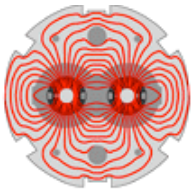


LARP

February 17th 2014

Answers to 2011 and 2012 DOE Review Recommendations for LARP

G. Apollinari, T. Markiewicz, J.D. Fox, G. Ambrosio, A. Ratti

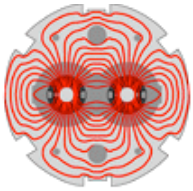
Historically, all past LARP activities have been subdivided into Accelerator System (AS), Magnet System (MS) and Management and Operations activities. Past DOE Reviews have reported and commented on each of these 3 main thrusts in 2011 and 2012.

Following the late 2012 identification of prioritized deliverables for the US contribution to the HL-LHC Project, the LARP program is being reconfigured and focusing its activities on Magnets systems, Crab Cavities system, Wide band Feedback system, a small residual of activities in Accelerator system and Management & Operations. Consequently these answers to previous DOE Review recommendations are re-arranged in terms of the new LARP priorities.

Magnet Systems

*2011 Review – Recommendation #1 on MS: The panel again **strongly** recommended that, during the coming year, in close consultation and cooperation with CERN, LARP undertake a substantial role for modeling energy deposition and radiation damage from beam losses and other collider issues related to the IR quad aperture decision.*

> There has been a lot of progress on this subject. Work was performed in collaboration with CERN, with the help of other experts (for instance Flukiger, and Weber) and dedicated workshops (WAMSDO 2013). The work was performed along these lines: thorough analysis of available data; experimental campaign under the EuCARD program. This work has shown that Tungsten absorbers centered in the midplanes of magnet aperture can keep the integrated dose for 3000 fb^{-1} as low as the dose for the present LHC low beta quadrupoles at 300 fb^{-1}. The materials presently used for LARP coil fabrication technology can withstand this level of dose with sufficient margin.



LARP

Work is in progress to assess that all auxiliary materials to be used in the MQXFs (for instance instrumentation wires and quench heaters) can withstand the expected dose with sufficient margin.

2011 Review – Recommendation #2 on MS: LARP/APUL magnet program should develop a detailed plan including budget and schedule to advise DOE on future transition to an HL-LHC construction project.

Such a plan has been developed for the Magnet System and was presented in the June 2013 Internal LARP Review. More on this point under "Management".

2011 Review – Recommendation #3 on MS: Begin integrating cryogenic and cryostat design into the magnets.

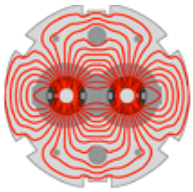
Following the 2012 DOE-LARP-CERN negotiation on possible US deliverables for the HL-LHC project, it was determined that the US would deliver quadrupole cold masses to CERN. Cryogenic and cryostat integration are a CERN responsibility. In 2012 CERN initiated the cryogenic design of the upgraded IRs and in 2013 they generated preliminary cryogenic requirements for the MQXFs (for instance, number and dimensions of the heat exchanger trough the magnet yoke) which have been taken into account in the present QXF design. Appropriate interactions with CERN will assure that the final QXF design will meet all the requirements.

2011 Review – Recommendation # 4 on MS: If possible seek qualified alternate strand vendors and improve piece length.

This task is being pursued by CERN, who is developing the PIT (Powder In Tube) conductor through the European manufacturer Bruker-EAS. The QXF cable design has been developed jointly by LARP and CERN in order to keep open the option of using the PIT conductor.

2012 Review – Recommendation #1 on MS: Seek access and/or collaboration with one or more of the venues with appropriate experimental facilities to broaden the database on radiation damage.

See answer to Recommendation #1



LARP

2012 Review – Recommendation #2 on MS: Quickly bring the effort on the 120 mm LHQ to an orderly conclusion and begin work on the 150 mm quad development.

Done. The work on the QXF (150 mm aperture quad) received the highest priority right after the review. The design of the first short model (SQXF1) is almost complete. At the end of last year (2013) we started QXF winding tests, and we are now starting the fabrication of SQXF practice coils.
The LHQ program was redirected toward risk reduction for the LQXF coils (full length QXF prototype) and reduced to 3 coils and one single coil test. The fabrication of the third coil is to be completed in February 2014 and the LHQ coil test, planned for this spring, is bringing the LHQ development to its end.

2012 Review – Recommendation #3 on MS: Produce a resource loaded schedule that establishes the path to the final production of the required number of 150 mm quadrupoles to ensure that resources are properly utilized by November 30, 2012.

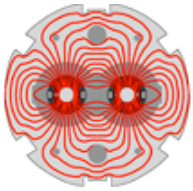
A resourced loaded schedule for the production of the required MQXF was developed and presented at the LARP internal project review (FNAL, June 2013). To paraphrase the reviewers statement in the final report (attached as addendum #1):

a. The technical feasibility of the quad program seems reasonable.
b. The costs have a decent basis in the LARP R&D program.
c. The scope is reasonable for a $200M US contribution.
d. The major uncertainties and risk appear to be programmatic in nature.

We are in the process of loading resources to the schedule for the development of the prototypes. A draft for FY14 is available and is being used to check consistence between the cost estimate through the resources loaded schedule and estimates based on past LARP experience.

2012 Review – Recommendation #4 on MS: Develop an acquisition strategy which seamlessly transitions from a research program into a construction project by November 30, 2012.

A plan for the acquisition strategy will be developed for the US-HL-LHC Project. A draft plan of the acquisition strategy including a conductor procurement plan was presented at the June 2013 LARP Internal Project Review. Interactions with CERN and all stakeholders to finalize the deliverable (single structure/ single structure with helium shell/ full cold mass with two structures and helium vessel)



LARP

are taking place. Consistency with the proposed overall LARP budget profile and plans will be checked and more details will be presented during this review.

Crab Cavity System

2011 Review – Recommendation #1 on AS: Work with the CERN-RF group to develop clear specifications and a realistic R&D plan with goals for the Crab Cavities

.

