US HL-LHC AUP: Ready for Production

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Outline

- Introduction
- Deliverables
- Schedule (and Cost)
- AUP Needs to “Really” Start
- Conclusions
Introduction

- US HL-LHC AUP has been properly introduced by Simona yesterday
- HL-LHC AUP is a 413.3b Project established to fulfill a US contribution to HL-LHC
  - CD-0 (Mission Need) approved in 2016
  - CD-1 (Cost Range) approved 2017
    - Also obtained CD-3a (Long Lead Procurement) for Nb3Sn
  - CD-2 (Project Baseline) in progress
    "Plan the Work, Work the Plan"
  - CD-3 (Start of Construction)
  - CD-4 (Project Completion)
HL-LHC AUP Scope – Technical Details

- 10 Q1/Q3 Cryoassembly
- 10 Dressed RFD Cavity
Performance Requirements

- Performance Requirements are documented in “Functional Requirements Specifications” documents
  - Approved by CERN
  - Accepted by HL-LHC AUP
- Under Document Control at CERN and US

Us-HiLumi-doc-36
Us-HiLumi-doc-64
Under Convergence
Us-HiLumi-doc-294
HL-LHC AUP Project Completion

- AUP is complete when 10 Q1/Q3 Cryoassemblies and 10 RFD Dressed Cavities are delivered to CERN and have undergone inspection to exclude shipment damage.
  - Performance Requirements Acceptance of US deliverables is agreed upon before shipment from the US to CERN (see, for example, US-HiLumi-doc-1148: “Q1/Q3 Cryoassembly Acceptance Plan”)

- It is in the common interest of US-AUP and CERN to find “good use” for Prototype elements
  - Prototype Cryo-Assembly usage in String Test @ CERN
  - RFD Prototype Cavities @ CERN for Integration Develop.

- **AUP does not contain any activity of Installation or Commissioning at the HL-LHC.**
Compliance & Integration with CERN Requirements

- CERN is final user of HL-LHC AUP deliverables
- First and foremost: magnet cryo-assemblies and RFD crab cavities must meet the CERN requirement of being compliant to the Essential Safety Requirements of the European Pressure Equipment Directive (PED).
  - In addition, both assemblies must be compliant with the FNAL ES&H Manual in order to be tested at FNAL.
- Compliance on several other aspects are documented and in various stages of approval between HL-LHC AUP and CERN:
  - Usage & Approval of materials
  - Performance: FRS and Acceptance Criteria
  - Quality of Manufacturing & Documentation:
    - Manufacturing and Inspection Plans (including holding points), Manufacturing and Test Folders and Deliverables Drawings
  - Definition and Signoff of Interfaces

More on this later
Agreement with CERN on Delivery Dates

- The AUP deliverables need to be at CERN well in advance of the HL-LHC operations to allow for installations and commissioning of the equipment.
- AUP-CERN have negotiated and agreed upon on “Early Delivery” and “Late Delivery” dates.
  - Difference between Early and Late Delivery can also be represented as “Schedule Float”
- During the latest DOE gate review (CD-1) in US, AUP was requested to increase the “Schedule Float”.
  - AUP plans toward a minimum of 11 months of float on CryoAssemblies and RFD Cavities delivery dates.
  - Dates agreed upon in Feb ‘18.
## Agreement with CERN on Delivery Dates (cont.)

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<tr>
<th>Q1/Q3</th>
<th>Early Delivery Date</th>
<th>Late Delivery Date</th>
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<tr>
<td>HL project schedule</td>
<td>US project schedule</td>
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<td>LQXFA/B10</td>
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### Points:
- The AUP baseline (to be approved in Dec ‘18) aims at delivering items to CERN by the “Early Delivery Date”.
- CERN selected to use the “Early Delivery Date” to build the HL overall Project schedule.
AUP Funding and Funding Profile

- **CD-2/3b DOE IPR Review:**
  - **TPC:** ~240 M$
    - BAC of ~178-180 M$ and ~36% Cont. on work-to-go
  - **Schedule Float:**
    - Minimum 11 Months to CERN “Drop-Dead Need-by” date
    - 36 Months to DOE CD-4

