Department of Energy
Review Committee Report

on the

Technical, Cost, Schedule, and
Management Review

of the

LINAC COHERENT LIGHT SOURCE (LCLS) PROJECT

October 2006

EXECUTIVE SUMMARY

A Department of Energy (DOE) Office of Science (SC) review of the Linac Coherent Light Source (LCLS) project located at Stanford Linear Accelerator Center (SLAC) was conducted on October 24-26, 2006, at the request of Dr. Patricia M. Dehmer, Associate Director for Basic Energy Sciences, SC. The purpose of this review was to evaluate progress in all aspects of the project: technical; conventional facilities; cost; schedule; management; and environment, safety and health (ES&H). In addition, the Committee was asked to provide a thorough assessment of existing SLAC laboratory and office space, and judge whether this space would be adequate to support the operation of the LCLS facility and other reasonably foreseeable activities at SLAC beyond FY 2008 without the LCLS Central Laboratory and Office Complex (CLOC).

The Committee found that the project has made good progress since the February 2006 DOE review. However, substantial challenges lie ahead, principally in meeting the critical path schedule milestones for conventional facilities. Due to extremely unfavorable conventional facilities bids, LCLS management has concluded that there is insufficient cost contingency to proceed with the CLOC. However, the Committee judged that the functionality of the CLOC to support LCLS operations can be provided at modest cost by renovating existing buildings. Overall, the Committee judged that there is adequate cost contingency to complete the project, provided that existing space at SLAC is used in lieu of the CLOC.

The LCLS project is a multi-laboratory partnership led by the LCLS Project Office at SLAC. The partners are Argonne National Laboratory and Lawrence Livermore National Laboratory. When completed, the LCLS will be a world-class scientific user facility 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. The LCLS project will provide the first demonstration of an X-ray free-electron-laser in the 1.5-15 Angstrom range and will apply these extraordinary, high-brightness X-rays to an initial set of scientific problems in disciplines ranging from atomic physics to structural biology.

With approximately 31 percent of the project completed as of August 31, 2006, the baseline Total Project Cost (TPC) was maintained at $379 million and project completion is still scheduled for March 2009. Cost contingency (24.7 percent of the Total Estimated Cost work to go, and 15.5 percent management reserve in Other Project Costs) is believed to be adequate. Overall schedule contingency has dropped from ten to about eight months, with an early finish date of July 2008. The Undulator Hall and undulator installation remain on the critical path, and the early finish schedule is extremely aggressive. The project's cost, schedule, and technical baselines are consistent with those in the FY 2007 LCLS Construction Project Data Sheet and the current DOE-approved LCLS Project Execution Plan, and there appears to be adequate progress to meet the baseline objectives. The information in the DOE Project Assessment Reporting System (PARS) is consistent with physical progress.

Overall technical progress has continued to be impressive. The injector drive laser was installed and has operated well under testing. It does not yet meet beam brightness requirements for full performance lasing. Installation of injector and linac equipment is ongoing during the current SLAC Linac shutdown. Although not on the critical path, the start of injector commissioning was delayed by two months (due to inattentiveness to detailed schedule requirements for ordering components). Undulator fabrication/assembly by ANL and its subcontractors, a critical path activity, is on track. Seven (of 40) production undulator units have arrived at SLAC and are being tested in the Magnet Measurement Facility. However, ANL has experienced problems (vacuum leaks) with the welds in the prototype undulator vacuum chamber design, and a back-up design is being developed to mitigate schedule risk.

Progress in Photon Systems (mirrors, diagnostics, X-ray end stations) is generally good. There is some concern of scope erosion due to contingency usage in other areas of the project. The LCLS interface with the LCLS Ultra-fast Science Instruments (LUSI) project needs more attention, both technically and organizationally.

Since the February 2006 DOE review, all four groups of conventional facilities bids were received by the Construction Manager (Turner), and these have consistently exceeded the base estimates by approximately 50 percent on average. Considerable effort was expended to achieve some cost savings on Bid Groups 1 and 2, which constitute most of the conventional facilities scope excluding the CLOC. Group 1 has been awarded and site preparation work is underway. Award of Bid Group 2 has been delayed pending a DOE procurement review by the Site Office and Chicago Operations Office; these cost proposals expire on November 15, 2006.

LCLS management reasoned, and the Committee affirmed, that proceeding with the CLOC would jeopardize the TPC. Consequently, LCLS management has instructed the Construction Manager not to proceed further with Bid Groups 3 and 4.

On the question of whether there is a credible scenario that allows the LCLS to be fully functional without a CLOC, the Committee concluded that SLAC presented a credible plan to convert existing space in two buildings for LCLS operations staff and users. The preliminary cost estimate for this was identified as approximately $4.0 million, which would be funded within the TPC.

The project has recently completed an Estimate-to-Complete for all WBS elements. Although project cost and schedule performance to date have been adequate (CPI = 0.96 and SPI = 0.97), a great deal of contingency is being consumed in awarding the first two CF Bid Group subcontracts. The remaining cost contingency, presuming not proceeding with construction of the CLOC, is adequate, but it will require focused management attention.

Both SLAC management and LCLS have satisfactorily addressed the actions and recommendations from the previous DOE reviews. SLAC management is very supportive and highly engaged in the LCLS project.

There was one action item resulting from this review: Conduct a DOE mini-review in January 2007 and a full DOE review in April 2007.

In summary, the Committee found that LCLS has made satisfactory progress in all areas; however, substantial challenges remain as the project proceeds into significant construction.

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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 25 percent of the available beam time, and the last one-third of the linac will be available for the LCLS a minimum of 75 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 over 10^{11} X-ray photons in a pulse with duration of 230 femtoseconds or less. These characteristics of the LCLS will open new realms of scientific applications in the chemical, material, and biological sciences. The LCLS Scientific Advisory Committee (SAC), 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 entire new regimes of spatial and temporal resolution to both techniques.

The LCLS project requires a 150 million electron volts (MeV) injector to be built at Sector 20 (S20) 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 (FFTB) tunnel will be removed and replaced by a new

120-meter undulator and associated equipment. Two new experimental buildings, the Near Experimental Hall (NEH) and the Far Experimental Hall (FEH), connected by an approximately 250-meter long beam line tunnel, will be constructed.

Critical Decision (CD) 0, Approve Mission Need, was approved by the Acquisition Executive, Raymond Orbach, Director of the Department of Energy (DOE) Office of Science (SC), on June 13, 2001. SLAC and its two partner laboratories developed a conceptual design and a supporting cost estimate and schedule, which were reviewed by a DOE/SC committee in April 2002. Subsequent to the DOE Conceptual Design Review, the Office of Basic Energy Sciences (BES) provided SLAC with additional funding guidance that delayed the construction start by one year to FY 2006. Under this scenario, long-lead procurements were initiated in FY 2005 and the project used a phased CD-2, Approve Performance Baseline: 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 (PEP), and CD-1, Approve Preliminary Baseline Range, were approved on October 16, 2002. These approvals authorized the project to start Title I design and expend Project Engineering Design (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.

During FY 2003, the project completed Title I design of the long-lead items planned for procurement in FY 2005. A DOE review to evaluate the baseline the scope, cost, and schedule aspects of those items was conducted in Germantown, Maryland on May 21-23, 2003. The review committee concluded that the project's long-lead procurement plans were fundamentally sound in all areas (technical, cost, and schedule), and that the project was ready for approval of CD-2a. On July 1, 2003, the Acquisition Executive approved CD-2a, which enabled the long-lead procurement funds ($30.0 million) to be included in the President's FY 2005 Budget Request. Later in FY 2003, SC re-evaluated the needs of future LCLS users for additional laboratory and office space and directed the project to include a CLO Building in the LCLS scope.

For FY 2004, Congress appropriated $7.45 million of PED and $2.0 million of Operating Expense funds for R&D. Once again, there was a Continuing Resolution that held the available funding to the level of the preceding fiscal year until an appropriation was enacted (in December 2003). The FY 2004 funds enabled the project to acquire architect engineering (AE) services from Jacobs Facilities, Incorporated, for the design of conventional facilities (CF) and make further progress on the design and R&D of the technical hardware, particularly the long-lead items. Title I design of the CF was completed in May 2004. Then, in preparation for CD-2b, Burns and Roe Enterprises, Incorporated (BREI) performed an External Independent Review (EIR). The BREI review team was on site at SLAC in June 2004, and provided their final report the following August. In summary, the EIR team concluded "the LCLS project can complete the baseline scope within the baseline schedule by September 30, 2008, and Total Project Cost (TPC) estimate of $315 million actual year dollars." They also found the LCLS baseline scope, cost estimates, and resource-loaded schedule to be complete and reasonable with adequate cost and schedule contingency margins. The EIR report contained a number of recommendations for improvements, but none that by themselves stood in the way of approving CD-2b.

The next DOE review of the LCLS project was conducted in August 2004, and its purpose was to determine the project's readiness for CD-2b and CD-3a, Approve Start of Long-Lead Procurement. The committee concluded that, in some areas, the cost and schedule contingencies presented did not appear to be adequate given the future risks (e.g., tunneling construction). Also, the planned procurement processing schedule durations for many of the long lead procurements were unrealistically short. The committee did not recommend approval of CD-2b and CD-3a, and instead recommended that LCLS management re-evaluate the project's proposed baseline TPC and schedule and submit a revision to DOE/SC by October 2004, which it did. The baseline proposal called for increasing the TPC to $379 million and extending the schedule by six months to March 2009 for CD-4, Approve Start of Operations. This would serve to increase the cost and schedule contingency amounts to more appropriate levels (35 percent of remaining Total Estimated Cost (TEC) work and 10.5 months, respectively) in keeping with the committee's recommendations. It also included the impact of the FY 2005 Continuing Resolution that lasted until December 2004. A SC mini-review of the new proposed baseline cost and schedule, chaired by the LCLS Federal Project Director, was conducted in November 2004. This committee, which contained several members of the August 2004 DOE review committee, concluded that the proposed TPC and schedule were reasonable.

The FY 2005 Appropriation for LCLS included $19.91 million of PED funds, $29.76 million for long-lead procurement and $4.0 million of Operating Expense funds for R&D. The long-lead items include selected critical path components such as: the 135 MeV injector linac magnets, drive laser, and RF gun system; the X-Band system and bunch compressor magnets for modifying the SLAC linac; the undulator strong back, magnets, and magnet blocks;

and renovations for S20 and the magnetic measurement facility (MMF) needed for verification of undulator performance. The FY 2005 Appropriation matched the amounts requested minus a relatively small General Reduction and Rescission.

From January through March 2005, the project underwent a Limited EIR by BREI at the direction of DOE's Office of Engineering and Construction Management (OECM) to validate the proposed baseline cost and schedule ($379 million TPC and March 2009 completion date). Meanwhile, the Acquisition Executive approved CD-3a on December 10, 2004, so as not to delay placement of the FY 2005 long lead procurements. The limited EIR ultimately resulted in an OECM validation of the LCLS baseline and the proposed baseline (CD-2b) was approved by the Acquisition Executive on April 8, 2005.

In early FY 2005 and with guidance from BES, SLAC began developing a Mission Need Statement for a suite of four instruments to be installed on LCLS after CD-4. They will be funded by BES as a Major Item of Equipment (MIE) and will be designed to address all but one of the science thrust areas in the *LCLS First Experiments* report. (The high-energy-density physics thrust area falls outside the scope of BES, and funding from other sources is required to acquire instrumentation for that thrust area.) SLAC has developed technical concepts for four instruments in close consultation with the scientific community through a series of workshops, conferences, and focused review committees. They have also been endorsed by the LCLS SAC, which is comprised of senior U.S. and foreign scientists and advises jointly the LCLS Project Director and Director of the Photon Science at SLAC. On August 10, 2005, this MIE project, known as LUSI (LCLS Ultrafast Science Instruments), received CD-0.

A DOE/SC conducted a status review of LCLS in May 2005. The committee's primary concerns were the schedule delay in getting the construction manager/general contractor (CM/GC) solicitation out for bid, and the Laboratory's inadequate level of support for the project as an institutional priority. Both areas received Action items. During the remainder of FY 2005, good progress was made in fabricating long-lead procurement items (undulator strong backs, magnet poles and blocks, and in the facility modifications for S20 and the MMF) and the AE worked towards completion of Title II design of the CF.

The FY 2006 Appropriation for LCLS included $2.52 million of PED funds, $82.17 million of line item funds for full-scale construction, and $3.5 million for Other Project Costs (OPC), mainly R&D. As before, the FY 2006 Appropriation matched the amounts requested minus a relatively small General Reduction and Rescission.

