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**US HL-LHC Accelerator Upgrade Project**

**AUP Integration Plan**

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**Revision History**

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| R1 | 27-May-2020 | Cover page46.2, 7.46.37.47.5 | Added L2 Managers to “Reviewed By” field; Changed “Technical Division” to “Applied Physics & Superconducting Technology Division”Added new reference [2] to Design Change ManagementAdded L2 Managers are Design Authority; (6.2) removed reference to CAMRemoved reference to CAM; added statement regarding design data exchange logAdded “Changes” to the section title; added reference to the Design Change Management procedure; removed reference to SLAC and added JLab; added clause regarding design data exchange logUnder *Interface Travelers* section, clarified that CERN is requiring all fabrication and testing data are to be delivered to CERN |
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1. Introduction

The US Hi-Lumi LHC Accelerator Upgrade Project (US HL-LHC AUP) is a U.S. Department of Energy (DOE) project charged with delivering upgraded Interaction Region Focusing Magnets (Q1/Q3) and dressed superconducting Radio Frequency Crab cavities to CERN for use in the Hi-Lumi LHC Upgrade. This AUP utilizes design, manufacturing and testing capabilities across multiple US National Laboratories and collaborating Universities. The purpose of this AUP System Integration Plan is to describe the System Integration processes and related procedures to be used on the HL-LHC AUP to ensure the design and integration of the multi-Lab supplied components and assemblies meet the AUP Key Performance Parameters (KPPs).

1. Scope

This plan provides requirements applicable to all project System Integration tasks, performed by or for the HL-LHC AUP. Each collaborating participant shall work with its own engineering procedure system which must be compatible with the requirements in this plan and associated procedures.

1. Definitions

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| **Term** | **Definition** |
| ANL | Argonne National Laboratory |
| BCR | Baseline Change Request |
| BNL | Brookhaven National Laboratory |
| CAM | Control Account Manager |
| CCB | Change Control Board |
| CDD | CERN Drawing Directory |
| CERN | European Organization for Nuclear Research |
| CMP | Configuration Management Plan |
| DCC | LBNL Document Control Center |
| DOE | Department of Energy |
| EDMS | CERN Engineering and Equipment Data Management Service |
| FNAL | Fermi National Accelerator Laboratory |
| FRS | Functional Requirements Specification |
| HSE | CERN Safety group |
| ICD | Interface Control Document |
| JLAB | Jefferson Laboratory |
| KPP | Key Performance Parameter |
| LBNL | Lawrence Berkeley National Laboratory |
| MIP | Manufacturing and Inspection Plan |
| MTF | CERN Manufacturing and Test Folder |
| ODU | Old Dominion University |
| PED | European Pressure Equipment Directive |
| PEP | Project Execution Plan |
| PMP | Project Management Plan |
| RFD | Radio Frequency Dipole |
| SLAC | Stanford Linear Accelerator Laboratory |
| WBS | Work Breakdown Structure |

1. References

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| **No.** | **Document Title** | **Document Number** |
| 1 | WBS Dictionary | HiLumi-Doc-39 |
| 2 | Design Change Management | HiLumi-Doc-2308 |
| 3 | Parts Exchange Document | EDMS 1825173 |
| 4 | MQXFA Materials | EDMS 1786913 |
| 5 | WP3 System architecture and interfaces identification - IR Magnets | EDMS 1405220 |
| 6 | Template for HL-LHC Non-Conformity reports not managed via MTF | EDMS 1501109 |
| 7 | Configuration Management Plan | HiLumi-Doc-1067 |
| 8 | Quality Assurance Plan | HiLumi-Doc-80 |
| 9 | Design Review Plan | HiLumi-Doc-170 |

1. Collaborators Scope and Deliverables

The AUP WBS Dictionary[1] describes the scope for each WBS element of the Project. The following table is a summary of the deliverables from each collaborating participant.

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| **Collaborator** | **Summary of Scope and Deliverable** |
| FNAL | Strand Procurement, Coil fabrication, Cold mass assembly, Cryo-Assembly, Cryo-Assembly cold testing, Shipping to CERN |
| BNL | Coil Fabrication and shipment, Coil and Magnet shipping fixtures, Magnet vertical testing and shipment |
| LBNL | Cabling and cable insulation, Magnet structure Assembly and shipment |
| CERN | Customer |
| SLAC | RFD Cavity and HOM Dampers Electro-Magnetic Design |
| ODU | RFD Cavity and HOM Dampers Warm and Cold Measurements |
| JLAB | HOM Dampers Fabrication |
| ANL | RFD Cavity Chemical Processing |

