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BEER – System Requirements Document

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1. INTRODUCTION

This document describes the system requirements for the subsystems of the BEER instrument. These requirements are based on the high-level scientific requirements derived from the scientific case of the instrument as outlined in the instrument proposal [1] and revised during the scope setting meeting as well as in the Concept of Operations (ConOps) document [2] that describes in addition, the expected operational scenarios of the instrument. In this document, the requirements correspond to the day one instrument configuration of BEER which is described in more details together with budget in the Scope Setting Report Instrument: Engineering Diffractometer BEER [3] with adaptation according to the Summary of BEER Scope-Setting [4]. Some of the requirements, especially that for the instrument cave, already reflect necessities which will be needed to accomplish for a future upgrade to the "full scope" option as described in the ConOps document [2].

The subsystems and their requirements in this document are based on the high-level product breakdown structure (PBS) which is shown in Figure 1.

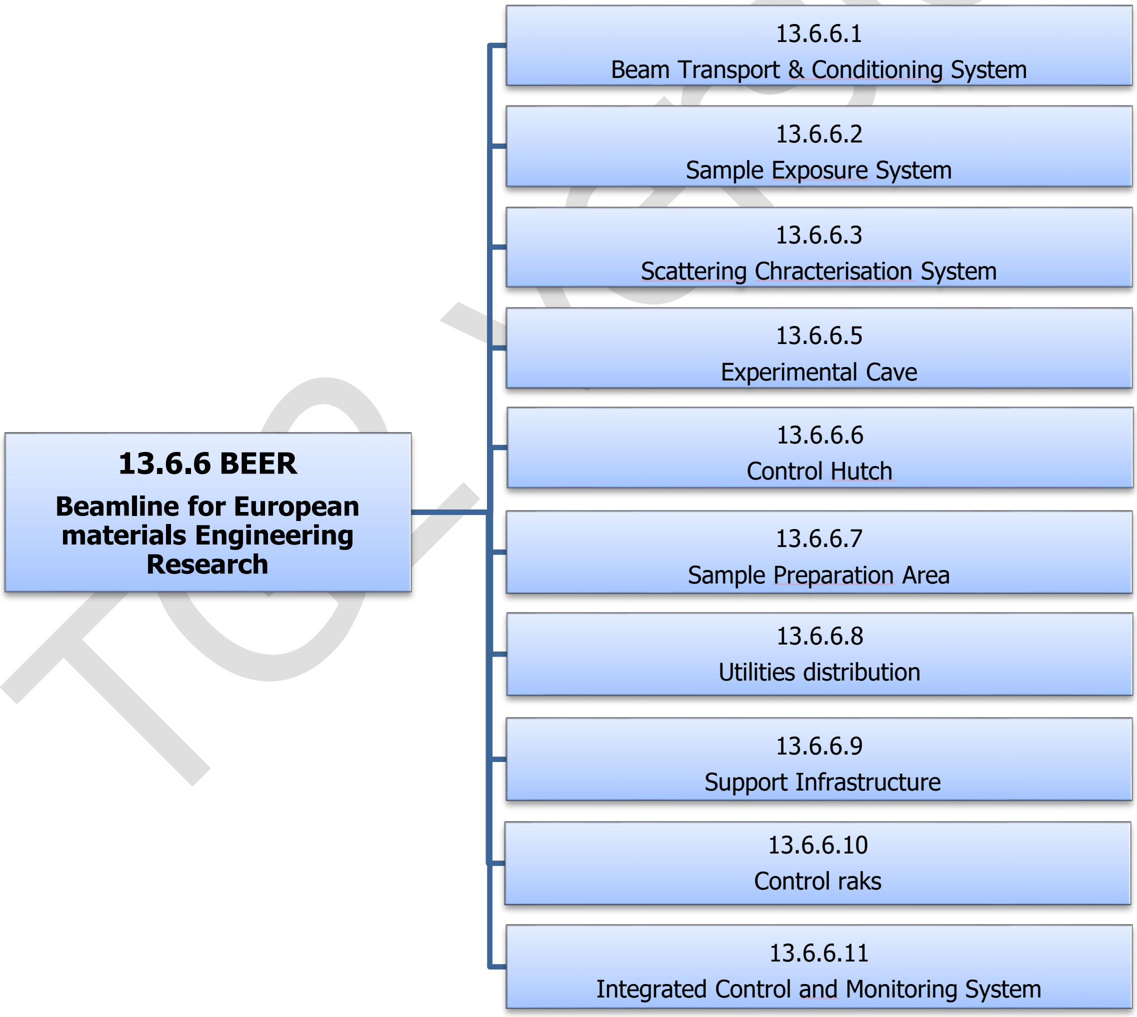

Figure 1: *BEER Product Breakdown Structure (PBS)*

The functional requirements will be structured accordingly.

In addition, there are also listed requirements that constrain and/or provide boundaries for the design and operation of the instrument. Those requirements are mainly related to the ESS facility and its requirements for conventional and radiation safety, environmental requirements, external interfaces limitations, etc.

2. SYSTEM CHARACTERISTICS

2.1 System purpose

BEER is a neutron diffractometer addressing the needs of material engineers to characterize bulk structures, microstructures, and/or stress states of advanced materials for industrial applications. The instrument is optimized for in-situ and in-operando experiments under thermal and mechanical conditions similar to those in real industrial processing and use.

