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System Requirements for the BIFROST instrument

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TABLE OF CONTENTS **PAGE**

1 SCOPE 3
2 ISSUING ORGANISATION 3
3 REQUIREMENTS 3
3.1 Background and guidelines for generation of requirements 3
3.1.1 Requirements Categories 4
3.1.2 Requirements pre-requisites 4
3.1.3 Requirement wording 4
3.1.4 System Requirements and Architecture Design 5
3.2 Functional Requirements 7
3.2.1 Beam Transport and Conditioning System (BTCS)– PBS 13.6.5.1 7
3.2.2 Sample Exposure System, SES – PBS 13.6.5.2 10
3.2.3 Scattering Characterization System, SCS - PBS 13.6.5.3 11
3.2.4 Experimental Cave, EC - PBS 13.6.5.5 15
3.2.5 Control Hutch, CH - PBS 13.6.5.6 18
3.2.6 Integration Control and monitoring, IC&M - PBS 13.6.5.12 19
3.3 Constraint Requirements 20
3.3.1 Operational constraint requirements 20
3.3.2 RAMI requirements 21
3.3.3 Environmental Requirements 23
3.2.1 Conventional Safety Requirements 24
3.2.2 Radiation Safety Requirements 24
3.2.3 External Interface Requirements 26
4 GLOSSARY 28
5 REFERENCES 28
DOCUMENT REVISION HISTORY 29

1 SCOPE

The scope of the BIFROST system, of which the requirements are presented in this document, is defined in accordance with the instrument system originally proposed, ref [1], endorsed by SAC and approved by STC (now Council). The scope of the system is limited to those items lying within the budgetary responsibility of the instrument project as defined in [xxxx] and excludes systems vital to the instruments purpose not lying within these boundaries like the ESS bunker, the spectroscopy related parts of the DMSC project, the ICS etc. These, however, represent essential functions for the functionality of the BIFROST system and hence those interfaces to BIFROST comprise indispensible requirements of the BIFROST system, which will be covered in this document as External Interface Requirements.

The scope of BIFROST for the system to enable to fulfil the high level scientific requirements as outlined in the BIFROST Concept of Operations document (2. High Level Scientific Requirements), ref [2]. Consequently, the system consists of and is limited to the subsystems outlined in the BIFROST Concept of Operations document, ref [2], in Chapter 3.4 (System Overview). These are reflected in the highest level PBS of BIFROST as follows:

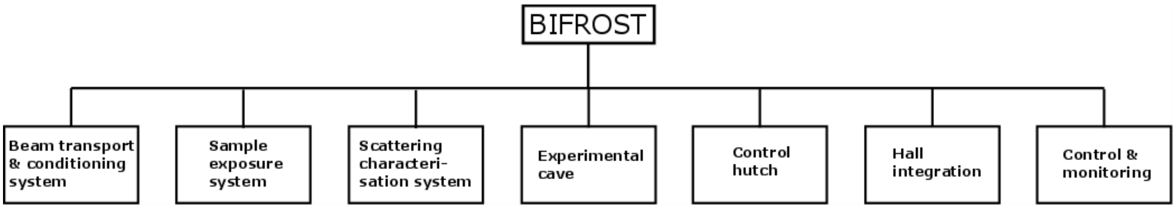

Figure 1. BIFROST Product Breakdown Structure, PBS

The functional requirements will be structured accordingly.

2 ISSUING ORGANISATION

ESS-ERIC, Science Directorate, NID/NSS

3 REQUIREMENTS

3.1 Background and guidelines for generation of requirements

This entire section should be regarded as a brief background providing guidelines, in support of the selected development approach for neutron instruments intended for the European Spallation Source ERIC, to this document; the System Requirements Specification (SRS).

The instrument team can choose to remove the section or keep it in the final document. However it could be beneficial to keep the section, at least until the conclusion of TG2 as the information contained herein could be useful to the TG2 review panel.

3.1.1 Requirements Categories

ESS has organized system requirements in three categories. Ideally they can be separated as follows: Functional categories – generally answering to the “what” is performed by the system, the second category is Constraint requirements (sometimes referred to as non-functional requirements) – generally answering to the “how” a function is performed by the system and finally the performance requirements category – generally answering to the “how well” a function has to perform or “to what extent” a constraint affects the system design.

