Review of FREIA TG2 documents

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The documentation is overall of good quality and includes the right information.

This review finds a number areas in which additional information, clarification or work is needed:

- Upgrades generally need to be better included in the various documents, notably in the System Requirement Specification (SRS). They are well described in the Initial Operations and Staging plan, but need to be systematically covered in the other documents too.
- Some edits are needed to the high-level and low-level requirements, as detailed further below. The requirements relating to keeping the upgrade paths open to the full-scope instrument need to be formulated and added to the SRS.
- The upgrade option of being able to use the full beam divergence needs to be better incorporated throughout the documentation.
- The space for sample environment (3.6 m width) needs justification.
- The cave exceeds its allocated 12deg wedge. It needs to be made smaller, or a justified request needs to be made to keep the current design.
- The plans for beam monitors need to be improved, in collaboration with the ESS detector group.
- The instrument performance calculations need to be complemented by updated simulations of standard reflectivity samples, as was done in the instrument proposal.
- The high-level statements in the WP specification need changing: The project aims are to achieve all the requirements outlined in the ConOps and SRS (not some other "critical success factors") and to do so within the agreed budget and time frame. The budget is the cost book value, keeping a 10% contingency of the cost to complete.
- The sharing of responsibility of WUs between ISIS and ESS does not seem reasonable. Each WU should have an identified single responsible. Depending on the definition of the prime contractor role, I would imagine that should be ISIS for all WUs.
- The risk table needs to be redone, using ESS risk management methodology as outlined further below.

Please see below for more detail on each of these points and many other, more detailed issues. The comments which follow are predominantly negative, which should not give the impression that the overall impression is negative. The focus is on the changes which should be made.

Concepts of Operations

Page 5, section 1, paragraph 2, line 4: change "engineering diffraction" to "reflectometry"

Page 7, Full-scope operational modes: this list only contains a subset of the various full-scope operational modes described in section 2.2 of the Initial Operations and Staging Plan (IOSP). It should be expanded to cover all of them, including measuring

with the full beam divergence and the very fast kinetics enabled by the fast shutter system.

Page 7, section 2.3, Day-1 requirement (I), line 1: insert "continuous". The Q-range needs to be both broad and continuous.

Page 8, Full-scope requirements: I see that there is a requirement corresponding to the fast shutter system. Another requirement should be added relating to the operational mode using the full divergence.

Page 9, section 3.2, day-1 requirement 1: Consider if a statement should be added that the Q-range needs to be continuous.

Page 9, section 3.2, day-1 requirement 5: It is unclear if this illumination includes the beam penumbra. Please clarify.

Page 9, section 3.2, day-1 requirement 9: no Q-min is given. Consider if this is necessary.

Page 10, section 3.2, day-1 requirement 11: Remove the requirement on the software, as it is not in scope.

Page 10, section 3.2, day-1 requirements: add 2 more requirements:
1. The instrument shall be straightforwardly upgradeable to the full scope, as defined in the Preliminary System Design Description (PSDD).
2. The instrument shall be compatible will all sample environment equipment needed to satisfy its science case.

Page 10, section 3.2, Full-scope requirements: add requirements relating to the full-scope operational modes: very fast kinetics and full divergence modes.

Page 10, section 3.2, Full-scope requirement 13: specify minimum and maximum wavelength for the polarised-neutron mode.

Page 11, Fig. 2: the starting point of the neutron beam appears to be labelled as the "moderator focal point". That is misleading. The beam starts at the origin of the Instrument Source Coordinate System (ISCS).
From the figure, it appears that the FREIA footprint significantly exceeds its 12deg wedge on the side away from LOKI. That has not been agreed. It is accepted that beamports N4 and N6 are made unusable by FREIA and LOKI. N3 needs to remain fully usable.

Page 12, paragraph 1, line 4: remove point (c): software is not part of the project scope.

Page 13, section 3.4.10: it is stated that the detector vessel will provide an evacuated or gas-filled flight path after the sample. There should be a similar statement somewhere relating to the flight path before the sample.

Page 14, section 3.5, lines 5-6: the statement is made that there "are also connections to the ESS". Clarify or remove.

Page 16, section 3.5.11: Please add a few points relating to LOKI and ESTIA:
LOKI: the FREIA and LOKI teams will work closely together on the design of the shielding between them.
ESTIA: the reflectometry software will be defined and developed in collaboration between FREIA and ESTIA
ESTIA: the sample environment equipment will be coordinated with ESTIA.