The CM/GC procurement was finally awarded in October 2005 to Turner Construction and their partner (for tunneling), Hatch Mott McDonald. The CM/GC reviewed and provided input to the Title II CF design, and the AE delivered the 100 percent Title II drawings to SLAC in early February 2006, with a corresponding cost estimate to arrive later that month. On March 21, 2006, CD-3b, Approve Start of Construction, was approved.

The FY 2007 President's Budget includes $0.16 million of PED funds for completing the design effort, $105.74 million of line item funds for construction, and $16.0 million for OPC. This is consistent with the project's baseline funding profile. Once again, however, there is a Continuing Resolution that is holding available funding to the level of the preceding fiscal year until an appropriation.

The LCLS project has continued with the necessary procurement actions. Several challenges have occurred throughout this process—the most concerning is the escalating cost for most all of the CF. The bidding climate in the San Francisco Bay area is volatile, specifically in terms of commodities costs and labor availability. The first and largest group of subcontracts has collectively exceeded the projects' cost baseline by about 50 percent. The second group of bids (primarily for the CLOC) continues to exhibit the current cost growth patterns.

1.2 Charge to the DOE Review Committee

In a September 6, 2006, memorandum (see Appendix A), Dr. Patricia M. Dehmer, Associate Director, SC/BES, requested that Daniel R. Lehman, Director of the Office of Project Assessment organize and lead a review to evaluate the progress of the LCLS project in all aspects: technical, cost, schedule, management, and environment, safety, and health (ES&H).

1.3 Membership of the Committee

Daniel R. Lehman chaired the Review Committee (see Appendix B). Members were chosen based on their independence from the project, as well as for their technical and management expertise, and experience with building large scientific research facilities. Several members served on one or more of the previous three DOE review committees and provided continuity and perspective. The Committee was organized into ten subcommittees, each assigned to evaluate a particular aspect of the project corresponding to members' areas of expertise.

1.4 The Review Process

The review was conducted October 24-26, 2006 at SLAC in Menlo Park, California. 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 was devoted to project plenary sessions with presentations given by members of the LCLS Project Office staff. On 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.

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2. TECHNICAL SYSTEMS

2.1 Accelerator Physics

2.1.1 Findings

The LCLS has responded positively to the recommendations made at the February 2006 review. Specifically, the controls effort has ramped up and sufficient controls capability is likely to be available for injector commissioning, now scheduled for March 2007. The development by the controls group of a MatLab programmer's guide for LCLS physicists is an important and necessary development.

The full gradient testing of the transverse cavity used for the bunch length monitor system is a significant accomplishment.

The Commissioning and Installation plan is being carefully developed to characterize hardware and accomplish physics goals.

Safety is well integrated into the accelerator design work.

There is good cooperation between LCLS and the SLAC operation group.

The new LCLS/SLAC controls group is fully engaged in addressing a large backlog of required tasks.

There is very little schedule contingency left in the commissioning schedule.

2.1.2 Comments

LCLS must more carefully utilize the system integration and shutdown planning process to avoid bottlenecks leading to further delay.

With a large number of different diagnostic devices scheduled to come online in a short period, LCLS must carefully schedule and prioritize the implementation of diagnostics and controls critical to the commissioning effort.

The use of MatLab scripts for simple physics application development is a good approach. However, the Committee was concerned that this short-term strategy for implementing high-level applications may delay development of necessary long-term capabilities.

Commissioning of the X-ray FEL will require a real start-to-end, online simulation, including the FEL physics in it. This will involve utilizing Parmela/Astra/Impact + Elegant + Ginger/Genesis, with the codes not only linked together and further developed, but also linked to the online control system so that operating machine configurations are readily available as input. In addition, the outputs must be aligned with real diagnostics of both the electrons and photons, so that simulation-to-measurement comparisons can be easily made.

2.1.3 Recommendation

1. Implement start-to-end modeling from the gun through the FEL in a manner useful in the control room to interpret diagnostics data and to optimize total system performance. Start evaluation of this task by initiating collaboration between physics and controls groups by January 31, 2007.

2.2 Injector/Linac Systems (WBS 1.2, 2.2, 1.3, 2.3)

2.2.1 Findings

The Injector/Linac subcommittee heard excellent presentations on the activities since the February 2006 DOE review. The Committee commended the team for the dedication in continuing to advance the knowledge and technical base required to make this ambitious project a success. Overall the design is mature and sound. The scope and specifications are sufficiently well defined to support long-lead procurement and substantial progress is evident in all key areas.

The injector is a crucial technology for the performance of the FEL system as a whole. The earlier it can be brought into operation, the sooner confidence can be established that the stringent requirements can be met. The specifications of the drive laser are at the leading edge of the current state of the art. Delivery of the drive laser now allows work to proceed to achieve the challenging goals of full control of the transverse and temporal profile with high stability. Overall performance of the drive laser remains the highest technical risk in this area. Close behind in criticality is the photoinjector. Hot checkout of the crucial photoinjector is underway with results of the initial RF conditioning very encouraging. Also, a duplicate gun is well along in assembly. The Committee looks forward to first beam next March.

Overall the project's cost, schedule, and technical baselines are consistent with the FY 2007 LCLS Data Sheet. The Committee was comfortable with cost contingency; it reflects risks as presently understood. There is good progress the meet the baseline objectives. The information in the reporting system is consistent with physical progress. While the injector has experienced overruns in many systems the combined Injector/Linac cost is generally under control because of savings due to component duplication. The Committee found the schedule to be tight and has experienced some slips that will unfortunately impact the time available for commissioning this year and increases the program risk. However, the project has not exceeded the allocated schedule contingency at this point, and the work is on track to meet the next year milestone.

Completing the commissioning plans is one key to efficiently bringing the systems into operation. This, in turn, will allow early resolution of any performance shortfalls that are evident. The Committee found substantial progress in this area since the February 2006 DOE review. The plans being produced are detailed and excellent working documents. The Committee encouraged their continuation.

There was a two-month schedule slip in the production of first beam due to miscommunications and fabrication conflicts. This is disappointing, as the slip depleted the commissioning schedule contingency, and put pressure on the injector commissioning schedule.

There will be conflicts (especially this year) for access to the linac tunnel due to PEP-II operation. This will necessitate top-level coordination so that the injector and linac commissioning can proceed apace. The required access will be more than can be covered in unplanned shutdowns due to equipment failures. Priority must be given to this commissioning effort.

The designs are sufficiently mature to support procurements. Most procurements are complete (or at least orders placed) in this area so procurement risk is becoming less of an issue. There are still a few element designs in process, mostly in the diagnostic area. Meeting the schedule will be tight but it is believed to be achievable and is not expected to hold up commissioning.

The gun load lock is not in the present budget or contingency allocation; therefore it will not be pursued (as such a system would reduce schedule risk for operation of the whole system).

The primary technical risk remains the drive laser performance. However, substantial progress can be made at the laser present performance to proceed with injector commissioning, but significant laser work is yet to be done to ensure the gun laser will meet the requirements to satisfy beam brightness needs for full performance lasing. The laser phase lock needs testing and remains a risk item until its performance is demonstrated. Achieving design laser operation is necessary to alleviating performance concerns. Another technical risk is the absolute calibration of the cavity field probes. Initial testing results have indicated a discrepancy in the measured fields using the cavity field loops versus the forward and reflected power. If the fields are lower than required, additional conditioning may be required during the commissioning phase.

Integrated Safety Management (ISM) is being addressed at all stages of the planning. Safety is taken seriously by staff, who are constantly attentive to the work environment. The team was encouraged to keep track of required documentation, approvals, and readiness reviews.

The project responded appropriately to all recommendations resulting from the February 2006 DOE review.

2.2.2 Comments

The LCLS Injector/Linac team agreed that good commissioning plans are key to keeping to the schedule, and present plans have sufficient detail to adequately generate a detailed commissioning schedule. Providing lots of commissioning time for the injector/linac will be useful in reducing the schedule for overall accelerator commissioning and early performance of the FEL. This will also have direct payoffs in lowered project cost. Management needs to make sure the group gets priority to do this. It is crucial to achieve prioritization between PEP-II linac operation requirements and the needs of the LCLC Injector/Linac Groups.

The schedule slip in the injector points to the problem that the project schedule tools do not provide sufficient detail to be useful. Detailed interface schedules are now being considered, but are not yet complete. It is important to determine schedule conflicts and slips early enough to deal with them. This work needs to continue with vigor.

There was good progress made on the diagnostic/controls issues that were evident at the February 2006 DOE review. The schedule is still tight but believed to be off the critical path. A lot of new components, controls, and software need to be developed, and controls should continue to be a focus of management attention.

The Committee heard there was a one-week schedule hit required to demonstrate vacuum qualification of gun with the linac. The Committee questioned rather this was really needed since the photoinjector delivers better vacuum than the SLAC requirements.

There was also a discussion on the discovery of bowing in the removed linac sections. At low energy this can lead to increased emittance. Is the straightness of the remaining accelerator sections known well enough to estimate the overall impact on beam emittance at the final energy?

Another area of interest is the location of the injector linac near the highway and the effect of vibrations on the overall beam stability. The team plans to make measurements of the injector spur line, and BC1 and BC2 locations. The Committee encouraged completion of this task.

2.2.3 Recommendations

1. Establish method and priority to ensure sufficient access to the linac will be provided to allow commissioning to proceed per the required schedule (March 2007).

2. Establish detailed integration plans to identify schedule impacts early enough to ameliorate potential issues (May 2007).

2.3 Undulator System (WBS 1.4, 2.4)

2.3.1 Findings

The LCLS Undulator System includes undulator magnets and supports, undulator diagnostics, vacuum systems, controls for the undulator equipment, and magnet measurement facility. Integration and installation are also included within this area. The project has developed the WBS such that the total cost for the LCLS undulator system planning, project management, design, construction, and installation are summed within this WBS level. There will be a total of 33 undulators installed in the tunnel. Additionally, there will be seven undulator operational substitutes, including three prepared for installation (mounted to full module assembly) at any given time. One is reserved as a standard.

In the present configuration, an undulator magnet is integrated onto a girder that also includes an electromagnet quadrupole, a RF beam position monitor (BPM), a vacuum chamber and support, vacuum pumping, and additional diagnostics. All module components will be aligned with respect to each other on a coordinate measurement machine. The fully integrated girder will be aligned as a unit in the undulator tunnel on a fixed support structure. The girder is mounted on precision cam position adjusters. The undulator is also mounted on a transverse translator that allows an undulator magnet to be remotely retracted from the vacuum chamber or, as a result of the canted poles of the undulator magnet, adjust the magnetic field (the undulator *K*-value).

The LCLS Undulator System continues to make very strong and notable progress since the February 2006 DOE Review. The main magnetic structures are in full production and delivery. Seven production undulators were delivered to SLAC and an additional production undulator was delivered to ANL. Eight more central magnetic structures have been accepted at the suppliers and are ready for shipment. The mu-metal magnetic shield has adequately demonstrated performance and is being fabricated, but its delivery has been delayed and so once the MMF is fully commissioned it might begin to hold up the beginning of production measurements. The last of the production undulators are slated for delivery in April 2007.

Other notable areas of progress include: the MMF, which is nearing completion of commissioning in preparation for full production measurements. The new MMF that was delivered in July 2006 will be used for fine tuning of the undulators. It is in final debugging and commissioning and will soon be fully operational. The Single Undulator Test (SUT) has been fully exploited by the Undulator System Team for extensive design verification tests for supports, movers, and the integrated system. The cavity RF-BPM development has demonstrated solid performance and stability. Additionally, installation, integration, and workflow on equipment delivered to SLAC are progressing well.

The LCLS Undulator System Team identified the following issues during the review: the vacuum chamber is behind schedule and a full-length prototype has not been completed. Consequently, baseline performance has not been demonstrated on a full-length device. Also, the electromagnetic (EM) quadrupole pole material exhibits hysteresis that will likely preclude the use of EM dipole correction incorporated into the EM quadrupoles. LCLS is in discussion with the supplier of the quadrupole, but the necessary dipole corrections can by provided with physical transverse movement of quadrupoles by means of the remote adjusters that are included in the present design.