2.2 System overview

The instrument consists of three main technical subsystems: the beam transport and conditioning system (BTCS), the sample exposure system (SES) and the scattering characterization system (SCS). In addition the instrument includes the structures that house and support these subsystems as the experimental cave (EC), control hutch (CH), etc. as well as the software to control the instrument and process the data, as described in the instrument product breakdown structure (PBS) illustrated in Figure 1.

3. SYSTEM REQUIREMENTS

3.1 Background of the system requirements

This entire section should be regarded as brief background information how to read the system requirements.

3.1.1 Requirements Categories

ESS has organized system requirements in three categories. Ideally, they can be separated as follows:

- Functional requirements – generally answering to the "what" is performed by the system,
- Constraint requirements (sometimes referred to as non-functional requirements) – generally answering to the "how" a function is performed by the system
- Performance requirements – generally answering to the "how well" a function has to perform or "to what extent" a constraint affect the system design.

In reality, it is often difficult to differentiate between what is functional and what is a constraint requirement. Performance requirements are in principle either functional or constraint requirements with limiting statements quantifying the satisfaction level.

To clarify, in principal, constraint requirements do not impact on the functionality of the instrument. They will, however, have a lesser or greater impact on the design choices of the instrument in order to achieve the intended functionality. They could also have an impact on the performance of the instrument.

3.1.2 Requirement wording

Each requirement is expressed as a natural language statement following the guidelines in the NASA Systems Engineering Handbook [5]. Statements using wording "shall" or "should", where the former implies a mandatory statement and the latter is a non-mandatory one. *Should* is used to set a goal which if fulfilled would increase the performance or functionality of the system.

3.2 Functional Requirements

The following sections break down the high-level scientific requirements into requirements that the major subsystems need to fulfil.

3.2.1 Beam Transport and Conditioning System (BTCS) – PBS 13.6.6.1

The beam transport system transports a beam of neutrons from the moderator surface to the sample. The size, divergence and wavelength spectrum of the beam are tailored to the needs of the experiment.

Id	**Text** (Beam Transportation and Conditioning System)	**Trace up to**
1	Wavelength resolution The BTCS shall transport from the moderator a *beam of neutrons* to the *sample* at a distance that leads to a wavelength uncertainty range of 0.1% - 0.3% ($\Delta\lambda/\lambda$) for the detected neutrons. A tuneable $\Delta\lambda/\lambda$ resolution permits to make the best use of the source brightness in the broad variety of user experiments ranging from strain mapping (high resolution) to fast real-time in-situ measurements (high intensity/low resolution). The wavelength resolution can be verified by the measurement of the time width of Bragg reflections from the sample at low incident beam divergence.	ConOps HLSR: I.-IV. 1.-5., 11.-12.
2	Beam size The BTCS shall transport from the moderator to the sample a beam of neutrons with adjustable size (full-width half maximum) up to 40 mm × 40 mm. By matching the beam size to the sample size the S/B is maximised. The beam size can be verified by measurement of the beam intensity profile at the sample position.	ConOps HLSR: I.-IV. 1.-5., 7., 10., 15.
3	Beam spot The BTCS shall allow to scale the beam spot by slits as close as possible from the sample to not introduce an additional increase of the divergence of the beam.	ConOps HLSR: II. 3., 7., 10., 15.
4	Beam homogeneity The BTCS shall provide a homogeneous beam spot allowing that both 90° detectors see the same scattered intensity.	ConOps HLSR: II. 3., 7., 10., 15.

Id	**Text** (Beam Transportation and Conditioning System)	Trace up to
5	Beam divergence The BTCS shall transport from the moderator to the sample a beam of neutrons with adjustable horizontal and vertical divergence with a maximum divergence of ±0.3° × 0.9° (H x V). A variation of the divergence allows the angular resolution to be matched to the wavelength resolution, which contributes to maximizing the S/B.	ConOps HLSR: I.-IV. 1.-5., 12., 15.
6	Bandwidth selection The BTCS shall transport from the moderator to the sample a beam of neutrons with a wavelength bandwidth of 1.7 Å. This bandwidth is determined by the instrument length, the position of the first chopper and the length of the ESS pulse. The bandwidth can be extended when using the modulation techniques. The width of the wavelength band changes the number of reflections observed.	ConOps HLSR: I.-IV. 1.-5., 11.-12.
7	Useful wavelength range The BTCS shall transport from the moderator to the sample a beam of neutrons with a bandwidth that lies within the wavelength range 1 Å - 8 Å. This wavelength range allows for diffraction measurements in the required range of inter-planar spacing.	ConOps HLSR: I.-IV. 1.-6., 11.-12., 15.
8	Background When the experimental cave is not *interlocked* the BTCS shall block radiation from the target to a level required by safety regulations allowing the user to change a sample. The background can be determined by measurement of the dose rate in the experimental cave.	ConOps HLSR: I.-IV. 1.-5. and 3.4.3.
9	Divergence profile The BTCS should transport from the moderator to the sample a beam of neutrons with a divergence profile sufficiently smooth to obtain smooth diffraction peaks. The beam divergence profile is convoluted with the wavelength resolution profile and its results in the measured diffraction peaks profile which have to be smooth to allow an accurate profile fitting.	ConOps HLSR: I.-IV. 1.-5. 10.-12., 15.
10	Wavelength contamination The BTCS should transport from the moderator to the sample a beam of neutrons where the total *contamination of wavelength* outside the selected wavelength band is <1 %. The neutrons outside the used wavelength band add to the background. It can be verified by the measurement of the neutron spectrum at the sample.	ConOps HLSR: I.-IV. 1.-5., 11.-12.

