Report of the CDR-1 for the Medium Beta Elliptical Cavity Cryomodule

April 10, 2017

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**Introduction**

The first Critical Design Review (CDR-1) of the Medium Beta Elliptical Cavity Cryomodules was held at CEA Saclay on April 3 – 4, 2017. The charge and committee are given in Attachment 1.

The committee was very impressed with the level and quality of detailed design. CEA Saclay, IPNO and their partners consistently demonstrate through their design the experience that they have from other projects. There is a very strong and well-established team at CEA for this project including engineering, planning, quality, procurement, safety etc.

The facilities for assembly and test at CEA Saclay are well developed and based on successful previous experience.

No technical showstoppers were identified and the cryomodule should meet its requirements. There are two important time critical interface issues that need to be solved by the end of April: the stress issue in the jumper and the final connection to the new Helium Collectors.

No significant safety issues were identified. However, it is clear that the burst disks protecting the cryomodule cryogenic lines will have to be connected into a collection header in the tunnel. The nature of this connection and the design of the header itself will have to be fixed by the end of April. The venting must be designed to not overstress the cavities or their associated cryogenic lines. CEA has started to work with the ESS Q Division to ensure that the cryomodules will be able to receive a “Declaration of Conformity”

A significant milestone reported at the review is the completion of the assembly of the cavity string for the M-ECCTD. This is the first complete cavity string produced by the ESS project and includes qualified cavities designed both by CEA Saclay and INFN LASA.

Consistent with ESS operation plans, it was confirmed that there should be no limit on the maximum cool down rate of the cavity string and no impact is expected by Q disease. There should also be no limit on the rate of cool down of the thermal shields.

CEA will assist with the installation of the doorknob with the first cryomodules in the Lund Test Stand 2 and in the tunnel and will train the ESS test stand and installation staff. CEA will also provide the design of the installation tooling required.

The single window coupler design is susceptible to damage by field emission electrons from the cavities. This puts significant importance on the RF interlocks working properly and means that operations with high field emission may not be advisable. This issue will have to be carefully considered in linac energy margin design and in the operation of the accelerator.

Modeling of transportation loads has been carried out. Detailed plans for transportation including the installation of transport fixtures are well advanced. A transportation test between Saclay and Lund is planned for later this year.

Detailed plans and procedures (including pictures) have been developed for the cryomodule assembly. More details are being developed and the CEA Team will learn from the prototype assembly. An assembly and test report format associated with these tasks has been created

The proposed use of the stycast epoxy and resin is a CEA decision and ESS has no requirements on this material. The majority of the committee agrees that risk of radiation damage to this material is not very high.

A second CDR (CDR-2) will be held after the summer to evaluate the results of the M-ECCTD prototype test and look at any proposed design changes that result from the prototype testing. ESS and CEA will agree upon a technical data set that will be provided to ESS for review five weeks prior to the CDR-2.

**Decision**

The committee agrees that the design is ready to move to procurement and production as long as the two significant interface issues: the stress issue in the jumper connection and the final design of the connection to the new helium collectors are solved as scheduled by May 2017.

A second CDR will be held after the results of the prototype testing are known.

**Answers to Charge Questions**

1. Has design and supporting activity for Medium Beta Cryomodule progressed and reached a level of technical maturity in accordance with the activities and milestones for this Work Unit recorded in the ESS ACCSYS Project and been documented sufficiently and presented in a suitable format to enable review at this CDR?

*Yes*

2. Are all or a sufficient coverage of requirements and specifications for the Medium Beta Cryomodule, including for its interfaces with other systems, documented by ESS, communicated to and understood by the Work Unit team?

*Generally Yes, there are a few interface requirements that still need to be finalized including the allowable stress at the jumper connections, the operating flows and temperatures at the subcooling heat exchanger and the final details of the connection to the helium collectors. All of these should be fixed by the end of April.*

3. Does the design meet these requirements and specifications?

*Yes. No major technical issues were seen*

4. Have safety issues and technical risks been identified and eliminated or otherwise mitigated for in the detailed design or identified for managing for manufacture, assembly and installation?

*No outstanding safety issues were found. The hazards of the RF bunker have been clearly identified and its control measures well implemented. The review committee believes that the lessons learned from this RF bunker in matters of safety will be very beneficial for the future operation of TS2.*

5. What quality assurance and quality control activities have been planned and how will these be conducted and documented or reported?