The LCLS Undulator Team has been responsive to recommendations of the February 2006 DOE Review. They have fully exploited the SUT with a complete series of tests, instrumentation, and integration fits. The work on the cavity RF-BPM has been accelerated and considerable progress has been made so that this is no longer an area of major technical concern. The LCLS has worked on carefully defining unambiguous roles and responsibilities within the Electron Beam Systems with regard to the Undulator System and this is no longer a concern. LCLS has made considerable progress on defining the assembly methodology, magnetic measurements, and fiducialization and installation of both undulator and ancillary systems. LCLS understands that there are several areas needing much work, but has clearly identified a process by which to proceed. There is an understanding of specific documentation needs and a completion plan for remaining specification/interface/technical baseline requirements documentation is in place—work in this area is in process. The LCLS Undulator Team has fully developed and demonstrated an approach that allows the removal of undulator magnetic sections without disrupting the vacuum or diagnostic alignment systems. The approach, which uses undulator section specific shims, should permit the seamless exchange of undulator sections.

Whereas the production of the undulator magnetic structure has gone very well, there have been specific *integrating* and *development* activities have gone significantly over budget and are behind schedule. The SUT (WBS 1.4.3.3.6) in the latest cost performance report (CPR) had a -$198K cost variance with a cost performance index (CPI) of 0.58. The MMF setup task (WBS 1.4.3.6.1) had a -$983K cost variance with a CPI = 0.70. The vacuum chamber development effort (contained within WBS 1.4.4.2) currently shows a -$167K cost variance (CPI = 0.60) on a budgeted cost of work scheduled (BCWS) of only $249K (total value for WBS 1.4.4.2 is $1,961K).

The area of greatest concern remains the undulator vacuum chamber. The physics requirements are demanding and have been difficult to fully identify. Surface finish and conductivity are all demanding requirements derived from wakefield effect calculations. Considerable amounts of engineering development and design tradeoffs have gone into the vacuum chamber. As a result of the requirements, the Undulator System Team converged on a stainless steel chamber with an aluminum inner coating to improve conductivity. At the February 2006 DOE review the baseline approach was to use a stainless steel sheet polished, given an aluminum coating, and then bent into a u-shape and laser welded to a stainless steel piece. This was to have been prototyped in July 2006. Surface roughness tolerances could not be maintained in the corners of the bent structure and this approach was completely abandoned.

A new vacuum chamber design is being pursued at present that consists of two flat polished stainless steel sheets laser-welded to long stainless blocks forming a rectangular cross-section vacuum chamber. The assembly is then machined down, thinning the sheet thicknesses, to the final outside vertical dimensions. The inner surface of the chamber is then plasma coated with aluminum to increase the conductivity. Vacuum pumping of this chamber is provided only at the ends. There are no fundamental technical issues with the proposed design, but there is significant technical, design, and fabrication development to be completed. Required performance has not yet been demonstrated on a full-length prototype. This design and the undulator vacuum system were reviewed by subject matter experts in September 2006. A 42-inch, four-weld vacuum prototype showed good mechanical results, but had a vacuum leak through a weld. Once the weld was repaired, the prototype had vacuum integrity, but vacuum instrumentation was only at the pumped side of the configuration. The two full-length prototype vacuum chambers will not be completed until the end of January 2007, which is also the *gate-point* at which time any additional developments or changes to the chamber fabrication approach will begin to impact the overall project schedule. This schedule in the words of the Undulator System Team is "success oriented." It has no schedule contingency and no time for iteration on any of the process or manufacturing elements that remain.

The LCLS stated that in an attempt to mitigate schedule risk posed by the undulator vacuum chamber, a separate set of design approaches are being considered. These include an aluminum extrusion, an aluminum clamshell, and an elliptically drawn tube. All of these designs are only at a concept or pre-conceptual design level. It was reported to the Committee that the selection of one of these alternative concepts is imminent. The costs associated with the development of an alternative design have not been captured in the most recent estimate to complete (ETC). The goal is that at the beginning of February 2007, if the baseline chamber is not ready for production, the alternative chamber design would be produced.

At the time of the review the Undulator System (WBS 1.4 and 2.4) cost, schedule, and technical baselines are consistent with those of the FY 2007 LCLS Construction Project Data Sheet and the current DOE-approved LCLS PEP. The budgeted cost of work performed (BCWP) was $17.8 million, with actual costs of work performed (ACWP) at $19.3 million within a budget at completion of $40.6 million. The CPI = 0.93 and the SPI was 0.95. The current ETC was reported at $22.7 million with an anticipated contingency of $4.3 million.

2.3.2 Comments

As noted at the February 2006 DOE review, the undulator system organization continues to benefit from a well-developed, well-managed project team. Integration of activities at both ANL and SLAC are in evidence. The technical and project progress since February 2006 has been very good. The SLAC Undulator System Manager, a position added to the Undulator System Team just prior to the February review, has proven key in the development of integration, installation, and logistics as the project is evolving from one focused on the placement of procurements. A smooth evolution in this area is essential if the undulator system is to be completely installed on schedule.

Both the SLAC and ANL portions of the Undulator System Team understand the necessary evolution of the project into one of integration and are responding appropriately. Both parts of the team (ANL and SLAC) appear to be working cohesively, and while integrating activities are only beginning, emphasis is now moving towards making the remainder of the

Undulator System area continue smoothly. For example, ANL is developing the Assemblies, Sub-assemblies, and Kits (ASK) database system that if developed as presented will clearly provide relationships and critical information about the various components, subsystems, and deliverables of the entire Undulator System. The Committee hopes that the ASK database will grow in a timely manner into a very useful tool.

Another area where the Undulator System Team has demonstrated its commitment to pursuing what is best for the overall project is in the area of the SUT. The work in this area since the February 2006 DOE review is *most commendable*. The team made the conscious decision to exceed the original estimates for the SUT and continued to work and fully exploit the critical information from a design and integration standpoint afforded by the SUT. This has been of great value to the overall LCLS project and continues to reap benefits worth several times the SUT variances. Since the February 2006 DOE review, the SUT has served primarily as a design tool with integrating aspects, but it is evolving into a complete integration and installation development tool and so the locus of influence should naturally shift from ANL to SLAC.

The Alignment Diagnostic System (ADS) appears to be progressing steadily and as planned with several complementary aspects incorporated into the design to maximize the potential for a successful system that will be used in conjunction with the beam instrumentation during commissioning and operations.

The production areas of the Undulator System demonstrate very strong management and careful attention to detail. As a result of this careful preparation and attention to detail, the Committee felt that the incentives present in the undulator structure procurements will result in the suppliers completing deliveries well ahead of schedule. The Committee anticipated that the same care and successful subcontract management that the Undulator Team has demonstrated in this area will be extended to the support structure, movers, and other subsystems moving into final production.

The Undulator System's cost, schedule, and technical baselines are consistent with those in the FY 2007 LCLS Construction Project Data Sheet and the current DOE-approved LCLS PEP. There has been demonstrated adequate progress to meet the baseline objectives and that the information reported from the Undulator System to the DOE Project Assessment Reporting System (PARS) is consistent with physical progress.

With the exception of the undulator vacuum chamber, the Undulator System technical systems are sufficiently mature to support the hardware procurements planned in FY 2007. The procurement plans and equipment installation plans for the Undulator System do support the overall project schedule, but much work remains to be completed in addressing integration tasks and deliverables. The Undulator System Team and the LCLS project as a whole appear to be well aware of this and the Committee felt that satisfactory progress would continue.

The estimated contingency (cost and schedule) within the Undulator System area of the LCLS project appears to be adequate to address the risks inherent in the remaining work. However, whereas previously the Undulator System had been able to return contingency to the LCLS project as work has progressed into production, that trend is unlikely continue. This is based on the cost and schedule overruns of key integrating activities in the Undulator System area. Consequently, the Committee judged that the Undulator System will consume the contingency estimated as being necessary ($4.3 million) as integrating activities and installation activities begin to dominate. So the LCLS project should be able to meet the baseline objectives within the Undulator System, but careful active vigilance is required.

The Committee judged that the Undulator System Team and its interactions with the Electron Systems Team and the LCLS project as a whole is being managed properly, ES&H aspects are being properly addressed, and recommendations resulting from previous DOE reviews have been properly addressed.

The undulator vacuum chamber is an area of considerable concern for the Committee. The remaining development schedule for baseline design to be completed by the end of February is highly unlikely to be achieved. There are simply too many issues to resolve, and while none are insurmountable, it is unrealistic to assume that addressing the remaining issues will not require some degree of iteration or refinement, which simply is not allowed in the present schedule. A simple example is the aluminum plasma coating of full-length vacuum chambers. As presented to the Committee, there was no plan to test the coating technique on a full-length glass tube and instead go directly to attempting to plasma coat the full-length (3.5-meter) vacuum chambers. With an internal diameter of 5 mm, the simple logistics of threading to aluminum tubes and circulating water through them executing the plasma coating, removing the tubes without damaging the coating appears somewhat daunting without initial testing on a full-length glass tube. The glass tube would provide valuable staging and handling opportunities and give a direct measure of the success of applying and maintaining a uniform coating over the entire length.

Unfortunately, the schedule risk mitigation strategy being pursued appears no more likely to succeed in the available timeframe than the baseline design schedule. It is highly unlikely that a design, not at full concept at the end of October 2006, could be fully developed and have a detailed design (and strong assurance of meeting all technical and scientific requirements) whereby fabrication could proceed in February 2007. The Committee was concerned that an alternative design cannot be developed in the timeframe available without relaxing some aspects of the vacuum chamber specifications. Likewise, without immediately narrowing the focus to an approach with minimum risk (such as aluminum extrusion of half shells that are polished, friction stir welded, and the finished machined) an alternative vacuum chamber design is simply not a viable *schedule* risk mitigation strategy.

In view of the extreme schedule pressure, LCLS must exercise great care in handling vacuum chamber issues to minimize disruption or delay of the baseline effort, and it is likely necessary to add selective additional resources to the baseline effort to attempt to relieve some schedule pressure in specific areas.

This leads the Committee to one of its major concerns within the Undulator System: *integration* issues. Integration used in this sense is one of its broadest interpretations. On individual activities, it can be interpreted to mean *any* activity where several deliverables or other activities culminate in order to achieve success. This continues to be the major area of concern for the Committee. A trivial example of this is the Risk Registry. While the LCLS project presented the Risk Registry as being a tactical tool and becoming a *punch list* for the project, the Committee noted that none of the undulator system risks have been updated in more than six months. The Risk Registry does not appear to influence, drive, or capture, project decision making in the area of Undulator System. As such, it is neither a tactical or strategic tool in this area

Additionally in the area of integration, the Committee noted that the cost and schedule overrun on the MMF has been principally labor. Originally, the MMF was to be fully commissioned and ready for magnetic measurements by August 2006 and production magnetic measurements begun by September 2006. At the end of October 2006, it was not yet fully operational. This is disconcerting as it is one of the few *integrating* tasks to be executed within the Undulator System since the February 2006 DOE review, and the Committee hoped that it will not be indicative of future integrating activities or their present estimates. Likewise, the transfer of scope between ANL and SLAC continues to be a concern. If meticulous care is not exercised, it may create unrecognized gaps in the trasfer.

2.3.3 Recommendations

1. Within two weeks of the selection of a backup vacuum chamber concept, explicitly add the cost of the backup vacuum chamber design and development work to the LCLS project plan.

2. Advance the development of the backup vacuum chamber design sufficiently that it could become a viable production option if the baseline chamber design is not successful by January 31, 2007.

3. Advance the development of the baseline vacuum chamber as much as possible and convene an independent set of third-party experts to recommend the selection of a design (baseline or back-up) to move into production before February 15, 2007.

4. To broaden the exposure and involvement of SLAC personnel in the undulator installation planning, consider installing or duplicating the Long-term Test Setup (LTS) at SLAC. A plan for this transition should be prepared before the next DOE review, April 2007.

2.4 Photon Beam Handling Systems (WBS 1.5, 2.5, 1.6, 2.6)

2.4.1 Findings

Progress, in general, has been good in the Photon Systems area since the February 2006 DOE review. The Front End Enclosure designs have been frozen (except the orientation of the high energy off-set mirror–details below), allowing engineering and design work to progress in an effective manner.

The suite of diagnostics tools is impressive. Most of the diagnostics are unique/state-of-the-art instruments and will require extensive commissioning and testing with the real beam to determine background rates, signal-to-noise ratios, etc. Nonetheless, the designers are confident that the instrumentation will work as planned.

The Photon Systems (XES) group has taken on the responsibility to coordinate all safety-related aspects for the user experiments and general user environment. This was the first time the Committee heard this—they felt that this is a very positive statement as it defines overall responsibility early in the design phase of the user instruments and stations.