In the past two years, planning for the crab cavity was defined and clearly focused: the current goal is to deliver four fully dressed cavities (two for each US model) to be installed in a cryostat built under CERN's oversight and tested before the next long shutdown of the LHC, presently scheduled to begin in 2018. Since both US designs have demonstrated the ability to meet the requirements for transverse kick for the system (3.5 MV per cavity), we are in track to meet our commitment.

In addition, CERN has released a functional specification document for the Crab Cavities in early 2013. This contains most of the requirements for the dressed cavities needed for the SPS test and many of these apply also to the LHC.

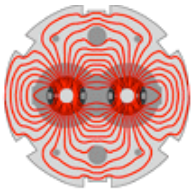
2011 Review – Recommendation #2 on AS: Prepare and submit a limited scope plan to DOE requesting potential funds to fabricate a prototype "bare" cavity conforming to specifications from the CERN crab cavity workshop.

One bare proof of principle cavity of each LARP design has been built and successfully tested to meet the requirements set in CERN's specification. In addition, the SBIR program is funding the construction of the four cavities that constitute LARP's final deliverable.

2012 Review – Recommendation # 2 on AS: Focus efforts on completing three prototype crab cavities and testing by the end of CY 2013 subject to budgetary constraints and other priorities.

The two LARP bare cavities have been completed and tested successfully in 2013. The third cavity is beyond LARP's responsibility and under development in the UK (Lancaster University and Daresbury Lab) in collaboration with CERN.

2012 Review – Recommendation #3 on AS: The plan for testing crab cavities at CERN Building SM18, the principal cryogenic test station, may not be doable. Review the current plan and modify test schedules to be more realistic.



LARP

We have been working with CERN to develop a plan to integrate all CC testing in SM18 and CERN has made significant investments in the infrastructure of that test facility to improve its capacity. The vertical tests of the US cavities have so far been performed at JLAB and BNL respectively. Plans for a horizontal test in the US go beyond the funding and resources available in the LARP program and therefore we depend on CERN's infrastructure for testing. Since the schedule for the next long shutdown (LS2) at CERN has been delayed by one year, we believe this will allow the needed time to complete the tests at CERN

Wide Band Feedback System

2012 Review – Recommendation #1 on AS: Develop a realistic plan with timeline to build a full prototype wideband feedback system for installation in SPS in 2013.

The FY13 effort brought the 4 GS/sec. demonstration channel feedback processing system to the SPS in November2012. This single-bunch demonstrator was used in a series of machine studies in November-February 2013 (the shutdown was delayed to February 2013). The results showed the system could excite multiple modes within a single bunch, and could stabilize a beam made unstable through chromaticity adjustments to the lattice. This was a significant technical accomplishment, and these machine measurements, and analysis of the achieved performance, were critical in CERN's recommendations to plan for the use of this technology for the HL-LHC upgrade.

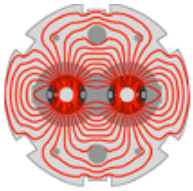
Detailed project plans, with necessary resources and timelines were developed as part of the LARP planning for a transition to a project basis with the Wideband Feedback as one of three LARP deliverables. These plans and timelines were presented at the June 2013 LARP Internal Review an at the July 2013 CERN LIU-SPS High Bandwidth Transverse Damper Review. The reviewers' comments were favorable to the project timelines and planning, which culminate in the LARP goal of a full-function instability control system for commissioning in the SPS after the LS2 shutdown and restart in 2018.

Accelerator Systems

2011 Review – Recommendation #1 on AS: Continue work on simulation of radiation damage to superconducting magnets in the LHC IR.

Already reported under Magnet System

2011 Review – Recommendation #2 on AS: Continue work on beam physics, especially beam-beam interactions



LARP

The studies of beam-beam effects within US LARP are aligned with the European HiLumi LHC Project activity. The goals of HiLumi/LARP Beam-Beam Task are

- Evaluate the HL-LHC scenarios with respect to beam-beam effects
- Provide guidance to the design team on the required tolerances and stability of key upgrade components such as the final focus triplet magnets and crab cavities.
- Analyze the LHC beam experiments with the goal to improve the understanding of beam-beam effects in the present machine and for simulation benchmarking.

Technically, the team achieves these goals using two major approaches: the single-particle tracking with weak-strong simulations, and through the development of self-consistent strong-strong simulations. US LARP personnel involved in beam-beam studies are: A. Valishev (FNAL, LARP and HiLumi LHC Task Leader), J. Qiang (LBNL), S. Paret (LBNL), S. White (BNL/Toohig Fellow).

2012 Review – Recommendation #4 on AS: Very quickly bring the effort on the on the rotatable collimator activity to an orderly conclusion. This should be done by the end of calendar 2012.

As proscribed in the July 2012 LARP DOE Review, the RC program was brought to a successful conclusion by the end of FY13. Two 60kW jaws were assembled without undue difficulty. The final full length jaws then had 20 flat facets cut to 25μm flatness. The cooling tubes were vacuum tested after each step of the operation.

For the final assembly, the main vacuum tank top and baseplate with jaw supports and bellows from the first generation prototype were reused. There were several modifications to the design to improve performance that was deemed inadequate in the first generation prototype.

Functional tests of the rotation mechanism and of the resistivity end-to-end were completed. A fixture to allow fine adjustment of the position of the rotation actuator even when the vacuum tank is welded was introduced. After final vacuum and cooling water pressure tests, the unit was air freighted to CERN. The CERN team is developing a test plan for the collimator.

LARP

Operation and Management System

2011 Review – Recommendation #1 on Management: Provide a detailed plan, including budget profile, to DOE on transition from LARP R&D into HL-LHC by February 1st, 2012. A similar recommendation was stated last year.

Between Summer 2012 and Spring 2013 a concerted effort was initiated to achieve a preliminary definition of the possible US deliverables for the HL-LHC Project. Following the definition of an "Activity Selection Process" (Appendix 2) describing a plan to down-select the US contributions to HL-LHC. The plan, based on funding assumptions of continued LARP support until the start of a construction project capped at approximately 200 M$ (at year cost), had the following milestones:

- Provide a management plan to give the process for down selecting deliverables for the LHC High Luminosity Project. **Sep. 4, 2012**
- Make the list of deliverables with fully burdened cost estimates and schedules within a total cost estimate of about $200M (at year dollars) and assuming a flat-flat LARP funding for the next four years. **November 1, 2012**
- Meet with CERN and DOE to finalize the list of U.S. deliverables and the schedule. **December 21, 2012**

All milestones have been met.