In reality it is often difficult to differentiate between what is a 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 principle, 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 Requirements pre-requisites

When creating requirements the following principles should be respected:

- each requirement is necessary,
- each requirement is unique,
- each requirement is verifiable, (although almost impossible to avoid especially in Scientific applications it is encouraged to not utilize statements such as: “optimize”, “maximize” or “minimize” which could be unverifiable),
- attempt to address each phase of the life cycle, as completely as possible, incl. decommissioning,

3.1.3 Requirement wording

Requirements are written in statements using 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. It can trigger discussions of prioritizing and how they can be achieved and at what impact (mainly to cost but also with respect to e.g. future upgrade possibilities etc.).

For examples see below:

Id	Text	Trace up to
xxx.nn1	When signal x is received **[Condition]**, the system **[Subject]** shall set **[Action]** the signal x received bit **[Object]** within 2 seconds **[Constraint],** so that signal x status can be assessed **<Rationale>.**	Yyy.nn3
xxx.nn2	At sea state 1 **[Condition]**, the Radar System shall detect targets at ranges out to **[Action or Constraint]** 100 nautical miles **[Value],** so that **<Rationale>.**	Yyy.239
xxx.nn3	The Invoice System **[Subject]** shall display pending customer invoices **[Action]** in ascending order **[Value]** in which invoices are to be paid**,** so that **<Rationale>.**	Yyy.nn7

3.1.4 System Requirements and Architecture Design

The top-level system requirements activity is generally followed by an activity to logically decompose the system (instrument in this case). The outcome is the Product Breakdown Structure, PBS. The PBS is the selected/preferred architectural design solution for the instrument. It could be developed and documented in a separate document – System Architecture Description. This is justified in the case of starting with a clean sheet of paper.

It is however encouraged that a mind-set of a semi-clean sheet of paper is established, as there could be opportunities to explore and come up with functional blocks that not yet exist (ESS definition-wise) but will solve design challenges in a more efficient manner.

When deriving the PBS one or more alternatives are generally created. This is done by grouping the functional requirements into logical blocks. In the case of Neutron Instrument development there already exists a basic number of established building blocks that inevitably will be used, in some configuration, in an architectural solution for the instrument. This combined with the stipulated utilisation of the generic Neutron Instrument PBS these building blocks and the selected level of breakdown of the Instrument for this SRS, i.e to the first sub-system level, ref Figure 1, implies that generated alternative architectures will most likely not lead to a different PBS structure for the sub-system level, as they all are catered for in the generic PBS. The different architectures will first differ on lower levels of the PBS, which is outside the scope of this SRS. Hence there is no need to develop a separate System Architecture Description for the instrument on this level. The logical grouping is done instead in this SRS and allocated in accordance with the generic PBS.

The logical decomposition will take place for the lower system levels, using the requirements in this SRS as the foundation to further breakdown and allocated as appropriate. This work will to some extent be done in the activities culminating in the scope setting meeting, as up to three instrument configurations, all able to meet the high level scientific requirements, shall be considered.

The selected System Architecture is used to define and generate interface requirements between the sub-system as defined by the generic PBS. While this is documented at a later stage it is suggested that interfaces between sub-systems are considered early on.

3.2 Functional Requirements

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

3.2.1 Beam Transport and Conditioning System (BTCS)– PBS 13.6.5.1

Id	Text	Trace up to
1	***Wavelength Transportation Range: 1.5 Å – 7 Å*** The BTCS shall transport neutrons with wavelengths from 1.5 Å to 7 Å from the cold moderator surfaces, with a minimum brilliance transfer of 20 % for the lowest wavelengths *Rationale:* Maintain a large dynamic range for BIFROST *Verification:* Gold foil measurements, vanadium measurements, inelastic benchmark measurements	ConOps HLSR: I, II, V and 3.2., 3.4.2
2	**Transported Divergence up to +/- 0.75 degrees** The transported divergence shall be +/- 0.75 degrees on average (intrinsically wavelength dependent) *Rationale:* Flux optimization, resolution flexibility *Verification:* Beam profile measurements with neutron camera	ConOps HLSR: I; 4,15 and 3.2., 3.4.2.
3	**Beam Divergence Symmetry** The wavelength dependent divergence transported by the BTCS shall have a symmetric distribution *Rationale:* Symmetric resolution function *Verification:* Measurements of inelastic modes in reference system	ConOps HLSR: I; 1,2,4,5, 15 and 3.2., 3.4.2.
4	**Beam spot size < 20 x 20 mm^2** *Rationale:* Small sample optimization, resolution optimization *Verification:* Neutron camera at sample position	ConOps HLSR: II-IV;7-9,11-15 and 3.2.

