System Verification Plan for the Common Shielding System

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1. SCOPE

The System Verification Plan (SVeP) documents the strategy that will be used to verify the system design of the Common Shielding System (CSS) for each instrument that adopts the system (CSS-X).

Verification of each system design will be through verifying:

- Does the system design clearly represent the system requirements that drove the design process?
- Has the system design been installed / integrated correctly?
- Does the system design fulfil ESS processes, rules, guidelines, etc.?

The System Verification Procedure (SVePr) for each CSS-X will with elucidation be developed from this plan and will layout the verification effort and detail the procedure that is the specific and detailed steps and methodology to be followed to perform the procedural verification activities.

2. ISSUING ORGANISATION

European Spallation Source ERIC, Science Directorate.

3. SYSTEM CHARACTERISTICS

3.1. System purpose

The Common Shielding System is designed with a system primary purpose to provide a common shielding design for the participating instrument systems. Each shielding system provides attenuation down to a safe level of the radiation emanating from the respective instrument system's elements along the sector between the bunker wall interface through to the respective instrument system cave interface.

3.2. System design

Refer to the System Design Description (SDD) for the Common Shielding System (CSS) [2] for the documented description of the preliminary system design.

The preliminary SDD for the CSS captures:

- Design engineering – 3d models; simulations & analysis; and preliminary engineering documentation.
- Neutronics – simulations & analysis.

4. SYSTEM VERIFICATION

The system verification process will comprise the following components:

- Quality Control of the system/design engineering detailed for manufacture procurement.
- Quality Control of manufacture and as-manufactured detailed system/design engineering.
- Quality Control of delivery.
- Quality Control of installation and as-built detailed system/design engineering.
- System Installation / Integration Inspection (SyIII) during and post installation.
- Verification of the system requirements.

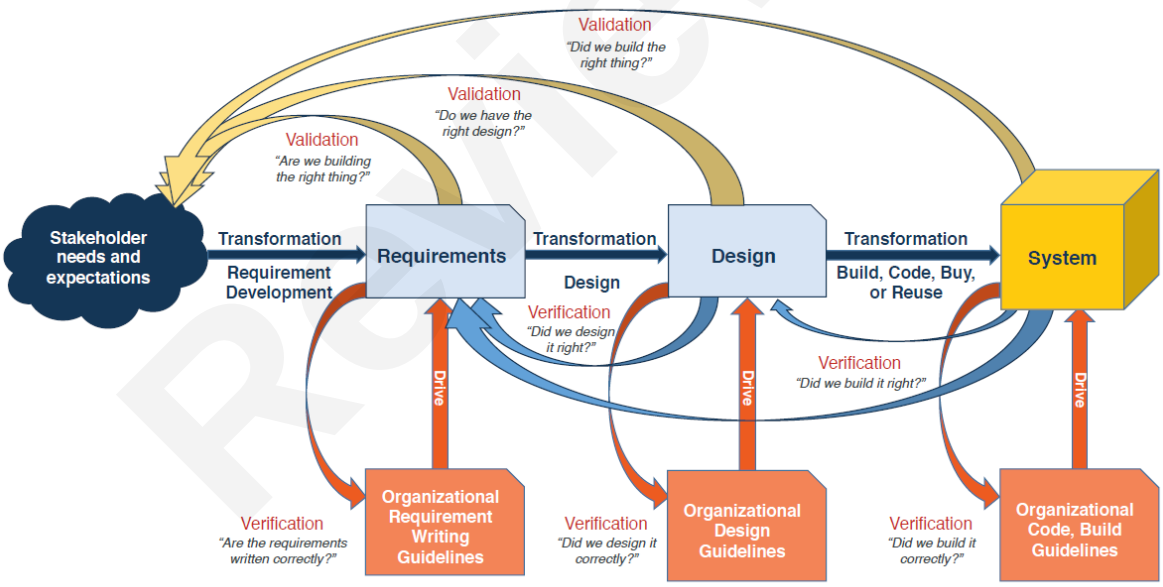


Figure 1. System verification in the design process.