Design of the atomic/molecular physics experimental station instrumentation is sound.

The Controls Department Leader assured the Committee that the needs of the Photon Systems would be met. The task seems to be vulnerable to delay due to other (earlier) demands on the controls team.

The two off-set mirrors systems are critical for the success of the experimental program as radiation cannot pass into the experimental stations without them (nor are the downstream experimental stations shielded for the Bremsstrahlung radiation associated with a direct line of sight to the undulators and linac). The low energy three-mirror system design is on schedule. A decision on the orientation (vertical vs horizontal beam deflection) of the high energy mirror pair is yet to be determined, but still on the planned schedule. Detailed design of mirror holder, chamber, and support is very important for mechanical stability to minimize mirror-pointing errors and cannot begin in earnest until the decision on the orientation is finalized. The reviewers were pleased that spare off-set mirrors are included in the OPC budget.

Feedback may be necessary to ensure both the mirror figure (which is designed to be flat) and overall pointing stability. Feedback systems such as these can be tricky and the mirror holder should be designed to accommodate the feedback systems.

The required figure error for the mirrors is achievable (<u>at</u> the state-of-the art, <u>not beyond</u>), but vendor delivery estimates for state-of-the-art mirrors tends to be optimistic. The estimated cost and contingency allocation (45 percent) is reasonable for the mirrors substrates and associated mechanical/vacuum systems.

2.4.2 Comments

The team has done a very good job on diagnostics instrumentation and expressed confidence that their instruments will work. Since these instruments are unique, they will most likely require considerable commissioning to resolve problems. Therefore, it may be prudent to consider backup/alternate plans should the performance of some not meet expectations. As described to the Committee, the diagnostics will provide users with required information on the beam parameters. If the diagnostics are ready in time they could be useful for FEL commissioning. If they are not ready, the accelerator commissioning team should be brought into the discussions on the diagnostic tools to share information being developed by the photon systems staff.

The very important interactions and discussions between the Photon Systems team and LUSI team (co-location of staff, common engineers/designers, and shared participation in reviews were some of the things mentioned) should be encouraged to ensure a seamless integration of the two teams.

At the February 2006 DOE review, the differing work styles between SLAC and LLNL staff was apparent; that working relationship seems to have improved/converged.

In the last six months the schedule of the entire WBS 1.6/2.6 was updated and revised, and the XES installation schedule was developed; however, in some cases installation and alignment schedules for the photon systems hardware seemed optimistic. This would be a good time to revisit those schedules and reevaluate the estimates.

There is the ongoing concern by reviewers that changes to other elements of the project will continue to erode the scope of the XTOD/XES and to cause schedule delay through resource diversion. Although the equipment removed from the atomic/molecular physics endstation, in particular streak camera and high-resolution monochromator, will not impede the initial phase of the proposed experimental program, it would be important to develop a funding strategy for these items.

There are many reviews/meetings between the DOE/SC reviews. To ensure the best use of staff and reviewers time, it would seem to prudent to: 1) clearly identify the scope of all reviews to reduce overlap/duplication and 2) provide DOE/SC committee members with copies of other review reports.

The Committee judged that has there adequate progress since the February 2006 DOE review to meet the baseline objectives and that the designs of the technical systems sufficiently mature (with perhaps the exception of the high-energy mirrors) to support the hardware procurements planned in FY 2007. The Photons Systems team has responded to recommendations from prior DOE/SC reviews including simulations of mirror performance with expected figure eroros, the use of TTF/FLASH and SSRL to test some concepts/ideas in the diagnostics area and firming up the front end enclosure designs have been frozen, allowing for serious engineering work to commence on the various attenuators (gas/solid attenuator) and diagnostics (such as the gas detector, total energy monitor).

2.4.3 Recommendation

1. Finalize the orientation (vertical vs horizontal deflection) of the high-energy mirrors by January 1, 2007 so that the procurement packages for both the low-energy and high-energy mirror substrates can be released nolater than May 2007 (early start date on the current schedule).

2.5 Control Systems

The Controls subcommittee met with Hamid Shoaee and many members of the LCLS Controls Project Team for a series of presentations and discussions. Ray Larson, Assistant Director in the Operations Directorate, took considerable time to explain the upcoming reorganization and its motivation. Much progress has been made since the February 2006 DOE review, and a strong focus on short-term deliverables has made it appear likely that the control system will be ready for injector commissioning next March. The schedule remains aggressive for the remainder of the project.

The control system design is mature in most global controls areas, beam injector, accelerator controls and undulator controls, and in the diagnostics for these subsystems. Controls and diagnostics for X-ray photon systems are being defined and developed. These will employ LCLS global controls elements for vacuum, the Machine Protection System (MPS), PPS, and most of event timing and data acquisition, but they will require a few new and as yet incompletely specified elements such as two-dimensional X-ray detectors and (possibly) active mirror figure controls.

2.5.1 Findings and Comments

The Controls Department was very much involved in the recent ETC. Approximately $3 million was added to the Controls TPC and $3 million more to the OPC. This amount was the result of a large number of "put and takes" across all subsystems—there is no simple "bumper sticker" explanation for the increase. With the exception of application programming, there is sufficient detail in the estimates for the downstream portions of the linac and for the photon systems to engender confidence. The Committee was comfortable that the current estimate is realistic, as is the 27 percent contingency estimate. "Scope creep" is always a cost risk, so scope will have to be carefully managed to keep within the estimate. (The Committee noted, for example, the possibility of a new requirement to control the X-ray mirror figure to correct for possible sag. This could result in a non-trivial cost increase.)

If current schedules are maintained, controls will be available for the injector vault and Linac pre-beam checkout starting in January/February that will meet the project schedule. This was a serious concern at the time of the February 2006 DOE review. The turnaround was achieved by redeploying some resources, by making temporary performance compromises in the MPS and timing systems and by delaying the XAL implementation of high-level applications. Controls features available to support injector commissioning include injection drive laser stabilization, fiducializing the cathode location, LLRF control for gun, dark current measurements, vacuum pump/gauge controls, feedback for gun temperature stabilization, magnet power supply controls, system timing, machine protection and beam containment.

Beam instrumentation and diagnostics are also required for injector commissioning including a beam profile imaging system, stripline BPM, toroids and Faraday cups, a bunch length monitor and wire scanners. This instrumentation will also be available if several aggressive schedules are maintained for BPM and toroid hardware and timing system software.

The cable plant, which appeared to have serious schedule issues in February 2006, has completed the first phase of a two-phased approach that successfully allowed the cables to be installed before the drive laser installation. For the current second phase of installation, almost all of the required cables have been delivered and installation of the cables, racks, chassis, and inter-rack wiring is proceeding on schedule.

A remaining short-term schedule concern is with the new global timing (event) system, which is still under development and is required in order to obtain beam synchronous data. There is no back-up plan for the March commissioning schedule. Unexpected technical difficulties could result in a schedule delay. A new project manager for this critical system was recently appointed only last week. Schedule-critical activities should be identified immediately, and personnel assigned as required.

The focus on the early commissioning milestone does little to alleviate concerns about the very large amount of work remaining to achieve later milestones, notably, but not exclusively, for X-ray system controls and diagnostics. The need to retrofit temporary systems such as the MPS installed for injector commissioning with the new systems to be used downstream while those downstream milestones are rapidly approaching will be extremely demanding.

The flexibility resulting from the new controls organization (described below) should position the controls team to meet these demanding schedule requirements, which would otherwise have been impossible.

SLAC controls have been reorganized to combine the LCLS Controls Team with the controls part of the former CPE department. Hamid Shoaee is leader of this integrated Controls Department, as well as of the LCLS Controls project team within it. He therefore has command of most of the resources required to meet LCLS controls goals. A deputy department head will take primary responsibility for other SLAC projects (PEP, ILC, SABER, fixed target experiments) so that Hamid can concentrate on LCLS. A new layer of subproject leaders within the LCLS controls organization reduces the number of direct reports and the management and technical load. Hiring is underway to fill identified personnel needs.

The integrated Controls Department includes approximately 80 people, of which approximately 60 are assigned to LCLS for at least some of their time. This amounts to approximately 45 FTEs, which is consistent with the requirements identified in the resource-loaded schedule at this time. During FY 2007 LCLS controls manpower will reach its maximum with an increase of about 30 percent above the current FTE levels. Internally the LCLS controls group has been organized into small project teams to address both short- and long-term objectives.

This reorganization largely addresses the concern from the February 2006 DOE review of conflicting priorities within CPE. The Committee felt the new organization significantly improved the probability of the LCLS controls team meeting its goals on time and within budget. Moreover, the reorganization is an indicator of strong project support from senior management.

The Committee was particularly pleased to note that the long-favored PLC-based PPS system has now been approved by the SLAC "Citizen's Committee." The delays in obtaining this approval had been a schedule concern, as well as a draw on resources to maintain a traditional relay-based back-up approach. Considerable progress has been made in the installation of this system, and the benefits are already evident in the clean (and hence easily maintainable) installation. An independently-developed certification procedure is being prepared, and a week has been reserved in the schedule for certification before the first commissioning run. All good.

The MPS has been initially scaled back as part of a two phase approach that meets the injector commissioning schedule with the first phase employing the current SLAC MPS design as an interim solution. For full LCLS operations, this interim solution will be replaced by a new flexible integrated MPS system that will be able meet the requirement to shut-down beam within one pulse at the full 120 Hz rate.

A systematic process is in place to inspect non-UL listed electrical equipment for electrical hazards. SLAC appears to be doing a good job of reducing the electrical safety risks introduced into the workplace from using non-UL listed electrical equipment. This good practice applies across the board, and not exclusively to LCLS or its controls team.

Successful demonstration of the "SLC-aware IOC" makes available to LCLS the rich suite of SLAC accelerator physics applications, as well as a model for most of the machine, including the injector. For devices where the SLC-aware IOC does not provide information to the legacy control system, such as the wire scanners and beam imaging system, a manual has been prepared to assist in the development of MATLAB applications by the Physics Group. This is an appropriate short-term strategy to mitigate late delivery of XAL-based applications, but should be recognized as only temporary. These are all important developments. It should be noted, however, that models and applications do not yet exist for important aspects of LCLS that were not already a part of SLAC—including space charge effects, the photo injector and X-ray handling and diagnostic systems. Many of these applications will be required for successful commissioning.

It is important to start work on these missing applications as soon as possible, and to do so using the tools and in the environment already selected for the final deliverable. That means XAL-based applications and extensive use of a relational database for the model and for configuration data. MATLAB has inherent limitations and cannot be the preferred tool for all of the global applications required for successful commissioning of LCLS. If there is resistance to the use of XAL and Java, it might be useful to arrange a visit to SNS for concerned physicists. There they would see XAL applications developed by accelerator physicists and used successfully for commissioning a complex machine.

2.5.2 Recommendation

1. Starting January 31, 2007, identify and specify the high-level applications required for those systems for which applications do not yet exist, and by April 1, 2007, mobilize the forces necessary to begin the design and implementation of those applications.

3. CONVENTIONAL FACILITIES (WBS 1.9, 2.9)

3.1 Findings

The LCLS Conventional Facilities (CF) scope represents a significant fraction (over 43 percent) of the LCLS TEC. The current CF baseline estimate is now $116.6 million, up from $106.5 million in February of 2006; however, this revised estimate represents a scope reduction of the $17 million line of the CLOC. As a result, the CF baseline scope estimate has actually increased by $27 million or 30 percent since February 2006. The rest of the scope of work including the on-grade construction, cut and cover, and tunneling construction has essentially remained the same. The total anticipated excavated soils quantities have increased to approximately 180,000 CY as compared to the 75,000 CY identified in February.

The CF project management team has been augmented over the past six months in preparation for the start of construction. LCLS Project Management has added an experienced Associate Project Director for Civil Construction. Further staffing actions are anticipated, specifically for University Technical Representatives.

LCLS has engaged Jacobs Facilities, Inc. to perform the Title III AE services for the construction phase of the work. Jacobs has provided an on-site, full-time liaison to expedite handling of construction documentation such as requests for information, submittals, and change orders.

The construction management/general contractor (CM/GC), Turner Construction, has entered the second phase of their contract and was issued an NTP in August 2006. The second phase is a fixed-price contract, incrementally funded with a construction schedule of 28 months. The current contract value for Turner is $77.4 million with $15.2 million funded as of October 1, 2006. Turner has competitively bid the majority of the bid packages (1-4), with the analysis and bid certifications complete and awarded for Bid Group 1; the work is ready to be awarded for Bid Group 2 pending approval from DOE Stanford Site Office. The four Bid Groups were estimated at approximately $70.5 million with bids received for approximately $94.7 million or an overage of approximately 34 percent.