Id	**Text** (Beam Transportation and Conditioning System)	Trace up to
11	Accessibility The BTCS outside the bunker or behind the secondary shutter shall be accessible for repairs while the *proton beam is on the target*. In that case, the instrument will be more fault tolerant hence increasing the throughput of experiments. It can be verified by measuring the dose rate at the relevant technical component.	ConOps HLSR: I.-IV. 1.-5. and 3.4.4.
12	Chopper Systems in the bunker The chopper systems in the bunker (6 m – 10 m) require a guide of reduced beam width (2 cm) with several gaps allowing an appropriate shaping and modulation, respectively, of the neutron beam. Neutron guide segments in this sector have to be designed together with the chopper vacuum housing and maintenance system in order to ensure minimization of guide interruptions and the system robustness with respect to alignment accuracy.	ConOps HLSR: I.-IV. 1.-5., 11.-12., 15. and 3.4.5.
13	Pulse Shaping Chopper System The BTCS shall allow the movement of the pulse shaping choppers to an open position or out of the bunker in case they are not used or in the case of failures. The unhindered passage of neutrons through a not used chopper is crucial for an effective use of the instrument. Some modes can be operated without PSCs.	ConOps HLSR: I.-IV. 1.-5., 11.-12., 15. and 3.4.5.
14	Pulse Shaping Chopper movement The BTCS shall allow the movement of 1 Pulse Shaping chopper along the beamline of up to 20 cm.	ConOps HLSR: I.-IV. 1.-5., 11.-12., and 3.4.5.
15	Modulation Chopper System The BTCS shall allow the movement of the modulation choppers to an open position or out of the bunker in case they are not used or in the case of failures. The unhindered passage of neutrons through a not used chopper is crucial for an effective use of the instrument. Some modes can be run without MCs.	ConOps HLSR: I.-IV. 1.-5., 11.-12. and 3.4.5.
16	Frame Definition Chopper System The BTCS shall allow the movement of the frame definition choppers out of the bunker (FC1) or shielding (FC2) in the case of failures. An easy and fast exchange for maintenance or repair of the FCs is crucial for an effective use of the instrument.	ConOps HLSR: I.-IV. 1.-5., 11.-12., and 3.4.5.
17	Chopper phase monitoring The BTCS shall allow appropriate monitoring of the chopper phases which is crucial for an effective use of the instrument as well as for data reduction and analysis.	ConOps HLSR: I.-IV. 1.-5., 11.-12., 15. and 3.4.5, 6.1.2.

Id	**Text** (Beam Transportation and Conditioning System)	**Trace up to**
18	Beam monitoring The BTCS shall allow the beam to be monitored at several positions allowing the allocation of problems close to the corresponding component and to properly set-up the BTCS system, e.g. the chopper system.	ConOps HLSR: I.-IV. 1.-5., 15.

3.2.2 Sample Exposure System, SES – PBS 13.6.6.2

The sample exposure system positions the sample in a beam of neutrons and controls the physical and chemical environment of the sample as dictated by the needs of the experiment. At BEER different positioning systems will be used, e.g. a robot or a hexapod.

Id	**Text** (Sample Exposure System)	**Trace up to**
19	Rotary stage A rotary stage shall allow a rotation of about 360° allowing the positioning of samples into the neutron beam.	ConOps HLSR: I.-II., IV. 1.-5., 13.-14.
20	Rotary stage (precision) The SES for heavy loads shall have an accuracy of about 0.1° for the rotation allowing the positioning of samples into the neutron beam. A more precise alignment of the sample will be done by a secondary stage if necessary.	ConOps HLSR: I.-II., IV. 1.-5., 13.-14.
21	Hexapod (movement) A hexapod shall allow positioning of heavy samples up to 2000 kg into the neutron beam and should provide movements of about x = ±200 mm, y= ±200 mm and z= ±250 mm.	ConOps HLSR: II. 1., 3.-4., 7.
22	Hexapod (precision) A hexapod shall allow positioning of heavy samples up to 2000 kg with high precision in the beam with an accuracy in x, y, z of about 0.02 mm allowing for example for stress mapping.	ConOps HLSR: II. 1., 3.-4., 12.
23	Robot system (footprint) The SES, e.g. a robot arm, should allow to position samples with a maximum weight up to 14 kg into the neutron beam allowing for example for texture or stress measurements.	ConOps HLSR: II.-III. 1.-4., 7., 13.
24	Robot system (movement) The SES, e.g. a robot arm , system shall define the orientation of the sample in the beam of neutrons about at least two *sample rotation axes* that intersects the *beam axis* with a repeatability of ±0.02° within a range of ±90° allowing for example for texture measurements.	ConOps HLSR: II.-III. 1.-4., 12.

Id	**Text** (Sample Exposure System)	**Trace up to**
25	Robot (automatic sample changing) The robot system should be able to change the sample automatically without physical user intervention. Automated sample changing is required in order to optimize the use of available beam time.	ConOps HLSR: II.-III. 1.-4., 7., 13.
26	Sphere of confusion The above-mentioned SES or a combination of it shall maintain the position of the sample in the neutron beam with a sphere of confusion of < 0.02 mm root mean square radius and shall guarantee for long term stability. The sample gauge volume has to be illuminated by the neutron beam during the entire experiment with high precision, in particular for stress mapping.	ConOps HLSR: II.-III. 1.-4., 7., 13.
27	Sample imaging The SES shall allow optical imaging of the sample during the experiment. For the definition of the gauge volume, the sample orientation must be controlled and known.	ConOps HLSR: I.-IV. 1.-5., 10., 15.
28	Beam imaging The SES shall allow the imaging of the neutron beam at the sample position when a sample is not mounted. The characterization of the neutron beam, e.g. size, homogeneity, etc., is essential for the set-up of experiments.	ConOps HLSR: I.-IV. 1.-5., 15.