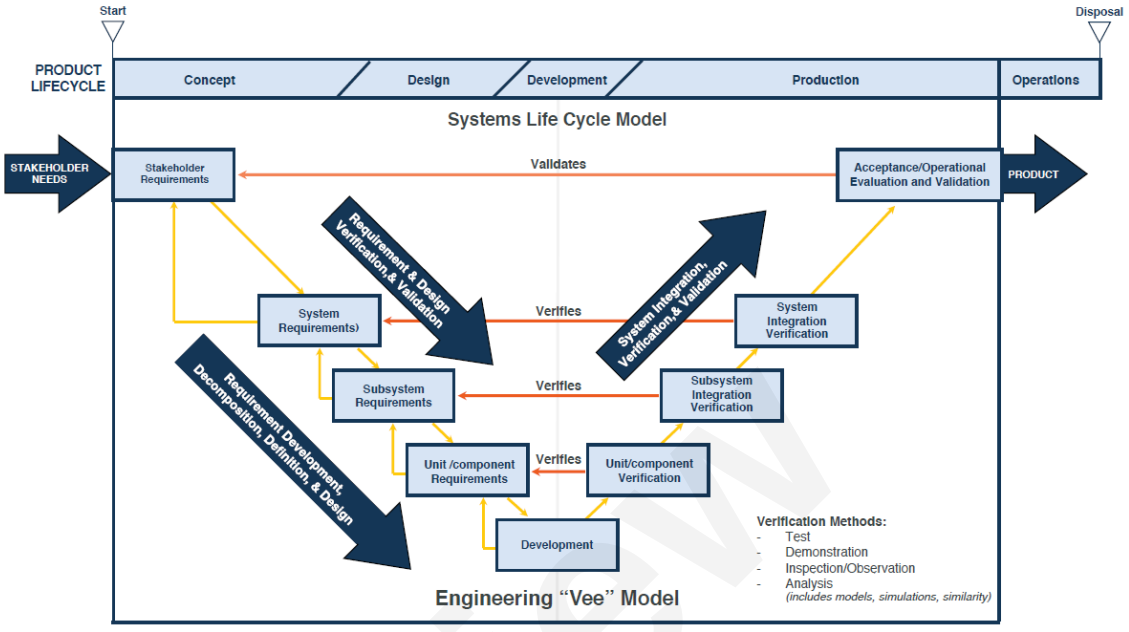


Figure 2. System verification in the life cycle model.

Figure 1 and Figure 2 are extracted from INCOSE Guide for Writing Requirements [3].

5. SYSTEM QUALITY CONTROL

5.1. Quality Control of System Design for Manufacture Procurement

Quality control of the system engineering documentation and design engineering documentation detailed for manufacture procurement is assured by:

- ESS review and approval process.
- ESS configuration management process.

5.2. Quality Control of As-Manufactured System Design

Quality control of the detailed design and manufacture of the system elements will be in accordance with the selected manufacturer quality control processes in agreeance with ESS.

Quality control of the detailed as-manufactured system engineering documentation and design engineering documentation is assured by:

- ESS review and approval process.
- ESS configuration management process.

5.3. Quality Control of Delivery

Quality control of the delivery of manufactured system elements will be in accordance with the selected manufacturer quality control processes in agreeance with ESS.

Due to the volume size of manufactured system elements, it is expected that a just-in-time delivery schedule from the manufacturer's premises will be implemented appropriate to the installation schedule at ESS.

Quality control of receiving delivery acceptance of manufactured system elements at ESS will be in accordance with ESS quality control process.

Quality control of the receiving delivery acceptance of Commercial-Off-The-Shelf (COTS) purchased system elements will be in accordance with ESS quality control process.

Quality control of quality control documentation is assured by:

- ESS review and approval process.
- ESS configuration management process.