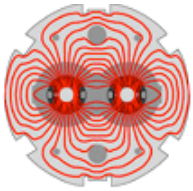
2011 Review – Recommendation #2 on Management: Provide to DOE by February 1st, 2012 a prioritized list of LARP R&D activities indicating which will be emphasized and which will be reduced.

The prioritized list of deliverables was presented to DOE by the beginning of February 2013. Appendix 3 highlights the Letter from the CERN Director General (Ralf Heuer) and the CERN Associate Director for Accelerators (Steve Myers) confirming the agreement on the prioritized list of deliverables. The list of R&D activities follows closely the preliminary list of deliverables.

2012 Review – Recommendation #1 on Management: Provide a management plan that documents the process for down-selecting deliverables for the LHC High Luminosity project by November 30th, 2012.

Achieved. See above.

2012 Review – Recommendation #2 on Management: Make the list of deliverables with fully burdened cost estimates and schedules within a total cost estimate of about 200



LARP

M$ (at year dollars) and assuming flat-flat LARP funding for the next four years by November 30th, 2012.

This task was completed and reviewed internally by LARP with DOE participation on June 2013. The timescale assumed at the time was the CERN baseline schedule, with LS3 ending by 2023. The funding plot is attached as Appendix 4. The report from the Internal Review is attached as Appendix 5. Modulo few inconsistencies in term of LARP budget flatness, the reviewers considered the deliverables, cost estimates and funding profile reasonable.
Obviously the new CERN baseline schedule, with LS3 ending by mid-2024 will require a reassessment of this point in preparation for the HL-LHC Project phase.

2012 Review – Recommendation #3 on Management: Meet with CERN and DOE to finalize the list of US deliverables and the schedule by December 21st, 2012.

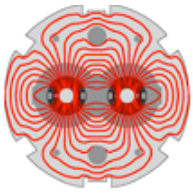
Achieved. See Appendix # 3

2012 Review – Recommendation #4 on Management: Plan the LARP budgets for the next four years to insure the R&D reduces the risk for the US deliverables by January 31st, 2013.

Achieved. LARP Plans for the FY14-FY17 periods will be presented at the next DOE Review.

2012 Review – Recommendation#5 on Management: provide a plan for transitioning from LARP R&D to a DOE Construction Project. This must include all aspects in a Project Execution Plan as noted in
http://science.energy.gov/opa/project-management/processes-and-procedures/ by April 1st, 2013.

The LARP "Project Management Plan" to transition from R&D to Construction is actively pursued by managing the activities on the prioritized deliverables with the goals of controlling scope, cost and schedule.
Elements of this plan will include convergence with CERN on finalize scope, convergence with DOE on timescale for Critical Decision (CDs) timescale, training of L2 and L3 Managers in all subjects related to DOE Project Execution such as Performance Baseline, Control Accounts, WBS Dictionary, EVMS, etc.
More on these aspects will be presented at the next DOE Review.



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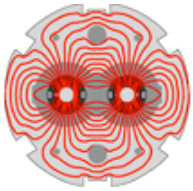


APPENDIX #1

Report from the LARP Internal Review of HL-LHC Project Contributions on June 2013.

LARP Internal Project Review
Committee Report
June 26, 2013

INTRODUCTION

The U.S. LHC Accelerator Research Program (LARP) has formulated a project plan for contributing to the LHC high luminosity upgrade in three technical areas: final focus quadrupoles, crab cavities, and a broadband feedback system for the SPS. A review of the project plan was conducted June 10, 2013, at Fermilab with the following reviewers in attendance:

Magnet Reviewers:
Mike Harrison, BNL (harrison@bnl.gov)
Jim Strait, FNAL (strait@fnal.gov), Chair

Crab Cavity Reviewers:
Mark Champion, SNS (championms@ornl.gov), Editor in Chief
Robert Laxdal, Triumf (lax@triumf.ca)
Ali Nassiri, ANL (nassiri@aps.anl.gov)

Feedback Reviewers:
Mike Brennan, BNL, (brennan@bnl.gov)
Dmitry Teytelman, Dimtel (dimtey@gmail.com)

The charge and agenda for the review are presented in Appendices 1 and 2, respectively.

RESPONSE TO CHARGE

1. Can the proposed project scope fit within the schedule and budget guidance given?

   The proposed scope appears to fit within the schedule, but only if the required budgets are funded. There is uncertainty in the schedule for the long shutdowns at CERN. This may provide schedule float in certain areas, but will present planning challenges to the project team.

2. Are the proposed cost, cost profiles and schedules reasonable?

   The proposed costs, profiles, and schedules are reasonable at this early stage of the project.

3. Is the plan to integrate external contributions within the constraint of a fixed budget adequate?

   External contributions are foreseen from several sources including: General Accelerator R&D (GARD) program, SBIR program, U.K. Science and Technology Facilities Council (STFC), and possibly CERN. These funding streams are uncertain at best and introduce significant risk to the project. It will be necessary to closely monitor the activities supported by external contributions. Project contingency will be needed to mitigate the risks.

4. Is the technical plan proposed by each sub-project optimally developed? Are there additional technical risks that should be considered?

   The technical plans are reasonable and will mature as the project progresses. The technical risks appear to be understood. A few specific points are discussed in the following Comments section.

5. Is the proposed management structure appropriate for the scope and scale of the project?

   The management structure is appropriate at this time. It will need to evolve as the project proceeds and becomes more formal. The recent update to the org chart is an improvement.

6. Are there additional comments the Committee feels are relevant, regarding either individual tasks or the project as a whole?

   The project needs clear guidance from DOE regarding scope, schedule, and funding.

   Numerous programmatic and technical issues are addressed in the following Comments section.

