Office of High Energy Physics

Report on the

LHC Accelerator Research Program (LARP) Review

July 9-11, 2012

SLAC National Accelerator Laboratory

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U.S. LHC Accelerator Research Program

Executive Summary

The review panel was generally pleased with the technical accomplishments and the coordination among the member laboratories on the research and developments within LARP. In particular are the results and the quality of work performed under the LARP program—the Accelerator Systems (AS) has delivered instrumentation to the LHC that has been instrumental in optimizing operations including the AC dipole, synchrotron light monitors, Schottky monitors, luminosity monitors and the tune tracker. The Magnet Systems (MS) effort continues to mature the technology for construction of Nb_3Sn based quadrupoles including conductor design and successful transition to the long quadrupole (LQ) prototype. LARP management has continued to keep the participating national laboratories working together cooperatively. Final testing and results from the 120 mm LHQ prototype are expected shortly.

As in previous years the committee found that LARP has made significant contributions to the continued commissioning and operations that have ensured the success achieved by the LHC. CERN has expressed their appreciation for these contributions. The Long Term Visitor and Toohig Fellows programs are viewed by CERN to be very attractive, successful and beneficial to both the U.S. and CERN programs. The Toohig program in particular has given the U.S. program a succession of some of the brightest new accelerator scientists and technologists. Many of the LARP activities have significant application to present and future accelerator R&D confronting U.S. accelerators.

The Chamonix meetings of the past three years have redirected the course of the LHC accelerator improvements for the coming decade that will require strategic planning for directed LARP activities. As a result of these meetings CERN is planning three shut downs of the LHC. The first will occur in the 2013 to 2014 time frame and will entail the examination of all of the magnet to magnet superconductor splices in the LHC. The second will occur in the 2017 to 2018 time frame to include bringing the luminosity to its nominal specification. The third shut down expected to occur in the 2020 to 2022 time frame will replace the interaction region magnets and collimators in order to achieve an order of magnitude increase in luminosity. It is for this last shutdown that LARP activities are targeted.

The LARP accelerator science program has delivered instrumentation to CERN as noted above. Detailed studies continue on radiation damage, beam-beam effects and electron cloud instabilities. Work on low level RF control was favorably commented upon.

With respect to management issues the committee found that LARP had not delivered results with respect to recommendations of the last two reviews. Specifically that LARP "Provide a detailed plan, including budget profile, to DOE on transitioning from LARP R&D to High Luminosity (HL-LHC) preparations by February 1, 2012."

The sense of the whole review committee might be summed up in the following quote from one of the reviewers' letters: "The technical ability of the magnet group is outstanding, although it tends to be a little unsure of itself in regards to using that expertise to skip steps. This may be more directed to management than the magnet program itself, but some risk taking is required to keep flexibility. One hopes that they have the foresight to grasp opportunity—converting research into construction—and move smoothly along this path."

The committee listed a number of recommendations for LARP. The key management recommendations are:

1. Provide a management plan that documents the process for down selecting deliverables for the LHC High Luminosity Project by November 30, 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 by November 30, 2012.
3. Meet with CERN and DOE to finalize the list of U.S. deliverables and the schedule by December 21, 2012.
4. Plan the LARP budgets for the next four years to insure the R&D reduces the risks for the U.S. deliverables by January 31, 2013.
5. Provide a plan for transitioning from LARP R&D to a DOE Construction Project. This must include all the aspects in a Project Execution Plan as noted in http://science.energy.gov/opa/project-management/processes-and-procedures/ by April 1, 2013.

Introduction

The 27 kilometer Large Hadron Collider (LHC) at the European Laboratory for Particle Physics (CERN) near Geneva, Switzerland has been operating at the world's highest collision energies for the past year. Almost concurrently with this review CERN announced the 5σ appearance of a new particle that has tentatively been identified as the Higgs Boson. CERN is a unique facility for basic research in high energy physics to probe the structure of matter and the underlying symmetries in the universe through controlled proton-proton collisions. The United States has contributed to the LHC construction with in-kind contributions for the final focusing at the interaction regions of the collider rings.

To maximize the science exploitation from its major investment in the technology and science of particle accelerators, the U.S. initiated the LHC Accelerator Research Program (LARP) to develop the tools and technology for improving the performance of this machine. This also serves to maintain U.S. core competency in accelerator technology in the areas of super-conducting magnet design and engineering as well as accelerator physics, commissioning and instrumentation. The R&D projects undertaken by LARP are expected to be consistent with the plans envisioned by CERN for the improvement program at the LHC.