5.4. Quality Control of As-Built System Design

Quality control of the detailed design and manufacture of the system elements will be in accordance with the selected manufacturer quality control processes in agreeance with ESS.

Quality control of the system installation / integration and detailed as-built system engineering documentation and design engineering documentation is assured by:

- ESS review and approval process.
- ESS configuration management process.

6. SYSTEM INSTALLATION / INTEGRATION INSPECTION

System Installation / Integration Inspection (SyIII) is to ensure that the installation / integration of each system element is verified through a procedural inspection.

The SyIII section of the System Verification Procedure, developed from this System Verification Plan, will identify each system element as detailed in the System Integration Procedure, which is developed from the System Integration Plan **Error! Reference source ot found.**, and define the procedural method of inspection as per Table 1 for obtaining the objective evidence.

Table 1. System Installation / Integration Inspection.

ID	Description
CSS.SyIII-01	**II ID:** CSS.II-01. **II Title:** *system element 1* **II Statement:** **Inspection method:** **Inspection:**
CSS.SyIII-02	**II ID:** CSS.II-02. **II Title:** *system element 2* **II Statement:** **Inspection method:** **Inspection:**

7. VERIFICATION OF SYSTEM REQUIREMENTS

To confirm that the system requirements, as identified and defined in the System Requirements Specification (SRS) for the Common Shielding System (CSS) [1], have been fulfilled verification activities will be procedurally performed in accordance with the developed System Verification Procedure. For that purpose, each system requirement is associated with a proposed method of verification for obtaining the objective evidence.

7.1. Verification of Functional Requirements

Verification of the functional requirements of the Common Shielding System is specified in Table 2.

Table 2. Verification of Functional Requirements.

ID	Description
CSS.SyRV-01	**SyR ID:** CSS.SyR-01. **SyR Title:** Safe restricted access for installation/removal. **SyR Statement:** CSS shall provide safe restricted access for the installation/removal of Instrument System (InS) elements and associated equipment. **Verification method:** Inspection. Review of the system design. Inspection of installation/integration. **Verify:** Does the CSS provide safe restricted access for the installation/removal of InS elements and associated equipment?
CSS.SyRV-02	**SyR ID:** CSS.SyR-02. **SyR Title:** Safe restricted access for maintenance. **SyR Statement:** CSS shall provide safe restricted access to the InS elements and associated equipment within. **Verification method:** Inspection. Review of system design. Inspection of installation/integration. **Verify:** Does the CSS provide safe restricted access to the InS elements and associated equipment within?

7.2. Verification of Constraint Requirements

Verification of the constraint requirements of the Common Shielding System is specified in Table 3.

Table 3. Verification of Constraint Requirements.

ID	Description
CSS.SyRV-03	**SyR ID:** CSS.SyR-03. **SyR Title:** Design to allow minimal suite of 22 Instrument Systems. **SyR Statement:** CSS shall be designed to allow for allocating volumes, with defined envelopes, for a minimal suite of 22 Instrument Systems that are to be located along 22 defined and allocated beam-port central axes. **Verification method:** Inspection. Review of system design. **Verify:** Is the CSS designed to allow for allocating volumes, with defined envelopes, for a minimal suite of 22 Instrument Systems that are to be located along 22 defined and allocated beam-port central axes?
CSS.SyRV-04	**SyR ID:** CSS.SyR-04. **SyR Title:** Programme plan delivery. **SyR Statement:** CSS design shall support NSS delivery of initial suite of instruments being operational in accordance with the NSS programme plan. **Verification method:** Inspection. Review of system design. **Verify:** Is the CSS designed to support NSS delivery of initial suite of instruments being operational in accordance with the NSS programme plan?
CSS.SyRV-05	**SyR ID:** CSS.SyR-05. **SyR Title:** Future expansion of instrument suite. **SyR Statement:** CSS design shall not impede upon reserve volumes along currently unassigned designated beam-port central axes in preparation for future installation of as yet undefined Instrument Systems whose envelopes will be constrained by said reserved volumes. **Verification method:** Inspection. Review of system design. **Verify:** Does the CSS design impede upon reserve volumes along currently unassigned designated beam-port central axes in preparation for future installation of as yet undefined Instrument Systems whose envelopes will be constrained by said reserved volumes?