1. Roles and Responsibilities
	1. Project Manager (L1 Manager)

The Project Manager is responsible for:

* Ensuring the Level 2 managers understand and follow the requirements and expectations regarding system integration.
* Approving requirements, acceptance criteria and interface control documents.
* Approving the System Integration Plan.
	1. Level 2 Managers

The L2 managers are responsible for:

* Developing, approving and managing the requirements and acceptance criteria for their system.
* Review and approve requirements, acceptance criteria and interface control documents.
* Ensure controlled documents are up to date in all stored locations.
* Design Authority for their scope of work
* Ensuring the L3 managers are complying with integration requirements.
	1. Level 3 Managers

The L3 managers are responsible for:

* Developing, approving and managing the Interface Control Documents for their system.
* Ensuring documents and drawings pertaining to their system are controlled and maintained per the integration requirements.
* Ensuring design data exchanged between design-responsible organizations is recorded in the tracking log.
* Developing and maintaining the MIPs and associated travelers.
* Ensuring the travelers and test data is completed and properly documented and shared with interfacing sub-systems.
	1. Systems Integration Engineer

The System Integration Engineer is responsible for:

* Provides guidance and support to the Project regarding system integration.
* Reviews and approves the Interface Control Documents.
* Coordinates the Interface Control Document reviews.
* Coordinates the transfer of data and documents to CERN.
* Participates in Design and Production Readiness Reviews.
* Primary author of the System Integration Plan.
	1. Quality Assurance Manager

The Quality Assurance Manager is responsible for:

* Provides input to the System Integration Engineer on Quality Assurance and Configuration Management.
* Participates in Interface Control Document reviews.
* Provides support for data and document transfer between sub-projects and with CERN.
1. Systems Integration Processes
	1. Document Control

The AUP Project Office has selected DocDB as its document control system. This means that all project-level documents are stored in the US HI-Lumi AUP DocDB system. For documents which require formal approval and document control, the Project utilizes the document approval mechanism in DocDB.

In addition, CERN requires certain documents to be stored and approved in their EDMS. The CERN document approval system is described in Section 12 of the Project Management Plan. In those cases, the documents will be stored in two systems; AUP’s DocDB and CERN’s EDMS. The authors of these documents understand that it is their responsibility to keep the two versions in sync whenever the “source” file in DocDB needs to be revised.

Similarly, the other two collaborating labs (i.e. BNL and LBNL) will be utilizing their own document control systems to manage their documents. Some of those documents are considered project-level documents, and so will be stored and approved in the AUP DocDB. The authors of these documents understand that it is their responsibility to keep the two versions in sync whenever the “source” file in the partner lab’s system needs to be revised.

* 1. Requirements and Acceptance Criteria Management

The following AUP components have a set of performance requirements and corresponding acceptance criteria.

* Magnet: MQXFA
* Cryo-Assembly: LMQXFA/B
* Dressed RFD Cavity

Requirements are managed through Functional Requirements Specifications. All functional requirements have corresponding Acceptance Criteria which are defined in an Acceptance Criteria document. FRS and Acceptance Criteria documents are reviewed and approved within the HL-LHC AUP and also through the CERN document approval system. An up to date copy of all FRS and Acceptance Criteria documents are kept in the HiLumi-DocDB and EDMS. It is the responsibility of the L2 Manager to ensure documents related to their sub-systems are kept up to date in the appropriate document database.

* 1. Interface Control

There are two types of interfaces within the HL-LHC AUP: internal and external. Internal interfaces are between project WBS elements; external interfaces are between HL-LHC AUP and CERN. Both interface types are identified and defined in Interface Control Documents (ICD). Each ICD contains physical interfaces and data interfaces and lists reference documentation for each interface identified in the ICD. An interface matrix identifying all of the ICDs can be found in HiLumi-doc-219.

Internal ICDs have two stages of preparation: CD2 level and CD3 level. CD2 level ICDs must identify each interface and list all reference documentation that is available at the CD2 review. CD3 level ICDs must identify and define each interface. Defining an interface means all reference documentation is identified by a document or drawing number and that reference document is under document control. ICDs must be reviewed and approved by all stakeholders prior to the start of fabrication. The review process is as follows:

* Prior to or part of the Production Readiness Review, the ICD will go through an ICD review.
* The ICD review consists of a meeting with all stakeholders present and the interfaces are presented and discussed during this meeting.
* After the review, the documents are loaded in the HiLumi-DocDB and the reviewers electronically approve the ICD. Approvers should be identified as follows:
	+ L3 manager on each side of the interface.
	+ L2 manager(s) on each side of the interface.
	+ System Integration Engineer
	+ Deputy Project Manager
	+ Project Manager
* During the fabrication phase, any changes to the ICDs must follow Configuration Management[7].