3.2.3 Scattering Characterization System, SCS - PBS 13.6.6.3

The scattering characterization system detects the neutrons interacting with the sample to produce meaningful experimental data, provided a minimized background at the detector position.

Id	**Text** (Scattering Characterization System)	**Trace up to**
29	Detection efficiency The SCS shall detect the scattered neutrons with a time constant *efficiency* according to the experiments. The efficiency shall have a value > 40% across the useful wavelength range (1 Å – 8 Å) and the total active detector area. The Neutron detection efficiency must be equivalent to current state-of-the-art technology.	ConOps HLSR: I.-IV. 1.-5., and 3.4.8.
30	Horizontal detectors (at ±90° positions) solid angle The ±90° detectors shall cover an azimuthal range of approximately ±15° allowing to measure two strain components at once.	ConOps HLSR: I.-IV. 1.-6., 7., 11. and 3.4.8.

Id	**Text** (Scattering Characterization System)	**Trace up to**
31	Spatial resolution (horizontal detectors) The SCS shall detect the scattered neutrons with a *spatial resolution* ≤ 2 mm x 5 mm (horizontal x vertical) in a sample-detector distance of 2 m. The spatial resolution contributes to the precision of determination of Δd/d effecting stress magnitude measurement and precision in phase analysis. The spatial resolution can be verified by imaging of a reference grid.	ConOps HLSR: I.-IV. 1.-5., 12. and 3.4.8.
32	Horizontal detectors movability The horizontal detectors shall be retractable in a range from 2 - 3 m from the sample allowing bulky sample environment to be placed at the sample position.	ConOps HLSR: I.-IV. 1.-5., 13.
33	Time resolved measurements In general the time-resolution of the SCS shall allow for in-situ and in operando diffraction studies on time scales shorter than 1 s. In special cases (appropriate sample size, geometry, composition, source power, etc.) it shall allow one pulse measurement.	ConOps HLSR: I., IV. 1.-4., 15.
34	Detection time resolution The SCS shall detect the scattered neutrons with a time of flight resolution better than 0.004 ms. This detection time resolution should be smaller than the time width of a reflection, given by the chopper system allowing for a Δt/t resolution below 0.1 %.	ConOps HLSR: I.-IV. 1.-5.
35	Neutron selectivity The SCS should detect gamma-rays incident to the detector system with a $<10^{-6}$ efficiency. Non-neutron originated detector signals (*e.g.* gamma-rays) contribute to the background and should be minimized.	ConOps HLSR: I.-IV. 1.-5.
36	Detector positioning and stability The SCS shall position the detectors with a *positioning accuracy* of 0.1 mm. Mechanical drifts of the detectors during the measurement shall be small compared to the shifts of the diffraction peaks due to the measured strain.	ConOps HLSR: I.-IV. 1.-5.
37	Neutronic background noise The environment where the SCS is placed in, should not cause more than 0.1 neutron counts/s in the active detector system when the shutter is closed. The lower the background of the environment the higher the achievable S/B ratio.	ConOps HLSR: I.-IV. 1.-5.

Id	**Text** (Scattering Characterization System)	Trace up to
38	Detector electronics noise The detector electronics of the SCS shall guarantee for a long-term counting stability of the detector for several days within the range of 0.01 counts/s. The detector electronic noise level must be significantly lower than the neutronic background with closed shutter, otherwise, the detector electronic noise becomes limiting.	ConOps HLSR: I.-IV. 1.-5.
39	Radial collimators The SCS shall define the sample gauge volume by exchangeable radial collimators placed in front of the horizontal detectors. The set of radial collimators shall cover the resolution range from 0.5 mm to 5 mm. The application of radial collimators additionally shall eliminate parasitical scattering from the sample environment.	ConOps HLSR: I.-IV. 1.-5.

3.2.4 Experimental Cave, EC - PBS 13.6.6.5

Id	**Text** (Experimental Cave)	Trace up to
40	Mounting components The experimental cave shall allow the mounting of technical components of the BTS, SES, and SCS with the required *precision* and stability. The technical components have to be physically mounted on a suitable support. It can be verified by metrology and acceleration measurements.	ConOps 3.4.2, 3.4.6, 3.4.7, 3.4.8
41	Mounting bulky sample environment The experimental cave shall allow the mounting of bulky sample environment devices. The materials science experiments may require bulky sample.	ConOps 3.4.6, 3.4.7, 3.4.8
42	Sample environment access The experimental cave shall allow horizontal access of sample environment and equipment with a footprint of about 1 x 3 m², a height of about 2 m and weight up to 3000 kg. Sample environment has to be transported easily and smooth into the experimental cave. Minimizing the exchange time maximizes the effective use of beam time. The smooth transport guarantees that the sample and its condition are stable during the transport, in particular in the case of long-term experiments.	ConOps 3.4.6,
43	Floor height The floor of the experimental cave has to be elevated to a floor–to-beam distance between 1.5 – 1.8 m allowing easy installation of equipment, e.g. sample environment.	ConOps 3.4.6, 3.4.7
44	Floor load	ConOps