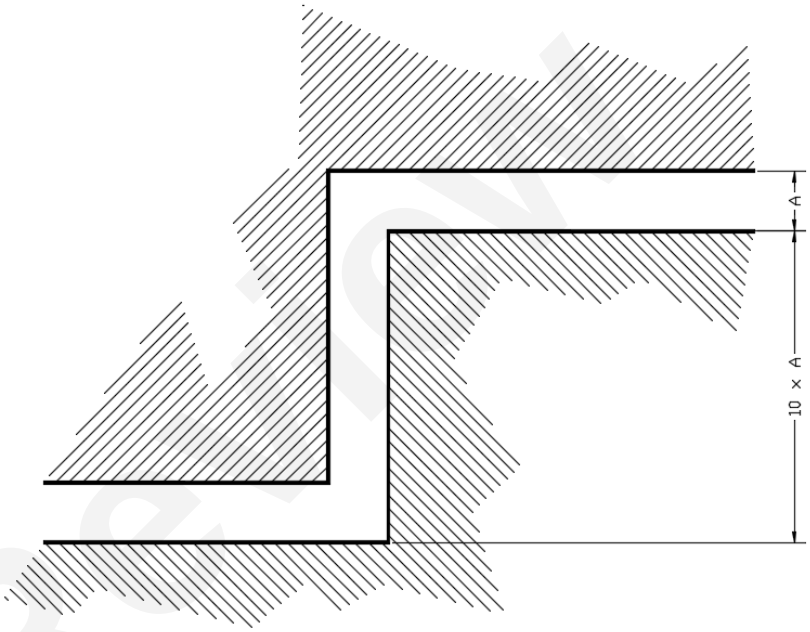
ID	Description
CSS.SyRV-06	**SyR ID:** CSS.SyR-06. **SyR Title:** Maximum load for primary lifting devices. **SyR Statement:** The maximum mass of CSS modular elements that will be serviced by the primary lifting devices shall be less than or equal to (≤) 5 t. **Verification method:** Analysis and Inspection. Calculation of mass in design phase. Weighing after manufacture, **Verify:** Is the maximum mass of CSS modular elements that will be serviced by the primary lifting devices less than or equal to (≤) 5 t?
CSS.SyRV-07	**SyR ID:** CSS.SyR-07. **SyR Title:** Maximum dimensions for primary lifting devices. **SyR Statement:** The maximum dimensions of CSS modular elements that will be serviced by the primary lifting devices shall be less than or equal to (≤) 3000 mm x 1500 mm x 1500 mm. **Verification method:** Inspection. Review of system design. **Verify:** Is the maximum dimensions of CSS modular elements that will be serviced by the primary lifting devices less than or equal to (≤) 3000 mm x 1500 mm x 1500 mm.?
CSS.SyRV-08	**SyR ID:** CSS.SyR-08. **SyR Title:** CSS modular element identification. **SyR Statement:** CSS modular elements shall have permanent markings with a unique identification and location in the installation. **Verification method:** Inspection. Review of system design. Inspection of installation/integration. **Verify:** Do the CSS modular elements have permanent markings with a unique identification and location in the installation?

7.3. Verification of Radiation Safety Requirements

Verification of the radiation safety requirements of the Common Shielding System is specified in Table 4.

Table 4. Verification of Radiation Safety Requirements.

