Scope Selection Process for US Contributions to the LHC Luminosity Upgrade

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# 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)[[1]](#endnote-1), 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[[2]](#endnote-2), we presented a list of potential contributions to the LHC[[3]](#endnote-3). 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[[4]](#endnote-4) 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
5x1034 cm-2s-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 Nb3Sn technology, that will provide a reduced \* 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 \*. 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 Nb3Sn 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[[5]](#footnote-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 Nb3Sn magnet. Up until now, this project has taken place at Fermilab outside of LARP, but it leverages LARP R&D into Nb3Sn quadrupoles. The cost to 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 Nb3Sn 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[[6]](#endnote-5):

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[[7]](#endnote-6). 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[[8]](#endnote-7) 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].*

1. **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. ]*

1. **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.

1. http://www.uslarp.org/ [↑](#endnote-ref-1)
2. 2012 DOE LARP Review, https://indico.fnal.gov/conferenceDisplay.py?confId=5409 [↑](#endnote-ref-2)
3. LARP-DOC-1068, http://larpdocs.fnal.gov//LARP-public/DocDB/ShowDocument?docid=1068 [↑](#endnote-ref-3)
4. HL-LHC: High Luminosity Large Hadron Collider, http://hilumilhc.web.cern.ch/HiLumiLHC/index.html [↑](#endnote-ref-4)
5. 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. [↑](#footnote-ref-1)
6. “LARP DOE Review Closeout”, slide 19, https://indico.fnal.gov/getFile.py/access?sessionId=0&resId=0&materialId=1&confId=5409 [↑](#endnote-ref-5)
7. *ibid.*,slide 24 [↑](#endnote-ref-6)
8. 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 [↑](#endnote-ref-7)