*Based on the PowerPoint presentations and previous performance such as with XFEL program, ESS thinks that CEA is sufficiently capable in planning and managing internal and subcontractor activities for quality assurance and control of design development, procurement, manufacturing, assembly, verification and acceptance, including reporting and documenting this work.*

*However, CEA’s processes and how they are applied are not well understood by ESS, nor does ESS have much visibility about quality control inspection and test planning and activities, nor detail about verification and acceptance activities, including FAT and SAT.*

6. Is there sufficient staff resources assigned to the Work Unit team by its parent CEA Saclay to allow to progress with work in accordance with activities, durations and milestone dates shown in the ESS ACCSYS Project plan?

*Yes. A strong team has been identified However, additional staff & support for alignment & metrology should be considered.*

7. Are the strategy, policies and regulations for procurement, manufacture and assembly sufficiently identified, defined, documented and understood by the Work Unit team or its parent CEA Saclay Laboratory, including supplier source(s) and pre-procurement activities and progressed to a sufficient stage?

*Yes. This work is well advanced and ready for procurement and manufacture.*

8. Is the schedule for delivery of materials, components and for the manufacture of Medium Beta Cryomodule sufficiently understood and in accordance with activities, durations and milestone dates shown in the ESS ACCSYS project plan? (This includes the time schedule and technical risk evaluations)

*Yes, it is understood and generally consistent with the agreed upon schedule. The shown SAR2 dates need to be updated to match the integrated SRF plan.*

9. Does the Work Unit team or its parent CEA Saclay require additional input from ESS or its other partners, or seek additional review, decision or approval from ESS to proceed with all work planed?

*Yes. The interface requirements need to be finalized and a second CDR (CDR2) will be held to review the results of the M-ECCTD tests against the technical set agreed upon between CEA and ESS prior to the testing activities.*

10. Is the design information and information on procedures required for the operation of the Medium Beta Cryomodule delivered and presented at CDR sufficient? (This includes operational modes and Medium Beta Cryomodule functionality including adjacent systems and interfaces).

*Yes at least sufficient for CDR. A final “Operations Manual” will be provided later.*

11. Are there any outstanding agreements to be made or other actions necessary to allow the work unit to achieve the Plan?