COMMENTS

Magnets

1. The magnet program follows fairly directly from the multi-year LARP Nb3Sn R&D program.

2. The LARP R&D program has achieved the LHC technical final focus quad requirements in a proof-of-principle sense. LARP R&D achieved its goals – well done magnet guys.

3. Cost estimate for twenty 4m cold masses is $140M + contingency. This is based on LARP actuals for both manpower and materials.

4. Obligation profiles are based on a schedule that is consistent with the strawman LHC operating schedule. DOE has given no funding guidance to compare with the obligation profile.

5. The LHC High Luminosity schedule is neither completely determined nor completely funded, thus there remains some uncertainty in the U.S. picture. However – taken at face value – there is a need for significant FY15 funding for to start magnet production. A softer start might be more realistic.

6. Some kind of formal CERN request for the U.S. magnet deliverables will be needed soon.

7. The cable looks okay, but it would help if CERN uses the same superconductor as the U.S. for the quadrupoles that they would build.

8. It appears that the Nb3Sn upgrade solution is the last man standing. We need to be very sure it will work. Some form of technical review with CERN could "formalize" the buy in. What does "accelerator quality" mean?

9. However:
    a. There is a curious mix of on-project and off-project funding. There is some reliance on GARD funding that is neither specified nor guaranteed.
    b. Prototype program uses scope contingency. Can this be used to save money rather than "it will not exceed" ? For example, the goal should be to make the prototype sufficiently good that it can become one of the production magnets.
    c. Final LHC upgrade TDR will not be available until 2016 – parameters risk?
    d. Beware scope creep, e.g. 11T dipoles.

10. Thus:
    a. The technical feasibility of the quad program seems reasonable.
    b. The costs have a decent basis in the LARP R&D program.
    c. The scope is reasonable for a $200M US contribution.
    d. The major uncertainties and risk appear to be programmatic in nature.

Crab Cavities

1. The proposed scope appears to fit within the schedule, but only if the required budgets are forthcoming. It will be challenging to meet the 2015 schedule for the prototype cryomodule, and it's likely the schedule contingency of up to one year will be needed.

2. The down selection on the cavity choice drives the schedule and should be made as soon as possible.

3. Costs & cost profiles: these are not unreasonable at this point in the project.

4. LARP funding, CERN schedule, GARD funding & priorities, and SBIR performance are all external risk elements. They have been considered. Uncertainty on how to mitigate them remains. It will be important to closely monitor and - where possible - guide these elements to ensure success.

5. The SPS test should be viewed as a technical test not just a beam test. A set of technical risks for the final LHC installation should be developed and the SPS test should be optimized with the goal to retire as many of the most challenging risks as possible:
    a. Consider incorporating one vertically deflecting and one horizontal deflecting cavity.
    b. Consider extra CM diagnostics and cavity diagnostics to investigate beam/cavity interactions.
    c. Can SPS beam modes be modified to replicate certain LHC beam conditions?

6. The bare cavity prototyping is well advanced. The ODU RF dipole had an outstanding first test while the DQWR requires further processing and retesting.

7. Conceptual thinking about the helium jacket design is progressing for both approaches and SLAC is involved with multipacting and HOM mitigation techniques. Further work for optimizing both designs is required in terms of HOM dampers and multipacting mitigation.

8. A plan for a final cavity down select process should be developed. The overall cryomodule design schedule should be included in the analysis.

9. The management structure is appropriate at this time. It will need to evolve as the project proceeds and becomes more "projectized." The recent update to the org chart is an improvement.

10. It is desirable that CERN and DOE come to agreement regarding the scope, schedule, and funding for the LARP program.

11. The project needs clear guidance from DOE regarding scope, schedule, and funding.

12. Exactly how things will proceed with the UK team is unclear. There is a risk of inefficiency. Parallel developments of two different solutions may not be affordable.

Feedback System

1. The R&D has shown significant progress in the last year, with a successful test of the single-bunch prototype in the SPS.

2. There is reasonable confidence that an extension of the demonstrated approach will fulfill the requirements of damping high frequency instabilities in the SPS. The general approach can be extended to solving similar problems in the LHC and PS.

3. Presented schedule estimates are optimistic and have minimal headroom to react to additional budget pressures.

4. To meet LS2 schedule for installation into the SPS, the engineering effort must clearly pivot from development mode to production mode by 2017.

5. We feel that proposed manpower allocations may be underestimated. To appropriately amortize the engineering work done in the research phase of the project (through 2016), there has to be continuity in engineering manpower.

6. To reduce external risk associated with the extent of CERN's commitment to make local expertise available to assist and participate in commissioning, a more formal statement from CERN is needed.

7. The project risks losing momentum if LS2 dates slide.

8. Kicker design is still in relatively early stage and several significant issues remain to be investigated and addressed, such as handling beam-induced power and ultra-high vacuum requirements.

9. We suggest exploring collaboration with RHIC, which has similar instabilities for which it is pursuing feedback damping.

10. Installation of a prototype wideband kicker in the SPS before the end of LS1 is critical.

Charge to the Review Committee for the Proposed LARP Project Scope and Plans

The US LHC Accelerator Research Program (LARP) has been a very successful R&D program to coordinate US involvement in the LHC accelerator and injector chain. Recently, the LARP organization has been charged by the DOE OHEP to develop a plan to provide significant US contributions to the LHC high luminosity upgrade constrained by a fixed budget. Based on the level of maturity of the R&D, a cost and schedule estimate developed by proponents, and CERN's preferences, a plan[i] which proposes contributions in three distinct areas of accelerator technology has been formulated. The schedule of milestones and deliverables is set by CERN's schedule of long shutdowns, the last of which is currently scheduled to take place during 2022 and 2023. While the DOE's formal project approval and funding process is scheduled to start in 2017, the need to develop a pre-project funding profile, using the base LARP budget and drawing on enhanced contributions from the General Accelerator R&D base program, makes it imperative that the plan be scrutinized by external experts as soon as possible.