- Funding Profile requested to DOE-HEP

<table>
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<th>FY16+17</th>
<th>FY18</th>
<th>FY19</th>
<th>FY20</th>
<th>FY21</th>
<th>FY22</th>
<th>FY23</th>
<th>FY24</th>
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<td>0.6 M$</td>
<td>27 M$</td>
<td>50 M$</td>
<td>50 M$</td>
<td>~43 M$</td>
<td>~40 M$</td>
<td>~20 M$</td>
<td>~10 M$</td>
<td>~240 M$</td>
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- **TPC and Funding Profile would support:**
  - Planned Scope and CryoAssemblies/RFD cavities delivered to CERN by “Early Delivery” date.
Tailoring Strategy

- Approvals phases for Procurement/Construction
  - Approval of Long-lead Procurements (July ’17)
    - Requested and obtained at CD-1 to advance the Nb₃Sn superconductor strand procurement due to schedule need
    - Obtained budget authority for 17.7 M$
  - Approval for Fabrication Start of coils and magnets.
    - Requested at CD-2 time to advance the critical path activities of magnets assembly.
    - CD-3b will also support the procurement of low-risk Crab Cavities raw materials.
    - Request budget authority for ~130 M$
  - Approve Full Construction on balance of Project (CryoAssemblies and Crab Cavities Fabrication)
    - No other subsystem is expected to have remaining final design activities at time of CD-3

Dec ’18
Design Reviews

- Preliminary and Final Design Reviews executed by independent external teams:
  - **MQXFA Design Criteria Review**
  - **MQXFA Final Design Review and Q1/Q3 Cold Mass and CryoAssembly Preliminary Design review**
  - **RFD Dressed Cavities Preliminary Design review and Nb Raw Material Final Design review**
  - **Mini-Review of MQXFAP2 Results**
    - Requested to show performance to MQXFA FRS for DOE to approve Magnet Construction (CD-3b)
“Optimizations”

- Opportunities for “Optimization” (or Changes) will inevitably present themselves during execution of the Project.
- The essence of changes in a DOE 413.3b Project like AUP is that they must be “controlled”. In AUP, changes proposals go through a process called Baseline Change Request (BCR). BCRs are:
  1. Proposed
  2. Examined for effects on
     - Cost
     - Schedule
     - Technical Performance & Interfaces
     - Resources
  3. Approved or Rejected
  4. Implemented in Project Baseline
- The AUP Change Control Board looks at 1) and 2) above.
- Approvals above 1M$ (Cost) or 6 months (Schedule) are beyond AUP Project Management/Laboratory authority

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Optimizations/Changes need to be controlled (and minimized). “Forward Looking” Optimizations are slightly easier to implement. “Retroactive” Optimizations can quickly become the kiss-of-death for AUP scope
Contingency Discussion

- Setbacks during FY18 (both within and outside AUP) are indicating that at this stage of the Project the low contingency (~32%) presented earlier to the funding agency might be overly optimistic.
  - Initial shaky EVMS Performance of some Control Accounts during “test period” before Baseline (Cold Mass and CryoAssembly efforts)
  - Large number of substantial changes with a risk of a rapidly escalating budget
  - Feb. ‘18 failure of MQXFAP1 for insufficient impregnation/erroneous operational procedure and failures and subsequent refurbishment of BNL Magnet Vertical Test facility (with addition of 3rd Cryo operator)
  - Failure of LCLS-II Cryomodule Shipment
  - AUP FY18 Funding level decrease by 2.5M$ in June ’18.
  - Risk of CERN “optimizations” after AUP Baseline and/or external dependencies on CERN provided components

- Event with important repercussion on the Total Cost require a course correction at this stage. A ~35-40% Contingency is more in line with Projects with CERN (CMS, ATLAS in early 2000) at this stage of execution.
Emojical Snapshot of (pre)Production Performance - MQXFA Magnets

- **Cables:**
  - Fabricated: 26 (12 by LARP, 14 by AUP)
  - Accepted: 25
  - Quarantined: 1 (cross-over close to minimum length)

- **Coils at FNAL:**
  - Fabricated: 10 (completed) + 3 (under fabrication)
  - Accepted: 6
  - Rejected: 1 (damage during curing)
  - Quarantined: 3 (electrical weakness to coil parts)