The annual program review of LARP was held on July 9–11, 2012 at the SLAC National Accelerator Laboratory (SLAC) by the Office of High Energy Physics (OHEP). The charge for the review was given in a memorandum from Michael Procario to Bruce Strauss on March 27, 2012 (attached as Appendix A). The review covered issues pertaining to the management of the program, various accelerator R&D activities, operation of components of the LHC hardware and beam instrumentation delivered by LARP for the accelerator as well as the development of Nb_3Sn superconducting magnets (see the agenda in Appendix B). The members of the review panel are included in Appendix C. The reviewers were asked to evaluate a number of issues that are listed at the end of this section.

Lucio Rossi of CERN presented an informative talk regarding the status of CERN thinking of the upgrade. Notable in his talk was the fact that a Joint Task Force after almost a year of discussions has now decided that the quadrupole magnets will have an aperture of 150 mm, an increase from the 120 mm previous design. CERN is also committed to luminosity leveling within a fill of the high luminosity LHC (HL-LHC) with the instantaneous luminosity staying below $5x10^{34}cm^{-2}s^{-1}$. While this could be achieved by using crab cavities there is a worry that a crab cavity might fail which could cause a beam to deviate from the orbit with possible damaging results. CERN is studying how to achieve luminosity leveling without crab cavities such as using beam manipulations.

Presentations made by LARP participants can be found at the LARP review webpage: https://indico.fnal.gov/conferenceDisplay.py?confId=5409. At the review, the panel questioned

the speakers during their presentations and discussed their observations in executive sessions in the presence of DOE representatives Michael Procario and Bruce Straus. Members of the panel provided both oral and written preliminary findings to LARP management at a close-out session at the end of the review. This report reflects the final conclusions of the individual panel members proffered in written evaluations sent subsequently to Dr. Procario.

The discussion in the remainder of this document, based on the written reports of the consultants and presentations made by LARP management, provides additional information on the views and recommendations offered by the committee of experts.

Answers to Specific Questions in the Review Charge

Answers to the charge questions:

The effectiveness in strategic planning, development of appropriate core competencies, implementing a prioritized and optimized program participating in future accelerator upgrades at the LHC at CERN; specifically are these LARP activities well aligned with the present and anticipated LHC schedule:

The strategic planning needs improvement. There are strong core competencies, but the committee was not told how they are being developed. There has been almost no prioritization or optimization. However, most of the work is well aligned with the LHC needs. An exception to this seems to be some of the collimator work, which has stretched out in schedule and does not appear to be something in which CERN is interested.

The quality and significance of the LARP scientific and technical accomplishments, and the merit, feasibility and impact of its planned research program;

The quality and significance of the LARP scientific and technical accomplishments is excellent. The planned research program needs to be structured so that its impact will lead to a successful construction project where the risks have been minimized due to the performance of the necessary R&D.

The effectiveness and appropriateness of the laboratory interactions to maximize the leveraging of existing infrastructure and expertise available at those laboratories;

The committee did not hear this information being presented. However, the committee found that all the labs are providing infrastructure and expertise which is effective and appropriate. However, they could not measure how much leveraging there is.

The strength and relevance of any new proposed research activities, to enable OHEP to make more fully informed decisions on this new scope of work.

The committee did not hear any new proposed research activities. The committee believes there are too many topics being pursued in LARP right now and some prioritization is needed.

Magnet Systems

Introduction

The review once again illustrated the remarkable progress achieved by the three laboratories participating in the Magnet Systems program. The net result is that target gradients, stress tests, cycling and the like have been achieved in a mix of quadrupole magnets.

While the Magnet Systems, representing approximately one half of the program, has most emphatically demonstrated the viability of niobium-tin superconductor as a technological material for magnet construction and thus suitable for an upgrade to the LHC, the strategic planning required to transform the LARP program (R = research) into a construction project has lacked attention.

There appears to be gap between what the ultimate LARP customer, CERN, wants and the direction in which the magnet development is going. The 120 mm LHQ does not have a place in the requirements, but significant effort is directed towards it, and it is the major task on the magnet development team's plate.

Energy Deposition

Findings

Energy deposition studies for the LHC luminosity upgrade are critically important for the operation and performance of the magnet systems and hence must be taken into account in the magnet design and construction. These words cover a number of phenomena which need study: quench stability, dynamic heat loads, radiation damage, shielding, collimating, machine protection, radio-activation, remote handling and the like.