The project review committee is charged to answer the following questions:

1. Can the proposed project scope fit within the schedule and budget guidance given?
2. Are the proposed cost, cost profiles and schedules reasonable?
3. Is the plan to integrate external contributions within the constraint of a fixed budget adequate?
4. Is the technical plan proposed by each sub-project optimally developed? Are there additional technical risks that should be considered?
5. Is the proposed management structure appropriate for the scope and scale of the project?
6. Are there additional comments the Committee feels are relevant, regarding either individual tasks or the project as a whole?

I would appreciate the Committee's answers to these questions submitted to me as a written report within three weeks following the review.

Thank You,

Eric Prebys
Program Director, LARP

[i] Proposed US Contributions to LHC High Luminosity Upgrade; *Eric Prebys, Oliver Brüning, John Fox, Marc Kaducak, Tom Markiewicz, Alex Ratti, Lucio Rossi, GianLuca Sabbi, Peter Wanderer; 12/20/2012.*

Appendix 2

LARP Internal Project Review

Monday, June 10, 2013 from **08:00** to **18:00** (US/Central)
at **Fermilab**

Description Internal Review of proposed scope of US contributions to the LHC high luminosity upgrade.
Material: Charge (REVISED) | Proposed Scope (Draft)

Monday, June 10, 2013

08:00 - 08:30 Executive Session (closed)
Location: Race Track (WH7XO)

08:30 - 10:00 Opening Plenary Talks
Location: Race Track (WH7XO)

08:30 **Project Overview** *30'*
Speaker: Dr. Eric Prebys (Fermilab)
Material: Slides

09:00 **CERN Plan and Support** *30'*
Speaker: Prof. Lucio Rossi (CERN)
Material: Slides

09:30 **DOE Funding Plan** *30'*
Speaker: Dr. Michael Procario (Department of Energy)

10:00 - 10:30 Coffee

10:30 - 12:30 Magnet Session
Location: Race Track (WH7XO)
Material: Remote connection information

10:30 **Magnet project overview** *20'*
Speaker: GianLuca Sabbi (LBNL)
Material: Slides

10:50 **Prototype development** *20'*
Speaker: Giorgio Ambrosio (FNAL TD/MSD)
Material: Slides

11:10 **Quadrupole production** *20'*
Speaker: Mr. michael anerella (BNL)
Material: Slides

11:30 **Conductor acquisition plan** *20'*
Speaker: Dr. Arup Ghosh (Brookhaven National Laboratory)
Material: Slides

11:50 **Cost and schedule** *20'*
Speaker: Marc Kaducak (Fermilab)
Material: Slides

12:10 **Questions/discussion** *20'*

Crab Cavity Session
Location: Fish Tank (WH13XO)

10:30 **Crab Cavity Project Overview** *15'*
Speaker: Alessandro Ratti (LBNL)
Material: Slides

10:45 **RF Design and Modeling** *20'*
Speaker: Zenghai Li (SLAC)
Material: Slides

11:05 **DQW Design and Plans** *20'*

Speaker: Dr. Sergey Belomestnykh (Brookhaven National Laboratory)
Material: Slides

11:25 **RFD Design and Plans** *20'*
Speaker: Prof. Jean Delayen (Old Dominion University)
Material: Slides

11:45 **Cryomodule Design and Integration** *20'*
Speaker: Tom Peterson (Fermilab)
Material: Slides

12:05 **Plans, budget and schedule** *20'*
Speaker: Alessandro Ratti (LBNL)
Material: Slides

10:30 - 12:30 Feedback Session
Location: Conjectorium (WH3NE)

10:30 **Overview and Proposal goals** *30'*
Speaker: John Fox (SLAC)
Material: Slides

11:00 **Wideband Kicker Development and Plan** *10'*
Speaker: John Cesaratto (SLAC)
Material: Slides

11:10 **CERN Contributions and Interests** *10'*
Speaker: Dr. Wolfgang HOFLE (CERN)
Material: Slides

11:20 **Detailed Cost breakout and timeline** *20'*
Speaker: John Fox (SLAC)

11:40 **Discussions with reviewers** *50'*

12:30 - 13:30 Working Lunch (Race Track)

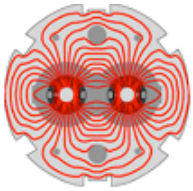
13:30 - 14:00 Budget and Management Summary
Location: Race Track (WH7XO)

13:30 **Budget and Schedule Overview** *30'*
Speakers: Dr. Eric Prebys (Fermilab), Marc Kaducak (Fermilab)
Material: Slides

14:00 - 15:30 Writing Session (closed)

15:30 - 16:00 Closeout
Material: Crab Cavity Closeout Slides | Feedback Closeout Slides | Magnet Closeout Slides

10:30 - 12:30



LARP

APPENDIX #2

Draft document describing the Scope Selection Process for US Contributions to the LHC Luminosity Upgrade.

Scope Selection Process for US Contributions to the LHC Luminosity Upgrade

Eric Prebys, Tom Markiewicz, Marc Kaducak, GianLuca Sabbi, Stuart Henderson

Introduction

The United States has played and will continue to play a large role in the Large Hadron Collider. In addition to the major role that US groups play on the LHC experiments, the US has also contributed significantly to the accelerator itself. This began with the construction of the final focusing triplets and feedboxes, and has continued through a number smaller construction and R&D projects over the years since. Starting in 2004, much of the work has been managed by the US LHC Accelerator Research Program (LARP)[i], but there have been some projects organized through bilateral agreements between CERN and individual US labs.

At the direction of the DOE, LARP has been charged with generating a plan for a set of fairly large-scale deliverables from the US to the LHC luminosity upgrade, currently scheduled for roughly 2022. The total cost is to be $200M, with full production (CD-3) commencing in 2017.

At the annual review of the LARP program in July of 2012[ii], we presented a list of potential contributions to the LHC[iii]. All of them would be useful to the LHC, and there is interest at US labs in pursuing them; however, the total cost would be at least a factor of two more than the allowed budget. Therefore, there will need to be a down selection of the candidate projects, as well as possible scope reductions in individual projects.