Page 21, section 5.2.2: I find it confusing to have off-specular and GISANS lumped together here. My understanding is that off-specular scattering refers to Q-vectors in the x-z plane, while GISANS probes Q-components in the y-plane (horizontal and perpendicular to the beam). The description here sounds very different.
FREIA will have off-specular reflectivity capabilities from day one: it comes for free when you have a multidetector. The GISANS capability requires additional collimation not included in the day-one configuration, a new detector and a much greater sample-detector distance.
Lines 5-6: it is stated that the scattering from the surface suffers from "inherent multiple scattering", unlike SANS. I don't understand that. Please explain or remove.

Page 23, section 5.2.3.6, line 4: please clarify what is meant by "low precision".

Page 26, section 6.1.1: it is stated that upgrade options shall be catered for "as much as possible". Please qualify what this means. They should be clearly formulated as requirements, and then incorporated into the design. There then needs to be some evaluation of the cost implications, so they do not unwittingly become significant cost drivers for the instrument design.

<u>System Requirements Specification</u>

Page 3, section 1, lines 4-5: correct sentence to read "… as defined in [2] and [3], and excludes systems …"

Page 3, fig. 1: the PBS is seen to include the sample preparation area. I had understood from the conops that this is not in scope. Please remove.

Page 4, section 3, lines 1-2: it is stated that it is important to include upgrades outside the day-one scope in this document. I agree, but they need to be clearly labelled as such. That is not always the case. Please qualify the statement.

Page 5, requirement 4: this requirement which uses the rather woolly expression "comparable efficiency" is probably made redundant by requirement 14 on the brilliance transfer.

Page 5, requirement 5: the wavelength resolution without the WFM system is strongly wavelength-dependent. With the WFM system it is roughly independent of wavelength. This somehow needs to be captured in the requirement.

Page 6, requirement 6: please state if the beam dimensions here relate to the full beam including the penumbra, or just the umbra, or something else.

Page 6, requirement 7: I do not understand the angular ranges here. Which operational modes do they correspond to? What is the sign convention?

Page 6, requirement 10: I do not understand what is meant by a "divergence profile that smoothly covers the sample footprint". Please rephrase.

Page 6, requirement 11: quantify what is meant by "quickly"

Page 6, requirement 12: line-of-sight avoidance relates to anything entering the guide entrance, not just the stuff originating from the moderator. Please change "to the moderator" to "from the guide entrance".

Page 6, requirement 15: This requirement is insufficient: a set of quantitative requirements are needed on the monitor performance: efficiency, attenuation, removability, stability, gamma-sensitivity, etc.

Page 6, requirements 16-18: these all relate to capabilities outside the day one scope. They do not belong in the same section as the other requirement. I propose to move them to a separate section on requirements relating to upgrades. They are also incomplete, as they do not cover all the requirements needed for the upgrades listed in section 2.2 of the IOSP.

Page 6, requirement 19: where does the value of 1% wavelength contamination come from? That seems much too high. Very low wavelengths leaking through would likely encounter 100% reflectivity and would seriously contaminate any high-Q measurement.

Page 6, requirement 22: where does the width of 3.6 m come from for the sample environment equipment? That is huge.

Page 6, requirement 23: the wording of this requirement on vibration isolation is a technical solution, rather than the requirement itself. The vibration requirement should ideally be stated as a graph of maximum acceleration versus frequency.

Page 7, section 3.2.3: this is where the quantitative requirements on the beam monitors belong – see my comments relating to requirement 15.

Page 7, section 3.2.3: a requirement is missing on the detector distance.

Page 7, requirement 32: change "least" to "most".

Page 8, requirement 34: where does the value of 0.001 counts/s/cm2 come from? It should be derived from the minimum reflectivity requirement in the HLSR.

Page 10, requirement 42: The maximum width of 3.6 m for sample environment equipment is huge. I would expect to find a justification for it in the PSDD.

Section 3.2.6, requirements 48-49: The sample prep area is not in the day-one scope. These requirements should be moved to the section on the upgrade requirements – see my comment on requirements 16-18.

Section 3.2.10, requirements 54-59: these are not requirements for the project scope. They are requirements for the software within the DMSC project. Remove completely, or move to a difference section which is appropriately labelled.