Comments

Radiation damage studies are particularly important because volumetric changes in copper, tin and tantalum can be substantial at the anticipated doses (300 MGy and up). There is a limited amount of data available and computational methods must be calibrated with experimental measurements.

Recommendations

1. Seek access and/or collaboration with one or more of the venues with appropriate experimental facilities to broaden the data base on radiation damage.

Magnet Systems: LHQ

Findings

The panel remarked that there appears to be a divergence between the requirements of the ultimate customer, CERN, and the direction in which the magnet development is going. The 120 mm LHQ does not have a rational place in the luminosity upgrade, yet a significant effort is being directed towards it, and it appears to be the major task on the magnet development plate.

Comments

Given that the time between the end of the 120 mm development and the need for a complete 150 quad system is very restricted, the risk can be reduced by lengthening the time available for the 150 mm development by abandoning the 120 mm effort. While this will probably add time to the prototyping of the 150 mm quads, undoubtedly overall costs and risks will be reduced.

It is the opinion of the committee that unless LARP Magnet Systems Team begins to develop a consistent research plan which seamlessly morphs into a production project plan, the LARP effort will have been vitiated at a critical time. No evidence was presented that critical thinking along these lines was part of the MS arsenal. As the matter stands at the moment, no data on proposed research activities substantial enough to enable OHEP to make informed decisions were presented. The scope of new magnet work beyond the demonstration of a working 120 mm aperture LHQ was discussed in a very indefinite manner.

Recommendations

1. Quickly bring the effort on the 120 mm LHQ to an orderly conclusion 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 November 30, 2012.
3. Develop an acquisition strategy which seamlessly transitions from the research program into a construction project by November 30, 2012.

Accelerator Systems

Introduction

The review panel commented favorably on the progress of the many tasks within the accelerator systems area of LARP. As in previous reviews of this program comments were made that some down selection process was in order.

Findings

It is proposed to use GHz-wideband feedback system to control electron cloud (E-cloud) and transverse multi-bunch coupled instability effects in SPS and LHC. This method is seen as a complementary to amorphous carbon coatings, grooved chambers and TiN coatings. In addition, multi-lab effort coordination is currently underway with focus on non-linear simulation codes, dynamics and feedback modeling, machine measurements, kicker models and simulation and hardware technology development.

Low-level RF configuration tools have been provided to CERN BE-RF Group and have been used for remote commissioning of the LLRF feedback loops of the RF stations. Several studies of RF noise effect on beam diffusion have been conducted to better understand RF-beam interaction. Measurements at LHC confirmed theoretical formalism and models.

A recently developed plan for the crab cavities calls for cavity testing and validation through 2013 with cryomodule prototyping complete in 2015 which will lead to SPS beam tests in 2015-2016. The production of crab cavities cryomodules is currently planned (as presented to the committee) to start in 2017 with final implementation in LHC in 2022-2033.

The accelerator team made good progress on deflecting cavities modeling and simulation including multipacting simulation on all three type cavities (ODU/SLAC, Lancaster and BNL). The committee was told that CERN is in preparation for SM18 tests aimed to field tests of all three cavities by the end of summer 2013. The committee also learned that the SPS tests (with crab cavity) are considered to be done in 2016 which will include cavity validation with beam, collimation, machine protection, beam physics issues (mainly emittance growth), effects of RF noise and demonstrating cavity transparency to operation.

In regard to collimation activities, SLAC is planning to ship the prototype rotatable collimator to CERN to be tested. It was noted that the RC (or other collimation initiatives within LARP) are not part of the current plan. Along with the RC, the Fermi hollow electron beams lens (which was demonstrated at Tevatron) is being considered to be shipped to CERN for possible test at LHC after LS1.

On the accelerator physics front, a number of comprehensive accelerator physics simulations have been performed in support of LARP activities. The accelerator physics team has taken advantage of accelerators such as RHIC and Tevatron to perform beam physics studies. Beam-beam efforts focused on developing and maintaining simulation tools, support beam-beam related experiments (at RHIC) and to apply the gained expertise to the LHC upgrade. It should be noted that LARP beam-beam task is well integrated into HL-LHC study.

Progress has been made on energy deposition analysis. FLUKA and MARS are being used for optimization studies of HL-LHC triplets. Both have given good agreement on power density and dynamic heat load in quadrupoles. It was reported that a factor 0f 12 reduction in peak dose can be achieved by the quadrupole aperture increase from 140 mm to 150 mm with thicker tungsten inserts.