Id	**Text** (Experimental Cave)	**Trace up to**
	The floor of the experimental cave shall have a floor load up to 2t/m² to be able to carry heavy equipment and sample environment	3.4.6, 3.4.7
45	Sample stage floor The floor around the sample stage with the footprint at least 1.5 x 1.5 m^2 shall have separated foundation from the rest of the floor level to allow stationary fixing of SE and prevent a transfer of vibrations from SE to detector and other equipment.	ConOps 3.4.6, 3.4.7, 3.4.8.
46	Utilities The experimental cave shall provide the required utilities to the elements of the BTS, SES, and SCS that are within it. The technical components need utilities (power, cooling vacuum, etc.).	ConOps 3.4.2, 3.4.6, 3.4.7, 3.4.8
47	Access The experimental cave shall allow personnel access when the proton beam is on target. The dose level in the Cave when the shutters are closed shall be < 3 μSv/h in accordance with ESS0001786 and ESS-0051603. Access for sample changes, maintenance, repairs or adjustments is necessary.	ConOps 3.4.6, ESS-0001786 [21], ESS-0051603 [11]
48	Video surveillance The experimental cave shall be equipped with video surveillance. Video surveillance of movements in the cave allows avoiding damages to equipment and people and helps to set-up and control experiments.	ConOps 3.4.6, 5.3.3
49	Biological shielding The experimental cave shall shield its surroundings against the radiation produced by the neutron beam to safe levels according to ESS radiation safety regulations (ESS-0001786 and ESS-0051603). The surroundings of the instrument must be safe for personnel. It can be verified by dose rate measurements.	ConOps 3.4.6, ESS-0001786 [21], ESS-0051603 [11]
50	Beam Stop A beam stop or get-lost-tube shall capture the beam after the sample to avoid scattering contribution from downstream and to increase safety for the control hutch.	ConOps 3.4.3, 3.4.6, 3.4.8, 3.4.9
51	Roof access The roof of the experimental cave shall allow access for equipment with a footprint of about 3 x 4 m² in case the crane of hall three is used.	ConOps 3.4.6.
52	Experimental cave crane The experimental cave shall provide a crane with a capacity of about 1.5 t and a hook height of about 4 m above the elevated	ConOps 3.4.6

Id	**Text** (Experimental Cave)	Trace up to
	floor allowing easy movement and positioning of sample environments and equipment within the experimental cave.	

3.2.5 Control Hutch, CH - PBS 13.6.6.6

Id	Text	Trace up to
53	Instrument control terminal The control hutch shall allow the user to remote control the technical components from a single dedicated computer terminal. The instrument control should be possible from one terminal.	ConOps 3.4.9, 3.4.11, 5.3.3
54	Data reduction terminal The control hutch shall allow the user to process the neutron data to an indexed list of fitted parameters of individually scaled reflections as a function of sample environment parameters at a single dedicated computer terminal. Data reduction must be possible from at least one terminal during the experiment in order to verify data quality.	ConOps 3.4.9, 3.4.11, 5.3.3
55	Working space The control hutch shall have sufficient working space for up to six persons. A user team typically consists of 1-4 people and there must be space for the departing team to finish working while arriving team is starting work.	ConOps 3.4.9
56	Comfort The control hutch shall be a comfortable working environment for the users. Users work long hours and a comfortable environment reduces fatigue and the probability of making mistakes and thus increases productivity. It can be verified by feedback of the users.	ConOps 3.4.9
57	Access to instrument The control hutch should be located as close as possible to the experimental cave. Users need to mount and change samples during their experiment and hence need easy access.	3.4.6, 3.4.9, 5.3.3

3.2.6 Sample Preparation Area, SPA - PBS 13.6.6.7

Id	Text (Sample Preparation Area)	Trace up to
58	Laboratory The engineering materials laboratory close to the experimental cave (distance <25 m) shall allow the preparation of samples for engineering experiments, the storage of sample environment and equipment as well as the set-up of experiments. The preparation and storage of sample, sample environment and equipment close to the experimental cave are essential for an effective use of beam time.	ConOps HLSR: I. – IV and 5.3.3
59	Laboratory crane The engineering materials laboratory shall provide a crane with a capacity of about 5 t and a hook height of about 5 m from the floor allowing easy movement of sample environments and equipment within the laboratory.	ConOps 5.3.3
60	Instrument area The area close to the instrument shall allow to store sample environment and equipment and to host long-term experiments which will be moved from time to time into the neutron beam. The storage of sample environment and long-term experiments close to the beamline allows an effective use of beam time.	ConOps I. - IV, 5.3.3

3.2.7 Utilities Distribution – PBS 13.6.6.8

Id	Text (Utilities Distribution)	Trace up to
61	Bunker area (D03) shall provide the required utilities as power supplies, vacuum, cooling water, LAN connection, etc. to the guide and choppers assemblies installed on its area.	ConOps 3.4, 5.1
62	Guide hall (E02) shall provide the required utilities as power supplies, vacuum, cooling water, LAN connection, etc. to the guide, secondary shutter and choppers assemblies installed on its area.	ConOps 3.4, 5.1
63	Experimental hall 3 (E01) shall provide the required utilities as power supplies, cooling water, vacuum, gas distribution, LAN connection, etc., to the experimental cave, control hutch and preparatory lab.	ConOps 3.4, 5.1