ID	Description
CSS.SyRV-09	**SyR ID:** CSS.SyR-09. **SyR Title:** Maximum radiation level in the freely accessible areas of the experimental halls and guide hall. **SyR Statement:** Maximum radiation level measured in the freely accessible areas of the experimental halls and guide hall during ESS facility normal full beam operation shall be less than or equal to (≤) 3 µSv/h. **Verification method:** Analysis and Inspection. The compliance of the CSS shielding design with the zoning requirements will be verified following the rules stated in "ESS Procedure for designing shielding for safety" [8]. After beam on target the predicted levels will be verified through measurement by the appropriate/assigned team. **Verify:** Is the maximum radiation level measured in the freely accessible areas of the experimental halls and guide hall during ESS facility normal full beam operation ≤ 3 µSv/h?
CSS.SyRV-10	**SyR ID:** CSS.SyR-10. **SyR Title:** Dose contribution from CSS to NSS dose budget. **SyR Statement:** The total dose from NSS sources during normal full beam operation, including the dose contribution from the CSS, shall comply with GSO allocated NSS dose budget. **Verification method:** Analysis and Inspection. The performance of the CSS shielding design will be verified following the rules stated in "ESS Procedure for designing shielding for safety" [8]. The total dose from NSS sources, including the dose contribution from the CSS, will be assessed through analysis to verify compliance with the GSO allocated NSS dose budget [4]. After beam on target the predicted levels will be verified through measurement by the appropriate/assigned team. **Verify:** Is the total dose from NSS sources during normal full beam operation, including the dose contribution from the CSS, in compliance with GSO allocated NSS dose budget?

ID	Description
CSS.SyRV-11	**SyR ID:** CSS.SyR-11. **SyR Title:** Reduction of radiation leakage through shielding. **SyR Statement:** No line of sight from the experimental halls and guide hall to sources of radiation within the CSS is allowed. The “10-fold rule” (refer to **Error! Reference source not found.**.) shall apply for all planes emanating from he radiation sources within the Common Shielding.  **Figure 3. Illustration of 10-fold rule for chicane design.** **Verification method:** Analysis and inspection. Review of the system design. Simulation of the CSS shielding performance in attenuation of radiological hazards emanating from within during full beam operations. Inspection of installation/integration. Measurement of the radiation level external to the CSS at specified proximities and time intervals set by the appropriate/assigned team after installation and during commissioning of the ESS facility. **Verify:** Does the CSS design ensure no line of sight from the experimental halls and guide hall to sources of radiation within the CSS is allowed? Is the “10-fold rule” (refer to **Error! Reference source not found.**.) applied for ll planes emanating from the radiation sources within the Common Shielding.

ID	Description
CSS.SyRV-12	**SyR ID:** CSS.SyR-12. **SyR Title:** CSS access restriction. **SyR Statement:** Opening of CSS shall be restricted by a Personnel Safety System (PSS) linked to proton beam operation. **Verification method:** Inspection and test. Review of the system design. Inspection of installation/integration. Test of the PSS. **Verify:** Is access to the CSS restricted when proton beam is operational by PSS? Is proton beam operation disabled by PSS when CSS is open?
CSS.SyRV-13	**SyR ID:** CSS.SyR-13. **SyR Title:** Surface coating of concrete surfaces. **SyR Statement:** All concrete surfaces of the CSS shall have surface coating to minimise dust contamination. Surface coating shall be flame retardant and comply at minimum to B-s1, d0. **Verification method:** Inspection. Review of system design. Inspection of installation/integration. **Verify:** Do all concrete surfaces of the CSS have surface coating to minimise dust contamination? Is surface coating flame retardant and comply at minimum to B-s1, d0?
CSS.SyRV-22	**SyR ID:** CSS.SyR-22. **SyR Title:** Removal of radioactive elements. **SyR Statement:** CSS design should enable removal of system elements that are radioactive before those non-radioactive. The system elements that are more radioactive should be removed first where possible. **Verification method:** Inspection. Review of the system design. **Verify:** Does the CSS design enable removal of system elements that are radioactive before those non-radioactive? Does the CSS design allow system elements that are more radioactive to be removed first where possible?

