Department of Energy
Review Committee Report

on the

Technical, Cost, Schedule, and
Management Review

of the

LINAC COHERENT LIGHT SOURCE (LCLS) PROJECT

May 2003

EXECUTIVE SUMMARY

A Department of Energy Office of Science status review of the Linac Coherent Light Source (LCLS) project located at Stanford Linear Accelerator Center (SLAC) was conducted on May 21-23, 2003. The purpose of the review was to assess the maturity and credibility of the design, cost, and schedule information for procuring $29.9 million of long-lead items for the injector, linac, and undulator systems as early as FY 2005. The Committee also evaluated the readiness for Critical Decision (CD) 2a, Approve Long-lead Procurement Budget, scheduled for June 2003.

The Committee found that at this stage, the project's long-lead procurement plans were fundamentally sound in all areas (technical, cost, and schedule), and that the project team was ready for approval of CD-2a. The cost estimate and schedule was credible and realistic.

Although there was no systematic risk analysis to support the contingency in the cost estimates for the long-lead items, the overall amount of contingency (28 percent) appears to be appropriate. The project is being managed as needed and the project team is highly skilled and competent, and has made considerable progress despite a five-month delay in receiving FY 2003 Project and Engineering Design funding. The ES&H aspects of the project have been properly addressed given the project's current stage of development.

The LCLS project will provide an X-ray source of unprecedented brightness and coherence, based on modifications to the existing SLAC linac. The project scope includes an injector, linac, undulator, and two experimental halls. The Total Project Cost range approved at CD-1 (Approve Preliminary Baseline Range) is $245-295 million, with a schedule for starting construction in FY 2006. The lead laboratory is SLAC, and the other major collaborators are the Lawrence Livermore National Laboratory and the Argonne National Laboratory.

The Committee made 25 recommendations including: carry out previous recommendations to complete a thorough value engineering and production analysis of the undulator mechanical design and focus the second undulator prototype on addressing mass production issues; perform a conceptual design review of the superconducting wiggler to establish procurement specifications; insure initial spares ordered do not impact other critical equipment orders; review participating laboratory material and supplies markup rates to determine who makes major procurement purchases; develop a detailed critical path schedule prior to CD-2b (Approve Performance Baseline); expand the configuration management system and implement change control processes before CD-2b; complete a comprehensive risk analysis and management plan of all systems and components before CD-2b; and evaluate the level of ES&H staffing needed to support design, construction, and installation activities.

No action items were assigned by the Committee.

In summary, the Committee found the long-lead procurement item designs are adequately mature with credible cost and schedule estimates and the LCLS project is ready to request long-lead procurement funding for FY 2005. The LCLS management team has done a commendable job under difficult funding circumstances. The LCLS project is judged to be ready for CD-2a, Approve Long-Lead Procurement Budget.

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1. INTRODUCTION

1.1 Background

The Linac Coherent Light Source (LCLS) project is a collaboration led by the Stanford Linear Accelerator Center (SLAC) and includes the Argonne National Laboratory (ANL) and the Lawrence Livermore National Laboratory (LLNL) to provide laser-like radiation in the X-ray region of the spectrum that is ten billion times greater in peak power and peak brightness than any existing coherent X-ray light source. This advance in brightness is similar to that of a synchrotron over a 1960's laboratory X-ray tube. Synchrotrons revolutionized science across disciplines ranging from atomic physics to structural biology. Advances from the LCLS are expected to be equally dramatic. The LCLS project will provide the first demonstration of an X-ray free-electron-laser (FEL) in the 1.5-15 Angstrom range and will apply these extraordinary, high-brightness X-rays to an initial set of scientific problems. This will be the world's first such facility.

The LCLS is based on the existing SLAC linac. The SLAC linac can accelerate electrons or positrons to 50 billion electron volts (GeV) for colliding beams experiments and for nuclear and high-energy physics experiments on fixed targets. At present, the first two-thirds of the linac is being used to inject electrons and positrons into Positron Electron Project II (PEP-II), and the entire linac is used for fixed target experiments. When the LCLS is completed, this latter activity will be limited to 30 percent of the available beam time, and the last one-third of the linac will be available for the LCLS a minimum of 70 percent of the available beam time. For the LCLS, the linac will produce high-brightness 5-15 GeV electron bunches at a 120 Hz repetition rate. When traveling through the new 120-meter-long LCLS undulator, these electron bunches will amplify the emitted X-ray radiation to produce an intense, coherent X-ray beam for scientific research.