Page 13, requirement 67: the project budget does not include provision for spares. Remove this requirement.

Page 15, requirement 79: "surveillable" is not a word.

I am completely missing the requirements relating to designing the instrument to allow upgrades beyond day-one scope. This could be part of section 3.3 Constraint Requirements. These requirements are needed to justify all the design choices for enabling future upgrades: space for the polariser and flipper, space for the fast shutter system, spaces for GISANS collimation, shielding which allows measurement with the full divergence, detector design which makes it easy to add the missing electronics, modular cave design for a long GISANS detector, chopper designs for adding second BW chopper disks, …

Preliminary System Design Description

There is a general mixup between horizontal and vertical geometries in this document.

Page 6, section 2.1, line 3: replace "horizontal" with "vertical" and "vertical" with "horizontal"

Page 6, section 2.1, paragraph 3, line 3: replace "horizontal" with "vertical".

Page 10, fig. 8: the top frame is completely not to scale on the horizontal axis – the s-bend is 13m long, but appears to be only about a quarter of the total length of 20m. This is misleading.

Page 11, table 2: I believe the distances shown are from the ISCS origin, not the moderator focal point, since the beam axis does not originate at the moderator focal point. This should be corrected both in the table itself and in the table caption.
It is stated that the bender ends at 15m. Does that mean that the multichannel structure ends then? Please state explicitly.

Page 12, section 3.1.4: the materials stated for the NBOA do not include Si, which is presumably used as the substrate material for the vanes in the s-bender. Please add.

Page 12, section 3.1.5: it is stated that the guide section in the bridge beam guide (BBG) is oversized and does not include internal channels, in order to accommodate misalignment of the LSS. That things sound like a bad idea. Has the effect of the misalignment been estimated? My guess is that oversizing the guide and leaving out the vanes will result in a much worse performance than any reasonable misalignment.

Page 15, section 3.2.4: ODIN will use a similar WFM chopper system as FREIA, and is scheduled to be completed much earlier. The FREIA team should make contact and see what they can learn from them.

Page 16, fig. 14: it is not clear from the time-distance diagram if all three of the frame overlap choppers are really needed. Has this been studied? Perhaps money

could be saved and a guide gap avoided by eliminating one or two of the FO choppers.

Page 17, section 3.3.1, line 3 below fig. 15: it is stated that the concept for the collimator selector will result in more guide windows than an alternative design. Has the increased background resulting from SANS from these windows been evaluated? This may be a significant background component which will prevent the instrument from reaching its Rmin requirement, and needs to be carefully evaluated.

Page 17, section 3.3.2, line 1: replace "horizontally" with "vertically".

Page 18, fig. 16: it would be useful here to indicate where the beam windows are. Is the number of windows the same for all 3 operational modes?

Page 18, line 4 below fig. 16: replace "vertical set of slits" with "vertical set of blades"

Section 3.3: there is no mention anywhere here about how a measurement would be made using the full divergence. That needs to be included for completeness.

Page 20, section 3.4, line 3: it is stated that a certain document does not contain a monitor with the "desired performance". The desired performance needs to be stated – it belongs in the System Requirements Specification (SRS).
There needs to be a statement here that the FREIA will at least enter into discussion with the ESS detector group, if it is not already engaged in such a discussion, to have appropriate monitors made available. What is the status of that?

Page 20, section 3.4.1, line 2: I would expect that the diagnostic monitors should be placed behind (i.e. downstream) of each chopper, rather than in front of it. Please correct.

Page 20, section 3.4.2: I agree that a retractable monitor before the sample sounds like a good idea. Its performance requirements need to be stated in the SRS.

Page 22, bullet point 1 under "Disadvantages": Please elaborate on what is meant by "minimal shielding". It should presumably be designed to have the same attenuation properties as the other shutter design.

Page 24, fig. 23: Two questions spring to mind in this figure, neither of which are adequately explained in the text here: (1) why is the width of the sample environment so huge at 3.6 m? (2) what is the massive filled block (about 2x2m2) downstream of the detector? If it is the beamstop, it seems completely over-dimensioned. What is it and why is it necessary?

Page 26, section 3.7.3, line 1: replace "horizontal" with "vertical".

Page 27, section 3.8.2: the cave shielding needs to be designed to be able to deal with the full beam divergence, in order to enable this operational mode. Has that been incorporated as a design criterion?

