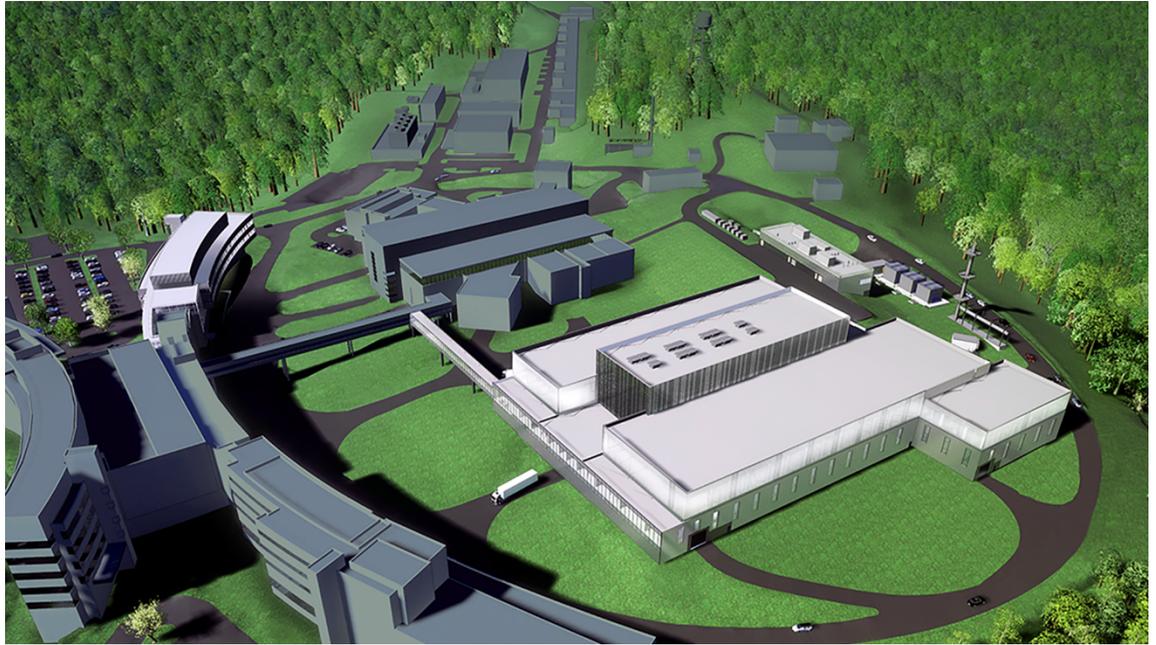


# Second Target Station Project: Preliminary Design Definition



January 2025



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Second Target Station Project

**PRELIMINARY DESIGN DEFINITION**

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January 2025

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00	Initial Release
01	Updated Accelerator, Target, and Instrument Systems section to reflect actual practice

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## Acronyms

A/E	Architectural Engineering
API	Application Programming Interface
A/R	As-Required
AIC	Accelerator Interface Components
AS	Accelerator Systems
ASME	American Society of Mechanical Engineers
BOA	Basic Ordering Agreement
BPVC	Boiler Pressure Vessel Code
BWI	Bunker Wall Insert
CAD	Computer Aided Design
CD	Critical Decision
CEC	Credited Engineering Control
CF	Conventional Facilities
CI	Configuration Item
CM/GC	Construction Manager/General Contractor
CMMH	Cold Monolith Modules Handler
CM SSC	Configuration Managed System Structure or Component
CMS	Cryogenic Moderator System
CV	Core Vessel
DAC	design analysis calculation
DI	deionized
DOE	Department of Energy
EDRM	Enterprise Data and Records Management System
ESH&Q	Environment, Safety, Health, and Quality
FMEA	Failure Mode and Effects Analysis
FSAD	Facility Safety Assessment Document
FTS	First Target Station
HVAC	Heating Ventilation and Air Conditioning
ICD	Interface Control Document
ICS	Integrated Control Systems
IS	Instrument Systems
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IFC	Issued For Construction
INCOSE	International Council on Systems Engineering
I/O	Input/Output
ISO	International Organization for Standardization
KPP	Key Performance Parameter
LINAC	Linear Accelerator
LLRF	Low Level Radio Frequency
M/E/P	Mechanical/Electrical/Plumbing
MIP	Manufacturing Inspection Plan
MRA	Moderator Reflector Assembly
PB	Performance Baseline
PBTA	Proton Beam Tube Assembly
PBW	Proton Beam Window
PDR	Preliminary Design Review
PFD	Process Flow Diagram
PHAR	Preliminary Hazard Analysis Report

P&ID	Process and Instrumentation Diagram
PLC	Programmable Logic Controller
PPS	Personnel Protection System
QA	Quality Assurance
R&D	Research and Development
RTBT	Ring to Beam Tunnel
RTST	Ring to Second Target
SEBoK	Systems Engineering Body of Knowledge
SEVocab	System and Software Engineering Vocabulary
SIL	Safety Integrity Level
SNS	Spallation Neutron Source
SSC	System, Structure or Component
STS	Second Target Station
TBD	To Be Determined
TS	Target Systems
TSS	Target Station Shielding
TVP	Target Viewing Periscope
WBS	Work Breakdown Structure

## PURPOSE

The purpose of this document is to provide definition of the term *preliminary design* and what is expected for a *Preliminary Design Review* for a System, Structure or Component (SSC) for the Second Target Station (STS) Project.

It is recognized that a clear objective definition of preliminary design that can be universally applied to every SSC does not exist. STS procedure *S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix* provides a guide for deliverables at various stages of the project, including preliminary design. Nonetheless, variations in business practices and the nature of the SSC result in variations of deliverables. Further, in the case of preliminary design, the guide cannot speak to the detailed contents or maturity of the deliverables that is appropriate for a given SSC.

This document identifies specific approaches to preliminary design for each system that comprises the STS project.