*All are complete except AIK 5.5 whose completion is expected in May.*

**Recommendations**

1. ESS and CEA shall decide on a baseline design for the additional Helium Collectors by the end of April 2017.
2. In order to solve the issue with forces on the jumper connection CEA shall provide to ESS by April 12 the thermal analysis report of the cryomodule piping.
3. ESS, CEA and WUST will work together to solve the issue of stress on the distribution line with a deadline for solution of April 30, 2017.
4. Measure the heat leak to the 2 K space in the double outer coupler wall during the M-ECCTD test.
5. Understand the possible impact of the cavity field emission on the coupler window. Set up limits on operation of the cavities in certain field emission conditions if needed.
6. CEA shall provide the doorknob installation tooling design and installation procedure to ESS as soon as possible and no later than September 2017.
7. CEA will provide as soon as possible after the M-ECCTD test to the LLRF group the operating conditions of the Piezo tuners and stepper motors.
8. The failure scenario of a broken tuning motor and its impact on the cavity upon warm up needs to be carefully analyzed and this may be imply certain allowed operating conditions.
9. Additional lifetime information for both the Piezo and tuner motors should be sought from other labs.
10. ESS will check and verify the maximum flow rate and temperature in the subcooling heat exchangers as soon as possible.
11. The set pressure of SV60 should be re-examined and possibly set lower.
12. Calculate or measure during the M-ECCTD test the deformation of the vacuum vessel due to gravity on the test stands.
13. Examine transport stress on the ceramic window in the power couplers.
14. Provide inputs (3D model of the connection line, availability on the market of burst disks that can withstand high pressure, mechanical consequences of a higher pressure on the inner components of the cryomodules) to the ESS team in order to move forward with the helium collector study.
15. Prepare, with the help of the ESS quality team, a technical file that meets the minimum essential safety requirements of the PED.
16. The goal should be to finalize all interfaces between the cryomodule and other work packages by mid-June 2017. It is possible that additional changes made after the results of the M-ECCTD test.
17. The cryomodule SAR2 dates have to be made consistent with the agreed upon consolidated cryomodule schedule.
18. The testing and production schedules should be examined by ESS to see if they should be optimized.
19. Add additional Survey and Alignment markers on the vacuum vessel as agreed
20. CEA is requested to deliver a Quality Plan by 31 May 2017. This may be either in the form of the PQP as per ESS-0037830 or in the form of a QMP described in TA AIK #1.1, paragraph 7.5. However organisation for QA/QC was presented via PowerPoint.
21. CEA is requested to deliver a Verification Plan with the technical data package five (5) weeks prior to CDR-M2 (summer 2017). This Plan should list the discrete testing and other verification events planned to be performed during FAT and SAT programs, to verify performance and other technical requirements. This Plan should include or alternatively make reference to documents which describe procedures for performing each verification/test.
22. Provide information on RAMI of the cryomodules based on the request of the ESS RAMI expert to ESS as soon as possible and before CDR2.
23. CEA should list planned test and inspection events required to demonstrate compliance with applicable EU directives and also any specifically identified standards required by ESS requirements and CEA’s quality management system (ISO 9001). CEA should describe or reference verification procedures and show dates and durations for quality control events during manufacturing and assembly. CEA should identify witness and hold points both those internally for CEA with their subcontractors, but also witness and hold points between ESS and CEA. QC inspection and test planning can either be included within the Quality Plan deliverable or in the Verification Plan deliverable, described in the above Recommendations.
24. The static heat leak from the RF power coupler to 2K is 50% of the total static heat leak budget. This parameter can be only tested in a cold cryomodule. Achieving the design value is important as the cryogenic plant capacity is fixed. Its measurement should be given priority in the upcoming M-ECCTD cryomodule test to permit rapid feedback.
25. Stress and vibration analysis of the ceramic window and the inner conductor should be done to ensure the ceramic windows are protected against complication or damage during transportation.
26. There is no margin by design for possible gradient degradation from single-cavity vertical qualification test to cryomodule acceptance test. This is a risk to the project schedule. Non-conformal cavities may be recoverable by cavity retreatment or reprocessing at a small incremental cost. The ESS project and the CEA team should plan ahead for a strategy for cavity retreatment or re-processing so as to balance the impact to the cryomodule cost and project schedule.
27. 5 weeks prior to the planned CDR2 a technical data package as agreed between ESS and CEA shall be delivered to ESS for review.

Attachment 1

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| Critical Design Review (CDR)  Medium Beta Cryomodules  April 3 – 4, 2017 |
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| **Charge for the CDR** |
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Purpose of this CDR

A CDR is scheduled as a milestone event for approving the transition from detailed design to manufacture (or to material or component procurement, to software coding, to construction etc.).

The design is reviewed against all design inputs, including technical and interface requirements.

A successful CDR gives confidence that the proposed design will meet all technical requirements and interface properly with all relevant accelerator subsystems. The completion of a CDR fixes the baseline design of the component being reviewed.

The objective and purpose of this CDR is to confirm that the design for Medium Beta Cryomodules on the cold LINAC is likely to meet all requirements with acceptable risk and within the cost and schedule constraints and is specified in sufficient detail to proceed to the next stage of procurement and manufacturing. The final design for production may still be affected by the results of prototype tests.

The CDR should confirm the detailed design output shall be traceable to design inputs from ESS for the Cryomodules which have been received, understood and agreed by CEA Saclay. The design for the cryomodules on the cold LINAC should demonstrate that agreed design inputs have been fulfilled or achieved i.e. that the requirements are verified by the design.

The inputs for detailed design may include the following, where applicable and agreed by ESS and CEA Saclay:

* The scope of work described in the HoA/In-kind agreement for cryomodules technical specifications /appendix.
* Facility Breakdown Structure (FBS) requirements for Level 2 (L2) Accelerator, L3 cryomodule sections, L4 disciplines, including interface requirements applicable for the cryomodules at various PBS Levels. These requirements are managed in the IBM® Rational® DOORS® database, implemented for ESS products.
* Any specifications agreed as inputs for the detailed design of the cryomodules.
* Any conceptual or preliminary design descriptions or other inputs provided during previous reviews, workshops, or other technical meetings, which have been agreed and accepted as applicable input to detailed design for the Cryomodule.