Id	Text	Trace up to
5	**Full Pulse Wavelength Resolution at 2.5 Å: less than 4 %** *Rationale:* Full utilization of ESS flux. The wavelength resolution translates to an energy resolution of 0.6 meV at E_i = 13 meV and ΔE = 8 meV, matching the range of cold triple axis spectroscopy *Verification:* Crystal field excitation measurement.	ConOps HLSR: II&IV;8,11,12, 14,15 and 3.2.
6	**Total flux in the wavelength range 2.3-4 Å > 10^{10} n/s/cm^2** *Rationale:* Unprecedented flux for spectroscopy *Verification:* Gold foil measurements	ConOps HLSR: II,III, 7-9, 11-15 and 3.2., 3.4.5.
7	**Pulse shaping: Pulse duration down to 0.1 ms** *Rationale:* A pulse duration of down to 0.1 ms results in an energy band of 50 µeV at E_i = 20 meV – matching the acceptance energy band of the high energy analyzer, allowing for energy resolution down to 0.33 % at ΔE = 15 meV *Verification:* Crystal field excitation measurements at ΔE = 15 meV	ConOps HLSR: I-IV;2-8,12-15 and 3.2., 3.4.7.
8	**Full utilization of the ESS pulse interval of 71 ms** *Rationale:* Optimizing the single setting wavelength range for the maximum bandwidth of 1.7 Å. Requires BW chopper outside the bunker *Verification:* Vanadium sample and event mode recording of elastic line without analyzers	ConOps HLSR: II&IV;8,11,12, 14,15 & 3.2. & 3.4.2 & 3.4.7.
9	**Frame overlap removal** *Rationale:* Unique identification of energy transfer, requires two choppers inside the bunker *Verification:* Vanadium sample and event mode recording of elastic line without analyzers	ConOps HLSR and 3.2., 3.4.7.
10	**Flexible collimation down to 20’** *Rationale:* Tailoring the Q-resolution using divergence jaws *Verification:* Steep dispersion measurement	ConOps HLSR and 3.2., 3.4.7.

Id	Text	Trace up to
11	**Bandwidth selection** *Rationale:* Flexible tailoring of the energy window with which to measure, in the range of 3-60 meV *Verification:* Measurement of multiple energy ranges on various test systems	ConOps HLSR and 3.2., 3.4.7. and 5.
12	**Beam Monitoring** *Rationale:* The BTCS shall allow for monitoring the beam flux with some indication of wavelength dependence via a model *Verification:* Test measurement of intensities on known sample.	ConOps HLSR I,II; 2,3,5, 12, 14,15 and 3.2.
13	**Inelastic background handling: Less than 5 cts / min** *Rationale:* The BTCS shall have substantial shielding of the direct beam, reducing the inelastic background *Verification:* Inelastic background without sample, but with sample environment.	ConOps HLSR I,II,III,IV; 2,3,5,7,12,13, 14 and 3.2., 3.4.3.. 5.3.3.
14	**Beam transport in cave** *Rationale:* The BTCS shall remove air scattering as a source of background from the direct beam, both before and after the sample by providing evacuated transport tubes *Verification:* Measurement of inelastic background with and without evacuation	ConOps HLSR I,II; 2,3,5, 12, 14,15 and 3.2.
15	**Low emittance beam stop – less than 100 kBq at tank wall** *Rationale:* The BTCS shall handle the direct beam outside the cave, with lead gamma shielding, reducing the gamma activity to 100 kBq at the tank wall. In addition, backscattered neutrons from the B4C beam stop shall be reduced by an order of magnitude *Verification:* Measurement of gamma intensity at tank wall in production mode.	ConOps HLSR I,II; 2,3,5, 12, 14,15 and 3.2.