## INTRODUCTION AND CONTEXT FOR PRELIMINARY DESIGN DEFINITION

DOE O 413.3B defines Preliminary Design as:

*“This is 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, Attachment 2*

Preliminary design marks a key milestone in the evolution of the STS. At the conclusion of preliminary design, all key design decisions should be made. Key design features should be identified. Where significant design choices have been made, trade studies should be complete and documented. Preliminary design analysis calculations (DACs) (neutronics, fluid flow, thermal, mechanical, etc.) should be complete to support the design configuration.

The Preliminary Design phase exists between the conceptual design and final design phases. The conceptual design phase adds enough detail and analysis to understand the feasibility, basic scope and order of magnitude cost. 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. Requirements for the SSC are defined early in the preliminary design phase. In the context of the STS, or any DOE O 413.3B project, the design of an SSC must be sufficiently mature to establish confidence that only minor changes are necessary to be complete. That is, mature enough to accurately estimate the cost and schedule, to procure, manufacture, test and install the SSC without exceeding the baseline plus contingency (typically 20% to 40%) established at CD-2. Given the variation of any SSC against another in technical maturity, risk, application, etc., design maturity differs across systems within the project.

It is helpful to view preliminary design by identifying the work remaining between preliminary and final design. The maturity of the preliminary design decisions should be such that the work remaining in the Final Design phase is limited to:

- Completion of final detailed geometry definition
  - Significant geometry changes are not expected after preliminary design

- Finalization of supporting analysis consistent with final geometry
  - Broad analysis conclusions should already be apparent from preliminary analysis
- Translation of established requirements and designs into detailed drawings and technical specifications
- Update and finalization of remaining preliminary design deliverables

In the simplest terms:

- Design choices are made during the Preliminary Design phase
- Final design deliverables are created during the Final Design phase
- Design evolution is minimized during the Final Design phase

Paraphrasing guidance from the SEBoK (the Guide to the Systems Engineering Body of Knowledge, a wiki owned by the International Council on Systems Engineering [INCOSE]) a Preliminary Design Review (PDR) is:

*“A review conducted to evaluate the progress, technical adequacy, and risk resolution of the selected design approach for one or more [SSCs]; to determine each design’s compatibility with the requirements for the [SSC]; 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 [SSCs] 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.”

Table 4 from *S01020500-PN0001 STS Systems Engineering Management Plan* states that the purpose of a Preliminary Design Review is to “Ensure design is sufficiently mature and integrated to establish project baseline”.

Table 5, from the same document, says that during a preliminary design review one should:

- Review design and compliance to requirements
- Review fabrication of test articles
- Review starts of long-lead procurement items
- Review ESH&Q

The *STS Quality Level Determination Procedure S01030200-PR0002* requires Preliminary Design Reviews for Configuration Managed Structures, Systems and Components (CM SSCs) (a category that includes Credited Engineering Controls [CECs]). Informal Preliminary Designs Reviews are required for Configuration Items (CIs) and are optional for Normal or Routine category designs. See *S01020000-PR0001 Configuration Management Procedure for the Second Target Station Project* for definitions of CM SSC and CI.

The Project will provide the following Preliminary Design Documents as prerequisites to achieving the CD-2 milestone:

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.

As indicated in *S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix*, Preliminary Design Reviews for all SSCs will provide the following deliverables for discussion:

- Interface Control Documents
- Interface Sheets
- Systems Requirements Documents
- Configuration Level Determination
- QA Level Determination

## S.02 – ACCELERATOR SYSTEMS PRELIMINARY DESIGN DEFINITION

Accelerator Systems Preliminary Design will be complete when the risk associated with the estimated schedule and cost for completion of the Accelerator Systems' scope is acceptable to the project.

To demonstrate this, it is necessary to document and review:

- Requirements. Requirements flow down from Accelerator Systems level to subsystems and components. Also, as design decisions are made for a particular subsystem, they can lead to requirements for interfacing subsystems. Requirements documents shall include:
  - Technical requirements
  - Project requirements (if applicable)
  - Seismic requirements (if applicable)
  - ESH&Q requirements (if applicable)Each requirement shall include a trace to the source of the requirement and a discussion of any assumptions. The discussion should also contain any background information useful for providing context to a reviewer
- Design description, including:
  - CAD models
  - Layouts, diagrams, and schematics sufficient to aid visualization and explanation of the design
- Evidence that the design will meet its requirements, including calculations and analyses necessary to demonstrate compliance
- Interfaces. Interfaces can be internal with other Accelerator Systems subsystems or components, or external with either other STS scope or SNS. External interfaces are typically documented via:
  - Interface Control Documents (ICDs)
  - Interface Sheets
- System verification plan. For preliminary design this is not expected to be a detailed plan but should describe the overall approach to verification of the system requirements
- System level installation plan. For preliminary design this is not expected to be a detailed plan but at a minimum should describe the installation approach, expected material handling methods and any special tooling required
- System level maintenance plan. For preliminary design this is not expected to be a detailed plan but at a minimum should show that the system can be serviced
- Risks, including:
  - Hazard analysis and evidence that hazards are mitigated (e.g. seismic analyses, neutronics analyses)
  - Technical risks. This may include a Fault Tree Analysis, DFMEA and/or PFMEA.
  - Risks to project cost and schedule
  - Risk mitigation
- Material cost estimate and basis for that estimate
- Configuration Level determination
- Quality Level determination

To reduce the risk of design changes being found to be necessary later in the design development process, the above design inputs and outputs should be documented and reviewed as early as possible. In general, they can be defined for any subsystem and component in the Accelerator Systems product breakdown

structure. It is the responsibility of the lead engineer for each subsystem to determine the most efficient level(s) at which these inputs and outputs will be documented.

For efficiency and to make Preliminary Design Reviews manageable in scope, they will be conducted for the subsystems listed below. The scope of each review extends to all of the subsystems and components below the subsystem being reviewed.