In general terms, the expected outputs of detailed design, which should be presented and reviewed in the CDR, are:

* CAD models, prototypes, mock-ups and simulations,
* Specifications and other descriptions resulting from detailed design activities,
* Reports from calculations, analysis, simulation, prototype testing and other design verification activities,

The specific information, which should be reviewed in the CDR, is listed as Deliverables. See Appendix 1.

**The CDR boundaries and limitations**

The CDR to be performed is dedicated to the Medium Beta Elliptical Cavity Cryomodules. It will stress the design, assembly studies and prototype results.

**Charge to the Committee**

The Review Committee is composed of the Chairman and members as identified in Appendix 2. This list also shows reviewers, who provide comments and review but are not on the formal committee and presenters.

The Review Committee is asked to:

1. REVIEW: Scrutinize and assess the deliverables listed in Appendix 1, presented through the material presented and discussions, at the CDR. Note that the presentations themselves are means of communication only, and it is the design and design documentation which must be reviewed. The crucial point for the reviewers is to scrutinize the intersection points between the different interfaces and organizational responsibilities and how the work is documented to the component. “Is the design and documentation mature enough to start the next stages of prototyping and procurement for production”?

2. ANSWER: Answer each question listed in Appendix 3.

3. DECIDE: The Review Committee is to elaborate and deliver at the conclusion of this CDR, a clear recommendation to ESS and to CEA Saclay about proceeding with procurement of components for manufacture and procurement of manufacture services for the Medium Beta Cryomodules.

Suggested forms for the decision are:

* Approved, without qualifying comments or further actions.
* Approved, but with recommended actions and or clarifications.
* Not approved, but with recommended actions, for further inputs and activities, and a proposal for a follow-on review.

(If the committee rules for “Approved with recommended actions” or “Not approved” of the CDR, it is of essence that the actions/comments requested are very precise in their formulation and that the fulfilment decision is transferred to CEA Saclay, all this due to time constraints in the manufacturing schedule and sequence).

4. REPORT: The Review Committee is to document in a short report to be delivered as soon as possible after the CDR, its recommendation and any specific actions for CEA Saclay for the Medium Beta Cryomodules identifying any further design necessary, and other guidance for assisting planning and future success of the Work Unit in for its scope and deliverables.

(If the CDR is “Approved but with recommended actions”, at the CDR, there shall be a summary list of requested actions defined and who is responsible to perform needed work. In order to facilitate the actions ESS will work with CEA Saclay to accommodate any defined actions in order to meet the schedule constraints. This while awaiting the final report from the CDR charge review team).

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| Appendix 1  **Scope and Deliverables for Review** |
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Scope

The scope for the review includes:

* Presentation of main Cryomodules requirements (including Licensing requirements for ESS CM and ESS CM components)
* Cryomodules design : choice of design and justifications
* Assembly studies
* Description of expected design changes between the M-ECCTD and the Series Elliptical cryomodule
* Development plan including procurement plan & preliminary high level tests plan
* Cryomodules interfaces files: internal and external
* Quality Assurance and Quality Control Organisation
* Safety aspects of cryomodules
* Reliability of cryomodules

The WU is responsible for the following scope relevant for this CDR:

* Analysis and simulations e.g.
  + Heat Leak analysis
  + Support and vibration analysis
  + Reliability Availability Maintainability and Inspectability (RAMI) analysis
* Detailed mechanical and engineering design
* Definition of the interfaces with relevant systems
* Prototyping
* Procurement
* Construction and assembly
* Leak test, residual gases analysis and pressure measurement of the assemblies and associated components to demonstrate their full compliance with the requirements
* Quality assurance and contract follow-up
* Documentation concerning design, construction, tests and measurements

Deliverables for CDR - Information to be reviewed

The information identified below is to be described and communicated through presentation at the CDR, and the source information is to be available to reviewers for reference during the CDR.

CEA Saclay is requested to deliver to the CDR Chairman for distribution to the Review Committee and other reviewers, an agreed subset of the following information for pre-review and comments no later than Five (5) working days prior to the CDR.

Reviewers should assess the design, manufacturing processes and the verification methods, which secure performance, functionality and future operation as defined through the relevant requirements.