3.2.2 Sample Exposure System, SES – PBS 13.6.5.2

Id	Text	Trace up to
16	**Flexible mount** *Rationale:* The SES system should be adjustable to accommodate a range of magnets and cryostats with a correct height to within 1 mm of the beam position, via adapters. *Verification:* Elastic scan with pointlike vanadium source	ConOps HLSR and 3.2., 3.4.7., 5.
17	**Precise sample rotation to within 0.01 degrees** *Rationale:* Precise sample orientation is crucial for correct measurements *Verification:* Laser alignment	ConOps HLSR and 3.2., 3.4.7., 5.
18	**Non-magnet surroundings, less than 20 kilos for 25 T at sample position** *Rationale:* To allow safe operation of high field magnets *Verification:* Force measurements on permanent magnets and cold cryomagnets in operation.	ConOps HLSR and 3.2., 3.4.7., 5.
19	**Maximum load: 5000 kilos** *Rationale:* Future capacity for a non-specfified high-Tc magnet design *Verification:* By design	ConOps HLSR and 3.2., 3.4.7., 5.
20	**Motor control for internal sample environment motors** Rationale: Flexible operation *Verification:* By design	ConOps HLSR and 3.2., 3.4.7., 5.
21	**Space for sample environment support structure** Rationale: Allowing for power supplies, gas handling, and cryogenics next to the sample position *Verification:* By design	ConOps HLSR and 3.2., 3.4.7., 5.

3.2.3 Scattering Characterization System, SCS – PBS 13.6.5.3

Id	Text	Trace up to
22	**Reachable scattering angle range: 10-130 degrees** *Rationale:* To maximize the Q-range for the wide range of recorded final energies.	ConOps HLSR 4, 15 and 3.2.
23	**Total coverage in a single setting > 70 degrees** *Rationale:* To cover more than half of the Q-range in a single setting, to enable single point parametric studies.	ConOps HLSR: 1, 14, 15 and 3.2.
24	**Total analyser area > 0.6 m^2** *Rationale:* To allow for fast and efficient determination of dispersion surface characteristics. Absolute minimum for basic scope	ConOps HLSR: II,III,IV; 3,7-9, 11-13, 14,15 and 3.2., 3.4.9.
25	**2D detector position sensitivity at analyser Bragg angles** *Rationale:* To allow variable Q-resolution and to allow for the prismatic analyser option	ConOps HLSR: 2 and 3.2.
26	**Non-prismatic resolution of analyzers < 180 µEv** *Rationale:* Optimizing the curvature for standard cold triple axis resolution – to be used in a maximum signal setting *Verification:* Elastic line resolution measurements	ConOps HLSR: 3 and 3.2.
27	**Prismatic resolution of highest energy analyzers < 60 µEv** Rationale: To use 1D position sensitivity of the detectors to improve the resolution of the secondary spectrometer *Verification:* Elastic line resolution measurements	ConOps HLSR and 3.2., 3.4.9.
28	**Vacuum in the secondary spectrometer tank** *Rationale:* To reduce background and sources of spurious signals. *Verification:* Pressure sensor	ConOps HLSR and 3.2., 3.4.9.
29	**Detector efficiency > 85 %** *Rationale:* To maximize inelastic signal *Verification:* Benchmark sample	ConOps HLSR and 3.2., 3.4.9.

30	**Detector saturation at count rate > 20000 cts/s** *Rationale:* To be able to detect medium strength Bragg peaks, for straightforward modelling the elastic region *Verification:* Beam profile examination	ConOps HLSR and 3.2., 3.4.9.
31	**Detector short burst capability > 100000 cts/s** *Rationale:* To be able to handle strong Bragg peaks, without damaging the detectors *Verification:* By design	ConOps HLSR and 3.2., 3.4.9.
32	**PG neutron mosaicity: 1 degree** *Rationale:* To enable the prismatic analyser option *Verification:* Neutron diffraction measurements	ConOps HLSR and 3.2., 3.4.9.
33	**Off-energy PG transmission above 95 %** *Rationale:* To efficiently allow full multiplexing capabilities *Verification:* Online commissioning.	ConOps HLSR and 3.2., 3.4.9.
34	**Spectrometer tank thermal neutron attenuation < 10^{-8}** *Rationale:* To efficiently shield powder Bragg peaks generated off the sample position *Verification:* Online commissioning.	ConOps HLSR and 3.2., 3.4.9.
35	**Spectrometer tank access: More than 80 cm to all sides** *Rationale:* Easy access to critical components *Verification:* By design	ConOps HLSR and 3.2., 3.4.9.
36	**Cross-talk shielding attenuation < 10^{-6}** *Rationale:* To efficiently spurious scattering from Bragg peaks, B4C and similar *Verification:* Direct beam measurements	ConOps HLSR and 3.2., 3.4.9. and 5.
37	**Beryllium filter high energy attenuation < 10^{-3}** *Rationale:* To reduce the accepted scattering energies to the interval [0:5] meV to reduce PG background *Verification:* Bragg peak measurements with and without filter	ConOps, ESS-0001786 "Supervised area" versus 3rd safety area
38	**Beryllium filter low energy transmission > 90 %** *Rationale:* To maximize inelastic signal *Verification:* Bragg peak measurements with and without filter	ConOps HLSR and 3.2., 3.4.9.