Page 27, section 3.8.3: the beamstop design should be shown in a figure. I can't believe that is needs to be anywhere near 2.5 m deep. The specularly reflected

beam, which is just as intense as the direct beam, is stopped in the detector, for which there seems to be no shielding provision at all.

Section 3.8: I am completely missing any description of shielding around the detector. This should be very important for minimising background.

Page 28, section 3.9.1, line 5: it is stated that the cave structure lies within the 12-dgree assigned wedge. However fig. 28 clearly shows that it falls outside the wedge on both sides. This is probably not a problem on the LOKI side, provided it is properly integrated with the LOKI shielding. There is no agreement from NSS management, however, for the additional land-grab on the other side.

Page 29, fig. 29, and page 30, section 3.11: is access to the cave roof needed with the FREIA beam on? How about with the proton beam on and the FREIA beam off? The part of the cave roof closest to the bunker may not end up as a supervised area, depending on the design of the bunker currently being finalised. The access needs should be considered.

Page 32, fig 32: the shielding towards LOKI is the same thickness as on the other side. This is overkill. The area on the N3 side of the FREIA cave is a supervised area. That is not the case on the other side. There is scope for FREIA to save some money on shielding here and gain some lateral space.

Page 32, fig. 33: there seems to be a wasted V-shaped area between the FREIA cave and the LOKI guide shielding. There is scope here for FREIA to gain space for free.

Section 6: I have made a quick flux calculation which confirms the non-WFM flux shown in Fig. 40. See attached report.
I would very much like to see calculations of the divergence distribution at the sample, and updated calculations of the simulated reflectivity curves from various standard samples, for comparison with those calculations in the instrument proposal.

<u>Work Package Specification</u>

Page 1: change the instrument name in the document title from "LOKI" to "FREIA"

Page 1: Similarly to the other documents, the owners of the WPS should be the members of the core instrument team: Tom, Hanna, Jim, David.

Page 4, section 1.1: The project aims to achieve all the requirements outlined in the ConOps and System Requirements Specification, not some other "critical success factors". That is the purpose of listing the requirements in those documents.
Remove the second half of the last sentence: "and to the agreed specification …". The project aim is to deliver the performance outlined in the ConOps and the System Requirements Specification, within the agreed budget and time frame. The "agreed science case" given as reference 4 has not been agreed with ESS.

Page 4, section 1.2, paragraph 1, line 3: the reassembly at the ESS needs to be supervised by the core FREIA instrument team, as it remains under the responsibility of the FREIA project.

Lines 3-4: I am puzzled by the wording that "It was also intended…", giving the impression that this was in the past and did not happen. If so, it should not be mentioned, as it is irrelevant. If it did happen or is planned to happen, please rephrase.
Line 5: the "feasibility stage" is mentioned. What is/was that?

Page 4, section 1.2, paragraph 3: It cannot be a key philosophy to maximise the UK in-kind contribution, since the budget needs to be contained. I suggest to rephrase as follows: "One of the key philosophies of this project is to maximise the proportion of in-kind contribution from UK to ESS, as well as to maximise knowledge transfer."

Page 4, section 1.2, paragraph 4: Please change "Once shipped to ESS" to "Upon successful completion of TG5".

Page 4, section 1.2 paragraph 5, last sentence "In order to ensure …": please remove the sentence. We understand that all partner labs will do their best to minimise duplication between national and ESS project management and will support that effort to the best of our abilities.

Page 5, section 1.3, last sentence: It is unclear to me what this sentence means. Please clarify or remove.

Page 5, section 1.4: Does ISIS taking on the "prime contractor" role mean that there can be no other partners? Clarification on the meaning of "prime contractor" would be helpful here.

Page 5, section 1.5, last paragraph: I don't think that management of the FREIA installation at ESS should be done by ESS staff. The handover does not take place until after successful cold-commissioning at ESS. That installation is still under the responsibility of the instrument project.

Page 5, section 2.1: Please correct abbreviation of Sample exposure system to SES.

Page 7, section 3.1: It is unclear what is meant by designating shared responsibility between ISIS and ESS for three of these work units (WUs):

05 Detectors and Beam monitors
09 Instrument Infrastructure
11 Personnel Safety Systems

If they are within the FREIA project (which I believe the above four WUs are), then ISIS should be responsible as the prime contractor. This is already the case for the other WUs (e.g. shielding, neutron optics) where significant work needs to be done by ESS, but ISIS takes overall responsibility.
I understand that the following three WUs

04 Sample Environment
06 Data acquisition and analysis
10 Vacuum

are not within the FREIA project scope and are paid for from other budgets. ISIS is therefore not responsible for them. That is fine.