The subsystems for which Preliminary Design Reviews will be held, along with some of the key items to be reviewed, are:

1. Beam optics:
  - Component layout
  - Anticipated beam losses
  - Proton beam transverse profile
  - Impact of RTST on RTBT proton beam
  - Fault studies
    - Ring extraction kicker failures
    - RTST pulsed dipole failures
    - Worst case magnet failures
2. Magnet systems:
  - Magnets
  - Magnet stands
  - Magnet power supplies
  - Cable type and routing
  - Magnet vacuum chambers
3. Cooling systems:

Conventional Facilities will provide the Accelerator Systems water cooling systems and will be responsible for any design reviews. Accelerator Systems responsibility is to provide the requirements for those cooling systems to CF via interface sheets
4. Vacuum systems:
  - Sizing of RTST vacuum systems equipment, including vacuum pumps, valves, gauges and other purchased equipment
  - Preliminary equipment layouts
  - RTBT vacuum interface
  - Target systems vacuum interface
  - Stored pressure energy hazard mitigation
5. Beam Instrumentation

Beam instrumentation systems are clones of systems in use in the FTS and require no separate design reviews
6. Cabling

Cabling procurement has been moved to CF scope. Accelerator Systems responsibility is to provide the cable requirements to CF via the STS cable database. The AS cabling preliminary design review will be limited to a review of the AS cable schedule
7. LLRF

Firmware development to upgrade LLRF systems for two-flavor beam operation are no longer in AS scope

## 8. Accelerator Systems

- Summarizes the RTST system design description
- Summarizes the status of Accelerator Systems interfaces to:
  - Integrated Control Systems
  - Conventional Facilities
  - Target Systems
  - SNS (including RTBT)
- Reviews RTST system serviceability
- Reviews RTST system expected reliability
- Reviews RTST system installation & material handling
- Reviews the status of actions resulting from the reviews listed above
- Reviews the AS / ES&H interfaces:
  - PHAR
  - Interfaces with PPS
  - Radiation safety
  - Seismic design
  - Access
- Reviews Accelerator Systems level cost and schedule
- Reviews risks to Accelerator Systems cost and schedule

Accelerator systems may also conduct preliminary design reviews for components and assemblies at lower WBS levels than those listed above. In general, these will be informal in nature although subject matter experts external to Accelerator Systems may be invited to participate.

### S.03 – TARGET SYSTEMS PRELIMINARY DESIGN DEFINITION

The following sections provide system level details for Target Systems at the conclusion of preliminary design. There are 2 subsections for each system:

1. Key parameters to be identified at preliminary design
2. Clarifications and/or exceptions to the deliverables in the guidance document, *S01020500- PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix*

#### **S.03.02 – Target Assembly Preliminary Design Definition**

##### **Key Requirements verified at Preliminary Design (by analysis or R&D efforts):**

- Seismic Limits (pending criteria and loads identified by others)
- Fatigue Performance (10 years) of the target segment
- Angular position methods
- Moderator Reflector Assembly (MRA) and shielding clearances
- Neutron output
- Target replacement timeframe

##### **Key Parameters identified at Preliminary Design:**

- Lifetime Factor of Safety for spallation materials
- System pressure drop
- System flow Rate
- Rotation Speed
- Recommended replacement interval

##### **Clarifications to *S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix*:**

- CAD Models
  - Detailed CAD model of drive
  - Component selection
    - Drive motor
    - Valves
    - Instrumentation
    - Vacuum Seal
    - Water Seal
- Interface Control Documents
  - MRA Clearances
  - Core vessel clearances
  - Process Systems – Geometry, flow, energy, pressure drop
  - Control Systems – Sensor type
- System Requirements Document
  - Target Assembly requirements identified
    - From Target Systems (untraced)
    - From Safety Basis (by others, out of scope)
    - No requirements at Level 4 or lower

- Design Description Document
  - General description of design
  - Description of maintenance activities
  - Description of operational sequence
  - Description of miscellaneous other sequences
- Design Analysis Calculations
  - Target lifetime DAC
  - Segment lifetime DAC
  - Drivetrain performance and component selection
  - Off-normal beam calculations
  - Structural calculations of shaft & segments (seismic verifications contingent upon loads provided by others)
- Acquisition Strategy
  - Acquisition of spallation material
  - Acquisition of key drive components
  - Acquisition of structural components
- Manufacturing strategy
  - Acquisition of spallation material
  - Acquisition of key drive components
  - Acquisition of structural components
- System Verification Plan
  - All requirements have an identified method by phase (Design, Fab, Install)
  - Individual test scripts not provided at preliminary design

**Exceptions to *S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix*:**

- None

**S.03.03 – Cryogenic Moderator System (CMS) Preliminary Design Definition**

**The following CMS specific parameters will be established at Preliminary Design completion and documented in the Design Description:**

- System heat loads within 20% of final specification including description of margins incorporated for expected normal and off-normal conditions
- Preliminary PFDs and P&IDs for the hydrogen system
- Total hydrogen inventory
- Hydrogen flow rates and pressure drop
- Hydrogen system component preliminary specifications including ortho para converter and diagnostic
- Hydrogen system geometry including:
  - Hydrogen system coldbox
  - Hydrogen transfer lines
- Preliminary PFDs for the helium system
- Sizing and layout of the helium coldbox, compressors, and other skids
- Helium supply and return temperatures and flowrate

**Clarifications and/or exceptions to *S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix:***

- DACs performed during preliminary design will be limited to analyses which support parameters described in the design description. These will consist of hydrogen system performance analysis during static runs and during beam ramps and trips to support the establishment of hydrogen and helium system parameters. DACs which are specific to individual components, such as ASME Boiler Pressure Vessel Code (BPVC) calculations will be performed during final design or component procurement.
- The hydrogen system safety requirements are critical to the safety basis of the STS facility; therefore, the hydrogen system safety basis and requirements should be final (no expected changes) at the completion of preliminary design.
- No Manufacturing Strategy will be produced as CMS components are a combination of standard cryogenic equipment, pressure vessels, and process piping.