3.2.8 Support Infrastructure, SPI - PBS 13.6.6.9

Id	**Text** (Support Infrastructure)	**Trace up to**
64	Mounting components (Hall two) The hall two shall allow the mounting of technical components of the BTCS with the required *precision* and stability. The technical components have to be physically mounted on a suitable support. It can be verified by metrology and acceleration measurements.	ConOps 3.4.2, 3.4.5
65	Utilities (Hall two) The hall two shall provide the required utilities to the elements of the BTS that are within it. The technical components need utilities (power, cooling vacuum, etc.).	ConOps 3.4.2, 3.4.5
66	Access (Hall two) The hall two should allow access to personnel when the proton beam is on target. Access for maintenance, repairs or adjustments is necessary.	ConOps 3.4.3, 5.4
67	Biological shielding (Hall two) The hall two shall shield its surroundings against the radiation produced by the neutron beam to safe levels according to ESS radiation safety regulations (ESS0001786 and ESS-0051603). The surroundings of the instrument must be safe for personnel. It can be verified by dose rate measurements.	ConOps 3.4.3, 3.4.4
68	Mounting components (Hall three) The hall three shall allow the construction of the optical and experimental caves with the required precision and stability. The cave has to be built on a suitable support. It can be verified by metrology and acceleration measurements.	ConOps 3.4.2, 3.4.6
69	Utilities (Hall three) The hall three shall provide the required utilities to the optical and experimental caves. The technical components need utilities (power, cooling vacuum, etc.).	ConOps 3.4.2, 3.4.6
70	Access (Hall three) The hall three shall allow access to personnel when the proton beam is on target. Access for maintenance, repairs or adjustments is necessary.	ConOps 3.4.3, 5.4

Id	**Text** (Support Infrastructure)	**Trace up to**
71	Sample environment transport (Hall three) The hall three shall provide sufficient space (width and height min. 3 m) to transport sample environment and equipment from the engineering laboratory to the experimental cave on the ground floor without crane support. Bulky and heavy sample environment (footprint of about 1 x 3 m² and max. 3000 kg) are difficult to handle by crane and have to be transported as smooth as possible to avoid damages on equipment and samples in case of experimental set-up in the laboratory or long-term experiments.	ConOps I.- IV. 3.4.6
72	Access to instrument sample position (Hall three) The layout of instruments and equipment in hall three shall permit access to the sample area of BEER many times per day for personnel, and equipment meeting the BEER sample environment requirements. Samples and sample environment equipment will need accessing and changing as part of the experimental workflow.	ConOps 3.4.6, 5.3.3
73	Hall three crane The crane in hall three shall have a capacity of at least 5 t and a hook height of 10.5 m from the floor allowing the movement of sample environment into the experimental cave from the roof.	ConOps 3.4.6
74	Mounting components (Neutron guide hall) The neutron guide hall shall allow the mounting of technical components of the BTS with the required *precision* and stability. The technical components have to be physically mounted on a suitable support. It can be verified by metrology and acceleration measurement.	ConOps 3.4.2, 3.4.5
75	Utilities (Neutron guide hall) The neutron guide hall shall provide the required utilities to the elements of the BTS that are within it. The technical components need utilities (power, cooling vacuum, etc.).	ConOps 3.4.2, 3.4.5
76	Access (Neutron guide hall) The neutron guide hall should allow access to personnel when the proton beam is on target. Access for maintenance, repairs or adjustments is necessary.	ConOps 3.4.3, 3.4.4
77	Biological shielding (Neutron guide hall) The neutron guide hall shall shield its surroundings against the radiation produced by the neutron beam to safe levels according to ESS radiation safety regulations (ESS0001786 and ESS-0051603). The surroundings of the instrument must be safe for personnel. It can be verified by dose rate measurements.	ConOps 3.4.3

3.2.9 Control racks – PBS 13.6.6.10

Id	**Text** (Control Racks)	**Trace up to**
78	Control racks shall include racks for DAQ, DMSC, Motion Control, Chopper Control, Vacuum Control and PSS.	ConOps 3.4, 5.3.3.

3.2.10 Integration Control and monitoring, IC&M - PBS 13.6.6.11

Id	**Text** (Integration Control and monitoring)	**Trace up to**
79	Instrument control GUI The integrated control and monitoring system shall allow the user to control the experimental parameters through a graphical user interface. A good graphical user interface makes instrument control fast and easy and reduces user errors.	ConOps 3.4.11, 5.3.3
80	Instrument control CLI The integrated control and monitoring system shall allow the user to control the experimental parameters through a scriptable command line interface (CLI). A good scriptable command line interface allows for flexibility for more experienced users and ESS staff.	ConOps 3.4.11, 5.3.3
81	Scattering pattern visualisation The integrated control and monitoring system shall allow the user to visualize the scattered neutron intensity as a function of detector coordinates and time-of-flight with user selectable binning while the data is taken. Visualization of the diffraction pattern is crucial for judging the data quality.	ConOps 5.3.3
82	Data processing GUI The Integrated control and monitoring system shall allow the user to process the neutron data to an indexed list of fitted parameters of individually scaled reflections as a function of sample environment parameters of scaled reflection intensities during the measurement. A good graphical user interface makes data processing fast and easy.	ConOps 5.3.3
83	Data processing CLI The Integrated control and monitoring system shall allow the user to process the recorded data through a scriptable command line interface to an indexed list of scaled reflection intensities. A good scriptable command line interface allows for flexibility for more experienced users and ESS staff.	ConOps 5.3.3

