egress less than NFPA 101, Life Safety Code and/or OSHA?
- Introduce hazards in adjacent work areas?
- Introduce electrical hazards?
- Introduce magnetic fields greater than 5 gauss?
- Introduce non-ionizing radiation? (RF, EMI)
- Introduce lasers (classes 3a, 3b, or 4)?
- Involve installation of hoisting and rigging equipment including cranes?
- Create an elevated work platform (3 meters above normal walking surface level)? Fall Protection concern.
- Create a pit with a depth greater than 3 meters? Fall Protection concern.
- Install permanent ladders and/or stairs, i.e. access areas above or below requiring more than one step?
- Create a confined space? Create a "Permit Required Confined Space"? (*A simple confined space can be okay. A permit space is the real concern because an acute hazard being present makes it a permit required space.*)
- Introduce cryogenic systems or chemicals exhibiting cryogenic properties?
- Introduce working with beryllium or beryllium contaminated equipment?
- Introduce the handling or storage of a carcinogen (as identified on the SDS)?
- Introduce working with lead, cadmium, mercury that could pose an inhalation, ingestion, or injection hazard?
- Introduce potential for worker's eyes/ skin be exposed to toxic/corrosive chemicals?
- Introduce explosive materials?
- Introduce robotic or autonomous systems?
- Limit access to toilet facilities?
    - There are no specific distance or location requirements for toilet facilities in 29 CFR 1910.141(c). An employer is, however, expected to use reasonable judgment in evaluating the proximity of sanitary facilities to employees. However, ANSI recommends that as far as practical, toilet facilities be located within 200 feet of all locations where workers are regularly employed.
- Allow for appropriate material storage especially chemical storage?
- Address specifications for appropriate safety signs?
- Limit the workspace around equipment?
- Other:

SBMS Subject Area Resources:

- *Asbestos*
- *Beryllium*
- *Biohazards*
- *Chemical Safety*
- *Compressed Gas Cylinders and Related Systems*
- *Confined Space*

- *Electrical Work*
- *Ergonomics*
- *Explosives*
- *Exposure Assessment*
- *Fall Protection, Scaffolding, and Aerial Lifts*
- *Fire Protection, Prevention & Control*
- *Hazardous Waste Operations and Emergency Response (HAZWOPER)*
- *Hearing Conservation*
- *Ladders*
- *Lasers*
- *Lead*
- *Lockout/Tagout*
- *Material Handling*
- *NEPA and Cultural Resources Evaluations*
- *Occupational Hazard Controls*
- *Pollution Prevention*
- *Pressure System Safety*
- *Ventilation, Local Exhaust*
- *Water Quality Impacts from ORNL Activities, Preventing*
- *Welding, Burning, and Hot Work*

APPENDIX D. Radiological Safety Checklist

Select applicable radiological hazards which may be introduced or have the potential for significant increases to existing hazards and indicate the controls required to be incorporated into design.

Radiological Hazards

Does the design:

- Introduce or modify a new process or equipment that will be used to contain or transport radioactive materials?
- Introduce or modify a radiation-producing device (including x-rays)?
- Introduce or modify radiation shielding (concrete, lead, steel, liquid, polyethylene, boron, etc.)?
- Involve materials with an atomic number of ≥90
- Make changes to the PPS or radiological safety equipment (such as shown in the list below)? If yes, fill out checklist below.
- Make changes to non-PPS equipment that interfaces with PPS equipment? If yes, fill out the check list below.
- introduce materials into the beam?
- Other:

PPS or Radiological Safety Equipment Items

Does the design involve?

- Beam Stop(s)
- Beam Stop Lock(s)
- Beam Stop Warning Sign
- Shutter Mechanism
- Shutter Indicator Lights
- Shutter Lockout Capability
- Shutter Inserts
- Get Lost Tube
- Shield Blocks
- Shield Locks
- Flight Tubes or Guides
- PPS Panels
- PPS Limit Switches
- PPS Magnetic Locks
- Instrument Mechanical Stops
- Intrusion Alarm
- Area Radiation Monitors and Alarm(s)
- Entrance Access Control
- Interlock with Shutter
- Emergency Exit Capability

- Interlock with Sweep Function
- Signage
- Safety Related Administrative Controls
- Kill Switch
- Audible Alarm(s)
- Radiological Work Permit (RWP) areas defined
- Devices to prohibit operation of shutter from inside enclosures
- Light curtain
- Proximity alarm
- Prompt radiation produced by beam operations
- Items and materials that have been activated by the beam
- exceeding design goal for normally occupied areas (> 0.25 mrem/hr)
- additional shielding
- radiological postings
- Neutronics team analysis of shielding or other radiation transport issues
- Accident conditions should be considered as well as normal operational conditions
- Other:

SBMS Subject Area Resources:
Radiological Design Requirements - ORNL General ALARA Design Requirements are located in SBMS Subject Area: Design

APPENDIX E. Facility Interface Checklist

Identify potential impacts to the operating facilities SSCs or other SSCs and provide comments indicating design considerations as needed.

Does the design require changes to Operating Facility SSCs?

- Structural
- Seismic
- Electrical
- Compressed/Instrument Air
- Nitrogen systems
- Helium Systems
- Lighting
- Phone or network devices
- Chilled Water
- HVAC
- Hot off-gas, SCE, Component exhaust systems
- Facility Cranes and/or Monorails
- Laboratory systems
- Building Exhaust
- Fire Suppression
- Fire Alarm System
- Fire Barriers
- Process Waste Drains
- Ingress/Egress
- Confined spaces
- Decommissioning Commitment
- Existing Shielding Structures
- Beam Tube Service Piping
- Security related system
- Emergency communications or evacuation systems
- Combustible Control Area
- Area radiation monitors
- Specialized facility ventilation confinement systems
- Process water system
- Sanitary sewer, storm sewer, or potable water systems
- Facility hazardous materials limits/exclusions
- Demineralized water system
- Cooling water system
- Floor loading
- Oxygen deficiency monitors
- Space Allocation Envelope

- Sample Environment Cage, Chopper Cage or Lay-down areas
- Sensible chilled Water
- Control System
- Personnel Protection System or other credited control
- Machine Protection System
- Installation into SNS building supporting operations
- Other

Does the design impact other facility systems?

- Access to neighboring system
- Magnetic fields
- Crane access to neighboring system
- Changes in RAD conditions on neighboring system
- Changes to radiation background
- Line of sight to laser tracker fiducials
- Vibration levels
- Noise levels
- Other