39	**Beryllium filter radial collimation 5 % acceptance radius at sample position < 7 cm** *Rationale:* To block both incoherent and coherent scattering from the bulk sample environment from entering the spectrometer tank *Verification:* By design, calculations	ConOps HLSR and 3.2., 3.4.9. and 5.
40	**Beryllium filter radial collimation 95 % acceptance radius at sample position > 1.5 cm** *Rationale:* To accept sample scattering regardless of sample environment *Verification:* By design, calculations	ConOps, ESS-0001786 “Supervised area” versus 3rd safety area
41	**Beryllium filter should be translatable out of the scattering plane** *Rationale:* To be able to align sample using second order analyser reflections *Verification:* By design	ConOps HLSR and 3.2., 3.4.9. and 5.
42	**Radial collimator 5 % acceptance radius at sample position < 2.5 cm** *Rationale:* To remove inelastic background from special sample environments that envelop the sample closely *Verification:* By design	ConOps, ESS-0001786 “Supervised area” versus 3rd safety area
43	**Radial collimator 95 % acceptance radius at sample position > 0.5 cm** *Rationale:* To accept full signal from small samples *Verification:* By design	ConOps HLSR and 3.2., 3.4.9. and 5.
44	**Radial collimator translatable out of the scattering plane** *Rationale:* To efficiently be able to use samples larger than 1x1x1 cm^3 *Verification:* By design	ConOps, ESS-0001786 “Supervised area” versus 3rd safety area
45	**Mechanical Bragg peak attenuation system** *Rationale:* To automatically block very strong Bragg peaks capable of damaging the detectors. *Verification:* By design	

3.2.4 Experimental Cave, EC – PBS 13.6.5.5

Id	Text	Trace up to
46	**The Experimental Cave – access to all components in production mode** *Rationale:* With experimental shutter closed, all intrinsic parts of the SCS and SES should be accessible *Verification:* By design	ConOps 3.& 5.
47	**The Experimental Cave – Flexible support structure** *Rationale:* Support structure for human access should be flexible to allow for various sample environments. *Verification:* By design	ConOps 3.& 5.
48	**The Experimental Cave – Utilities access** The Experimental Cave shall have access to a variety of utilities including various power outlets (10A, 15A, 20A 32A), chilled water, compressed Instrument air and gas supplies.	ConOps 3.& 5.
49	**The Experimental Cave – Utilities removal** The Experimental Cave should allow for removal of exhaust gases and cooling water etc. Helium exhaust is especially needed to allow for cryogenics.	ConOps 3.& 5.
50	**Biological shielding, Experimental Cave – Access SES while proton be on Target, acceptable dose level** The dose level in the Experimental Cave when accessing SES in it, with shutters closed, shall be 3μSv/h in accordance with ESS-0001786 & ESS-0051603.	ConOps 3.& 5. ESS-0001786 ESS-0051603
51	**Biological shielding, Experimental Cave – Access to SES during irradiation** Experimental Cave shall prevent access to the SES while a sample irradiation is occurring.	ConOps 3.& 5.
52	**Biological Shielding, Experimental Cave – dose attenuation** The Experimental Cave shall attenuate the dose rate emanating from the SES and SCS during a sample irradiation , i.e shutter open, to 3μSv/h, in accordance with ESS-0001786 & ESS-0051603,	ConOps 3.& 5. ESS-0001786 ESS-0051603