Considerable effort was expended to achieve some cost savings on the “beam track” bids (Groups 1 and 2.) Group 1 (including the rock tunneling) was awarded and construction began September 11, 2006. Group 2 has been accepted but not yet awarded. Groups 3 and 4 included the work for the CLOC. If accepted, the cost of this work would have jeopardized the completion of the rest of the work. A decision to eliminate the CLOC from the project scope was made, and the implementation of this decision is underway.

Turner has mobilized on site and begun mass excavation and other mobilization activities. Turner has proposed a 24-month construction schedule with a peak of approximately 200 craft and a peak monthly expenditure rate of over $7 million. Conversations associated with removal of the CLOC, as well as early occupancy of the Undulator Hall have begun with Turner though no formal contract actions have been taken.

The two contracts for the limited CF work at locations separate from the majority of the LCLS site have been completed, as have other minor preparatory construction activities.

Tunnel rescue training has been completed for the SLAC emergency response team, and the construction safety program is functional.

Turner's latest construction schedules (submitted to LCLS management) does not reflect the latest mutually accepted value engineering modifications, nor the elimination of the CLOC.

3.2 Comments

Turner's project manager alleged that the work is behind schedule. It is difficult to evaluate Turner's progress due to the absence of a current resource-loaded schedule. The conversations regarding value engineering efforts, reduction of the CLOC, and the difficulties with the bid results may have clouded this issue; however, it is critical that a resource-loaded schedule is agreed upon immediately. It is necessary to understand the obligations profile required by this Turner schedule in order to maintain a schedule in face of uncertainties of possible additional continuing resolutions.

Furthermore, Turner's approach to representing uncertainties with weather and other potential delays will make it difficult to evaluate actual progress; this should be re-evaluated and incorporated into the CF plans in a way that allows for appropriate EVMS reporting. Careful consideration should be given to the time and approach to discussing early occupancy plans with Turner; given the existing uncertainty in their schedule and cost profiles, those issues should be resolved first. As Turner begins to perform well against the agreed upon schedules, discussions could begin regarding the appropriate way to involve early special equipment installations. It might prove efficient to increase the scope of Turner's work to include most of the proposed "early occupancy" work.

The Committee understood the approach taken to evaluate needed contingency; however, this should be re-evaluated based upon the current history and the potential for modifications due to changes from the newly created integration management team, LUSI, and other design changes proposed by the special equipment teams. The Committee was concerned that the proposed contingency will not be adequate, yet cannot make recommendations to increase it at this time due to so much uncertainty in the scope and schedule for the work.

The decision to eliminate the CLOC as previously planned to maintain the project TPC below the authorized amount requires further analysis to understand the technical details of this decision, including secondary impacts. The CF team needs to identify a lead to rapidly define the scope of these impacts, identify the options for retaining certain scope and to ensure follow-through with Jacobs and Turner contracts in a timely manner. It appears that uncertainty in the actual scope to be removed or re-defined is already impacting field activities.

The fixed price guarantees for Group 2 bid packages were extended once, and are currently set to expire on November 15, 2006. A problem was identified by the CF team with the DOE approval because of the increase of the Turner work under contract to over $75 million. This must not result in the loss of the current fixed pricing.

3.3 Recommendations

1. Obtain from Turner a current resource-loaded project schedule. Discuss the schedule with DOE by Thursday, November 2, 2006.

2. Reevaluate cost and schedule contingency after accepting the Turner resource-loaded schedule and completing contract renegotiations.

3. Obtain DOE approval for the award of the Bid Group 2 contract before the November 15 price expirations.

4. Define what the elimination of the CLOC includes, and fix any secondary impacts.

5. Finalize and complete renegotiation of the Turner contract. If possible include more powerful incentive methods. Complete all value engineering changes, including the CLOC deletion, as quickly as possible, no later than the end of November.

6. Adjust the Turner schedule to eliminate any false indicators of delay.

7. Prepare an obligations profile for the Turner contract work. This might be necessary to work around the effects of possible ongoing continuing resolutions in FY 2007.

8. Complete the technical designs and consider LUSI impacts as quickly as possible and evaluate these designs for additional impact on CF work under contract.

4. COST, SCHEDULE, and FUNDING

4.1 Findings

The LCLS cost baseline was approved in April 2005 (CD-2b) at $379 million (as spent) with project completion in March 2009. It contains $315 million for construction funded activities (TEC), and $64 million for OPC. As of August 2006, $99.1 million has been costed, and total obligations are $144.5 million. Approximately 75 percent of the planned procurements have been awarded. There is $43.77 million of available contingency, or 24.7 percent based on the remaining TEC and pending baseline changes (-$1.3 million). A recent baseline change removed the CLOC from the cost baseline and returned approximately $17 million to contingency. There is also $7.4 million (15.5 percent) of management reserves for remaining OPC work. A breakdown of the TEC and contingency can be found in Appendix D. A formal change control process exists and is being utilized for baseline changes.

The project's earned value data shows that through August 2006, the overall project is approximately 31 percent complete. The CPI is 0.96 and the SPI is 0.97. The project's PARS data is consistent with the project earned value reporting and is current through August 2006.

A bottoms-up ETC was performed, and incorporated in the baseline, in July/August 2006, along with a risk-based contingency analysis. The project's bottoms-up risk based contingency needs assessment indicated that 19.7 percent of contingency on the remaining TEC was needed. An ETC is to be performed annually and the contingency analysis will be performed every six months.

The funding profile and BCWS for the LCLS project is contained in Appendix F. Through FY 2006, the project received $149 million in funding, and $106 million has been requested for FY 2007. The funding profile is consistent with the baseline schedule. It appears that the Continuing Resolution (CR) will not impact the project, unless the CR continues into 2007. Phase-funded contracting is being utilized to optimize budget authority (BA) use.

Project representatives presented cost estimate information to each of the technical subcommittees (see Section 2 for cost estimate comments on specific systems).

At the end of August 2006, the project Risk Registry documented 114 risks of which 66 have been retired, leaving 48 still open. The Risk Registry contains input from the project system managers on a monthly basis. The risks impacts and probability of occurring are not kept current. An evaluation of the risks is not utilized in developing the EAC. The EAC is a calculated value based on variances and pending baseline changes (BAC+0.9CV+0.1SV+PBCRs).

LCLS uses Primavera Project Planner (P3) as the scheduling tool with Cobra as the cost processor. The project baseline in May 2005 had a resource-loaded schedule comprised of 12,341 activities. As of August 2006, there were 10,469 activities remaining of which 7,405 were resource loaded. The schedule baseline date for CD-4 (Approve Start of Operations) is March 2009. The project's early finish schedule shows project completion in August 2008. "Early occupancy" dates have been proposed by the project to allow installation to begin prior to beneficial occupancy; as of October 26, 2006, early occupancy dates were not negotiated with Turner. In addition, the re-negotiated resource-loaded civil construction schedule were not incorporated in the project baselines; construction started September 11, 2006, yet craft construction progress performance has not been reported.

The project's controlling path starts from the Undulator Hall early occupancy (target date to permit installation prior to beneficial occupancy) to installing the Undulators to FEL commissioning to delivery of photons in the Far Experimental Hall. This controlling path has not changed since February 2006, but the schedule contingency has decreased from approximately ten months (213 days) to approximately eight months (166 days). The next controlling path is the undulator vacuum system and undulator testing.

Milestones are reviewed and monitored regularly by the LCLS project management team. There are 28 Level 2 milestones, of which eight have been completed to date. Of the 142 Level 3 milestones, 51 are complete, ten of which were completed since February 2006. The upcoming key Level 3 milestones are on or ahead of schedule.

4.2 Comments

The contingency funds appear adequate to complete the remaining project scope, but will need continual management attention.

Based on current plans, FY 2007 activities could become constrained by the FY 2007 BA. It will be essential to continue focus on BA management, phase fund procurements, and be prepared to re-plan if needed.

It is extremely important to maintain/review a current EAC, especially when civil construction begins, to evaluate and ensure sufficient contingency funds remain.

The project identified several “false” cost variances in their earned value reporting that need to be corrected with cost transfers within the TPC through the SLAC accounting system. For example, some spares have been costed with TEC funds, which are more appropriate to be costed with OPC funds.

The Committee felt that the project early finish schedule was optimistic, and in civil construction, extremely optimistic. However, the early finish schedule provides approximately eight months of total schedule contingency and CD-4 should be achievable.

The re-negotiated resource-loaded construction schedule from Turner needs to be integrated into the project cost and schedule baselines to understand impacts and so that accurate progress reporting can be performed.

4.3 Recommendations

1. Update the EAC monthly based on a management assessment of variances, key risks, and upcoming changes (especially those in CF).

2. The SLAC financial office needs to support the project with timely financial/ accounting actions to ensure accurate reporting of earned value data (by the next SC review).

3. Integrate the re-negotiated Turner resource-loaded construction schedule into project plans, and determine the impact to the project cost estimate, schedule, contingency assessment and FY 2007 obligation plan (by November 30, 2006).

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5. PROJECT MANAGEMENT

5.1 Findings

The LCLS Project Team has made good progress across the board. The Project Director and Deputy Project Director are providing diligent, focused leadership of the project. SLAC has also significantly strengthened the LCLS management team. An Associate Project Director for Civil Construction has been hired; an Associate Project Director position for Engineering is in recruitment; and several senior procurement people were also hired.

SLAC management has clearly established LCLS as the top priority of the Laboratory. This is evidenced by such actions as support of the Laboratory Director's Office in staffing; reorganization of SLAC Controls; announced plans for reorganization of the linac operations group; and creation of an Ombudsman to resolve issues between LCLS and other groups at SLAC.

The internal Project Management Oversight Group (PMOG) and external Facilities Advisory Committee (FAC) are actively engaged and providing constructive advice to the project and Laboratory management.

The System Integration (SI) aspects of the project have been significantly strengthened. Detailed planning on installation and commissioning has been initiated by a newly created management team. This function should assist in overall integration of activities, address management and technical interfaces, and ensure good communication among systems owners.

The Turner Civil Construction contract is on the critical path of the project; however delays in DOE review and approval of the Bid Group 2 could delay important work. SLAC has removed the CLOC from the baseline earned value management system scope to ensure that adequate contingency remains for the scientific scope of the project following civil construction bids that came in approximately 50 percent over estimate, including the CLOC. A Space Working Group (SWG) was established to help identify suitable alternatives.

5.2 Comments

The LCLS project's cost, schedule, and technical baseline is generally consistent with the FY 2007 Project Data Sheet and PEP.

The recently completed update of the ETC resulted in remaining contingency of approximately 20 percent of costs to go, which is considered sufficient, especially considering that this figure does not take credit for the substantial amount of work for which there are firm fixed price awards placed but not yet costed.

The internal schedule is aggressive, and has experienced slips of approximately two months in initial phases of civil construction and commissioning. The remaining schedule contingency relative to the official CD-4 milestone was reported to be approximately eight months, which is considered to be adequate.

The project is being managed adequately to proceed with construction. Support from SLAC overall is good, but some attention may be needed in some areas (e.g., financial).

DOE needs to take prompt action to resolve the Turner subcontract approval issue.

The Management subcommittee judged that there are options for preserving essential CLOC functionality in the baseline that are also prudent with respect to budget and contingency and are more consistent with the Project Data Sheet.

The management relationship with Turner has been somewhat strained, but seems to be improving. Because of the importance of the civil construction to the LCLS project, this situation should continue to receive close SLAC/LCLS management attention.

Earlier issues associated with obtaining timely Citizen Committee input into pre-construction work activities seem to be resolved. LCLS management should work to ensure that there is adequate time for any necessary future reviews as part of its overall work planning.

As LCLS moves closer to installation and commissioning, other SLAC groups will have an increasing impact on the project. It is important that SLAC management continue to assure that appropriate support and resources are provided to keep the project on cost and schedule while not confusing management accountability.

The System Integration management team has been in place for approximately one month and appears to be functioning effectively. SLAC/LCLS management should ensure that appropriate staffing of this group is maintained as the pace of installation and commissioning is increasing.

More attention is needed to assure that appropriate interfaces between the LUSI Project and LCLS are established.

SLAC management should assure that priorities for the APD for Civil Construction are aligned with the most urgent needs of the project.