The LCLS makes use of technologies developed at SLAC for the Stanford Linear Collider (SLC), Sub-Picosecond Particle Source (SPPS) and the next generation of linear colliders, as well as the progress in the production of intense electron beams with radio-frequency photocathode guns. These advances in the creation, compression, transport, and monitoring of bright electron beams make it possible to base this next generation of X-ray synchrotron radiation sources on linear accelerators rather than on storage rings.

The LCLS will have properties vastly exceeding those of current X-ray sources (both synchrotron radiation light sources and so-called "table-top" X-ray lasers) in three key areas: peak brightness, coherence (i.e., laser like properties), and ultrashort pulses. The peak brightness of the LCLS is ten billion times greater than current synchrotrons, providing 10^{12}-10^{13} X-ray photons in a pulse with duration of 230 femtoseconds. These characteristics of the LCLS will open new realms of scientific applications in the chemical, material, and biological sciences. The LCLS Scientific Advisory Committee, working in coordination with the broad scientific community, identified high priority initial experiments that are summarized in the document, *LCLS: The First Experiments*. These first five areas of experimentation are: fundamental studies of the interaction of intense X-ray pulses with simple atomic systems; use of the LCLS to create warm dense matter and plasmas; structural studies on single nanoscale particles and biomolecules; ultrafast dynamics in chemistry and solid-state physics; and studies of nanoscale structure and dynamics in condensed matter.

The experiments fall into two classes. The first follows the traditional role of X-rays to probe matter without modifying it, while the second utilizes the phenomenal intensity of the LCLS to excite matter in fundamentally new ways and to create new states in extreme conditions. The fundamental studies of the interactions of intense X-rays with simple atomic systems are necessary to lay the foundation for all interactions of the LCLS pulse with atoms embedded in molecules and condensed matter. The structural studies of individual particles or molecules make use of recent advances in imaging techniques for reconstructing molecular structures from diffraction patterns of non-crystalline samples. The enormous photon flux of the LCLS may make it feasible to determine the structure of a single biomolecule or small nanocrystal using only the diffraction pattern from a single moiety. This application has enormous potential in structural biology, particularly for important systems such as membrane proteins, which are virtually uncharacterized by X-ray crystallography because they are nearly impossible to crystallize. The last two sets of experiments make use of the extremely short pulse of the LCLS to follow dynamic processes in chemistry and condensed matter physics in real time. The use of ultrafast X-rays will open up entire new regimes of spatial and temporal resolution to both techniques.

The proposed LCLS project requires a 150 million electron volts (MeV) injector to be built at Sector 20 of the 30-sector SLAC linac to create the electron beam required for the X-ray FEL. The remaining third of the linac will be modified by adding two magnetic bunch compressors. Most of the linac and its infrastructure will remain unchanged. The existing components in the Final Focus Test Beam tunnel will be removed and replaced by a new 120-meter undulator and associated equipment. Two new experimental buildings, the Near Hall and the Far Hall, connected by a beam line tunnel, will be constructed. The Far Hall will also provide laboratory and office space for the LCLS users.

CD-0, Approve Mission Need, was approved by DOE's Office of Science (SC) on June 13, 2001. The LCLS preliminary Total Project Cost (TPC) range, established during the conceptual design phase, was $180-240 million, with Project Engineering and Design (PED) funds beginning in FY 2003 and construction starting in FY 2005.

Subsequent to the DOE Conceptual Design Review in April 2002, the Office of Basic Energy Sciences (BES) provided SLAC with additional guidance that resulted in a revised TPC range of $245 million to $295 million and delayed the construction start to FY 2006. Under this scenario, long-lead procurements would be initiated in FY 2005. For this reason, CD-2 (Approve Performance Baseline) was split into CD-2a (Approve Long-lead Procurement Budget) and CD-2b (Approve Performance Baseline).

Based on the above cost and schedule assumptions, the LCLS Acquisition Execution Plan, Preliminary Project Execution Plan, and CD-1 (Approve Preliminary Baseline Range) were approved by SC on October 16, 2002. This step authorized the project to start Title I design and expend PED funding which was included in the President's FY 2003 Budget Request. However, due to a series of Continuing Resolutions, Congress did not appropriate the FY 2003 PED funding for LCLS until February 2003, and it was not available to the project to begin Title I design until mid-March 2003. In addition, the amount provided ($5.925 million) was less than that requested ($6.0 million) because of a General Reduction and Rescission. The President's FY 2004 Budget Request includes $7.5 million of PED and $2.0 million of Operating Expense funds for R&D.