53	**Experimental Cave – Liquid nitrogen line and wire access** *Rationale:* Cryogenics should be able to be filled automatically from a dewer placed outside the cave, and sample environment power supplies and sensor cables should be able to traverse the cave wall while in operation. *Verification:* By design.	ConOps 3.& 5.
54	**Experimental Cave – Sample radiation interlock** *Rationale:* Gamma radiation monitors should be positioned close to the sample and automatically prevent cave access in case of a sample dose larger than 100 uSv/h at 1 meter distance *Verification:* By design.	ConOps 3.& 5.
55	**Experimental Cave – Visual monitoring of cave** Live CCTV shall allow for visual control of movements in cave.	ConOps 3.& 5.
56	**Experimental Cave – Floor Space** The Experimental Cave shall provide a floor space > $40m^2$	ConOps 3.& 5.
57	**Experimental Cave – Beam access height** The Experimental Cave shall have a floor to beam axis height of 1.5m at least along beam for manual manipulations (to be specified)	ConOps 3.& 5.
58	**Experimental Cave – Object accommodation** Entry to the Experimental cave shall allow for the movement of apparatus up to 1m wide X 1m thick X 2m tall.	ConOps 3.& 5.
59	**Experimental Cave – SES accessibility** Access to the SES at from the top is necessary for craning dilution sample sticks and other sample environment	ConOps 3.& 5.

3.2.5 Control Hutch, CH – PBS 13.6.5.6

Id	Text	Trace up to
60	**Control Hutch – Instrument control terminal(s)** The control hutch shall allow the user to remotely control the technical components from dedicated computer terminals and view live streams of detectors and CCTV.	ConOps 3.& 5.
61	**Control Hutch – sample environment terminals** The control hutch shall allow the user to remotely control the sample environment systems detector systems from dedicated computer terminals.	ConOps 3.& 5.
62	**Control Hutch – Data reduction terminal** The control hutch shall allow the user to process the neutron data	ConOps 3.& 5.
63	**Control Hutch – Data analysis terminal** The control hutch shall allow the user to analyse the processed data, using benchmark models.	ConOps 3.& 5.
64	**Control Hutch – Comfort** The control hutch should be a comfortable working environment for up to 6 users. ISO 11064-6 provides good guidelines for defining comfort and should be followed where possible.	ConOps 3.& 5.

3.2.6 Integration Control and monitoring, IC&M – PBS 13.6.5.12

Id	Text	Trace up to
105	**IC&M – Instrument Control and Automation** All motorized axes and electronic driven systems shall be remotely controllable with the instruments computer system	ConOps 3.& 5.
106	**IC&M – Monitoring** All viable systems shall be monitored electronically and feed back into the control system	ConOps 3.& 5.
107	**IC&M – Source pulse synchronizing** A hardware signal synchronized with the source pulse shall be available to the system	ConOps 3.& 5.
108	**IC&M – BIFROST Standalone mode** All electronic systems shall be configured such that the instrument can be controlled and utilized in a standalone mode independent of the ICS.	ConOps 3.& 5.
109	**IC&M – Personal Safety System (PSS)** The PSS shall be fully integrated into the Instrument control such that the Instrument can be operated safely.	ConOps 3.& 5.

[1] Optimised refers to the best possible given the boundary conditions that will affect this requirement including other requirements and external influences.

[2] Natural resolution and natural bandwidth refer to values achievable without further pulse shaping, but provided by the source time structure at specific distances.

[3] The specific requirements for this system are under development and will be detailed at a later time.

3.3 Constraint Requirements

3.3.1 Operational constraint requirements

Id	Text	Trace up to
110	**Operation Mode Changes – Mode Redundancy** Maintenance or failure issues of one mode shall have a minimum impact on other modes (That 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 & 6.1.2
111	**Sample environment changes** Change of sample environment itself should take less than 1 full workday to perform, excluding setting time of temperature, field etc.	ConOps 3.& 5.
112	**Sample environment succession** Fast acquisition experiments should be scheduled to save beam time costs, by pre-preparation of sample environment, in-situ sample changes and timely user coordination. An SAD representative should be involved in scheduling.	ConOps 3.& 5.
113	**Handling of radioactive samples at BIFROST** Samples with reactive isotopes shall be scheduled at the end of cycles to allow for cool down. Feasibility evaluation for experiments at BIFROST should take radiation safety and requirements into consideration. Special procedures from the ESS side will be necessary for handling short lived active sample (days to weeks), and user caution is necessary for long lived active samples – especially those containing cobalt (Co-60 has a half-life of 5 years)	ConOps 3.& 5.