The PEP needs to be updated (same comment as February 2006 DOE review).

5.3 Recommendations

1. Resolve the office/laboratory issue to develop a plan that maintains the required functionality by November 30, 2006.

2. Resolve the Turner contract approval issue as soon as possible (i.e., October 26, 2006).

3. Update the Integrated Project Schedule (IPS) to reflect actual status and current plans, particularly with respect to conventional facilities, by December 15, 2006.

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6. ENVIRONMENT, SAFETY and HEALTH

6.1 Findings and Comments

The February 2006 DOE review committee recommended implementation of an ES&H tracking system. A Corrective Action Tracking System (CATS) has been implemented and refinement of that system continues. An additional tracking system called Preliminary Notification Reports complements the CATS system. The combination of the two reporting systems is effective and continues to improve.

LCLS is preparing for the start of commissioning of the Injector within the next few months. A Safety Analysis Document (SAD) is required prior to accelerator operations by DOE Order 420.2B. The LCLS project has prepared a SAD for the upcoming commissioning activities. The SLAC SAD is currently being updated and LCLS activities should be incorporated into it during this revision or at least in time for the second (transfer line) commissioning effort.

An Accelerator Safety Envelope (ASE) derived from the SAD is also required by DOE Order 420.2B. The project has developed an ASE for injector commissioning which fits within the authorized SLAC operating parameters.

The LCLS project safety staff has been aggressive in assisting Turner Construction implement its safety program. Project engineers (University Technical Representatives or UTRs) provide on-site front-line ES&H oversight of construction activities on behalf of LCLS. The UTRs are in turn supported by LCLS safety professionals.

Turner Construction also operates a formal, documented safety program. All incoming workers are drug-tested and given SLAC and Turner safety orientations. Daily safety inspections are documented and corrective actions are tracked. Safety observations are trended locally and against Turner’s nation-wide operations. To date, the project’s construction safety record has been very good, and continued emphasis on safety will be necessary as the number of subcontractors and construction workers balloon in the next year.

ISM has been significantly implemented into construction activities at LCLS, both by project management and the major contractor Turner Construction as evidenced by:

- Regular surveillances,
- Safety briefings,

- Regular management safety walks,
- Tracking and trending of safety observations,
- 100 percent drug testing for new construction employees, and
- Some personnel reassignments based on safety.

Note: The project took the initiative to halt work once on the construction site in order to correct less-than optimum Turner safety practices.

Anticipated radiation safety issues at LCLS are a subset of those already faced and solved by SLAC operations. ALARA and design support were provided to the project from existing resources as needed, and existing SLAC safety processes and procedures are being effectively utilized during initial commissioning activities.

LCLS has prepared for its upcoming initial Accelerator Readiness Review. There have been delays in vital components needed for initial operations, and installation activities for some other systems have been relaxed accordingly. Schedules have been established for components and systems that will not be ready for operations by the time of the review.

Citizen Committees and safety specialists perform safety-related reviews and approve work as directed by the Chair of the Safety Oversight Committee. These relationships are defined in Chapter 31 of the SLAC ES&H manual. However, the charters for at least some of the Citizen Committees do not clearly specify the committee's role (advisory or authorizing) nor do they specify to whom the Committees will report. The roles and authorities of the Citizen Committees would be clearer to affected workers if the committee charters were updated and made more descriptive.

An extensive pool of electrical experts have been trained to perform UL-equivalency inspections on unlisted equipment. This capability will improve safety and prevent operational delays, and the effort expended to train and qualify these experts is commendable.

ES&H aspects of the LCLS project are being properly addressed given the project's current stage of development. The project has responded appropriately to previous ES&H recommendations.

6.2 Recommendation

None.

7. LABORATORY SPACE

7.1 Findings

While the current project baseline includes budget for a CLOC, the project has been reassessing requirements, as well as exploring alternate means of providing the office space to support LCLS operations and photon science. SLAC senior management has been engaged in these efforts as well, first, by establishing a very high-level SWG chaired by both SLAC deputy directors, and second, beginning to socialize the issue of appropriate space utilization throughout the laboratory community. The SLAC Director published a column on September 25, 2006, in the Laboratory's daily electronic newsletter "SLAC Today", to talk about the SLAC's "significant space crisis". In that column, he made the following statement:

> "Although many long-held associations of space with certain functions exist, this is a time for economy and logical planning, not for tradition. In assessing and reassigning space, prior and current occupancy cannot be seen as determining ownership. No one owns space at SLAC – it needs to be used in the way that benefits the laboratory as a whole."

The SWG was charged to review all Laboratory space and to identify space that would be adequate to support the operation of the LCLS facility and other reasonably foreseeable activities at SLAC beyond FY 2008 without a LCLS CLOC. This formal charge directly parallels the review charge of this Laboratory Space subcommittee.

The original scope of the CLOC included primarily offices and support space for the following groups (including number of desks required): LCLS operations and users (170); PULSE (65); SSRL staff, partially supporting LCLS, (25); and Photon Sciences Directorate (20). In addition, the CLOC included four laboratories to support the PULSE program.

As presented in SLAC's space scenario, the SLAC SWG broke space needs into three priority groups. The first two define the work needed to support LCLS operations and users and consists of refurbishment of the Central Experimental Hall (CEH, Bldg 750), and the conversion of warehouse space in Building 28 to offices. The third priority will support the development of the PULSE, but is not required for LCLS operations. This work consists of the refurbishment and conversion of space in the Central Laboratory Building (Bldg 40).

The CEH (Bldg 750) is a high bay experimental facility with a three-story section that includes shops, a former control room/computer room, offices, and storage space. The

Laboratory proposal uses the facility to house approximately 40 users, 16 LCLS operations staff, 22 students, and provides shop space for approximately ten technical staff. In addition, there is lay down/assembly space in the high bay that could be used by the project for those types of functions; however, those functions were not part of the CLOC. The building is located close to the Near and Far Halls of the LCLS.

On the ground floor of the CEH, shops are proposed for either reuse to support the LCLS operations or to be condensed and a portion of the space converted to offices, as needed. The former control room/computer area can be outfitted with cubicles with the possibility of portions converted to walled offices. While this space has a raised floor (a common feature of computer rooms), the floor could remain or be carpeted over. The existing conference area adjacent to the former control room would remain as conference space.

The second floor of the CEH was previously converted to cubicles and currently serves as offices for a portion of the Facilities Division. The plan includes relocation of this function, although no specific details were provided. The Facilities Division is already spread throughout various areas of the Laboratory. The Committee was advised that a budget for relocation of the staff has been included in the overall budget estimate.

The third floor of the CEH has two approximately 1,000 gsf rooms, one on each end, with a mechanical equipment room separating them. The proposal is to use the third floor as workspace for approximately 22 students. The elevator that serves the pit, ground, and second floors does not extend up to the third floor, a potential ADA compliance issue. The rooms do not have a clear second means of egress (emergency exit), as one would have to exit through mechanical space.

The preliminary budget estimate for the CEH work of $1.6 million includes costs to relocate the staff from the second floor.

Building 28 was originally used as a warehouse. A few years ago, 5,990 gsf, approximately 28 percent of the space, was converted into office space. Using currently allocated funds, an additional 5,990 gsf of warehouse space is being converted into offices for several programs to use. In addition, that project will upgrade the electrical service for the entire building.

A Building 28 third-phase, 9,500-gsf, build-out of warehouse space to offices, to house approximately 50 LCLS and proton-sciences staff, is part of the proposed space plan, estimated at $2.4 million. While details were not provided, the Committee was advised it included allowance for relocating the function currently occupying the space, including excess equipment staging, storage, and general material storage. Details of where the excess material staging and storage could be relocated had not been developed. It was suggested that when the B-Factory Collider ceases operation in FY 2008, some of the IR Halls could be made available for storage. However, the timing of this may not support the schedule for the third-phase build-out of Building 28.

Building 40 is the Central Laboratory Building and is proposed to house PULSE, the Center for Photon Ultrafast Laser Science and Engineering. This building houses a number of functions, some of which will need to be relocated to free-up space to serve as the central facility for the PULSE staff, users, and laboratories. The PULSE will be a user of the LCLS machine, but is not a function required to support full LCLS operations.

Most of the Building 40 space proposed for PULSE use is currently occupied. Some space was observed to be vacant and this was explained as the result of certain programs (GLAST, for example) completing. The space proposed to accommodate the PULSE functions that would have been in the CLOC, seems credible. However, with no detailed documentation, there was no way to assess the credibility of the preliminary $13.2 million estimate. No specific plans have been developed for relocation of the impacted staff and laboratory space, however, SLAC has proposed they can be spread to a number of locations.

7.2 Comments

Overall, this space concept appears to be a credible scenario (scope and cost) for providing space to satisfy the needed functions.

The commissioning of the high-level SWG by the Laboratory Director in September 2006 supports the credibility of the space plan in that it helps to demonstrate senior management commitment to this effort.

Buildings 28, 40 and 750 are identified in the DOE Facility Information Management (FIMS) database as fully utilized. However, some programs have completed recently, and a new building was constructed resulting in relocation of some staff and the creation of vacant space. FIMS should be updated to reflect these changes.

The plan for the reuse of the CEH, Building 750, seems credible (scope and cost). However, the issues of ADA and life safety egress identified should be investigated as part of the detailed space planning.

The plan for the third-phase, build out (conversion of warehouse space to offices) in Building 28 seems credible (scope and cost) particularly in light of SLAC's experience with the previous build-outs. However, the Committee felt the relocation costs for the material, which needs to be relocated, may not be adequately covered by the estimated $2.4 million budget. Additionally, the relocation costs, which are location dependant, and are more likely to be funded with operations funds as they are not betterments. The Committee felt that this type of low-level storage space could be found.

The space reviewed in Building 40 (CL) appears to be suitable for conversion for use by the PULSE. However, this conversion is significant and SLAC management has not identified a funding source to fund the estimated $13.7 million scope of work. Without adequate office and laboratory space, the development of the PULSE will be hampered. Without adequate documentation, the Committee was unable to determine whether the proposed budget was appropriate for the given scope of work.

7.3 Recommendation

1. Generate a detailed plan for accomplishing Phase 1 scope (space required for LCLS operations), including detailed scope, engineering estimate and schedule, to be presented to the Federal Project Director by the end of December 2006, to determine appropriate funding sources.

APPENDIX A

CHARGE MEMORANDUM

DOE F 1325.8
(08-93)

United States Government
Department of Energy

memorandum

DATE: September 6, 2006

REPLY TO
ATTN OF: SC-22

SUBJECT: DOE Review of the Linac Coherent Light Source (LCLS) Project

TO: Daniel R. Lehman, Director, Office of Project Assessment, SC-1.3

I would like to request that you organize and lead an Office of Science (SC) semi-annual status review of the Linac Coherent Light Source (LCLS) project at the Stanford Linear Accelerator Center (SLAC) during October 24-26, 2006. The purpose of this review is to evaluate progress in all aspects of the project: technical, conventional facilities, cost, schedule, management, and environment, safety and health (ES&H). In addition, the Committee should provide a thorough assessment of existing SLAC laboratory and office space, and judge whether this space would be adequate to support the operation of the LCLS facility and other reasonably foreseeable activities at SLAC beyond FY2008 without a LCLS Central Laboratory and Office Complex (CLOC).

During the past several months, substantial progress has been made in fabricating the LCLS technical hardware, and overall, the project was about 29 percent complete as of June 30, 2006. Although limited civil construction began in March 2006, the project has just recently begun to award fixed-price subcontracts (via its Construction Management contractor – Turner Construction) for the bulk of the civil construction work, including tunneling. Cost growth and contingency usage in this area have been an ongoing cause for concern, and the final group of civil construction subcontract bids due in early October 2006 will enable the project to determine the full extent of the cost impact. These bids are mainly associated with construction of the CLOC.

In carrying out its charge, the Committee should respond to the following questions:

1. Are the project's cost, schedule, and technical baselines consistent with those in the FY2007 LCLS Construction Project Data Sheet and the current DOE-approved LCLS Project Execution Plan (i.e., Total Project Cost of $379 million and CD-4 in March 2009) and is there adequate progress to meet the baseline objectives? Is the information in the DOE Project Assessment Reporting System consistent with physical progress?

2. Are the designs of the technical systems sufficiently mature to support the hardware procurements planned in FY2007? Will the procurement plans and equipment installation and commissioning plans support the project schedule?