1.2 Charge to the DOE Review Committee

In a March 28, 2003, memorandum (see Appendix A), Dr. Patricia M. Dehmer, Associate Director for BES in SC, requested that Daniel R. Lehman, Director of the Construction Management Support Division organize and lead a review of to evaluate LCLS preparations for CD-2a (Approve Long-Lead Procurement Budget).

1.3 Membership of the Committee

The Review Committee (see Appendix B) was chaired by James R. Carney. Members were chosen on the basis of their independence from the project, as well as for their technical and management expertise, and experience with building large scientific research facilities. Continuity and perspective were provided by the fact that several member served on the previous DOE review committee. The Committee was organized into two subcommittees: one for long-lead technical scope, and the other for project management, cost, schedule, and procurement.

1.4 The Review Process

The review was conducted May 21-23, 2003 at a conference facility in Rockville, Maryland. The agenda (See Appendix C) was developed with the cooperation of the LCLS Project Office, DOE/SC, and the DOE Stanford Site Office. Comparison with past experience on similar projects was the primary method for assessing technical designs, cost estimates, schedules, and adequacy of the management structure. Although the project requires some technical extrapolations, similar accelerator projects in the United States and abroad provide a relevant basis for comparison.

The first day and a half were devoted to project plenary sessions with presentations given by member of the LCLS Project Office staff. On the afternoon of the second day, there were presentations and discussions in subcommittee breakout sessions to answer detailed questions from the Committee. The third day was spent on Committee deliberations, report writing, and drafting a closeout report. The preliminary results were discussed with LCLS staff at a closeout session on the last day.

2. LONG-LEAD TECHNICAL SCOPE

2.1 Findings

With respect to the technical scope of long-lead procurement items, there were three charge questions that the Committee considered.

1. Is the design of the long-lead items sufficiently mature to support their procurement as early as FY 2005?

The Committee commended the team for continuing to advance the knowledge and technical base required to make this ambitious project a success despite delays in FY 2003 PED funding due to Continuing Resolutions. As a whole, the LCLS project team is focused and nothing that the Committee learned suggested that the goals of this project cannot be successfully achieved. The team is highly skilled and competent and has made considerable progress within a constrained funding profile. The Committee appreciated their candor in reviewing the technical status of the various subsystems. There are three main areas with scope requiring long-lead procurement.

In the first area, the injector, the design is quite mature. The Committee found the team fully prepared for procurement of the entire system as a long-lead item and encouraged this action. The injector is a crucial technology for the performance of the system as a whole and the earlier it can be brought into operation, the sooner confidence can be established that the stringent requirements can be met. Despite encouraging modeling, no existing injector linac system has yet met all of the requirements proposed, so early operation is vital. One area where long-lead procurement may be difficult is the drive laser, since the requirements for this laser are near, but not met, by any existing commercial system with regard to repetition rates required for the amplifier. It may be difficult to find commercial vendors sufficiently interested in this one-of-a- kind system to devote the proper effort required for its development, as well as its characterization. In this case, an in-house effort may be required or developed within another national laboratory (LLNL or Lawrence Berkeley National Laboratory (LBNL)). Sufficient expertise exists at SLAC and nearby institutions, such as LBNL and LLNL (which maintain close collaborations), so that this is not of particular concern. It is important to start development of the required laser technology skill base and hardware as soon as possible. It is unfortunate that some of the injector long-lead procurements are delayed by budgetary constraints and the Committee encouraged project management to review the allocation of resources to ensure that risk in long-lead procurements is properly balanced.

In the second area, the undulator, less progress has been made over the past year. There is concern that attention to the difficulties of manufacturing and procuring 33 high tolerance components has not been sufficiently addressed. Recommendations from the April 2002 DOE review included (among other things):

- Completing a thorough value engineering and production analysis of the undulator mechanical design. Trade-offs on the choice of strongback materials, thermal compensation and phasing control, physical tolerances, and relationship between stringent tolerances, and post assembly tuning must be completed. This should be completed prior to submitting any long-lead procurements for bid.

