Department of Energy
Review Committee Report

on the

Technical, Cost, Schedule, and
Management Review

of the

LINAC COHERENT LIGHT SOURCE (LCLS) PROJECT

May 2008

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 May 13-15, 2008, at the request of Dr. Harriet Kung, Acting 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).

The Committee found that the project has made significant progress since the July 2007 DOE review, in particular, commissioning, hardware fabrication, and progress in conventional facilities. The Committee judged that the project is proceeding as planned for successful achievement of technical, cost, and schedule goals at Critical Decision (CD) 4, Approve Start of Operations.

The LCLS project is a multi-laboratory partnership (with partners are Argonne National Laboratory and Lawrence Livermore National Laboratory) led by the LCLS Project Office at SLAC. When completed, the LCLS will be a world-class scientific user facility to provide laser-like radiation in the hard X-ray region of the spectrum that is ten billion times greater in peak power and peak brightness than any existing coherent hard 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.

Approximately 73 percent of the project is completed as of February 29, 2008. The revised baseline Total Project Cost (TPC) is $420 million and project completion is scheduled for July 2010. The current project's cost, schedule, and technical baselines are consistent with those in the FY 2009 LCLS Construction Project Data Sheet and the current DOE-approved LCLS Project Execution Plan. The information in the DOE Project Assessment Reporting System (PARS) is consistent with physical progress.

Progress in commissioning the injector, linac, and bunch compressors has been outstanding. Beam quality at the end of the linac meets the requirements for commissioning the undulator system. Plans for commissioning the undulator system and for early Self Amplified Spontaneous Emission operation at 15 Angstroms are well developed. Current accelerator performance is acceptable for meeting the CD-4 milestone. The Undulator System has made notable progress in addressing the vacuum chamber, radio-frequency beam position monitor, and

beam loss monitor that were issues at the July 2007 DOE review. Focus is on the integration and commissioning of this system. Undulators (24 each) need to be re-fiducialized due to temperature excursions while in storage. The photon system appears to have a realistic schedule to receive X-rays at Near Experimental Hall in the summer/fall of 2009. The early science milestone in July 2009 appears to be ambitious and could be at risk if advance funding above the FY 2009 continuing resolution level is not attained in first-quarter FY 2009. Plans for transition to operations are in development along with a draft User Access Policy.

Substantial progress has been made in conventional facilities construction since the July 2007 DOE review. The Turner contract is over 85 percent complete and planned for completion before December 2008. Approximately $8 million of additional work remains (Far Experimental Hall hutches and office renovations) to be designed and constructed. Adequate contingency must be retained for these activities.

The project was re-baselined in January 2008—the TPC increased from $379 million to $420 million and CD-4 extended from March 2009 to July 2010. The project has an aggressive plan for FY 2009 to initiate early experimental operations. The baseline assumes no funding constraints in FY 2009. The risk management process is well developed and is being utilized for decision making for the Total Estimated Cost.

Planning for transition of LCLS from a construction project to an operating facility is underway. A vision for restructuring the LCLS organization has been developed and is partly implemented. An "End Game Plan" is needed to more fully develop the strategy for completing project activities and transitioning to operations. LCLS safety performance of the Turner Construction managed work has failed to meet DOE goals. The Days-Away-and-Restricted-Time rate is approximately twice the average construction industry rate. LCLS and the DOE/Stanford Site Office have taken proactive steps to improve safety by increasing site presence, daily team walkthroughs, reinforce positive safety practices by engaging workers, and formation of a Safety Stewardship Committee. The safety trend is improving; however, constant management attention is necessary to complete civil construction safely.

There were no action items resulting from this review.

In summary, the Committee found that LCLS has made satisfactory progress in all areas, and is on track for successful achievement of technical, cost, and schedule goals.

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1. INTRODUCTION

1.1 Background

Now under construction at the Stanford Linear Accelerator Center (SLAC), the Linear Coherent Light Source (LCLS) is designed to be the world's first hard X-ray Free Electron Laser. The goal of the LCLS is to produce intense, ultrashort, coherent laser pulses of X-rays with wavelengths between 15 and 1.5 Angstroms. The technical approach is to inject the energetic electron beam from the SLAC LINear ACcelerator (linac) into an undulator magnet in order to generate synchrotron radiation of two types—spontaneous emission, as well as Self Amplified Spontaneous Emission (SASE) X-rays. When fully operational, the LCLS will be a scientific user facility to enable researchers in the U.S. and abroad to apply this new X-ray tool to the study of ultrafast chemical reaction dynamics, precision imaging of macromolecules, novel physical effects (of atoms, molecules, and condensed matter), and behaviors of other material systems.