- **Coils at BNL:**
  - Completed commissioning of new winding & curing equipment for MQXFA coils
  - Completed winding and curing of 1st production coil

- **Structures:**
  - Assembled MQXFAP2
  - Procurement of MQXFAP3 parts in progress.
  - Issues with procurement of Magnets #4 to #7 ARMCO iron

- **Vertical Test**
  - MQXFAP2 under test at BNL
Technical Progress - Magnets

- All eyes on MQXFAP2 Vertical Test at BNL
  - Visit from FNAL team during setup and QP Tests
  - Magnet cooled-down to 4K by mid-September.
    - HiPot: 1.15 kV Coils to Gnd.
    - 7 quenches performed:
      - 13.27 kA(#1) to 14.97 kA(#9), Δ~200 A
  - Goals: 16.5 kA (Objective) and 17.9 kA (Ultimate)
- Early Finish Date (30 training quenches): 11/1
- Late Finish Date: (50 training quenches): 11/14
- MQXFAP1 stopped ~400A from Ultimate and saw Δ~120 A
Technical Status - RFD Cavities

- Validated new rotational-BCP tool at ANL
- Newly fabricated HOM dampers by JLab
  - Warm and cold tests performed at Jlab/ODU
- Continued cold-tests on LARP prototypes
  - Exceeded requirements of field and quality factor (FNAL)
  - Still troubleshooting damper losses (ODU/Jlab/FNAL)
- Placed contract for bare cavity fabrication
  - Prototype + Option for full Production

Successful test of bare cavity at 2K (Fermilab).
Exceeded field and quality factor requirements.

2K Test of cavity with HOM dampers showing successful field (~5MV) and low Quality Factor (ODU/Jlab).
Compliance & Integration with CERN: Requirements to Satisfy US Funding Agency

- HL-LHC AUP approach to approval status:
  - **Baseline for Cavities, CM & CA (CD-2 Scope):**
    - FRS approved by CERN and accepted by AUP
    - Materials List in draft form within AUP
    - Acceptance Criteria in draft form within AUP
    - Interfaces Identification completed within AUP
  - **Magnets Construction (CD-3b Scope):**
    - Materials List approved by CERN and accepted by AUP
    - MIPs approved by CERN and accepted by AUP
    - Acceptance Criteria approved by CERN and accepted by AUP
    - Interfaces fully documented and approved, including CERN approval of AUP-CERN external interfaces
What we really need to obtain DOE Approval (i.e. “start AUP”)

- Magnet Construction (CD-3b)
  - CERN Approval of Magnet Acceptance Criteria. *Good Progress*
    - EDMS 2031083 – US HiLumi Docdb 1103
  - Interface Documents from CERN
    - Q1/Q3 Electrical Schematic & Quench Protection Specification
  - MQXFA Interface Specification:
    - EDMS xxx – US HiLumi Docdb 1674
  - Definition of all MQXFA Materials – EDMS 1786261 & 1786913
    - Approval on CLIQ Leads and of MQXFA Material list with G11 (vs. G11-CR)
  - Approval of MIPs. *Good Progress*
    - LBNL Cable MIPs – EDMS 1866230
    - FNAL Coils MIPs – EDMS 1866237
    - BNL Coil MIPs – Last touches from AUP, EDMS 1995810
    - LBNL Magnet MIPs – Last touches from AUP, EDMS 1866238
  - Approval of AUP Conductor QA Plan – EDMS 2004979 and Parts/Cost Exchange – EDMS 1825173. *Good Progress*

- Interactions with WP3 in full swing for the last few months
  - Friday satellite Meeting

- *After DOE Approval, will call PRR (and MRR) with CERN representatives*
“AUP start” (cont.)

- **Baseline for Cavities, Cold Mass & CryoAssembly (CD-2 Scope):**
  - CERN Approval for Cryo-Assembly FRS. **Good Progress**
    - EDMS 1828585 - US HiLumi Docdb 246
  - Other documents (Acceptance Criteria, Interfaces identification and Material List) needed in draft form, and are being developed by AUP in Collaboration with the appropriate WP.
Summary

- AUP continued with steady progress in 2018
- Experience from (pre)Production in line with expectations
- HL-LHC AUP is ready for Baseline
- MQXFA Magnet Fabrication is ready to Start
  …with help from CERN on documents approval…