**Technical Data Package**

The contents of the technical data package for each CDR shall be specifically agreed in each charge, and should include but not be limited to:

* Requirements, agreed or proposed updates to documents comprising the baseline reference design, such as [REQ] , [SPN] etc.
* Design Reports, including reports of prototyping and other design-related analyses, tests, simulations.
* Design Data, (detailed design level) including 3D CAD models and CAD drawings, general arrangement drawings, P&ID, FE models, etc., and detailed interface descriptions including interface identification and definition for controlling interface design.
* Hazard analysis Report, an initial version of a report including identified hazards and evaluation of the likelihood of incidents occurring during operation and maintenance and severity of potential consequences on personnel, as well as the list of control measures). Examples of hazard analysis studies can be made available upon request.
* Verification Plan, (including planned FAT and any SAT activities)
* [PQP], updates for the Project Quality Plan applicable for the systems and components for each particular CDR, including identification of Standards applied in design, procurement, manufacture and assembly, and planning for compliance testing and inspection.

Where applicable, a CDR technical data package shall also contain documentation to initiate a competitive tender for the procurement of the systems or components whose design is the subject of the CDR. In such cases, the CDR data package should additionally include but not necessarily be limited to:

* Procurement Package, a complete documentation package for the procurement of the facility element including as a minimum a statement of work, manufacturing follow-up description, applicable and reference documentation
* Project Plan , updated plan in Gantt chart form, describing in detail remaining Stage 1 activities, describing in detail Stage 2 Realisation & Verification activities, and an outline of any Stage 3 Installation, Commissioning and Initial Operations activities for the Partner.
* Risks, Risk Register, showing identified project management risks and/or technical risks.
* verified results

**Safety**

Conventional Hazards

Present on any identified modes of operation or maintenance tasks for medium beta cryomodules, which could expose personnel to conventional hazards (e.g. high voltage hazards, magnetic field hazard, pressure etc.).

**Quality**

Quality Planning

Describe planning for Quality, or provide a Project Quality Plan for LWU scope. Use ESS-0037830 as guidance (not mandatory) for the planning of activities for Quality assurance and control.

Standards

List the standards used for engineering design, construction and verification of the vacuum and support systems. Note that ESS-0001515 Operating Procedure “Standards & Norms applicable for ESS” identifies radiation protection Standards, namely ICRP, IAEA, Erratum standards, and also more general engineering Standards, such as SIS, CEN and ISO, which ESS considers would be applicable for the design and construction of ESS systems and components. The ESS vacuum handbook also makes specific reference to applicable standards.

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| Appendix 2  **Review Committee and other Reviewers, Presenters and Observers** |

The CDR Committee conducts this review of design with the authority of ACCSYS Project Leader, Mats Lindroos, and ESS Chief Executive Officer, John Womersley.

The Committee serves in an advisory capacity to:

* the Work Unit team for Cryomodule and for its parent CEA Saclay
* the ACCSYS WP 5 Leader, and
* the ACCSYS management team

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| Name | Organisation | Appointment for CDR |
| John Weisend II | ESS, ACCSYS Deputy Project Leader | Chairman of the Review Committee |
| Matthew Conlon | ESS, ACCSYS QA Lead | Review Committee member |
| Duy Phan | ESS, ACCSYS Safety Group | Review Committee member |
| Rongli Geng | Jefferson Lab | Review Committee member |
| Daniel Piso1 | ESS, Integrated Controls Systems | Review Committee member |
| Jarek Fydrych1 | ESS, Cryogenics Section | Reviewer |
| Marcelo Ferreira1 | ESS, ACCSYS Vacuum Systems Section Leader | Reviewer |
| Enric Bargalló1 | ESS, ACCSYS Accelerator Reliability | Reviewer |
| Christine Darve | ESS, WP4/5 Deputy Work Package Leader | Reviewer |
| Nuno Elias | ESS, Cryogenic Engineer | Reviewer |
| Wolfgang Hees1 | ESS, WP10 Leader | Reviewer |
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1 Denotes attendances remotely from ESS ERIC, Lund

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| Appendix 3  **CDR Charge Questions** |