The review recommendations set forth a timetable to select a list of projects and provide a fully resource-loaded schedule. They have asked to be provided with a formal plan for doing so by September 4th, 2012, and this document summarizes that plan. It will include our time line to meet the other milestones set forth in both the Magnet Studies and Management sections of the review.

As part of the overall preparation to produce large scale deliverables, a new structure for LARP itself and its oversight and advisory committees is being developed. Our goal is to integrate the activities described in this document into that structure, but the exact details of how that will be done are still under discussion.

LHC Luminosity Upgrade Design Study and Schedule

It's important to formulate US plans in the context of the overall upgrade plans for the LHC. Toward this end, LARP has been integrating its activities into the HL-LHC design study[iv] currently going on at CERN

and in the rest of Europe. The goal of the design study is to produce a technical design report in 2015 for a set of upgrades which will increase the luminosity of the LHC to a *leveled* luminosity of $5x10^{34}$ $cm^{-2}s^{-1}$. The upgrades will take place during what is currently referred to as "Long Shutdown 3" (LS3), scheduled to begin in approximately 2022. The details of these upgrades are still being finalized, but there is general agreement about many of the elements that the plan will contain, and those that present opportunities for US contributions include:

- New focusing quadrupoles, based on Nb_3Sn technology, that will provide a reduced β^* at the interaction point.
- Crab cavities, to compensate for the effect of the crossing angle. This effect is small now, but will become more pronounced with a smaller β^*. Crab cavities will also provide a straightforward way to level the luminosity.
- Enhanced collimation, to protect the LHC from increased beam intensity.
- New, larger aperture separator dipoles near the interaction points, to accommodate larger beams.
- Feedback systems to control instabilities, both in the LHC and SPS.

These upgrades form the basis for this discussion.

Candidate Deliverables

In this section, we will briefly describe the candidate deliverables which were presented at the July review. We will include the costs as presented, with the understanding that they are for scale only, and should not be directly compared.

Six potential projects were discussed:

- **Final Focus Quadrupoles Based on Nb_3Sn Superconductor.** The R&D leading to these magnets has been the cornerstone of LARP since the beginning. We are nominally proposing to build half of the required cold masses for a cost of approximately $140M. Contact persons: GianLuca Sabbi, Giorgio Ambrosio, and Peter Wanderer.
- **Crab Cavities.** LARP was an early proponent of crab cavities, and there is hope that the US can build at least some of the cavities required by the LHC. The cost to build all of the cavities has been estimated to be about $90M over and above the R&D already planned for LARP. Contact persons: Alex Ratti, Rama Calaga[1].
- **11 Tesla Dipoles**. These magnets would be used to free up space in the LHC for collimation, because the high field would allow them to provide the same integrated bend field as one of the existing NbTi magnets with a shorter Nb_3Sn magnet. Up until now, this project has taken place at Fermilab outside of LARP, but it leverages LARP R&D into Nb_3Sn quadrupoles. The cost to

[1] Rama Calaga was the original head of the crab cavity program within LARP, but he is now a CERN employee. Alex Ratti has taken over, but on this time scale we expect Rama to continue to play an important role.

produce all the magnets for the maximum collimation configuration has been estimated to be about $73M. Contact person: Alexander Zlobin.

- **D2 Separator Magnets**. The D2 magnets are the first twin aperture magnets on each side of the interaction region. As part of the luminosity upgrade, the existing D2 magnets would be replaced with larger aperture versions, still based on NbTi. This project has been proposed at Brookhaven, outside of LARP. This leverages BNL experience with the original separator magnets as well as with the RHIC dipoles. The cost is on the order of $20M. Contact persons: Peter Wanderer, David Lissauer.
- **High Bandwidth Feedback for the SPS.** This is a project to produce a feedback system for the SPS to combat electron cloud and other instabilities. It has grown out of LARP R&D and the cost is on the order of $9M, some of which would be covered by existing LARP funds. Contact person: John Fox.
- **Collimation.** LARP R&D which could *potentially* lead to deliverables includes:
    - The rotatable collimator that has been developed for the last several years by LARP.
    - A beam scraper system using hollow electron beams, a project which was pioneered by LARP, based on studied of electron lenses for beam-beam compensation.
    - Crystal collimators as a replacement for the primary collimators, based on LARP R&D.

  Unfortunately, the LHC will not finalize its collimation plans until after the collimation review in 2013 and possibly not until after the beam comes back on in 2014, so it would be impossible to develop a formal collimation proposal on the time scale mandated by the DOE. *We will therefore not consider a collimation component for the project.* There is, however the possibility that collimation could be added later as part of a scope change.

Funding Assumptions

We have been instructed to plan for flat-flat LARP funding ($12,390k/year) for the next four years; that is, FY13 through FY16, and a total of $200M to fund US contributions to the CERN LHC Hi-Lumi project, based on achieving CD-3 in FY17.

We are going to work under the assumption that, if required, some of the $200M could be allocated prior to FY17, based on an earlier CD-3a approval. One example might be the purchase of superconductor for the Nb_3Sn magnets.

The DOE has also mandated that an as yet unspecified amount of General Accelerator Development (GAD) funds be allocated for this effort, and such funds will certainly be necessary. Determining the specific amounts and profile for GAD support will be an important part of planning.

We feel that there is a good case to continue LARP funding at some level even after the formal project begins. We will need clarification of whether these continued R&D funds will need to be provided by the project or through some extension of the existing LARP program.

Selection Process

It was clear at the review that one of the major issues was that the various candidate projects are in very different states of planning, as far as cost and scheduling are concerned. The first step in the down selection process will therefore be to normalize the estimation process so that the projects can be compared directly.

We have identified project personnel to work with the contact persons for each project, with the goal of bringing them to an acceptable state of planning for the down selection process. This will include, at the very least, consistent treatment of:

- Material and Personnel costs
- Overhead
- Contingency
- Escalation
- Bases of estimation (BoEs)
- Programmatic assumptions such as funding and critical decision schedule

Support personnel will need to be well versed in standard tools and methodology associated with large projects. Project support will serve in advisory and assistance role and play no direct part in the down-selection process.