**S.03.04 – Moderator Reflector Assembly (MRA) Preliminary Design Definition**

**The following MRA specific parameters will be established at Preliminary Design completion and documented in the Design Description:**

- Overall MRA geometry including:
  - Moderator and pre-moderator geometry
  - Beryllium geometry
  - MRA backbone
  - MRA pipe routing
- Hydrogen flow rates, pressure drops, and supply and return temperatures
- Water flow rates, pressure drops, and supply and return temperatures
- Key MRA fabrication and installation tolerances
- Clearances between MRA and surrounding structures
- MRA Material choices/specifications

**Exceptions and/or clarifications to *S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix:***

- The goal of the preliminary DACs is to verify all thermal hydraulic and structural requirements for the MRA moderators, reflectors, and backbone with analysis; however, it is expected that up to 5% of the regions of the MRA will *not* meet requirements at the completion of preliminary design and will be modified during final design to meet requirements.
- The hydrogen boundary within the MRA is a part of the CMS hydrogen boundary. The MRA hydrogen boundary design will support the CMS hydrogen boundary safety basis and requirements established during preliminary design.

**S.03.05 – Accelerator Interface Components (AIC) Preliminary Design Definition**

**The following AIC specific parameters will be established at Preliminary Design completion:**

- Complete overall AIC CAD geometry of:
  - Proton Beam Window (PBW) Assembly
  - Target Viewing Periscope (TVP) Assembly
  - Proton Beam Tube Assembly (PBTA)
  - Proton Beam Window Shielding

- Helium pressure for PBW inflatable seal & water flow rates for PBW and TVP
- Key fabrication and installation tolerances for all AIC components
- Clearances between AICs and surrounding structures of TSS, CV and CV shielding
- AIC material choices/specifications
- TVP R&D for windows
- Interface with other Target Systems and Accelerator Systems well defined and captured in ICDs/Interface Sheets
- DACs for individual systems for structural and neutronics analysis complete
- Acquisition Strategy, Manufacturing/Fabrication strategy established
- Installation and System Verification plan complete

**Clarifications and/or exceptions to *S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix*:**

- None

**S.03.06 – Vessel Systems Preliminary Design Definition**

**The following Vessel Systems specific parameters will be established at Preliminary Design completion:**

- Overall CAD geometry including:
  - Core Vessel
  - Core Vessel Lid
  - Interior vessel shielding (cooled and uncooled)
  - Utility piping runs leading to interfaces with Process Systems
  - Nozzle Extensions
  - Gamma Gate Assembly
- Core Vessel beltline water cooling flow rates and pressure drops
- Core Vessel cooled shielding water flow rates and pressure drops
- Thermal performance of all cooled components within Vessel Systems
- Key Vessel Systems fabrication and installation tolerances
- Clearances between Vessel Systems structures and surrounding structures
  - Including Target, MRA, TVP and Monolith Inserts
- Vessel Systems material choices and specifications
- Vessel Systems component design compliance with all seismic requirements
- Interfaces with other Level 3 Target Systems
  - Target, MRA, TVP, PBW, remote handling, process systems, vacuum systems
- Interfaces with other Level 2 Systems
  - Instrument Systems, Conventional Facilities, Integrated Controls

**Clarifications and/or exceptions to *S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix*:**

- The following DACs may not be completed during preliminary design because they do not significantly impact Vessel Systems design:
  - Core Vessel wetted surface area
  - Core Vessel drain line volume
  - Core Vessel vacuum throughput

### **S.03.07 – Target Station Shielding (TSS) Preliminary Design Definition**

**The following TSS specific parameters will be established at Preliminary Design completion:**

- Overall CAD geometry including:
  - Bulk Shielding
  - Removable Shielding
  - Bulk Shielding Liner including embed plate for Core Vessel location
  - Monolith Pipe Pans
- Key TSS fabrication and installation tolerances
- Clearances between TSS structures and surrounding structures
  - Including Proton Beam Window, Vessel Systems and Process Systems
- TSS material choices/specifications
- TSS component design compliance with all seismic requirements
- Interfaces with other Level 3 Target Systems
  - Vessel Systems, PBW, Remote Handling, Process Systems
- Interfaces with other Level 2 Systems
  - Instrument Systems, Conventional Facilities

**Clarifications and/or exceptions to *S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix*:**

- None

### **S.03.09 – Target Process Systems Preliminary Design Definition**

**The following Process Systems parameters will be established at Preliminary Design completion:**

- Design information for all water-cooled Target components including
  - Heat load
  - Flow
  - Component pressure drop
  - Energy deposited in water
  - Cooled component maximum design pressure
- Helium and nitrogen utility usage, system pressures, and delivery pressures for Target Systems
- Required throughput capacities, both continuous and batch, as appropriate, for the Low-Level Liquid Waste and Leak Collection systems
- Piping and equipment layouts (CAD model) of Process Systems
- Thermo-hydraulic models of activated cooling loops
- P&IDs and PFDs for Process Systems
- Process Control Description for Process Systems to define the operation of instruments, controls, and interlocks shown on the P&IDs
- Sizing of Process Systems equipment, including heat exchangers, pumps, ion exchange columns, vessels, and relief devices
- Interfaces with Target Systems, Conventional Facilities, and Integrated Control Systems

**Clarifications and/or exceptions to *S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix*:**

- P&IDs and PFDs will be developed during Preliminary Design since they form the basis for the design of Process Systems and communicate needed design information to other WBS leads.