ID	Description
CSS.SyRV-23	**SyR ID:** CSS.SyR-23. **SyR Title:** Removal of elements with dispersible radioactivity. **SyR Statement:** CSS design shall enable removal of system elements with dispersible radioactivity to limit contamination. System elements with dispersible radioactivity should be separately removed. **Verification method:** Inspection. Review of system design. **Verify:** Does the CSS design enable removal of system elements with dispersible radioactivity to limit contamination? Does the CSS design allow separate removal of system elements with dispersible radioactivity?

7.4. Verification of Conventional Safety Requirements

Verification of the conventional safety requirements of the Common Shielding System is specified in Table 5.

Table 5. Verification of Conventional Safety Requirements.

ID	Description
CSS.SyRV-14	**SyR ID:** CSS.SyR-14. **SyR Title:** Conventional safety barriers. **SyR Statement:** CSS shall provide conventional safety barriers to restrict freedom of movement of personnel into unsafe areas. **Verification method:** Inspection. Review of system design. Inspection of installation/integration. **Verify:** Does the CSS provide conventional safety barriers to restrict freedom of movement of personnel into unsafe areas?

7.5. Verification of Environmental Requirements

Verification of the environmental requirements of the Common Shielding System is specified in Table 6.

Table 6. Verification of Environmental Requirements.

ID	Description
CSS.SyRV-15	**SyR ID:** CSS.SyR-15. **SyR Title:** Radioactive waste handling and storage limitation. **SyR Statement:** CSS radioactive waste shall be limited so NSS overall handles and stores no more than 550 ton of radioactive waste at a time, pending shipment to final disposal. **Verification method:** Analysis. Review of system design. Analysis of the possible radioactive waste. **Verify:** Does the CSS design limit radioactive waste so NSS overall handles and stores no more than 550 ton of radioactive waste at a time, pending shipment to final disposal?

7.6. Verification of Interface Requirements

Verification of the interface requirements of the Common Shielding System is specified in Table 7.

Table 7. Verification of Interface Requirements.

ID	Description
CSS.SyRV-16	**SyR ID:** CSS.SyR-16. **SyR Title:** Provision for safe routing of utilities. **SyR Statement:** CSS shall be designed to allow the safe routing of required utilities for InS elements installed within the CSS. **Verification method:** Inspection. Review of system design. Inspection of installation/integration. **Verify:** Does the CSS installation allow the safe routing of required utilities for InS elements installed within the CSS?

ID	Description
CSS.SyRV-17	**SyR ID:** CSS.SyR-17. **SyR Title:** Load on D01 floor. **SyR Statement:** CSS elements combined with all other systems elements loading the floor in D-building D01 shall not exert more than 14 t/m^2 load on average over the whole area of this floor. **Verification method:** Analysis **Verify:** Does the CSS elements combined with all other systems elements loading the floor in D-building D01 not exert more than specified maximum loading?
CSS.SyRV-18	**SyR ID:** CSS.SyR-18. **SyR Title:** Load on D03 floor. **SyR Statement:** CSS elements combined with all other systems elements loading the floor in D-building D03 shall not exert more than 14 t/m^2 load on average over the whole area of this floor except in region from inside face of D03/E02 wall to 3 m inwards where they shall not exert more than 10 t/m^2 on average. **Verification method:** Analysis **Verify:** Does the CSS elements combined with all other systems elements loading the floor in D-building D03 not exert more than specified maximum loading?
CSS.SyRV-19	**SyR ID:** CSS.SyR-19. **SyR Title:** Load on E02 floor. **SyR Statement:** CSS elements combined with all other systems elements loading the floor in E-building E02 shall not exert more than 20 t/m^2 load on average over the whole area of this floor (Constraint: maximum gathered load shall not to exceed 80 t/4m^2.) and 5 ton/m2 on large areas. **Verification method:** Analysis **Verify:** Does the CSS elements combined with all other systems elements loading the floor in E-building E02 not exert more than specified maximum loading?