Concurrently, we will form a down selection committee, consisting of:

- LARP program director (chair)
- LARP L2 managers
- One to two CERN representatives
    - To be agreed upon by the LARP Director and the head of the HiLumi LHC project

In addition, the following will serve in an advisory role:

- The Chair of the LARP Laboratory Oversight Group (LOG), who will act as a liaison to the member labs. A particular responsibility of this person will be information regarding the use of GAD funds toward the project goals.
- The DOE Program Manager for LARP, or his designee.

Other personnel from the US labs and CERN will be brought in as needed to advise the committee.

The job of this committee would be to determine the final list of projects and deliverables and to guide the process of generating a CD-0 level cost and schedule. It is envisioned that this committee, or some version of it, will maintain a permanent role as the project evolves.

The selection of deliverables will involve iteration and negotiation. Factors that will be considered will include:

- Impact on integrated LHC luminosity

- Application of unique US expertise
- Benefit to US facilities
- Likelihood that the candidate deliverables would be successfully completed.
- Risk that the candidate deliverables would not be included in the final upgrade design.

Schedule

In establishing the schedule for this process, we start with the recommendations given at the July review. The following recommendations were made for the Magnet Systems program[v]:

1. Abandon the effort on the 120 mm LHQ and begin work on the 150 mm quad development.
2. Produce a resource loaded schedule that establishes the path to the final production of the required number of 150 mm quadrupoles to ensure that resources are properly utilized, by **September 4, 2012**.
3. Develop an acquisition strategy which seamlessly transitions from the research program into a construction project, by **November 1, 2012**.

The first is being addressed with a new magnet plan, currently under review. The second two are specific milestones, which we intend to merge with the milestones recommended for Management at the review[vi]. The first three of those were:

1. Provide a management plan to give the process for down selecting deliverables for the LHC High Luminosity Project. **Sep. 4, 2012**

2. Make the list of deliverables with fully burdened cost estimates and schedules within a total cost estimate of about $200M (at year dollars) and assuming a flat-flat LARP funding for the next four years. **November 1, 2012**

3. Meet with CERN and DOE to finalize the list of U.S. deliverables and the schedule. **December 21, 2012**

While we consider it axiomatic that the magnet production will be the central part of the proposal, the exact scale of the US production is still under discussion, and will have to be decided in the context of the overall US program. Thus, we cannot see a path for satisfying the Magnet Systems recommendations separately and in advance of the overall planning schedule, as implied by the schedules given above. We therefore make the following proposal for combined milestones.

1. **September 4, 2012:** Submit[vii] this plan.
   [Following submission of the plan, our project support team would work with the contact persons to refine their cost estimates. The down selection committee would meet to establish the relative overall priority of the sub-projects].

2. **November 1, 2012:** Submit a prioritized list of candidate projects with consistent methodology for cost, schedule, and scalability (if applicable). This list would also include details for each project regarding what funds, if any, would be required over and above the LARP funding prior to FY17. Note that at this point, the total cost would certainly still well exceed $200M.
   [At this point, the down selection committee would begin meeting in earnest to reduce the scope to fit within the $200M. This reduction would include de-scoping individual projects and almost certainly eliminating some projects entirely.]
3. **December 21, 2012:** Submit a preliminary proposal for a list of US deliverables to the LHC which will fit within the mandated cost. This proposal will include the schedule for the milestones of a Project Execution Plan (PEP), in accordance with DOE Order 413.3B.

In this version, the original milestones for the Magnet Systems have effectively been shifted, with the original September 4th milestone combined with the new November 1st milestone with the November 1st Magnet Systems milestone becoming part of the December 21st proposal. We stop short of referring to this as a CD-0 proposal, as we feel it will not be up to that standard on this time scale. We also feel that it's premature to set deadlines beyond the December 21st deadline at this point, instead leaving them for the committee to establish.

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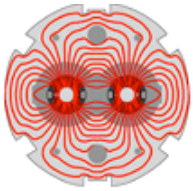
[i] http://www.uslarp.org/
[ii] 2012 DOE LARP Review, https://indico.fnal.gov/conferenceDisplay.py?confId=5409
[iii] LARP-DOC-1068, http://larpdocs.fnal.gov//LARP-public/DocDB/ShowDocument?docid=1068
[iv] HL-LHC: High Luminosity Large Hadron Collider,
http://hilumilhc.web.cern.ch/HiLumiLHC/index.html
[v] "LARP DOE Review Closeout", slide 19,
https://indico.fnal.gov/getFile.py/access?sessionId=0&resId=0&materialId=1&confId=5409
[vi] *ibid.*,slide 24
[vii] In all cases, the submission will be to:

- Stuart Henderson, Fermilab Associate Director for Accelerators
- Bruce Strauss, LARP DOE Program Manger for LARP
- Lucio Rossi, HL-LHC Project Manager and CERN Liaison to LARP for Magnet Systems
- Oliver Bruning, HL-LHC Deputy Project Manager and CERN liaison to LARP for Accelerator Systems.
- Steve Meyers, CERN Associate Director for Accelerators



LARP

APPENDIX #3

Letter from CERN Management Dr. Rolf Heuer – Director General and Dr. Steve Meyers – Director of Accelerators and Technology to Dr. James Siegrist – Associate Director for High Energy Physics, Office of Science, US DOE with concurrence on LARP down-selection process.

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Office of Science
U.S. Department of Energy
1000 Independence Avenue, S.W.
Washington, DC 20585-1290
USA

Our reference : DG/2012-355

Geneva, 19 December 2012

Dear Prof. Siegrist,

Following recent discussions, CERN is assuming that the total US contribution to the Hi-Lumi project is of the order of US$200 million (construction project, excluding the R&D carried out within the LARP program that is due to continue for another 3-4 years in order to finish the R&D on the hardware and to continue the support for the important activities of accelerator physics and the long term visitor program).