Id	**Text** (Integration Control and monitoring)	**Trace up to**
84	Remote Control The integrated control and monitoring system shall allow controlling the experiment by expert users from outside the control hutch (e.g. inside the experimental cave or at home). The remote control allows for the efficient use of beam time by setting up the experiment inside the experimental cave or supports the users from home (e.g. in the case of failures).	ConOps 3.4.11, 5.3.3
85	Offsite data processing The integrated control and monitoring system shall allow to access and process data from outside of ESS. Data access and process from outside allows users to handle measured data after the experiments in an effective way and avoids the loss of data.	ConOps 5.3.3
86	Hazard detection The Integrated control and monitoring system shall detect hazards that may compromise safety for personnel or equipment. Detection of hazards such as fire, radiation, flooding or asphyxiating gasses can prevent injury to personnel or damage to equipment.	ConOps 3.4.11, 3.4.10

3.3 Constraint Requirements

3.3.1 Operational constraint requirements

Id	**Text** (Operational constraint requirements)	**Trace up to**
87	Operation Mode Changes – Mode Redundancy Maintenance or failure issues of one mode shall have a minimum impact on other modes (Those choppers are removable or that it is always possible to set them to an open position is more important than repair and maintenance times, which should be kept to a minimum, however).	ConOps 5.3.3, 5.4
88	Operation Mode Changes – Mode Switching Time No mode change shall take longer than 30 min.	ConOps 5.3.2, 5.3.3
89	Operation Mode Changes – BTSC-access, configuration time No configuration mode change requiring access in the experimental cave shall take longer than 8 hours (including alignment).	ConOps 3.4.6, 5.3.2, 5.3.3
90	BTSC Ergonomics The beam and BTCS components in the experimental cave shall be accessible at a comfortable height to the average user.	ConOps 3.4.2, 3.4.6, 3.4.7

3.3.2 RAMI requirements

Reference to related system design and testing standards, requirements imposed by regulation or management decisions.

Id	**Text** (RAMI requirements)	Trace up to
91	Operation Schedule The system shall be operational according to the schedule of the ESS source and the set availability goals of NSS RAMI Handbook	RAMI Handbook [6], BEER ConOps 5.4
92	Maintainability The system shall be maintainable in a way fulfilling the Operation Schedule requirement (above).	RAMI Handbook [6], BEER ConOps 5.4
93	Access Instrument components shall be accessible for all maintenance and repair activities needed to fulfil the Operation Schedule and Maintenance requirements (above).	RAMI Handbook [6], BEER ConOps 5.4, ESS-0039408 (Annex N) [8]
94	Reliability – MTBF (Mean Time Between Failure) Instrument components and sub-systems shall meet MTBF requirements (as specified elsewhere in detail) that enable to meet the Operation Schedule requirement (above).	RAMI Handbook [6], BEER ConOps 5.4
95	Availability – MTTR (Mean Time To Repair) Instrument components and sub-systems shall meet MTTR requirements (as specified elsewhere in detail for critical sub-systems) that enable to meet the Operation Schedule requirement.	RAMI Handbook [6], BEER ConOps 5.4
96	Internal Interfaces (physical connection) Instrument sub-systems shall be connected and integrated such to enable to meet the functional and other RAMI requirements.	BEER ConOps 5.4
97	Design Robustness The overall system design shall enable to meet the Operation Schedule requirements through robustness against single sub-system failure.	BEER ConOps 5.4
98	Spares The system shall include spares critical to meet OS requirement.	BEER ConOps 5.4

3.3.3 Environmental Requirements

Environmental requirements related to sustainability and Environmental court ruling.

Id	**Text** (Environmental Requirements)	**Trace up to**
99	Shielding The radiological shielding of the system shall satisfy all applicable legal regulations incorporated in ESS procedures, guidelines, handbooks etc. to guarantee safe operation concerning radiation hazards.	ESS-0019931 [12], ESS-0052625 [13], ESS-0039408 [8]
100	Activation The Activation of system components shall comply with ALARA criteria, corresponding ESS procedures, guidelines, handbook, etc. incorporating applicable legal regulations, in particular also with respect to disposal.	ESS-0020168 [14], ESS-0052491 [15]
101	Sample handling The system shall allow for sample handling procedures complying with ESS environmental policies and legal regulations incorporated in ESS procedures, guidelines, handbooks etc., in order not to pose an environmental risk.	ESS-0024112 [16]
102	Materials The materials used in the system shall avoid environmental hazards and comply with all applicable legal regulations incorporated in ESS procedures, guidelines, handbooks etc.	ESS-0011452 [17], ESS-0011458 [18]

3.3.4 Conventional Safety Requirements

Safety and security requirements not related radiation protection.

Id	**Text** (Conventional Safety Requirements)	**Trace up to**
103	Safety The system and all required operational procedures shall comply with ESS safety procedures, guidelines, handbooks etc. and legal regulations, incorporated in the former.	ESS-0043151 [19], ESS-0039408 (Annex N) [8]

3.3.5 Radiation Safety Requirements

Safety and security requirements related to radiation i.e. SSM conditions.