Page 8, section 3.1.5, paragraph 3: it is stated that the detector and monitor are supplied by ESS to the value stated in section 5. Section 5 states the total value of the WU (including the detector vessel and detector position system), not the value of

the detector and the monitor. I suggest to remove the statement here about the value, unless an agreed value for the detector and monitor exists and can be added.

Page 13, section 5.1: It is not clear what is covered by the cost breakdown line "ESS labour & travel". Some ESS labour is charged to the project (e.g. towards building the detector or installation at ESS), management and review is not (e.g. my time). I suggest to remove this line which adds confusion.

Page 13, section 6: separating the risks into those which the instrument controls and those they do not, is not helpful. There are many factors outside the control of the instrument project (e.g. raw materials prices, mechanical strength of carbon fibre disks). They still need to be treated as risks and they can still be mitigated by appropriate action.

Page 14, risk table: the project team seem to have invented their own grading and not explained it. The grading to be used is: impact (rated 1-5) and probability (rated 1-5), resulting in a rating which is the product of the two. I also see no point in having separate columns for "Rating" and "Overall Rating" with different numbers. Where the risk is high, a mitigating action plan needs to be formulated. The column labelled "Current Controls in Place" sometimes includes a mitigation (e.g. "ISIS have recruited a neutronic calculation person to work on ESS instruments") which is good, and sometimes just a statement of fact (e.g. "ESS to supply" – sample environment in this case). There needs to be a mitigation plan for all the highly-rated risks.
I would like to see the top (red-rated) risks discussed at the TG2 review.

Page 15: remove section 6.2. Add risk(s) relating to monitors to the risk table in section 6.1.

Initial Operations and Staging Plan

Page 4, fig. 1: what is the Technical advisory board and what is its role? Please clarify

Page 7, section 2.1: do not repeat the day-one requirements from the ConOps.

Page 8, section 2.2: do not repeat the full-scope requirements from the ConOps.

Page 9, paragraph 1, line 3: it is stated that upgrade options have been considered during the design, as listed in the bullet points below. That is good. However, the provision for their future implementation needs to be properly recorded as design requirements of the instrument. That belongs in the System Requirements Specification (SRS).

Page 9, section 2.2.2, line 3: I do not understand what is meant by the statement that some operation options "do not meet the full requirements". That needs to be clarified. All the alternative operational modes involve design requirements for their future implementation, which need to be properly formulated in the SRS, so they can be integrated into the design.

Page 10, section 2.2.2.1: this is the only place that the full-beam divergence option is mentioned in any of the five documents. The possibility of measuring in this way

relies on the detector being able to deal with the count rate, and the cave shielding being able to deal with the flux, as stated here. The way to handle that is to formulate these as requirements and add them to the SRS.

Page 10, section 2.2.2.2, paragraph 2: If a prism is to be installed in the reflected beam one day, then that presumably impacts on the design of the detector tube. As above, this should result in a design requirement which should be expressed in the SRS.

Page 10, section 2.2.2.2, paragraph 3: if a prism can act as a risk mitigation, then it should be added to the risk analysis in the WPS.

Page 10, section 2.2.2.2, paragraph 4, line 1: it is stated that the post sample space is quite flexible and adaptable to the inclusion of a prism. That is good, but needs to be formalised as a design requirement in the SRS.

Page 11, section 2.2.3, line 3: it is stated that the addition of full electronics is "prepared for". Again, that is good, but needs to be formalised as a design requirement in the SRS.

Section 2.2.4, 5, 6, 7: similar comments again: formulate design requirements to enable the upgrades and add them to the SRS.

Page 12, section 2.2.6, line 1: it is stated that the double disk choppers are particularly useful during commissioning. That makes no sense. As an upgrade, they will not be there for commissioning.

Page 12, section 2.2.7: The GISANS option is possibly the least likely of the various upgrade options. ESS is actively pursuing the inclusion of a dedicated GISANS instrument in its instrument suite. If that is successful, it is unlikely that FREIA will ever need such an upgrade. The amount of effort and additional cost which can go into enabling such an upgrade should therefore be kept very small.