3.3.2 Reliability, Availability, Maintainability & Inspectability (RAMI) requirements

Id	Text	Trace up to
114	Operation Schedule The system shall be operational according to the schedule of the ESS source and the set availability goals of NSS RAMI Handbook	ESS-xxxxxx NSS RAMI Handbook ; ESS-TBD, BIFROST ConOps 5.1
115	Maintainability The system shall be maintainable in a way fulfilling the Operation Schedule requirement (above).	NSS RAMI Handbook ; ESS-TBD, BIFROST ConOps 5.3
116	Access Instrument components shall be accessible for all maintenance and repair activities needed to fulfil the Operation Schedule and Maintenance requirements (above).	NSS RAMI Handbook ; ESS-TBD, BIFROST ConOps 5.3, ESS-0039408 NOSG Handbook (Annex N)
117	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).	NSS RAMI Handbook ; ESS-TBD, BIFROST ConOps 5.3
118	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.	NSS RAMI Handbook ; ESS-TBD, BIFROST ConOps 5.3
119	Internal Interfaces (physical connection) Instrument sub-systems shall be connected and integrated such to enable to meet the functional and other RAMI requirements.	BIFROST ConOps 3.4
120	Design Robustness The overall system design shall enable to meet the Operation Schedule requirements through robustness against single sub-system failure.	BIFROST ConOps 5.3.3 & 6.1.2

Id	Text	Trace up to
121	Spares The system shall include spares critical to meet OS requirement.	BIFROST ConOps 5.3.3

3.3.3 Environmental Requirements

Id	Text	Trace up to
122	**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 ESS Procedure for designing shielding for safety , ESS-0052625 NOSG Phase 2 guidelines for designing instrument shielding, NOSG Handbook
123	**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 NSS radioactive inventory - Part 2 (Exp. Hall and instruments), ESS-0052491 NSS radioactive inventory - Part 3 (Bunker)
124	**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 Sample Handling Procedure
125	**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 ESS Procedure for sustainable selection of materials, ESS-0011458 ESS Guideline for sustainable selection of materials

3.2.1 Conventional Safety Requirements

Id	Text	Trace up to
126	**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 Conventional Safety, Energy and SSM Requirements , ESS-0039408 NOSG Handbook (Annex N)?

3.2.2 Radiation Safety Requirements

Id	Text	Trace up to
127	**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 NSS radioactive inventory - Part 2 (Exp. Hall and instruments), ESS-0052491 NSS radioactive inventory -Part 3 (Bunker)
128	**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 Sample Handling Procedure

Id	Text	Trace up to
129	**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 NOSG Handbook, ESS-0042895 Materials guideline intended for the construction of neutron chopper systems for use at ESS, ESS-0001786 "Supervised area" versus 3rd safety area Etc.
130	**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 Basic Principles & Functions for PSS

3.2.3 External Interface Requirements

Id	Text	Trace up to
131	**CF environment** The system shall fit within and profit from the boundary conditions set through CF.	ConOps 3.& 5. NSS-Site Infrastructure IRS ESS-TBD; ref [4].
132	**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 (complying with ref. [x])	ConOps 3.& 5.
133	**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.& 5.
134	**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.& 5.
135	**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. A specification of which components and operations require remote control is provided elsewhere in the instrument documentation [x].	ConOps 3.& 5.
136	**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 mayor part of the interface with DMSC/Data Reduction and are, while in a process of development available elsewhere [x].	ConOps 3.& 5.
137	**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 3.& 5.
138	**The system shall comply with the bunker design.**	ConOps 3.& 5.
139	**Vacuum** The system shall connect with vacuum services where required.	ConOps 3.& 5.

140	**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.& 5.
141	**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 3.& 5.

4 GLOSSARY

Term	Definition
HLSR	High Level Scientific Requirements

5 REFERENCES

[1] ESS Instrument Construction Proposal; ODIN – Optical and Diffraction Imaging with Neutrons
[2] Concepts Of Operations Example for the ODIN Instrument, ESS-0053465
[3] NSS RAMI Handbook, ESS-TBD
[4] NSS-Site Infrastructure Interface Requirement Specification (IRS), ESS-TBD
[5] NSS-Target Station (Beam Extraction System) Interface Requirement Description, ESS-TBD
[6] "Supervised area" versus 3rd safety area, ESS-0001786
[7] NSS zoning document - part 1, ESS-0051603

DOCUMENT REVISION HISTORY

Revision	Reason for and description of change	Author	Date
1	First issue	Markus Strobl/Peter Sångberg	2016-05-10