### **S.03.10 - Remote Handling Preliminary Design Definition**

**The following Remote Handling specific parameters will be established at Preliminary Design completion:**

#### **S.03.10.02 - Service Cell**

- Preliminary CAD design for Service Cell, to include:
  - Overall sizing of service cell facility
  - Layout of service cell boundary within target building
  - Storage pit sizing and layout
  - Layout of casks and other waste disposal prep equipment staged in Service Cell
  - Bottom Loading Access Hatch
  - Shipping cask cart & rail system
- Notional CAD design for Service Cell, to include:
  - Overhead bridge crane
  - Top loading access hatch(es)
  - Entry shield door
  - Liner
  - Window Workstation (A/R)
  - Thru-wall manipulator (A/R)
  - Servomanipulator (A/R)
- Remote Handling interfaces to Conventional Facilities to include laydown space claim, floor loading requirements, and HVAC requirements
- Preliminary specification documents for design build items that fall within Conventional Facilities scope, to include all items listed above in notional CAD design sub-section

#### ***Clarifications and/or exceptions to S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix:***

- DACs provided will only support detailed CAD design for Remote Handling scoped items only

#### **S.03.10.03 - S.03.10.05 - AIC, Target, MRA Conveyance Systems**

##### **Key Requirements verified at Preliminary Design:**

- Preliminary CAD designs for shielded transfer casks to include:
  - 2 PBW Shield Block casks
  - PBW cask
  - TVP cask
  - 2 MRA Shield Block casks
  - MRA cask
  - 2 Target Segment Shield Block casks
  - Target Segment cask
- Preliminary CAD design for multi-purpose vessels used for drying, storage, and as a waste shipping liner to include:
  - MRA vessel and lid
  - PBW vessel and lid
  - TVP vessel and lid
  - Target Segment vessel and lid

- Preliminary CAD design for other customized tooling required to perform maintenance activities to include:
  - Target/MRA gamma gate assembly
  - PBW maintenance interface plate
  - Hook extenders
  - Ziplift extenders
- Remote Handling interfaces to all other Target Systems critical components required to be handled during maintenance events, to include hoisting and rigging interfaces
- Remote Handling interfaces to Conventional Facilities, to include floor loading and laydown space claims

**Clarifications and/or exceptions to S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix:**

- None

**S.03.10.06 - Mockup Facility**

**Key Requirements verified at Preliminary Design:**

- Preliminary CAD design for Mockup Facility, to include:
  - Simplified core vessel structure to include at least one nozzle extension
  - Simplified internal core vessel shielding and other critical components
- Notional CAD design for Mockup Facility, to include:
  - External structural support system
  - Interfaces to Target Building

**Clarifications and/or exceptions to S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix:**

- DACs provided will only support detailed CAD design for Remote Handling scoped items

**S.03.11 - Target Vacuum Systems Preliminary Design Definition**

**The following Vacuum Systems parameters will be established at preliminary Design completion:**

- Selection of Vacuum Systems equipment, including vacuum pumps, valves, gauges, and other purchased equipment supported by pump down calcs/simulation for Target Systems monolith components
- Preliminary vacuum piping model and equipment layouts
- Interfaces to Target Systems components and to Conventional Facilities

**Clarifications and/or exceptions to S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix:**

- None

## **S.04 – INSTRUMENT SYSTEMS PRELIMINARY DESIGN DEFINITION**

The following sections detail the definition of preliminary design for Instrument Systems, which consists of Scientific Software, Bunker and 8 neutron scattering instruments. Definition common to all 8 instruments are provided in the section labeled S.04.X to avoid unnecessary repetition. Instrument specific definition is provided in subsequent sections organized by WBS. There are 3 subsections for each system:

- Key requirements verified at preliminary design (*by analysis or R&D efforts*)
- Key parameters identified at preliminary design
- Clarifications and/or exceptions to the deliverables in the guidance document,
  - *S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix*

### **S.04.02 – Scientific Software**

#### ***Key Requirements defined at Preliminary Design:***

- STS instrument calibration, data reduction, and data analysis software architecture is consistent with Neutron Scattering Division strategies.
- Initial supporting computational infrastructure/hardware performance.
- Operational use cases including defining who interacts with scientific software and in what mode.
- Software will be capable of real time data processing with reduced data available within five minutes of data collection completing.
- (Reduction) Software shall adhere to the guiding principles of FAIR (Findable, Accessible, Interoperable, and reusable).

#### ***Key Requirements verified at Preliminary Design (by analysis or R&D efforts):***

- None

#### ***Key Parameters identified at Preliminary Design:***

- Interactions between instrument design and scientific computing.
- Definitions of reduced (user ready) data for each instrument.
- Instruments requiring automated remote operation.
- Simulated instrument data rates derived from MC simulations including corrections for detector efficiencies and scattering power for standard samples.

#### ***Clarifications and/or exceptions to S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix:***

- Major software components and their interactions/interfaces have been identified with particular emphasis on instrument data acquisition and control systems.
- Data analysis methodology and solutions defined.

### **S.04.03 – Bunker Preliminary Design Definition**

The Bunker Preliminary Design Definition is broken up into its constituent Level 4 subsystems.

#### **S.04.03.02 – Shielding**

The primary components/systems defined in this WBS element include the Monolith Modules (Monolith Inserts, Optics Modules, and Monolith Beam Stop), the Bunker Wall Penetration Frames and Bunker Wall Inserts (BWIs), the Bunker Roof Panels, and the Trench Covers for the cooling water headers located in the floor of the bunker. The scope of work also includes the neutronics analyses needed to inform their designs.

#### ***Key Requirements verified at Preliminary Design (by analysis or R&D efforts):***

- Monolith Beamstop neutronics performance
- Roof panel neutronics performance & structural requirements
- Bunker & Monolith walls' neutronics performance
- Monolith Modules' neutronics performance
- Bunker Wall Insert neutronics performance
- Monolith insert cooling performance
- Alignment tolerances of Monolith Modules

#### ***Key Parameters identified at Preliminary Design:***

- Monolith Insert internal atmosphere (vacuum or gas composition)
- Vacuum interfaces defined

#### ***Clarifications and/or exceptions to S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix:***

- CAD models, drawings, sketches, and other design expression tools
  - Bunker components assembled together with CF & Target components
  - Preliminary IS/CF/TS interface sheets
  - Preliminary P&ID's (pneumatic, control, etc.)
- Design Analysis Calculations
  - Monolith insert cooling calculation sheet
  - Monolith Modules' thermal expansion

#### **S.04.03.03 – Motion systems for Bunker Components**

The primary systems defined in this WBS element include the Maintenance Shields and Shutters. These are expected to be generic designs which are applicable to all beamlines but with some customizations as needed. Generic shutters will be designed for straight beamlines (which will require “heavy” shutters) and those whose optics curve out of direct views of the moderator (which can accommodate a “lite” shutter). A custom Maintenance Shield will be required for QIKR.