- Focusing the second undulator prototype on addressing mass production issues. The design and technical approaches have been sufficiently advanced that production issues are the most critical. If a second prototype is pursued, this recommendation must be completed prior to CD-3, Approve Start of Construction. If industrial production is selected, the second prototype should be produced in industry.

These recommendations still need to be addressed. In particular, the materials choice on the strongback and the method of thermal management have not been adequately addressed to give confidence that minimal changes would be required from the existing design. There are also outstanding issues regarding end sections and interfaces to diagnostics. There is (barely) sufficient time over the next year to resolve these concerns with attention by experienced and knowledgeable engineers. Ongoing quality assurance during the long-lead procurements in this area is particularly important.

The third area is the accelerator. SLAC experience in this area is extensive and the design is well advanced in most subsystems. Early procurement and testing of several of these systems is important to ensure performance. X-band linac components need testing to establish phase and amplitude stability. Designs and existing similar hardware for the linac exists and can proceed as funding is available. The superconducting wiggler is a long-lead item because of the lack of extensive commercial capability in this technology and the specialized design creates a schedule risk. A successful conceptual design review of this system planned for fall 2003 should put this system on track to be ready for approval of long-lead procurement in April 2004, but production schedules will remain a concern for this one-of-a-kind device.

2. Are the cost estimate and schedule for the long-lead scope credible and realistic? Do they include adequate contingency margins based on a systematic risk analysis?

The cost estimate and schedule are reasonable for the long-lead scope. There is concern in a couple of areas primarily because of the lack of extensive commercial support in high repetition rate laser amplifiers and superconducting wigglers. The approach on the undulator will require review over this year to address manufacturing issues of strongbacks and magnetic components. It will be appropriate to revisit this area before final approval of procurement, but the Committee judged that the budget as it exists is sufficient to cover expected costs. There was no systematic presentation on risk analysis to establish contingency, but overall the long-lead procurement budget contingency appears appropriate. It is desirable to revisit the allocation of long-lead resources during the coming year to manage risk while maintaining overall project schedule. This question is addressed in more detail in Section 5, Project Management.

3. Have the technical and non-technical risks associated with the long-lead scope been realistically assessed, and has the project identified appropriate risk mitigation measures?

The technical risks have been adequately addressed, and in many cases little more progress can be expected until real hardware can be obtained, making it crucial that long-lead procurements proceed as soon as funds are available. This is also generally true in the non-technical risks (cost and schedule creep due to manufacturing problems, for example) although additional attention will be needed in the undulator area to review procurement strategy, design manufacturability, and quality assurance during performance of the manufacturing contracts. Appropriate risk mitigation measures have been taken; in most cases there are alternate approaches possible, although there are a few areas where alternates are not easily or cheaply available: the drive laser power amplifier, superconducting wiggler, and X-band linac. These will require particular management attention as the project proceeds to ensure that they do not impact the overall schedule.

2.2 Comments

Although management stated that the identification of long-lead items had been optimized with respect to balancing risk while maintaining overall schedule, it was not clear from the presentations that this criteria had been evenly applied over the various subsystems. The Committee encouraged management to continue to look at these allocations during the coming year to balance these needs. Working with DOE to move long-lead acquisition funding forward is very desirable.

With PED funding just becoming available due to FY 2003 Continuing Resolutions, the ANL project staff is just beginning its effort. They will need to establish a strong team of individuals experienced in not only the magnet design, but also in manufacturing technology and control. It will be crucial for the success of this project to have the strong backing of ANL management so that these key individuals are made available. There has been little work on the undulator diagnostics, and it requires prototyping and testing to validate the ability to achieve a 1 micron position resolution at the required bunch charge. The first undulator prototype has performed well, but the team must now ensure that this effort can be repeated identically 33 times. Close communication with DOE will be helpful to assure the proper attention of ANL management.

The injector effort scales up dramatically in FY 2005. The rate of increase is so large as to suggest there will be difficulties in handling the effort successfully.

2.3 Recommendations

1. Carry out previous DOE review recommendations regarding design trade-offs of the undulator and fabrication of the second prototype by CD-2b (April 2004).

2. Develop a prototype of the undulator beam position monitor, and test with beam to demonstrate resolution by September 2004.

3. Establish a dedicated team of experienced personnel at ANL for the manufacturing procurement activity, and develop a quality assurance plan for the procurement by CD-2b (April 2004).