Instrumentation developed under LARP has been making significant contributions to LHC, including AC dipole, synchrotron light monitors, Schottky monitors, luminosity monitors and tune tracker. Luminosity monitor is now being utilized to measure collision rate in order to optimize IP.

Comments

The panel was pleased to learn that good progress has been made understanding E-cloud/TMCI dynamics by modeling, simulation and machine development (MD). The committee considers the GHz-bandwidth transverse feedback system development to be important to the injector complex and to LHC. Its priority, compared to other tasks, is not well defined. Follow-up development on a wideband kicker technology and its implementation and test in SPS is encouraged.

The committee supports the SPS LLRF upgrade and encourages the team to design and develop new cavity controller for the 200-MHz and 800-MHz cavities system.

The committee acknowledged that the work done by the accelerator team on crab cavities is high quality. The team made excellent progress since 2011 LARP review. The main goal should be prototyping of cavities to validate technology of crab cavities. Toward this goal, RF design of several compact cavities has progressing well. The committee expresses concern over the safe operation of the crab cavities in the LHC. There may be potential failure modes which could result in damage to the machine. Therefore, establishing a safe mode of operation is a key milestone going forward. The scope of US contribution to crab cavities effort is not clear at this time due to uncertain future funding. The committee believes that US has technical leadership in crab cavities R&D but playing a leadership role in the production phase will depend on the outcome of down selection of the project scope. If crab cavities go forward a new leader is needed.

The committee considers the field testing of crab cavities in the SPS to be a CERN issue. Detailed planning to accomplish this task including design requirements, installation and commissioning plans requires immediate attention by the CERN staff.

Beam tests with bent crystals, which could be used as primary collimators, at both Fermilab and CERN have shown promising results. The use of this technology and implementation could be effective to direct beam halo more cleanly into secondary collimators than an ordinary scattering collimator. As was commented in a previous review, the committee agrees with the proposed plan to wrap up the rotatable collimator project in a timely fashion. This starts with SLAC providing CERN with a good prototype for testing.

The beam dynamics team is commended for its concentrated effort for conducting beam-beam experiments at Fermilab before the end of the Tevatron run. They continue to perform simulations and develop codes to support LHC. It is noted here that the Optical Stochastic Cooling (OSC) is an interesting idea for LHC. Passive OSC may be sufficient to prevent emittance dilution and also provide luminosity leveling. It is a worthwhile effort to further explore this idea.

The work on energy deposition is progressing. The team should continue with its benchmarking studies. The team is encouraged to continue with the optimization studies (simulations) for 150-mm triplet design with W inserts.

The reviewers responsible for this area of the program made the following comment: “Given future funding constraints, it is absolutely essential to prioritize all R&D tasks based on technical merits, impact, and technological needs. In light of the recent DOE guidelines (presented at this review), all LARP tasks should be priority-based activities conducted in a fashion that would lead to a “Project” (beyond R&D phase) as defined by the DOE. The goal and scope of LARP accelerator R&D must be clear and a path leading to the project phase should be clearly defined. The LARP program priorities and detailed implementation of activities should be considered in an integrated fashion, driven by the scientific and technological requirements must mutually benefit U.S labs and CERN.”

Recommendations

1. Develop a realistic plan with timeline to build a full prototype wideband feedback system for installation in SPS in 2013.
2. Focus efforts on completing three prototype crab cavities and testing by the end of the CY 2013 subject to budgetary constraints and other priorities.
3. 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 schedule to be more realistic.
4. 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.

Management

Findings

LARP management is overseeing a $12 million R&D and operations program. Elements of this program include accelerator science, instrumentation, crab cavities, Nb_3Sn high gradient quadrupole development, long term visitors at CERN and the highly successful Toohig Fellowship program. Many of these LARP activities have significant applications to present and future accelerator needs.

CERN's representative described the present LHC schedule covering the period 2012-2023 with three long shutdowns (~2013-2014, 2018, & 2022). CERN has expressed their appreciation of LARP work, and has documented this with letters to DOE. The high-luminosity upgrade is planned for installation in the 2022 long shutdown.

DOE has communicated that the total project cost of the US LHC High-Luminosity contribution should be approximately $200 million. Further the immediate goal of LARP is to demonstrate reduced risk for potential US contributions in kind to the high-luminosity upgrade. The LARP team and the U.S. base program are leading the world effort in Nb_3Sn superconducting magnets for accelerators. The high-luminosity upgrade depends on LARP technology for these magnets.