#### ***Key Requirements verified at Preliminary Design (by analysis or R&D efforts):***

- Neutron and Gamma blocker neutronics performance
- Heavy Shutter neutronics performance
- Shutter fail safe operation
- Maintenance Shield remote and manual drive system performance

***Key Parameters identified at Preliminary Design:***

- Maintenance Shield gate optic section alignment
- Shutter guide positioning (repeatability, accuracy)

***Clarifications and/or exceptions to S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix:***

- CAD models, drawings, sketches, and other design expression tools
  - Generic shutter designs shown in context of instrument assemblies
- Design Analysis Calculations
  - Shutter drive systems performance

**S.04.03.04 – Infrastructure & Utilities**

The primary systems defined in this WBS element include the Neutron Guide Vacuum System, the In-bunker Chopper Rough Vacuum System, the Bunker Remote Viewing System, and any required bunker access equipment such as handrails, cover plates, ladders, and bridges for bunker roof openings.

***Key Requirements verified at Preliminary Design (by analysis or R&D efforts):***

- Routing paths and capacities for all bunker utilities established
- Bunker access and surveillance methods satisfy ES&H requirements

***Key Parameters identified at Preliminary Design:***

- Vacuum pumps capacity, location identified
- Lighting satisfies minimum Lux levels
- Fire detection and prevention systems are accommodated within the bunker

***Clarifications and/or exceptions to S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix:***

- CAD models, drawings, sketches, and other design expression tools
  - Vacuum system P&ID's
  - Preliminary IS/CF/TS interface sheets
- Design Analysis Calculations
  - Utility capacities are suitable for service/supply

**S.04.03.05 – Installation Equipment**

The primary systems and components defined in this WBS element include the Cold Monolith Modules Handler (CMMH) and various additions to accommodate other components like QIKR modules. Designs for a Hot Monolith Modules Handler, a Monolith Beam Stop Cask, and a Monolith Insert Cask will be developed to some level, but these components will not be procured by the STS Project.

***Key Requirements verified at Preliminary Design (by analysis or R&D efforts):***

- CMMH operation (inserts and removes monolith modules)
- Storage cask designs meet radiation protection requirements

***Key Parameters identified at Preliminary Design:***

- The Cold Monolith Modules Handler (CMMH) range and accuracy
- CMMH monolith beam port alignment scheme defined

**Clarifications and/or exceptions to S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix:**

- CAD models, drawings, sketches, and other design expression tools
  - All handlers fit and function within the bunker space constraints
  - Hot handler can extract monolith beamstop and insert it into a shielded storage container
- Design Analysis Calculations
  - CMMH structural, drive and handling DACs

**S.04.X – Instrument Common Preliminary Design Definition**

The following parameter descriptions are common to all 8 of the STS neutron scattering instrument sub-systems.

**S.04.X.02 – Optics**

***Key Requirements verified at Preliminary Design (by analysis or R&D efforts):***

- Neutron brightness at sample based on Monte Carlo simulations and moderator neutron source files (this will be used to determine Transition To Operations Plan document values described in project Key Performance Parameters)
- Alignment requirements/tolerances analyzed and defined

***Key Parameters identified at Preliminary Design:***

- Guide specifications established including m-value of guide coating, roughness & flatness, guide geometry (sizes and location) & substrate material selection
- Vacuum interfaces defined
- Internal vacuum level

**Clarifications and/or exceptions to S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix:**

- CAD models, sketches, and other design expression tools
  - Detailed model of guide housing external geometry incorporated into full instrument model showing support details & clearances to shielding
  - McStas Monte Carlo model of the instrument exists which tracks neutron paths from the moderator to the sample and sample to detector and matches the latest update to the respective instrument technical design document

**S.04.X.03 – Neutron Choppers**

***Key Requirements verified at Preliminary Design (by analysis or R&D efforts):***

- Neutron transmission at relevant neutron wavelengths as a function of time following proton pulse on target (T0) for all routinely anticipated operating modes
- Alignment requirements/tolerances analyzed and defined
- Chopper failures cannot negatively impact neighboring instruments or safety critical systems (e.g., moderators & shutters)

***Key Parameters identified at Preliminary Design:***

- Bandwidth and high-speed chopper specifications – rotation frequency, disk size/materials, disk open angle(s)
- T0 choppers – rotation frequency, blade dimensions/materials

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- Vacuum interfaces defined and window thickness & materials established
- Internal atmosphere (vacuum level or gas composition)

**Clarifications and/or exceptions to *S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix:***

- CAD models, sketches, and other design expression tools
  - Neutron chopper locations incorporated into instrument model
  - Locations identified for controllers and racks
  - Chopper performance is included in McStas Monte Carlo model of the instrument
- Design Analysis Calculations
  - Preliminary failure mode analysis

S.04.X.04 – Shielding

***Key Requirements verified at Preliminary Design (by analysis or R&D efforts):***

- Instrument biological shielding meets requirements of Second Target Station (STS) Project Radiation Safety Policy and Plan (*S01030100-PN0001*)
- Shielding meets seismic requirements
- Use of hydrocarbon shielding follows fire protection guidance as to maximum quantities and encapsulation

***Key Parameters identified at Preliminary Design:***

- Shielding composition and geometry
- Clearances to interior components (i.e., guide vacuum housings and supports, and neutron choppers)

**Clarifications and/or exceptions to *S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix:***

- CAD models, sketches and other design expression tools
  - Space claiming representation of shielding included in the instrument CAD model
- Design Analysis Calculations
  - Preliminary neutronics analysis of shielding requirements (thickness and materials)
  - Preliminary seismic restraint analysis