ID	Description
CSS.SyRV-20	**SyR ID:** CSS.SyR-20. **SyR Title:** D03/E02 floor dilatation joint. **SyR Statement:** CSS installation shall not impede upon nor hinder the D03/E02 floor dilatation joint. **Verification method:** Inspection. Review of system design. Inspection of installation/integration. **Verify:** Does the CSS installation interfere with the performance of the D03/E02 floor dilatation joint which allows for interference free movement/settlement of D-building D03 relative to the E-building E02?
CSS.SyRV-21	**SyR ID:** CSS.SyR-21. **SyR Title:** E01/E02 floor dilatation joint. **SyR Statement:** CSS installation shall not impede upon nor hinder the E01/E02 floor dilatation joint. **Verification method:** Inspection. Review of system design. Inspection of installation/integration. **Verify:** Does the CSS installation interfere with the performance of the E01/E02 floor dilatation joint which allows for interference free movement/settlement of E-building E01 relative to the E-building E02?

8. GLOSSARY

Term	Definition
10-fold rule	The "10-fold rule" mentioned in this document refers to relationship of expected gap versus the length of the possible streaming path through shielding including penetrations such as chicanes as shown in Figure 3.
Beam-port central axis	Centre-line axis of the notional straight beam-line emitting outward from the respective beam-port at target monolith.
Beam-port coordinate system	Defines each one of the neutron beam-ports inserts within the target monolith. There is a total of 42 neutron beam-port inserts each one with a central axis and a BPCS. [9]
Bunker	Cavity shielding bunker end-product of the Bunker System design.
CSS-X	Instruments that adopt the CSS will have individual system ID that replaces the X. E.g., CSS for Heimdal will be CSS-H.
Target centre	x=0, y=0, z=0 in the target coordinate system.
Target centre plane	z=0 plane in the target coordinate system
Target coordinate system	Primary coordinate system at ESS. The origin is in the centre of the target monolith defined as the intersection of the proton beam with common vertical axis of the two moderators. [9]

9. LIST OF ACRONYMS

Acronym	Definition
BCS	Beam-Port Coordinate System
BS	Bunker System
BWS	Bunker Wall System
CF	Conventional Facilities
CHESS	Collaboration Home at ESS
ConOps	Concept of Operations
CSS	Common Shielding System
ERIC	European Research Infrastructure Consortium
ES&H	Environment Safety & Health
ESS	European Spallation Source
GSO	General Safety Objectives
I	Infrastructure
ICS	Integrated Control Systems
ID	Identification

Acronym	Definition
II	Installation / Integration
InS	Instrument Systems
NSS	Neutron Scattering Systems
PSS	Personnel Safety Systems
RMH	Radioactive Material Handling
RMHF	Radioactive Material Handling Facility
S&SS	Shielding & Safety System
SAD	System Architecture Description
SI	Site Infrastructure
SRS	System Requirements Specification
SIP	System Integration Plan
SIPr	System Integration Procedure
SIR	System Integration Report
SSM	Swedish Radiation Safety Authority (Strålsäkerhetsmyndigheten)
SVeP	System Verification Plan
SVePr	System Verification Procedure
SVeR	System Verification Report
SyIII	System Installation / Integration Inspection
SyR	System Requirement
SyRV	System Requirement Verification
TCS	Target Coordinate System

10. REFERENCES

[1] ESS-0472974, SRS for the CSS
[2] ESS-0472979, SDD for the CSS
[3] Guide for Writing Requirements, INCOSE-TP-2010-006-02.1, 30 June 2017
[4] ESS-0000004, General Safety Objectives
[5] ESS-0051603, NSS Zoning document, part 1 (safety)
[6] ESS-0050516, NSS zoning document - part II (security /protection classes)
[7] ESS-0001786, Definition of Supervised and Controlled Radiation Areas
[8] ESS-0019931, ESS Procedure for designing shielding for safety
[9] ESS-0035090, Main Coordinate Systems at the ESS

DOCUMENT REVISION HISTORY

Revision	Reason for and description of change	Author	Date
1	First issue	Mark Ridgley	2019-01-14