LARP management showed all conceived construction project activities and described their present thinking on priorities. Also, they described preliminary costs and schedule for these construction projects.

Comments

As noted above LARP did not describe a plan to down select deliverables for the LHC High-Luminosity project. Nor did LARP describe a plan for the transition from R&D to a DOE Construction Project, with associated deliverables, fully burdened costs and resource loaded schedule. The cost and schedule that LARP described is preliminary and some parts did not contain contingency or escalation (e.g., crab cavity construction). Given the constrained R&D funding going forward, it is important that LARP prioritize the R&D tasks and limit or even terminate some tasks.

Recommendations

1. Provide a management plan that documents the process for down selecting deliverables for the LHC High Luminosity Project by November 30, 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 by November 30, 2012.
3. Meet with CERN and DOE to finalize the list of U.S. deliverables and the schedule by December 21, 2012.
4. Plan the LARP budgets for the next four years to insure the R&D reduces the risks for the U.S. deliverables by January 31, 2013.

5. Provide a plan for transitioning from LARP R&D to a DOE Construction Project. This must include all the aspects in a Project Execution Plan as noted in http://science.energy.gov/opa/project-management/processes-and-procedures/ by April 1, 2013.

Appendix A

Department of Energy
Washington, DC 20585

MAR 27 2012

MEMORANDUM FOR: BRUCE STRAUSS
LARP PROGRAM MANAGER
FACILITIES DIVISION
OFFICE OF HIGH ENERGY PHYSICS

FROM: MICHAEL PROCARIO
DIRECTOR
FACILITIES DIVISION
OFFICE OF HIGH ENERGY PHYSICS

SUBJECT: U.S. Large Hadron Collider Accelerator Research Program (LARP) Annual Technical and Management Review

This memorandum is to request that you organize and conduct a Technical and Management review of the U.S. Large Hadron Collider (LHC) Accelerator Research Program (LARP). This review should appropriately involve the input and participation of related programs in the office of High Energy Physics (OHEP).

LARP, encompassing research and development activities in superconducting materials and magnets, accelerator systems, beam instrumentation, and LHC accelerator commissioning efforts, plays an important role in the nation's high energy physics program with its strong participation I the experiments at the LHC at CERN. It is important for OHEP to understand the progress and future plans of the research program, the effectiveness of its management and whether resources and planning are being directed optimally to support the scientific goals of the nation's high energy physics program. At present it is most important to ascertain how this program will evolve into efforts for the LHC luminosity consolidation plans as well as follow on upgrades.

It is requested that your review evaluate:

- The effectiveness in strategic planning, development appropriate core competencies, implementing a prioritized and optimized program for potential participating in future accelerator upgrades at the LHC at CERN; specifically, are these LARP activities well aligned with the present and anticipated LHC schedule;
- The quality and significance of the LARP scientific and technical accomplishments, and the merit, feasibility and impact of its planned research program;
- The effectiveness and appropriateness of the laboratory interactions to maximize the leveraging of existing infrastructure and expertise available at those laboratories;
- The strength and relevance of any new proposed research activities, to enable OPEP to make more fully informed decisions on this new scope of work.

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In the context of these general review criteria, there are special circumstances that the nation's high energy physics program is facing where additional information at this time would be helpful for this office in its planning. In particular, with respect to the most current LHC schedules and plans, what should be the priority and levels of activity and organization for LARP to undertake in the superconducting magnet and accelerator systems that would be most effective and optimum in positioning the U.S. for participation in the LHC upgrades? Is the multi-year plan developed by the LARP management consistent with these goals? What is the time line and the resources needed to mount this program? What are the scientific and technical risks associated with the proposed program, and are the available resources for LARP being optimally used to achieve the planned goals?

The review should also comment upon what progress has been made towards addressing action items, if any, from previous LARP Reviews.