S.04.X.05 – Neutron Detectors

***Key Requirements verified at Preliminary Design (by analysis or R&D efforts):***

- Detector meets peak neutron counting rate
- Detector satisfies spatial resolution requirement
- Alignment requirements/tolerances analyzed and defined

***Key Parameters identified at Preliminary Design:***

- Detector type and geometry (e.g., scintillator, <sup>3</sup>He, detector size)
- Detector efficiency at specified neutron wavelength
- Detector mounting/installation package (single-detector units or pre-assembled modules)
- Operation in vacuum or atmosphere

**Clarifications and/or exceptions to *S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix:***

- CAD models, sketches, and other design expression tools

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- Detector modules included in instrument CAD model
- Location of electronics/power supplies/racks identified
- Routing path for cabling indicated

#### S.04.X.06 – Motion Systems

##### ***Key Requirements verified at Preliminary Design (by analysis or R&D efforts):***

- Accuracy and repeatability requirements

##### ***Key Parameters identified at Preliminary Design:***

- Motor types and sizes (e.g., stepper, servo, gearing, & torque)
- Identify configuration levels of motion systems (i.e., maintenance shields and shutters)

##### ***Clarifications and/or exceptions to S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix:***

- CAD models, sketches, and other design expression tools
  - Location of electronics/power supplies/racks identified
- Design Analysis Calculations
  - Motion systems meet performance specifications (load, speed, accuracy/repeatability, etc.)

#### S.04.X.07 – Instrument Specific

See instrument specific information following this general S.04.X section. Not all instruments have actual Instrument-Specific WBS elements, but for this document that label applies to items specific to that instrument regardless of where in the WBS it resides.

#### S.04.X.08 – Infrastructure & Utilities

##### ***Key Requirements verified at Preliminary Design (by analysis or R&D efforts):***

- Mezzanine and Control Hutch heights are less than maximum height allowed by Instrument Systems guidance (document TBD)

##### ***Key Parameters identified at Preliminary Design:***

- Instrument requirements for maximum loads on standard utilities

##### ***Clarifications and/or exceptions to S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix:***

- CAD models, sketches, and other design expression tools
  - Routing paths for utilities identified in instrument CAD models including any penetrations through shielding

### **S.04.04 – Applicable Requirements, Parameters and Clarifications for Individual Instruments**

#### **CHESS Specific**

##### ***Key Requirements verified at Preliminary Design (by analysis or R&D efforts):***

- Detector Vessel pump down time requirement

##### ***Key Parameters identified at Preliminary Design:***

- Detector Vessel vacuum level

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### **PIONEER Specific**

#### ***Key Requirements verified at Preliminary Design (by analysis or R&D efforts):***

- Sample environment re-entrant vessel pump down time requirement

#### ***Key Parameters identified at Preliminary Design:***

- Sample environment re-entrant vessel vacuum level
- Polarizer vessel vacuum level

### **CENTAUR Specific**

#### ***Key Requirements verified at Preliminary Design (by analysis or R&D efforts):***

- Detector Vessel pump down time requirement

#### ***Key Parameters identified at Preliminary Design:***

- Detector Vessel vacuum level

### **OIKR Specific**

#### ***Key Requirements verified at Preliminary Design (by analysis or R&D efforts):***

- Viability of producing a 20cm x 20cm pixel scintillator with  $\leq 1\text{mm} \times 1\text{mm}$  pixels
- Guide performance with realistic components in place ( housings, polarizer, choppers, windows, etc.)
- Incident table performance: load capacity, range/accuracy/resolution of motion, stiffness & vibration behavior
- End station performance: load capacity, range/accuracy/resolution of motion, stiffness & vibration behavior
- Remotely operated sample changer and sample storage unit performance: range of motion, interference risk with other cave components, user accessibility/usability
- Polarizer elevator performance (if used): load capacity, range/accuracy/resolution of motion, repeatability of position
- Sufficient shielding between upper and lower caves for independent operation

#### ***Clarifications and/or exceptions to S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix:***

- Design Analysis Calculations
  - Guide performance with realistic components in place
  - Static load of motion components
  - Neutronic analysis of shielding between upper and lower caves

### **BWAVES Specific**

#### ***Key Requirements verified at Preliminary Design (by analysis or R&D efforts):***

- Detector Vessel pump down time requirement
- Detector Vessel catastrophic rotor failure containment requirement

#### ***Key Parameters identified at Preliminary Design:***

- Detector Vessel vacuum level

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**Clarifications and/or exceptions to S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix:**

- Design Analysis Calculations
  - Preliminary detector vessel containment calculations complete

**EXPANSE Specific**

***Key Requirements verified at Preliminary Design (by analysis or R&D efforts):***

- Magnet design produces required field integral and homogeneity

***Key Parameters identified at Preliminary Design:***

- Magnetic utility requirements (cooling water and power)

**Clarifications and/or exceptions to S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix:**

- Design Analysis Calculations
  - Magnetic shield wall performance achieves field stability requirements

**S.04.12 – Sample Environment Preliminary Design Definition**

The sample environment equipment scope is meant to enable the early science programs of the neutron scattering instruments. Final selection of this equipment will be done relatively late during the execution phase of the project to match emerging science priorities. A representative list will define the scope and schedule at the end of preliminary design.

***Key Requirements verified at Preliminary Design (by analysis or R&D efforts):***

- Geometry of representative equipment matches the instrument interface.
- Standard infrastructure to support sample environment equipment is adequate to meet operations requirements (e.g., power, cooling water, compressed air, exhaust, etc.)

***Key Parameters identified at Preliminary Design:***

- Sample sizes and equipment operating ranges (e.g., temperature, pressure, magnetic field, shear rate, etc.)
- Clearances to interior components (i.e. guide vacuum housings and supports)

**Clarifications and/or exceptions to S01020500-PCD10000 Second Target Station Project Design Deliverables by Project Phase Matrix:**

- As noted above, this equipment will be representative only at the end of preliminary design.