4. Establish a section of laser/optical physics within the project's organization. The section will serve both the injector drive laser, beam transport, and optical diagnostics, but inevitable support will be needed for LCLS experimental efforts by CD-2b (April 2004).

5. Review approaches with adequate optical modeling for drive laser power amplifier and compressor components with vendors, and pursue in-house development if sufficient vendor interest cannot be established by CD-2b (April 2004).

6. Find space at SLAC or elsewhere (LLNL or LBNL) for early development of the laser capability. Such a crucial development of critical performance cannot wait until the last year for the first on-site test efforts. Also develop a plan so that long-lead procurement may be placed at the earliest possible time as soon as funds are made available. The facility must be available before delivery of the laser; the plan must be in place by CD-2b (April 2004).

7. Perform a successful conceptual design review of the superconducting wiggler to establish firm specifications for procurement by January 2004.

8. Review and update the schedule prior to CD-2b (April 2004) for injector development to optimize resource loading in FY 2005, and to demonstrate the required performance of critical components at earliest possible time.

9. Establish an engineering change control board by CD-2b (April 2004).

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3. COST and FUNDING

3.1 Findings

In summary, and based on the technical review of the design status, the cost estimate data presented supports the $29.9 million long-lead procurement budget request for FY 2005.

The PED funding profile (see Appendix D) contains $5.925 million in FY 2003, $7.5 million in FY 2004, $20.075 million in FY 2005, and $2.5 million in FY 2006. The R&D funding profile (see Appendix D) contains $2 million in FY 2004 and $4 million in FY 2005. Aside from the FY 2005 long-lead procurement request of $29.9 million, the remainder of the project's funding profile has not yet been established nor has the project been re-evaluated since the April 2002 DOE review.

Complete comparisons of current cost estimates and contingency assessments to previous ones were not performed for either the long-lead procurements or for the overall project.

It was not readily evident that a systematic, or an overall project consistent method was used to assess contingency needs for the long-lead procurements.

The reduction in the cost estimate (including contingency) from the CDR estimate for the undulator long-lead procurements is significant at $3.1 million. Further analysis will have to be conducted to determine if this will translate to a project bottom line adjustment.

3.2 Comments

Cost and contingency tables comparing estimates to those from the previous DOE review(s) would greatly enhance communicating the progress made between reviews.

The project may wish to review who holds the vendor contract for the undulators. This comment is made from a project cost aspect only. SLAC's materials and services overhead burden is apparently less than ANL. ANL could still manage the undulator fabrication effort while SLAC administers the contract. An additional search for vendors/ suppliers for the critical materials and equipment could still provide cost and schedule benefits.

3.3 Recommendations

1. Provide comparison cost tables (with contingency segregated) to show changes that have been made between DOE reviews. It will be important to have this comparison available for CD-2b (April 2004).

2. Review which participating laboratory should make major procurements with consideration of the laboratory's materials and services markup rates.

3. Insure that initial spares ordered with the long-lead procurements portion of the project budget are necessary and do not impact other more critical equipment orders.

4. SCHEDULE

4.1 Findings

Progress on the LCLS project since the April 2002 DOE review has been good, based on the limited funding received. The first PED funding ($5.925 million) was just made available in March 2003. The PED funding profile has been established, and thus, the schedule starts with significant resource constraints. The overall project funding profile has not yet been established nor has the project re-evaluated it since the April 2002 DOE review. The overall project schedule (see Appendix E) may have to change, based on the yet-to-be-determined out year funding profile for the rest of the project.

Approval of CD-2a results in the establishment of a baseline for all the long-lead equipment. Thus, progress reporting and baseline control will be required.

The schedule critical path through the long-lead procurements was not clearly demonstrated. As a result, the linkage between the overall project critical path to CD-4, Approve Start of Operations, and the long-lead procurements was difficult to communicate.

A comprehensive project risk assessment has not been completed. At this point in time, the attention to risk assessments has focused on the technical risks. Current plans are to complete a comprehensive risk assessment prior to CD-2b, Approve Performance Baseline.

The PED and R&D funding profiles are driving a late-start schedule and an end-loaded staffing plan. This form of planning increases risk, both in cost and schedule.

4.2 Comments

Appropriate staffing levels are totally dependant upon a good critical path schedule, even when that schedule is limited by funding.