Id	**Text** (Radiation Safety Requirements)	**Trace up to**
104	Activation The Activation of system components shall comply with ALARA criteria, corresponding ESS procedures, guidelines, handbook, etc. incorporating applicable legal regulations, in particular also with respect to disposal.	ESS-0020168 [14], ESS-0052491 [15]

Id	**Text** (Radiation Safety Requirements)	Trace up to
105	Sample handling The system shall allow for sample handling procedures complying with ESS environmental policies and legal regulations incorporated in ESS procedures, guidelines, handbooks etc., in order not to pose an environmental risk.	ESS-0024112 [16]
106	Materials The materials used in the system shall avoid environmental hazards and comply with all applicable legal regulations incorporated in ESS procedures, guidelines, handbooks etc.	ESS-0039408 [8], ESS-0042895 [20], ESS-0001786 [21], Etc.
107	PSS The system shall feature a PSS complying with ESS regulations and policies that enables radiological safety for the access to sub-systems.	ESS-0004620 [22]

3.3.6 External Interface Requirements

Id	Text	Trace up to
108	CF environment The system shall fit within and profit from the boundary conditions set through CF.	BEER ConOps 3.4, Site Infrastructure IRS [7]
109	Neighbourhood Systems The system shall comply with the physical requirements of neighbouring systems and its design shall take into account needs of potential future neighbours.	ConOps 3.4.6, 3.4.12
110	ICS The system shall connect to the ICS in order to be controllable and survailable with respect to all viable functions through ICS.	ConOps 3.4.11
111	Data Streaming The system together with ICS shall enable to stream all recorded data through ICS to central data storage and back to instrument control/data computers.	ConOps 3.4.11, 5.3.3
112	Remote Control Software The system shall interface with control software to satisfy all remote control requirements for operation, testing, maintenance and meta-data production for users and operators.	ConOps 3.4.11, 5.3.3

Id	Text	Trace up to
113	Data Reduction Software The system shall be the basis for the specification of all required data reduction and visualisation through a GUI and through command line interface, suitable for use by users with only minor training requirements. Detailed requirements for the reduction software constitute the major part of the interface with DMSC/Data Reduction and are, while in a process of development available elsewhere [23].	ConOps 5.3.3
114	Data Analyses Software The system shall be the basis for the specification of all required data analyses and corresponding visualisation through a GUI and through command line interface, suitable for use by users with only minor training requirements. Detailed requirements for the analyses software constitute the major part of the interface with DMSC/Data Analyses and are, while in a process of development available elsewhere [23].	ConOps 5.3.3
115	Sample Environment The system shall enable the use of pooled sample environment, as well as it should support custom designed SE from users or other groups.	ConOps 5.3.3
116	In bunker parts The system shall comply with the bunker design.	ConOps 3.4.2, 3.4.3, 3.4.5
117	Vacuum The system shall connect with vacuum services where required.	ConOps 3.4.2, 3.4.5
118	Monitoring The system shall enable monitoring with regards to radiological data, safety functions, operational conditions of sub-systems, vacuum, smoke, heat, specific gases etc. as required for safe operations by other sub-systems, systems and policies, and regulations.	ConOps 3.4.10
119	Required Services The system shall enable connection to all support systems and services provided centrally and required for operation not limited to but including these specified in these requirements.	ConOps 5.4

4. GLOSSARY

Term	Definition
HLSR	High Level Scientific Requirements

Term	Definition
HLSR	High Level Scientific Requirements
ConOps	Concept of Operations Description
BEER	Beamline for European materials Engineering Research
ESS	European Spallation Source
PBS	Product Breakdown Structure
BTCS	Beam Transport and Conditioning System
SES	Sample Exposure System
SCS	Scattering Characterization System
EC	Experimental Cave
CH	Control Hutch
S/B	Signal to Background ratio
PCS	Pulse Chapping Chopper
FC	Frame selection Chopper
SPA	Sample Preparation Area
SPI	Support Infrastructure
CF	Conventional Facilities
GUI	Graphical User Interface
CLI	Command-Line Interface
RAMI	Reliability, Availability, Maintainability, and Inspectability
TOF	Time Of Flight
IC&M	Integration Control & Monitoring
PSS	Personal Safety System
DMSC	Data Management and Software Centre
ICS	Integrated Control System

5. REFERENCES

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[2] Concepts Of Operations for BEER
[3] Scope Setting Report Instrument: Engineering Diffractometer BEER
[4] Summary of BEER Scope-Setting
[5] NASA Systems Engineering Handbook, Washington, DC, USA: National Aeronautics and Space Administration (NASA). NASA/SP-2007-6105
[6] NSS RAMI Handbook, ESS-TBD

[7] NSS-Site Infrastructure Interface Requirement Specification (IRS), ESS-TBD
[8] European Spallation Source Neutron Optics and Shielding Handbook, ESS-0039408
[9] NSS-Target Station (Beam Extraction System) Interface Requirement Description, ESS-TBD
[10] "Supervised area" versus 3rd safety area, ESS-0001786
[11] NSS zoning document - part 1, ESS-0051603
[12] ESS Procedure for designing shielding for safety, ESS-0019931
[13] NOSG phase 2 guidelines for designing instrument shielding for radiation safety, ESS-0052625
[14] NSS radioactive inventory - Part 2 (Exp. Hall and instruments), ESS-0020168
[15] NSS radioactive inventory - Part 3 (Bunker), ESS-0052491
[16] ESS Sample Handling Procedure, ESS-0024112
[17] ESS Procedure for sustainable selection of materials, ESS-0011452
[18] ESS Guideline for sustainable selection of materials, ESS-0011458
[19] Conventional Safety, Energy and SSM Requirements – Deterministic derived requirements Baseline part 1, ESS-0043151
[20] Materials guideline intended for the construction of neutron chopper systems for use at ESS, ESS-0042895
[21] "Supervised area" versus 3rd Safety barrier, ESS-0001786
[22] Basic Principles & Functions for PSS (Personal Safety System), ESS-0004620
[23] BEER – Preliminary System Design Document

DOCUMENT REVISION HISTORY

Version	Reason for revision	Date
0.6	First issue based on ODIN template	2016-05-09
0.7	Draft version for STAP meeting	2016-05-31
0.8	Updated according STAP comments and after Scope setting meeting decision	2016-12-01
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