## **S.05 – CONVENTIONAL FACILITIES PRELIMINARY AND FINAL DESIGN DEFINITION**

For Conventional Facilities Preliminary Design will consist of Draft, Final Draft, and Final Design packages. The Final Design package will include Draft, Final Draft, Final, and Issued for Construction (IFC). See the Table 1, below, for expected levels of completion for each discipline.

Preliminary Design will ensure that most system requirements have been validated, allocated, and requirements and interface sheets are complete. It will show that the proposed design is expected to meet the functional and performance requirements, sufficient maturity in the proposed design approach, and that the design is verifiable and that the risks have been identified, characterized, and mitigated where appropriate. To provide valuable input for things such as construction feasibility, cost implications, and sustainable design strategies, construction contractors, design consultants, and estimators will be included in the preparation of the design package at this stage as well. Internal reviews will occur at Draft and Final Draft, and an external review will be held at Final Preliminary Design.

The package will include grading requirements, storm water mitigation strategies, and site utility layouts. Major dimensions, materials, features, and fire ratings will be established and shown. Floor plans will depict rooms, corridors, and other spaces. Wall sections reflected ceiling plans and schedules (room finishes, doors, and windows) will be part of the Preliminary Design package as well.

The foundation systems will be well established, preliminary structural framing shown, and initial structural detail sheets started. Equipment rooms, distribution zones, and riser diagrams for both mechanical and electrical systems will be included. Optimal systems for M/E/P will also be selected and incorporated.

Each discipline will have specification packages including a detailed table of contents, a brief description of the project, materials and systems, and other preliminary content. A refined cost estimate prepared by the Architect/Engineering consultant (A/E) will also be submitted with the Preliminary Design package. Final Design will continue progress from the Preliminary Design documents, ultimately completing the project with an IFC package. The IFC package will consist of checked and signed drawings, calculations, specifications, and models. Architectural, structural, and M/E/P systems will be detailed and integrated with each other. Elevations, wall sections, other sections and details will be included. Required coordination with other Level 2 technical systems will have also occurred.

The A/E will prepare estimates based on the Draft, Final Draft, and Final submittals. They will provide the complete Final Design submittal package to both the CM/GC and an independent cost estimator to ensure information is consistent between all parties involved. The result being three, independent estimates to be included in the IFC package.

Like Preliminary Design, internal reviews will occur at Draft and Final Draft and an external review will be held for the Final submittal package.

**Table 1. Conventional Facilities Percent Design Completion Table**

Deliverables	Preliminary Design			Final Design			
	Draft	Final Draft	Final	Draft	Final Draft	Final	IFC
General	30%	40%	70%	80%	90%	100%	100%
Architectural	30%	50%	60%	60%	80%	100%	100%
Civil	40%	55%	75%	90%	100%	100%	100%
Structural	30%	40%	60%	80%	90%	100%	100%
Electrical	30%	40%	50%	60%	90%	100%	100%
Fire Protection	30%	40%	50%	60%	90%	100%	100%
Piping	30%	40%	50%	60%	90%	100%	100%
HVAC	30%	40%	50%	60%	90%	100%	100%

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## S.06 INTEGRATED CONTROL SYSTEMS PRELIMINARY DESIGN DEFINITION

Many Integrated Control Systems (ICS) designs are closely coupled with the designs of the technical systems with which the ICS interfaces. As the design of these technical systems evolve, the ICS design may need to be adapted. Additionally, ICS designs commonly need to be modified based on evolving technology. Preliminary Design shall present a viable approach for system implementation. It shall provide a sufficient level of detail to develop the cost and schedule baseline for the system. Implementation details are likely to evolve (for example, the selection of specific I/O modules), but the Preliminary Design must provide a basis for the cost and schedule estimates.

Common design deliverables for ICS Preliminary Designs include:

- Requirements Document
- Design Description Document
- Interfaces with other STS L2 systems
- Interfaces with SNS systems
- Block diagrams
- Test and/or verification plan
- System risks (captured and managed in project Risk Register, as needed)
- Documentation for Basis of Estimate
- Cost and schedule estimate suitable for project baseline (in P6)
- ESH&Q requirements
- Configuration Level determination
- Quality level determination
- System Safety classification

ICS subsystems have additional deliverables, provided below for I/O-based systems, software-based systems, custom hardware-based systems, and safety systems. In practice, a specific system may be a combination of one or more of these types, for example an I/O-based safety system. Discretion may be applied to tailor the deliverables to the specific system.

For a hardware I/O based system (for example, a PLC-based system) additional deliverables include:

- Functional block diagram
- I/O lists and expected instrumentation
- Hardware, equipment, and cable estimates (i.e., bill of materials) for cost estimates
- Remote I/O topology
- Preliminary design drawings and cable/connector lists
- Preliminary rack layout drawings
- Space needs (e.g., floor space for racks, wall space for cabinets)
- Estimated electrical power requirements
- Any special needs for location, installation, or mechanical interfaces (e.g., temperature stability or cooling, electrical noise sensitivity, vibration sensitivity)
- Acquisition strategy
- Manufacturing/fabrication strategy
- Installation plan

For a software-based system, additional deliverables include:

- System architecture diagram or description
- Programming language or toolkit to be utilized

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- Software Application Programming Interface (API)
- Server and network requirements
- Network security requirements

For a custom hardware-based system, additional deliverables include:

- System architecture diagram or description
- Firmware block diagram
- Hardware platform to be utilized
- Hardware interfaces
- Software interfaces
- Prototype build and test plan
- Acquisition strategy
- Manufacturing/fabrication strategy
- Installation plan

For a safety system, additional deliverables include:

- Safety Basis and classification including expected safety integrity level (SIL)
- Quality Assurance (QA) level determination
- Failure Mode and Effects Analysis (FMEA)
- Traceability of design to the Preliminary Hazard Analysis Report (PHAR)