1. Has design and supporting activity for Medium Beta Cryomodule progressed and reached a level of technical maturity in accordance with the activities and milestones for this Work Unit recorded in the ESS ACCSYS Project and been documented sufficiently and presented in a suitable format to enable review at this CDR?
2. Are all or a sufficient coverage of requirements and specifications for the Medium Beta Cryomodule, including for its interfaces with other systems, documented by ESS, communicated to and understood by the Work Unit team?
3. Does the design meet these requirements and specifications?
4. How does the series Medium Beta Cryomodule differ from the M-ECCTD?
5. Have safety issues and technical risks been identified and eliminated or otherwise mitigated for in the detailed design or identified for managing for manufacture, assembly and installation?
6. What quality assurance and quality control activities have been planned and how will these be conducted and documented or reported?
7. Is there sufficient staff resources assigned to the Work Unit team by its parent CEA Saclay to allow to progress with work in accordance with activities, durations and milestone dates shown in the ESS ACCSYS Project plan?
8. Is the design information and information on procedures required for the operation of the Medium Beta Cryomodule delivered and presented at CDR sufficient? (This includes operational modes and Medium Beta Cryomodule functionality including adjacent systems and interfaces).
9. Are the strategy, policies and regulations for procurement, manufacture and assembly sufficiently identified, defined, documented and understood by the Work Unit team or its parent CEA Saclay Laboratory, including supplier source(s) and pre-procurement activities and progressed to a sufficient stage?
10. Is the schedule for delivery of materials, components and for the manufacture of Medium Beta Cryomodule sufficiently understood and in accordance with activities, durations and milestone dates shown in the ESS ACCSYS project plan? (This includes the time schedule and technical risk evaluations)
11. Does the Work Unit team or its parent CEA Saclay require additional input from ESS or its other partners, or seek additional review, decision or approval from ESS to proceed with all work planed?
12. Are there any outstanding agreements to be made or other actions necessary to allow the work unit to achieve the Plan?

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| Appendix 4  **Detailed checklist, can be used as guidance for clarification** |

The 5 main question areas for the Medium Beta Cryomodule CDR are:

1. The design:
   1. Is the design documented sufficiently and presented in a suitable format to enable review at this CDR?
   2. Does the design meet the requirements and specifications?
   3. Does the design meet the ESS needs? (Plant integration, testing, operability, maintenance, future changes/upgrades)
   4. Are all or a sufficient coverage of requirements and specifications for the Medium Beta Cryomodule, including its interfaces with other systems, documented, communicated to and understood by the Work Unit team?
   5. Has the design and supporting activity for Medium Beta Cryomodule progressed and reached a level of technical maturity to start prototyping/manufacturing?
      1. What open technical questions exist?
      2. What is the path forward to clarify the open questions?
   6. Have a proper safety and risk analysis been performed?
      1. What safety issues and technical risks have been identified?
      2. Are they documented?
      3. What mitigations have been implemented? Are they documented? What is the result?
      4. Future actions planed? To eliminated or otherwise mitigated in the detailed design or identified for managing for manufacture, assembly, installation or operation?
   7. Does the Work Unit team or its parent CEA Saclay require additional input from ESS or its other partners, or seek additional review, decision or approval from ESS to proceed with all work planed?
   8. Are there any outstanding agreements to be made or other actions in the work unit necessary to realize the Plan?
2. The manufacturing:
   1. Is there a Manufacturing strategy and sequence?
   2. Are the strategy, policies and regulations for procurement, manufacture and assembly sufficiently identified, defined, documented and understood by the Work Unit team or its parent CEA Saclay, including supplier source(s) and pre-procurement activities and progressed to a sufficient stage?
   3. Are all needed manufacturing procedures and DWG completed? If not what is open?
   4. Are all needed procedures/inspection plans including risk analysis for manufacturing performed including plan for mitigating actions? (E.g. lamination stamping, construction of the coils, overall manufacturing sequence, procedures, etc.)
   5. Is the manufacturer given sufficient time to perform the work?
3. Scope split:
   1. Is the scope split clear between CEA Saclay, INFN Milan and ESS?
   2. Are the responsibilities clear and agreed?
   3. Is the requirement verification/validation agreed and understood?
4. Time schedule and critical paths:
   1. Which critical paths exist?
   2. What Top 3 risks are identified and how are they managed?
   3. Is the schedule for delivery of materials, components and for the manufacture of LWU sufficiently understood and in accordance with activities, durations and milestone dates shown in the ACCSYS project plan?
5. CEA Saclay Resource plan to meet the schedule:
   1. Are all resources named?
   2. Is the schedule resource loaded?
   3. Are all resources available and released by management in due time?
   4. Is there any surplus in the critical areas?
   5. Which bottlenecks exists?