3. Is there a credible scenario that allows the LCLS operations to be fully functional without a LCLS Central Laboratory Office Complex

4. Is there adequate contingency (cost and schedule) to address the risks inherent in the remaining work and is it being properly managed? Is the contingency supported by and consistent with an appropriate project-wide risk analysis?

5. Is the project being managed (e.g., properly organized, adequately staffed) as needed to proceed with construction? Is there adequate support from SLAC in all necessary areas (e.g., procurement, human resources)?

6. Are ES&H aspects being properly addressed given the project's current stage of development?

7. Has the project responded appropriately to recommendations from prior DOE/SC reviews?

Jeff Hoy, the LCLS Program Manager, and Tom Brown, the LCLS Ultra-fast Science Instruments Program Manager, will serve as the Basic Energy Sciences point of contacts for this review. I would appreciate receiving your committee's report within 60 days of the review's conclusion.

/signed/

Patricia M. Dehmer
Associate Director of Science
for the Office of Basic Energy Sciences

cc:
N. Sanchez, SSO
H. Lee, SSO
J. Dorfan, SLAC
K. Hodgson, SLAC
J. Galayda, SLAC
M. Reichanadter, SLAC
S. Tkaczyk, SC-1.3
P. Montano, SC-22.3
J. Hoy, SC-22.3
T. Brown, SC-22.3
L. Cerrone, SC-22.3
M. Martin, SC-22
E. Rohlfing, SC-22.1
P. Debenham, SC-25.1

APPENDIX B

REVIEW PARTICIPANTS

Department of Energy Review of the Linac Coherent Light Source (LCLS) Project
October 24-26, 2006

SC1	SC2	SC3	SC4	SC5
Accelerator Physics	**Injector/Linac**	**Undulator**	**Photon Beam Handling Systems**	**Control Systems**
* Sam Krinsky, BNL	* George Neil, TJNAF	* Kem Robinson, LBNL	* Dennis Mills, ANL	* Dave Gurd, ORNL
Glenn Decker, ANL	Richard Sheffield, LANL	Erik Johnson, BNL	Chi-Chang Kao, BNL	Michael Thout, Consultant
		Will Oren, TJNAF		

SC6	SC7	SC8	SC9	SC10
Conventional Facilities	**Cost and Schedule**	**Project Management Procurement/Pre-Ops**	**ES&H**	**Lab Space**
* Dixon Bogert, Fermilab	* Suzanne Herron, ORNL/SNS	* Les Price, ORO	* Don Gregory, ORNL	* Jim Krupnick, LBNL
Jerry Hands, SNL	Steve Tkaczyk, DOE/SC	Jeff Atherton, LLNL/NIF		John DiNicola, BNL
Valerie Roberts, LLNL	Bob Simmons, PPPL	Ed Temple, Fermilab		Randy Ortgiesen, FNAL

Observers

Pat Dehmer, DOE/SC	Hanley Lee, DOE/SSO
Jeff Hoy, DOE/SC	Nancy Sanchez, DOE/SSO
Pedro Montano, DOE/SC	
Tom Brown, DOE/SC	
Aesook Byon-Wagner, DOE/SC	

LEGEND

SC Subcommittee
* Chairperson
[ ] Part-time Subcom. Membe

Count: 25 (excluding observers)

APPENDIX C

REVIEW
AGENDA

Department of Energy Review of the
Linac Coherent Light Source (LCLS) Project

AGENDA

Tuesday, October 24, 2006—B048/Redwood Room

8:00 am	DOE Executive Summary	D. Lehman
9:00 am	Welcome	J. Dorfan
9:15 am	Welcome/Photon Science at SLAC	K. Hodgson
9:30 am	LCLS Project Overview and Assessment	J. Galayda
10:15 am	LCLS Integrated Safety Management System	M. Scharfenstein
10:30 am	LCLS Project Management	M. Reichanadter
11:00 am	Break	
11:15 am	E-Beam Systems	D. Schultz
11:45 pm	Undulator Status	S. Milton
12:15 pm	Lunch	
2:00 pm	Photon Beam Systems	J. Arthur
2:30 pm	Conventional Facilities	J. Albino
3:00 pm	LCLS Global Controls	H. Shoaee
1:00 pm	Site Tour (Construction Site, MMF, S20)	CF PMs
3:30 pm	Break	
4:00 pm	Breakout Sessions (see detailed agenda)	
5:00 pm	DOE Executive Session	D. Lehman
6:30 pm	Adjourn	

Wednesday, October 25, 2006-B048/Redwood Room

8:00 am	Breakout Sessions
12:00 pm	Lunch
1:00 pm	Breakout Sessions
3:00 pm	DOE Executive Session
5:30 pm	Adjourn

Thursday, October 26, 2006-B048/Redwood Room

8:00 am	DOE Closeout Dry Run	Lehman
10:30 am	Closeout Presentation to LCLS Management	
11:30 am	Adjourn	

APPENDIX D

COST
TABLE

LCLS Cost Estimate & Contingency

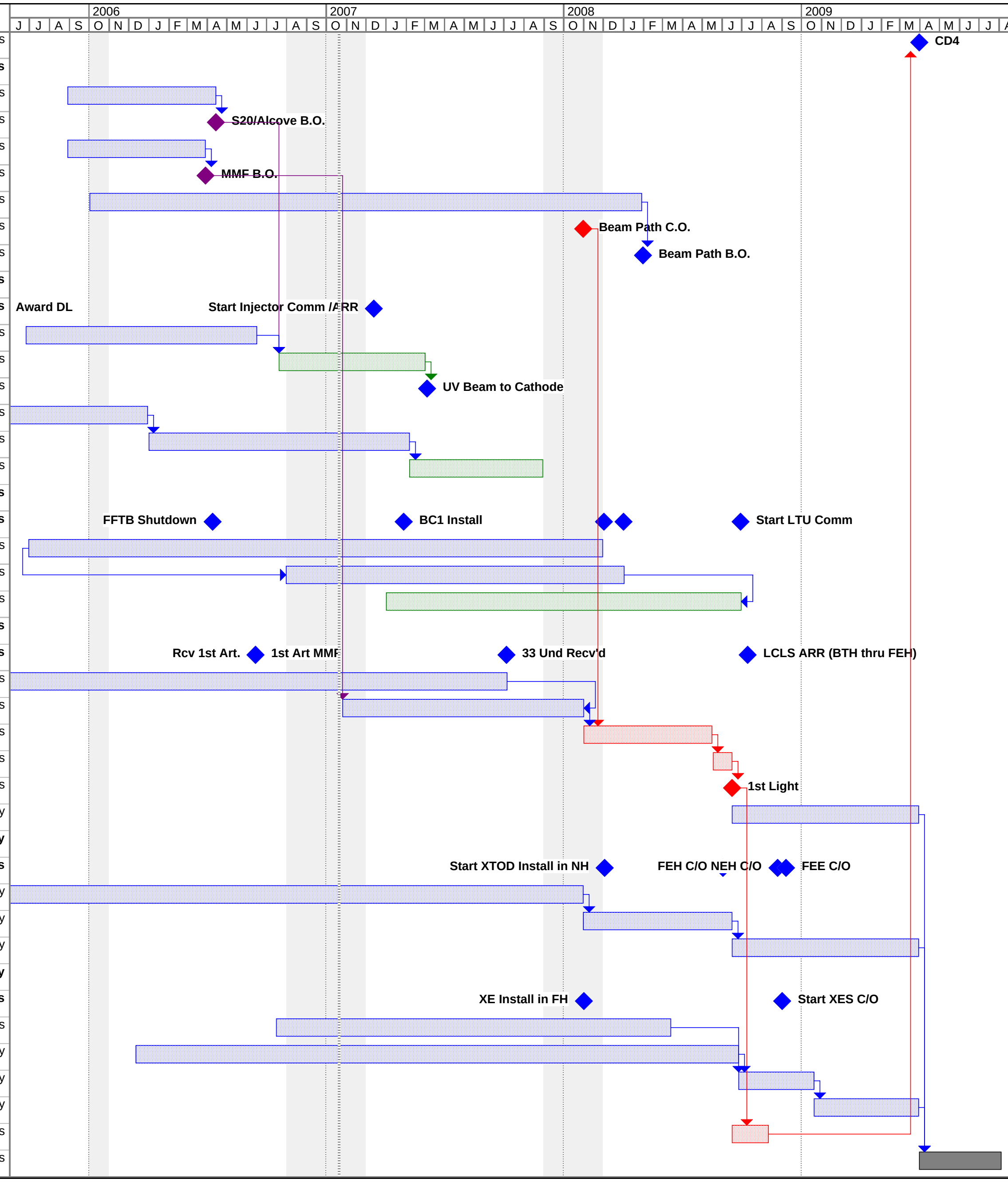
WBS Number	WBS Title	ACWP Thru August 2006	Work Remaining (BAC-BCWP)	EAC (Formula+ Pending BCRs)	Base Cost ($K) including escalation	Contingency Assessment % on Work Remaining	Contingency Assessment $K	Total ($K)
1.01	Project Management	14,045	5,252	19,296	17,875	23.0%	1,206	19,081
1.02	Injector	16,746	2,188	18,981	16,768	33.2%	725	17,494
1.03	Linac	7,236	10,873	18,175	18,136	22.7%	2,466	20,602
1.04	Undulator	18,980	20,448	39,965	37,831	18.8%	3,841	41,672
1.05	X-ray Transport	8,856	13,986	23,163	22,531	28.7%	4,010	26,541
1.06	X-ray Endstations	1,181	8,317	10,532	9,580	26.9%	2,239	11,819
1.09	Conventional Facilities	22,318	95,884	117,632	118,943	15.5%	14,835	133,778
1.XX	LCLS Controls	9,774	21,691	30,975	30,863	27.0%	5,857	36,720
	subtotal	**99,135**	**178,640**	**278,719**	**272,527**	**19.7%**	**35,179**	**307,706**
	Actual Contingency				**42,473**			
	TEC (as spent)				**315,000**			**315,000**
2.01	Project Management	6,067	21,604	27,791	27,618			
2.02	Injector	775	3,510	4,193	4,213			
2.03	Linac	31	1,729	1,760	1,730			
2.04	Undulator	784	5,569	6,328	6,637			
2.05	X-ray Transport	427	4,055	4,487	4,544			
2.06	X-ray Endstations	270	4,963	5,231	5,559			
2.09	Conventional Facilities	0	683	683	683			
2.XX	LCLS Controls	264	5,364	5,768	5,638			
	subtotal	**8,618**	**47,477**	**56,241**	**56,622**			
	Management Reserve				**7,378**			
	spent)	**8,618**	**47,477**		**64,000**			
	Total Project Cost (as spent)				**379,000**			