External ICDs must follow the CERN document approval system described in Section 12 of the Project Management Plan. A signed up to date copy of the ICD will also be kept in HiLumi-DocDB.

* 1. Design Authority, Responsibility, Changes, & CAD Data/Drawing Management

L2 Managers are the Design Authority for their scope of work. This means that all designs, and changes to them, are approved only by the appropriate L2. Once a design is baselined, authorization to implement design changes is managed at the Project level through the Design Change Management procedure[2].

Due to the organization of the Project deliverables, there are multiple design-responsible organizations. Each of these labs utilizes their own systems for managing drawings:

* FNAL: Teamcenter
* BNL: Windchill / PDMLink
* LBNL: Windchill and Document Control Center (DCC)
* JLab: Document Repository and Teamcenter
* CERN: EDMS and CERN Drawing Directory (CDD)

Design integration, particularly where the designs of one lab interface with the designs at another, is critically important for the success of the Project. An Interface Matrix has been written to show the internal and external interfaces (DocDB #219).

All AUP staff are able to be provided:

* a CERN “NICE” account to be able to access EDMS and CDD
* an FNAL “Services” account to be able to access Teamcenter
* an LBNL User account to be able to access DCC

Design integration, i.e. the integration of one lab’s design data into another lab’s designs, is accomplished through the sharing of design data (e.g. models and drawings) between the design responsible organizations. As such it is critically important that each Lab (listed in table 1 below) maintain the latest designs in their systems and communicate changes which affect interfaces to the other labs in “real time”. As an aid to the design development processes throughout the AUP collaboration, all design data exchanged between design-responsible labs for the purpose of integrating designs is kept track of through a log.

Eventually all designs will be uploaded into CDD, but it is not intended that CDD serve the function of design integration while designs are being completed.

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| **Table 1 – Design Responsibilities and MIP Scopes** |
| System | Design Responsibility | MIP Scope |
| SC Cable | LBNL | LBNL |
| Coils | FNAL | FNAL and BNL |
| Magnet Assembly | LBNL | LBNL |
| Magnet Test | N/A | BNL |
| Coldmass Assembly | FNAL\* | FNAL |
| Cryoassembly | CERN# | FNAL |
| Cryoassembly Test | N/A | FNAL |
| RFD Dressed Cavity | AUP and CERN\*\* | FNAL |
| HOM Dampers | AUP and CERN\*\* | FNAL and JLAB |

\* CERN is designing some components for the coldmass assembly, and AUP is acquiring them from CERN. For specifics refer to the Parts Exchange Document in EDMS[3].

# CERN is the design authority for the cryostat (including the associated tooling and assembly procedures), and is delivering the components, tooling, and procedures to AUP for final assembly.

\*\* AUP is responsible for the electro-magnetic design, CERN is responsible for the mechanical design.

* 1. Manufacturing Data

Due to the distributed manufacturing it is of critical importance that production/assembly and test data be shared amongst the collaborating labs; FNAL, LBNL, and BNL. The more transparency between the three labs the lower the Project risk.

**Travelers**

Although Fermilab’s electronic traveler system, Vector, is available for all labs to use, the Project has adopted the approach to allow each lab to utilize the process control systems for which they are comfortable, i.e. their own traveler systems. At the same time the Project has agreed to deliver production and assembly data to CERN via the CERN “Measurement and Test Folder” system (MTF), and there is a need for data integration/sharing between the three production sites.

All manufacturing, assembly, and testing operations need to be included within the scope of a set of “Manufacturing & Inspection Plans” (MIP). The MIPs define the overall workflow of the manufacturing and inspection operations and include identifying when outcomes of certain steps are so-called “Notification Points” or “Hold Points” either internal to the Project or to CERN. Table 1 indicates the organizations responsible for which MIPs. MIPs are written by collaborating labs and are done so in conjunction with CERN. CERN ultimately approves the MIPs within their EDMS.

**Interface Travelers**

Regarding interfaces between the distributed manufacturing sites (i.e. across the collaborating labs), the AUP Project Office has decided that “interface travelers” will be put in place in Vector. These travelers will include “containers” for data and/or records to provide:

1. hold points to be implemented when the individual to approve the HP is at another lab (e.g. the magnet L2 at Fermilab approving shipment of coils fabricated at BNL), and
2. the receiving collaborating lab with the information needed to use the component/assembly/system in their assembly and/or test process (e.g. coil information needed by LBNL in order to assemble the magnets).