The principle item of this contribution would be the Nb3Sn low-beta triplet. We understand that a preliminary evaluation of the quadrupoles (with 150 mm aperture) based on a joint study by LARP and CERN amounts to about 75% of the total US contribution, or US$150 million, for half of the magnets (i.e. 10 cold mass quadrupoles, without cryostat, with no integration nor installation). This proposal (half USA and half CERN) is the preferred solution not only to stay inside budget but it also leverages the advanced US technology (LARP) and would allow CERN to fully master the technology for future maintenance and consolidation. Mutual agreement on this proposal can be discussed at a later date.

CERN proposes that the remaining 25%, or US $50 million, be used to support hardware contributions on the following items (either full or part system):

a. High bandwidth feed-back system for the SPS/Crab cavity with a cryo-module
b. 11 T dipole (cold mass no cryostat)/electron-lenses

The feed-back system is of course subject to the success of the final prototype, like the Nb3Sn quadrupoles. Its cost is rather modest compare to the other items, so this could possibly leave some margin for other significant and visible contributions. The other items are not yet fully defined and/or their actual installation in the HL-LHC machine is not yet approved pending development of a final design and validation test results. So our suggestion is to keep the above list as a prioritized list to be reviewed depending on the outcome of the tests.

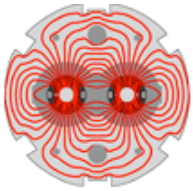
CERN would also like to express its gratitude if the DoE would support the continuation of the design of the D2 magnet based on the extensive expertise of BNL.

We remain at your disposal for any further information or clarifications.

Yours sincerely,

Rolf Heuer
Director-General

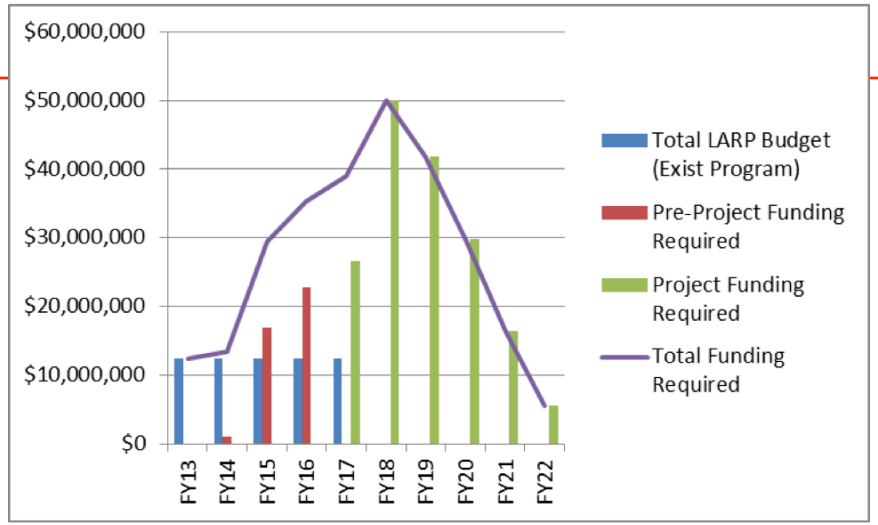
Stephen Myers
Director of Accelerators and Technology



APPENDIX #4

LARP and US-HL-LHC Project funding profile needs as of June 2013.

Funding



Totals											
w/Distributed Contingency	**FY13**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**FY19**	**FY20**	**FY21**	**FY22**	**Total**
Existing LARP Management	$900,000	$900,000	$900,000	$900,000	$900,000	$0	$0	$0	$0	$0	$4,500,000
IR Quad Prototypes	$5,428,000	$6,674,495	$10,787,491	$6,128,707	$2,092,806	$432,039	$0	$0	$0	$0	$31,543,537
Crab Cavity Prototype	$797,492	$1,200,000	$2,298,266	$187,697	$0	$0	$0	$0	$0	$0	$4,483,455
Feedback System Des/Dev	$1,317,124	$1,409,219	$1,772,012	$1,711,097	$0	$0	$0	$0	$0	$0	$6,209,452
Add'l Mgmt for Construction	$0	$302,287	$991,260	$1,300,231	$1,678,290	$2,075,913	$2,132,028	$2,189,578	$2,248,830	$2,152,449	$15,070,867
IR Quad Construction	$0	$0	$9,445,813	$18,642,867	$25,211,021	$29,682,904	$26,944,355	$19,340,937	$10,411,064	$1,043,069	$140,722,029
Crab Cavity Construction	$0	$0	$195,681	$3,386,538	$3,831,668	$15,353,475	$11,615,261	$8,190,661	$3,800,762	$2,342,882	$48,716,928
Feedback System Construction	$0	$0	$0	$0	$2,330,342	$2,536,272	$1,199,412	$0	$0	$0	$6,066,027
Totals	**$8,442,617**	**$10,486,001**	**$26,390,523**	**$32,257,136**	**$36,044,127**	**$50,080,604**	**$41,891,056**	**$29,721,175**	**$16,460,656**	**$5,538,400**	**$257,312,295**
US-LARP Budget											
LARP Budget for Projects	**$9,400,000**	**$9,400,000**	**$9,400,000**	**$9,400,000**	**$9,400,000**						**$47,000,000**
Other LARP Budget: **-General Accelerator R&D** **-Toohig and Long Term Visitors** **-Programmatic Travel**	**$3,000,000**	**$3,000,000**	**$3,000,000**	**$3,000,000**	**$3,000,000**						**$15,000,000**
Total LARP Budget (Exist Program	**$12,400,000**	**$12,400,000**	**$12,400,000**	**$12,400,000**	**$12,400,000**						**$62,000,000**
Pre-Project Funding Required	**$0**	**$1,086,001**	**$16,990,523**	**$22,857,136**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$40,933,660**
Project Funding Required	**$0**	**$0**	**$0**	**$0**	**$26,644,127**	**$50,080,604**	**$41,891,056**	**$29,721,175**	**$16,460,656**	**$5,538,400**	**$170,336,019**
Total Funding Required	**$12,400,000**	**$13,486,001**	**$29,390,523**	**$35,257,136**	**$39,044,127**	**$50,080,604**	**$41,891,056**	**$29,721,175**	**$16,460,656**	**$5,538,400**	**$273,269,679**