The project should be able to complete a detailed critical path schedule in less than six months. The initial critical path schedule does not need to be totally resource loaded. It should, however, reflect constraints imposed by the critical resources. Subsequent to the initial critical path schedule development, remaining details can be added and resources leveled.

4.3 Recommendations

1. Development of a detailed critical path schedule must be completed prior to CD-2b (April 2004).

2. The schedule associated with the completion of the undulators, magnetic measurement, and installation must be examined to increase, or maximize schedule contingency prior to CD-2b (April 2004).

5. PROJECT MANAGEMENT

5.1 Findings

The LCLS project management organization (see Appendix F) has continued to develop and expand. An experienced chief project engineer will start June 1, 2003. The Linac Senior Team Leader started approximately one week prior to the review. The Undulator Senior Team Leader at ANL is on board and actively engaged in managing and organizing the effort. The Injector System Team is one of the most mature within the project and demonstrates a strong cohesiveness. The management model of senior team leaders with scientific system managers appears to operate well, and in effect, provides a type of scientific quality assurance for the project.

The LCLS project will be elevated to the status of a separate division within SLAC in 2004 and will begin co-locating personnel starting in the summer of 2003. The LCLS Undulator System has been elevated to a direct report to the ANL Associate Laboratory Director within the Advanced Photon Source organization.

Frequent and open project communication has been established and fostered. Bi-weekly videoconference meetings are being held. All system teams meet on a weekly basis and interactions between the system manager and the senior team leaders occur on a frequent and regular basis.

LCLS PED funding for FY 2003 is $5.925 million. The Administration's Budget Request for FY 2004 is $7.5 million for PED and $2 million for R&D. In FY 2005, the planned funding level is $20.075 million for PED, $29.9 million for long-lead procurement, and $4 million for R&D. The abrupt increase in total funding from FY 2004 to FY 2005 presents a major challenge to all systems and to the project as a whole.

The five-month delay in receiving FY 2003 PED funding subsequently delayed progress both in project management and technical areas. The project team has accomplished a substantial amount of work in view of these funding constraints.

There is a discrepancy between the PED and R&D funding projected for allocation to the Undulator System for FY 2004 ($1.45 million) in contrast to the desired staffing level (13 full-time equivalents or FTEs) for FY 2004. A balance between realistic workloads, deliverables, and available funding levels needs to be established.

In the time since the April 2002 DOE review, the project has established a Project Execution Plan for the PED Phase (approved September 20, 2002), an Acquisition Execution Plan (approved October 16, 2002), an Environmental Assessment for the LCLS Experimental Facility (DOE/EA-1426; approved February 28, 2003), and completed a Preliminary Hazard Analysis.

5.2 Comments

The cost estimate and schedule for the long-lead scope appears generally credible and realistic. The tuning, measurement, and installation of the undulators remain an area of concern. Generally the project has included adequate contingency margins, though contingency associated with the magnets and poles appears to be light. The contingency numbers are based on expert judgment. A complete systematic risk analysis has not yet been completed throughout the project.

The project is being managed (i.e., properly organized, adequately staffed) as needed to carry out long-lead procurements as early as FY 2005. The delay of FY 2003 PED funding has slowed the maturation of the project organization, but indications of proper control and management practices are in evidence.

Considerable work remains to be accomplished in anticipation of a full project baseline in April 2004. This includes the full implementation of a project management control system, a configuration management system, change control process, and finalized interface definitions and handoffs.

Staffing plans are not consistent across the systems and the project in general. The ability to accommodate the rapid increases of funding and staffing from year to year will be extremely difficult to accomplish in an efficient manner. The project needs to aggressively address the risks and impacts associated with these rapid increases in staffing levels and funding. Increasing staff levels consumes considerable resources of an already taxed management and reduces productivity for a time before the benefits the increased staff are realized. This is a major issue in all system areas.

Balancing external expectations in the face of funding profile constraints is always challenging, and the project and the stakeholders of the project need to fully understand the impact of limited funding profiles. Technical risks associated with the long-lead scope have been realistically assessed, and the project has identified appropriate risk mitigation measures. Additional attention to non-technical risk assessment, analysis, and mitigation should be undertaken.

5.3 Recommendations

1. Expand the configuration management system and implement change control processes before CD-2b to minimize the risk of post-procurement changes to long-lead procurements.

2. Examine solidification of matrix agreements between various functional units within SLAC and the ANL Advanced Photon Source with the LCLS project. Some laboratories employ a formal matrix agreement that clearly establishes levels of support required, responsibilities and obligations of the project, and the functional organization. The project may wish to examine such agreements as a model.