This approach of using “interface travelers” will also provide for a solution of maintaining product identification and traceability across the three AUP manufacturing sites.

CERN requires that all production/assembly/testing records be delivered along with the hardware. This is accomplished through exporting all data from Vector, including attachments, into PDF documents and an associated meta-data spreadsheet, and sharing those files with CERN for them to import into EDMS/MTF.

**CERN’s Manufacturing and Test Folder (MTF)**

MTF instances (i.e. the folder which has been issued for each serialized assembly and is used to collect data for that assembly) are based on Manufacturing & Inspection Plans (MIP). “Notification Points” which are for CERN are accomplished via “real time” entry by the responsible AUP lab to MTF. CERN “Hold Points” are handled by the AUP L2 Managers through Vector.

Any steps remaining, i.e. not Notification or Hold Points, can be filled in in “real time”. However, they do not have to be completed in real time, but they are required to be filled in by the time the item is delivered to CERN.

MTF can be filled in “by hand”, or through a spreadsheet upload.

**Identification and Traceability**

It is required that:

1. Only approved materials are used in the deliverable hardware, and
2. ID, traceability, and serialization of components is properly integrated across the three collaborating labs.

The material which is going into the magnet deliverables has been approved by CERN and is available in EDMS[4]. Any modification to these materials needs to go through review and approval by the AUP project office and CERN before being implemented. It is very important that each collaborating lab responsible for procurement ensure that only the approved materials are purchased and used in their work.

CERN has also defined a series designation scheme for the magnet deliverables, and it is available in EDMS[5]. The collaborating labs must adopt the series designators defined by CERN and use them in the travelers/records which are shared with the other labs as part of the distributed manufacturing.

**Nonconformances**

Related to production/assembly and test data are the sharing of nonconformances across the three collaborating labs, and sometimes with CERN. Again, the more transparency the lower the Project risk.

Just as with travelers, each collaborating lab is using their own NCR systems/processes. If those systems are not accessible by the other collaborating labs, then mechanisms must be developed by which the necessary information is shared with the AUP project office, the other collaborating labs, and with CERN.

As part of the “interface travelers”, the submitting lab will include a listing of all the NCRs associated with the device.

The AUP project office has committed to CERN that significant NCRs will be communicated to CERN through the CERN NCR form[6] within EDMS/MTF. This communication will occur from the AUP project office, not from the collaborating Labs.

* 1. Integration with CERN

AUP is responsible for the final project deliverables but many of the components and procedures come from CERN. CERN is providing AUP with the following:

* Components that integrate with the magnets.
* Shell material and components for the cold masses.
* CERN is designing and providing all the cryostat components in cryostat kits: vacuum vessel, thermal shields, MLI, support posts, etc.
* CERN is procuring and providing the tooling to assemble the cold mass into the cryostat.
* CERN is providing the work instructions / procedures for the cryo-assembly.

Formal agreements regarding these CERN deliverables will be developed, reviewed and approved by AUP and CERN.

The following documentation will be transferred to CERN. Procedures for transferring this data will be developed and shared within the AUP project and with CERN to ensure proper delivery into the CERN systems.

* Requirements and specifications
* Acceptance criteria
* Drawings
* Interface control documents
* Fabrication data
	+ Travelers
	+ Material specifications
	+ QC data
	+ Test data
* Safety documentation

The System Integration Engineer is responsible for managing the delivery of this documentation to CERN.

* 1. Configuration Management

All changes to designs and documentation referenced in this Plan must follow the Configuration Management Plan[7]. Revised documentation must be shared with the appropriate collaborating partners and stored in the proper document databases.

* 1. Quality Assurance Support

The QA Manager is responsible for developing and implementing the Quality Assurance Plan[8]. The System Integration Engineer provides support to the QA Manager by:

* Managing the interface documentation.
* Contact with CERN HSE for PED compliance.
* Managing the delivery of documentation to CERN from the US Labs and ensuring all CERN documentation requirements are met.
1. Reviews and Assessments
	1. Reviews

Project reviews are defined in the Design Review Plan[9].

* 1. Assessments

As is stated in each lab’s QA Plan, assessments are an important part of the Project’s overall QA program. It is expected that the following assessments will take place during the Project:

1. Internal, conducted by the collaborating lab on its own operations.
2. Project, conducted by the AUP project office on the collaborating lab’s operations.
3. External, conducted by CERN on the project office and the collaborating labs.