APPENDIX E

SCHEDULE
CHART

Linac Coherent Light Source Project

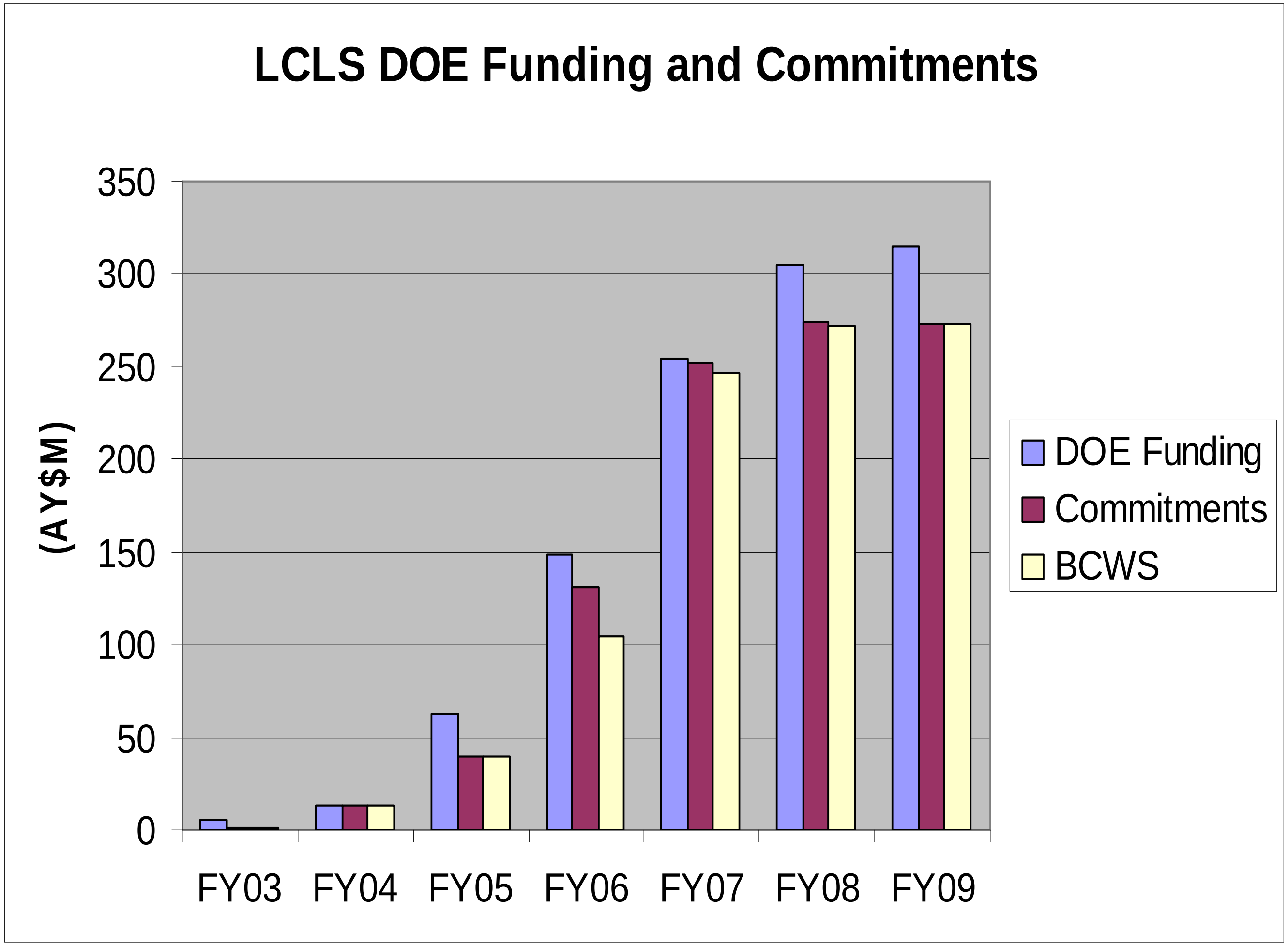
ID	Task Name	Start	Finish	Total Slack
1	**Critical Decision 4**	3/31/09	3/31/09	0 days
2	**Conventional Facilities (Title 3)**	**10/4/04**	**8/4/09**	**0 days**
3	Sector 20 Injector Facility	8/30/05	4/14/06	700 days
4	S20/Alcove B.O.	4/14/06	4/14/06	700 days
5	Magnetic Measurement Facility	8/30/05	3/29/06	317 days
6	MMF B.O.	3/29/06	3/29/06	317 days
7	Beam Path Construction	10/3/05	1/29/08	395 days
8	Beam Path C.O.	11/1/07	11/1/07	166 days
9	Beam Path B.O.	2/1/08	2/1/08	393 days
10	**Injector**	**10/15/04**	**8/30/07**	**0 days**
11	**Injector Major Milestones**	**10/15/04**	**12/14/06**	**0 days**
15	Drive Laser Design/Procure	6/27/05	6/16/06	655 days
16	Drive Laser C/O & Commissioning	7/21/06	3/2/07	631 days
17	UV Beam to Cathode	3/6/07	3/6/07	630 days
18	RF Gun Design/Procure	1/3/05	12/30/05	503 days
19	RF Gun Installation	1/2/06	2/6/07	503 days
20	RF Gun Commissioning	2/7/07	8/30/07	503 days
21	**Linac**	**7/1/05**	**6/30/08**	**286 days**
22	**Linac Major Milestones**	**4/10/06**	**6/30/08**	**287 days**
28	Design/Procure	7/1/05	11/30/07	437 days
29	Installation	8/1/06	1/2/08	414 days
30	Commission	1/2/07	6/30/08	286 days
31	**Undulator**	**10/4/04**	**3/30/09**	**91 days**
32	**Undulator Major Milestones**	**3/23/05**	**7/11/08**	**278 days**
38	Undulator Design/Procure	10/4/04	7/6/07	250 days
39	Testing at MMF	10/27/06	11/1/07	166 days
40	Installation	11/2/07	5/16/08	166 days
41	Pre-Photon Undulator Commissioning	5/19/08	6/16/08	166 days
42	1st Light	6/16/08	6/16/08	166 days
43	Commission	6/17/08	3/30/09	1 day
44	**X-Ray Transport & Diagnostics**	**5/2/05**	**3/30/09**	**1 day**
45	**X-Ray Transport & Diagnostics Major Milestones**	**12/4/07**	**9/8/08**	**237 days**
50	Design/Procure	5/2/05	10/31/07	1 day
51	Installation	11/1/07	6/16/08	1 day
52	Commission	6/17/08	3/30/09	1 day
53	**X-Ray End Stations**	**12/13/05**	**3/30/09**	**1 day**
54	**X-Ray End Stations Major Milestones**	**11/2/07**	**9/2/08**	**241 days**
57	Design/Procure/Assy	7/17/06	3/14/08	75 days
58	2-D X-Ray Detector Design Procure	12/13/05	6/26/08	1 day
59	2-D X-Ray Detector Installation	6/27/08	10/20/08	1 day
60	2-D X-Ray Detector Commission	10/21/08	3/30/09	1 day
61	Photons Detected in Far Hall	6/17/08	8/11/08	166 days
62	**Operations**	4/1/09	8/4/09	0 days



APPENDIX F

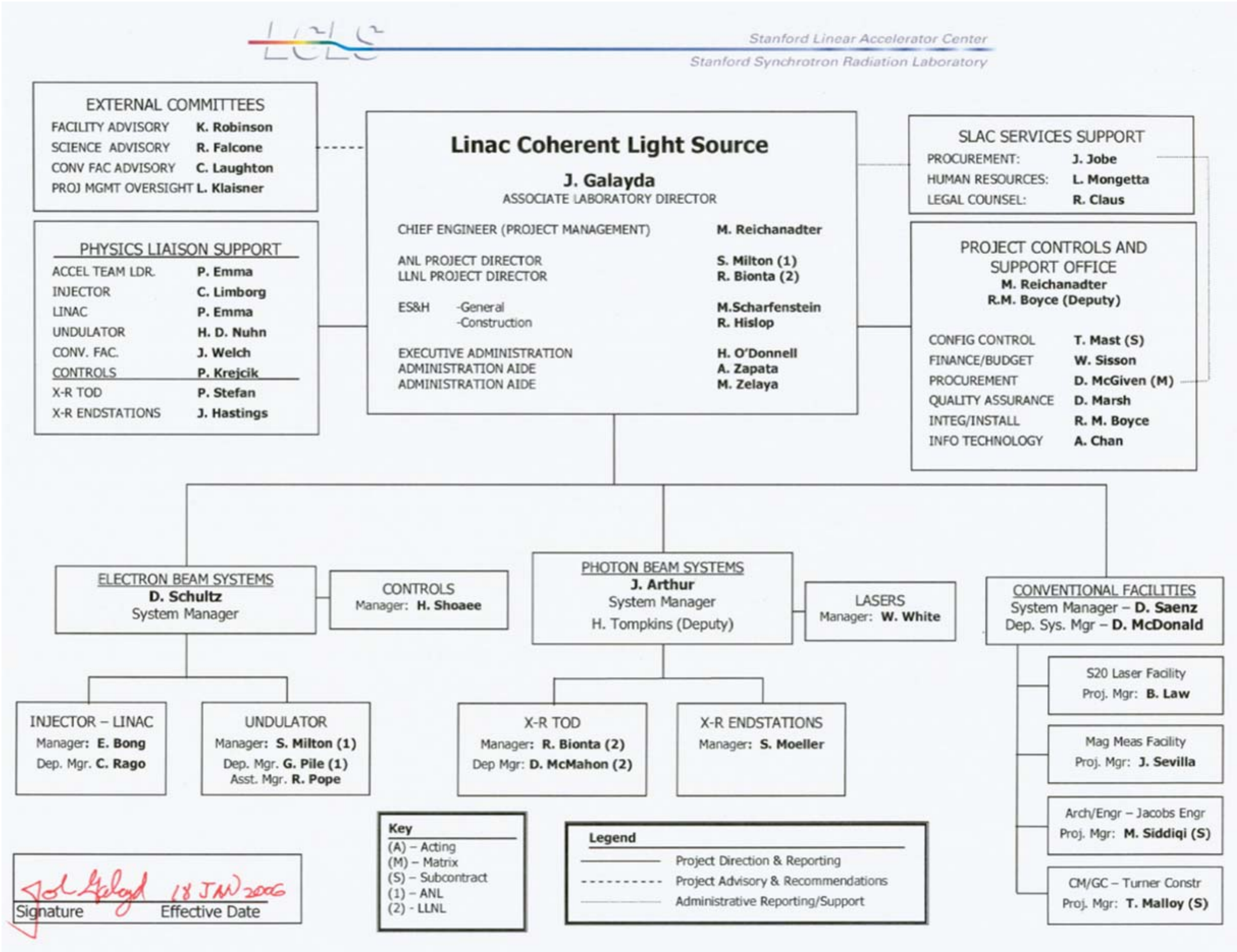
FUNDING CHART

LCLS Funding Chart



APPENDIX G

MANAGEMENT TABLE


LCLS
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Stanford Synchrotron Radiation Laboratory
EXTERNAL COMMITTEES
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SCIENCE ADVISORY R. Falcone
CONV FAC ADVISORY C. Laughton
PROJ MGMT OVERSIGHT L. Klaisner
Linac Coherent Light Source
J. Galayda
ASSOCIATE LABORATORY DIRECTOR
CHIEF ENGINEER (PROJECT MANAGEMENT) M. Reichanadter
ANL PROJECT DIRECTOR S. Milton (1)
LLNL PROJECT DIRECTOR R. Bionta (2)
ES&H -General M.Scharfenstein
-Construction R. Hislop
EXECUTIVE ADMINISTRATION H. O'Donnell
ADMINISTRATION AIDE A. Zapata
ADMINISTRATION AIDE M. Zelaya
SLAC SERVICES SUPPORT
PROCUREMENT: J. Jobe
HUMAN RESOURCES: L. Mongetta
LEGAL COUNSEL: R. Claus
PHYSICS LIAISON SUPPORT
ACCEL TEAM LDR. P. Emma
INJECTOR C. Limborg
LINAC P. Emma
UNDULATOR H. D. Nuhn
CONV. FAC. J. Welch
CONTROLS P. Krejcik
X-R TOD P. Stefan
X-R ENDSTATIONS J. Hastings
PROJECT CONTROLS AND SUPPORT OFFICE
M. Reichanadter
R.M. Boyce (Deputy)
CONFIG CONTROL T. Mast (S)
FINANCE/BUDGET W. Sisson
PROCUREMENT D. McGiven (M)
QUALITY ASSURANCE D. Marsh
INTEG/INSTALL R. M. Boyce
INFO TECHNOLOGY A. Chan
ELECTRON BEAM SYSTEMS
D. Schultz
System Manager
CONTROLS
Manager: H. Shoaee
PHOTON BEAM SYSTEMS
J. Arthur
System Manager
H. Tompkins (Deputy)
LASERS
Manager: W. White
CONVENTIONAL FACILITIES
System Manager – D. Saenz
Dep. Sys. Mgr – D. McDonald
INJECTOR – LINAC
Manager: E. Bong
Dep. Mgr. C. Rago
UNDULATOR
Manager: S. Milton (1)
Dep. Mgr. G. Pile (1)
Asst. Mgr. R. Pope
X-R TOD
Manager: R. Bionta (2)
Dep Mgr: D. McMahon (2)
X-R ENDSTATIONS
Manager: S. Moeller
S20 Laser Facility
Proj. Mgr: B. Law
Mag Meas Facility
Proj. Mgr: J. Sevilla
Arch/Engr – Jacobs Engr
Proj. Mgr: M. Siddiqi (S)
CM/GC – Turner Constr
Proj. Mgr: T. Malloy (S)
Key
(A) – Acting
(M) – Matrix
(S) – Subcontract
(1) – ANL
(2) - LLNL
Legend
Project Direction & Reporting
Project Advisory & Recommendations
Administrative Reporting/Support
18 JAN 2006
Signature
Effective Date

APPENDIX G

ACTION ITEMS

Action Items
DOE Review of LCLS
October 24-26, 2006

ITEM DESCRIPTION	DUE DATE	RESPONSIBILITY
1. Conduct DOE Mini-Review	January 2007	LCLS / SC / SSO
2. Conduct full DOE review	April 2007	LCLS / SC/ SSO

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