3. Begin detailed procurement planning of long-lead items by September 2003. This should include the formal trade study of the various procurement options mentioned during the review; the critical planning and scheduling of requirements, specifications, bid, and quality assurance packages; bid preparation by potential suppliers, and bid evaluation and award. Every effort should be made to permit the immediate award of procurements as soon as funds are provided rather than waiting to release requests for bids/proposals until after such authorization is in hand.

4. Conduct an internal project review of the complete undulator system procurement management, support, and logistics sufficiently in advance of the release of bid packages to provide assurance of the completeness of the approach.

5. The procurement, responsibility, and oversight of the long-lead magnetic measurement system should be clarified before CD-2b.

6. Complete a comprehensive risk analysis and management plan of all systems and components before CD-2b. This risk analysis must include all sources of risks and should be controlled and maintained with a central risk registry for the project and each system.

7. Examine and establish a global quality assurance plan for the project prior to CD-2b. This plan must include roles and responsibilities associated with all systems and relationship to the LCLS Project Office.

8. Resolve the discrepancy between the Undulator System staffing requirements and the funding profile, and balance workloads and expectations prior to FY 2004.

9. Establish a monthly reporting plan for the long-lead procurements to allow accurate reporting immediately after Critical Decision-2a is approved.

6. ENVIRONMENT, SAFETY AND HEALTH

6.1 Findings

The environment, safety and health (ES&H) aspects of the LCLS project are being properly addressed given the project's current stage of development. ES&H and documentation requirements are in place to support CD-2a.

The project's overall ES&H progress since the April 2002 DOE review is positive and moving forward in integrating ES&H with the project. The DOE responsibility is to review the proposed project under the National Environmental Policy Act (NEPA) prior to CD-2a approval. The Environmental Assessment (EA) was completed and a Finding of No Significant Impact was approved on February 28, 2003, by the Director of the NNSA Service Center Oakland. The DOE Stanford Site Office (SSO) has verified that the appropriate NEPA documentation is in place for the work being conducted by the partner laboratories (ANL and LLNL). The Preliminary Hazard Assessment Report was completed by the project and approved by SSO in October 2002.

6.2 Comments

The project is using existing SLAC and Stanford Synchrotron Radiation Laboratory (SSRL) processes and resources in ES&H. Several of the SLAC safety committees are participating in review and oversight of the project and the ongoing design process. The SLAC Radiation Safety Committee (RSC) is actively involved and currently is reviewing the beam loss estimates and the shielding designs of the LCLS Injector.

The April 2002 DOE review report stated that the "FY 2003 ES&H staffing plan cannot support the current schedule". The project made adjustments and completed the ES&H requirements necessary for CD-2a. The project's ES&H Coordinator is matrixed from SSRL and currently is working approximately at the 0.2 FTE level in support of the project. This current level of ES&H support has been adequate to support the design initiatives, but will need to be evaluated for its continuing ability to support the project through the remainder of design and into construction, installation, and operations. This will be important to ensure that work is done on schedule, while maintaining safety, staying compliant, and remaining accident free.

The ES&H aspects of the project work conducted by the partner laboratories at their sites must meet the DOE and local standards in place there for protection of people and the environment. The SLAC safety standards must be met for the components delivered to SLAC by the partners, such as seismic safety standards. The project will verify and assure that the components received at SLAC meet the required standards.

The geotechnical study of the site area to be tunneled and for placement and construction of the Near Hall and Far Hall is in progress now and is expected to be completed by the end of June 2003. The location and footprint of the Near Hall are still being reviewed and reconsidered. It may be moved to a point farther from the linac, which may require more excavation than in the current plan. The results of the geotechnical study should be evaluated in light of the potential for redesign of the Near Hall, and against the information and analyses in the Environmental Assessment, to ensure that it continues to be valid and adequate to support the entire project.

6.3 Recommendations

1. Review the analyses and conclusions in the Environmental Assessment against the evolving designs of the LCLS, its components and Halls, and the results of the geotechnical study to be sure that it remains valid to support the project through design, construction, installation, and into operations.

2. Evaluate the level of ES&H staffing needed to support the continuing design process, as well as construction, installation of components, and operations. Determine that point in the future schedule when dedicated full time ES&H support may be needed.