I should appreciate receiving the review reports, suitable for transmission to the laboratories, within 45 days after the review.

cc: Eric Prebys, FNAL
Stuart Henderson, FNAL
LK Len, SC-25

Appendix B

- Monday 09 July 2012
- 08:30 - 09:00 Executive Session (closed)
  Executive Orientation Session
  Location: Research Office Building (048), SLAC (Redwood A&B)

- 09:00 - 10:30 Opening Plenary
  Introductory Session
  Material: Teleconference Services

- 09:00 **Introduction** *20'*
  Speaker: Eric Prebys (Fermilab)

  Material: Slides

- 09:20 **LHC Upgrade Projects and Design Studies** *30'*
  Speaker: Lucio Rossi (CERN)

  Material: Slides

- 09:50 **LHC Optics Impact to Magnets** *15'*
  Speaker: Yunhai Cai (SLAC)

  Material: Slides

- 10:05 **Magnet Energy Deposition Studies** *15'*
  Speaker: Nikolai Mokhov (Fermilab)

  Material: Slides

- 10:20 **Discussion** *10'*
- 10:30 - 10:45 Coffee
- 10:45 - 12:30 Magnet Systems A
  First Magnet Systems parallel session
  Location: Cedar Room

  Material: Teleconference Services

- 10:45 **Overview and HQ Program** *45'*
  Speaker: Sabbi GianLuca (LBNL)

  Material: Slides

- 11:30 **LQ Program** *30'*

Speaker: Giorgio Ambrosio (FNAL TD/MSD)

Material: Slides

- 12:00**Discussion** *30'*

- 10:45 - 12:30Accelerator Systems A
  First Accelerator Systems parallel session

  Material: Teleconference Services

- 10:45**Crab Cavity** *40'*
  Speaker: Rama Calaga (CERN)

  Material: Slides

- 11:25**SPS Feedback** *30'*
  Speaker: John Fox (SLAC)

  Material: Slides

- 11:55**Instrumentation** *20'*
  Speaker: Alessandro Ratti (LBNL)

  Material: Slides

- 12:15**Discussion** *15'*

- 12:30 - 13:30Lunch
- 13:30 - 15:30Accelerator Systems B
  Second Accelerator Systems parallel

  Material: Teleconference Services

- 13:30**LLRF in the LHC and SPS** *30'*
  Speaker: Claudio Rivetta (SLAC)

  Material: Slides

- 14:00**Beam-beam and Electron Lens** *30'*
  Speaker: Alexander Valishev (Fermilab)

  Material: Slides

- 14:30**Collimation** *30'*
  Speaker: Thomas Markiewicz (SLAC)

  Material: Slides

- 15:00**Discussion** *30'*

- 13:30 - 15:30 Magnet Systems B
  Second Magnet Systems parallel
  Location: Cedar Room

  Material: Teleconference Services

- 13:30 **Materials Program** *30'*
  Speaker: Arup Ghosh (Brookhaven National Laboratory)

  Material: Slides

- 14:00 **LHQ Program and Nb3Sn Technology Demonstration** *30'*
  Speaker: Giorgio Ambrosio (FNAL TD/MSD)

  Material: Slides

- 14:30 **HL-LHC IR Quadrupole Development** *30'*
  Speaker: Sabbi GianLuca (LBNL)

  Material: Slides

- 15:00 **Discussion** *30'*
- 15:30 - 15:45 Coffee
- 15:45 - 17:15 Plenary Session
  Afternoon Plenary
  Material: Teleconference Services

- 15:45 **US-LHC 10-Year Plan** *45'*
  Speaker: Eric Prebys (Fermilab)

  Material: Paper Slides

- 16:30 **Discussion** *45'*
- 17:15 - 18:30 Executive Session (closed)
  First day closing executive session
- 19:00 - 20:30 Dinner (SLAC (Cafeteria))
- Tuesday 10 July 2012
- 08:30 - 10:00 Question and Answer Session
  Plenary with answers to questions and discussion from previous day
  Material: Teleconference Services slides

- 10:00 - 10:15 Coffee
- 10:15 - 12:00 Writing Session (closed)
  Executive writing session
- 12:00 - 13:00 Lunch

- 13:00 - 14:00Writing Session (closed)
  Executive writing session
- 14:00 - 15:00Closeout
  Closeout presentations
  Material: Teleconference Services slides

Appendix C

Members of the review panel included:

Dr. Howard Gordon
Brookhaven National Laboratory

Dr. Alireza Nassiri
Argonne National Laboratory

Dr. Steve J. St. Lorant
SLAC National Accelerator Laboratory (Retired)

Dr. Al Zeller
FRIB / Michigan State University

Dr. Sergio Zimmermann
Lawrence Berkeley National Laboratory

Observer:
Prof. Lucio Rossi
CERN

DOE Staff:
Dr. Michael Procario
Dr. Bruce Strauss