The LCLS beam's peak brightness, coherence, and ultrashort (sub-picosecond) pulses will vastly exceed those of current X-ray sources (e.g., other synchrotron radiation sources and "table-top" X-ray lasers). Producing this beam will be an important engineering feat, and using a beam with these characteristics will be the goal of early scientific experiments. These experiments plan to probe material system effects that can only be detected with the LCLS beam; that is, they depend upon one or more of the LCLS X-ray beam properties (unique characteristics not available elsewhere) for their detection. The LCLS Scientific Advisory Committee (SAC), working in coordination with the broad scientific community, identified several such high-priority initial experiments in the document, *LCLS: The First Experiments* (SLAC-R-611, September 2000).

The scope of LCLS project is to build the facilities and equipment needed in order to produce the X-ray beam and direct it to locations of experimental stations. Key components include the following:

- An "injector" (laser light pulses impinging upon a photocathode to produce electrons in a radio frequency (RF) "gun" that are accelerated and steered into Section 20 of the linac);
- Modifications to the last kilometer of the linac system, including installation of magnetic bunch compressors and beam diagnostics for the electron beam;
- A Beam Transfer Hall (BTH) to direct the energetic electron beam to the undulator;
- Construction of a Front End Enclosure (FEE), Near Experiment Hall (NEH), X-ray transport tunnel, and Far Experiment Hall (FEH), all below grade;
- X-ray beam optics, diagnostics, and controls systems; and

- An Undulator Hall (UH, built under a hill to aid in temperature stability), containing an undulator magnet assembly composed of sections of rare earth magnets that when aligned produce a magnetic field to oscillate and bunch the electron beam (producing X-rays), and a vacuum system whose chamber vessel is compatible with the electron and X-ray beams.

Current plans call for the X-ray beam to be delivered to several endstation locations (or "hutches") in the NEH and FEH that will contain instrumentation to enable experiments of different types to be performed. As part of the LCLS construction project, one instrument—designed for atomic, molecular, and optical physics studies—will also be built (in the NEH) to support early science experiments.

Attainment of Major Milestones for the LCLS Project

Below is a brief history of the LCLS project's progress to date to achieve major milestones. More complete descriptions are included in the July 2007 DOE review report and other project documentation.

This project's formal history began with Critical Decision (CD) 0, Approve Mission Need, approved by the Acquisition Executive, Dr. Raymond Orbach, Director of the Department of Energy (DOE) Office of Science (SC), on June 13, 2001. The mission need summarizes the technical specifications and scientific value of the LCLS. Next, SLAC and its two partner laboratories (Argonne National Laboratory (ANL) and the Lawrence Livermore National Laboratory (LLNL)) developed a conceptual design and a supporting cost estimate and schedule, which a DOE/SC committee reviewed in April 2002. Dr. Orbach then approved CD-1, Approve Preliminary Baseline Range, on October 16, 2002, a decision that authorized the project to start preliminary (Title I) design using Project Engineering Design (PED) funding in FY 2003.

During FY 2003, the project completed Title I design of the long-lead items planned for procurement in FY 2005, and presented these results to a DOE review committee. This 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 CD-2a, Approve Long-Lead Procurement Budget, which was approved on July 2, 2003, by the Acting Acquisition Executive for Science, Dr. James F. Decker. This approval enabled long-lead procurement funds 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 Central Laboratory and Office (CLO) Building in the LCLS scope.

The FY 2004 funds enabled the project to acquire architect engineering (A/E) 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. In preparation for CD-2b, Approval of the Performance Baseline, the contractor Burns and Roe Enterprises, Incorporated (BREI) performed an External Independent Review (EIR) with an on-site visit at SLAC in June 2004, and a final report in August 2004. The EIR team concluded that "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 stood in the way of approving CD-2b.

A DOE review of the LCLS project was conducted in August 2004 in order to determine the project's readiness for CD-2b and CD-3a, Approve Start of Long-Lead Procurement. This review 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 the project did. This revised project 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 (CR) 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 funds for long-lead items that were critical path components, such as the 135 MeV injector linac magnets, drive laser, RF gun system, the X-Band microwave system, bunch compressor magnets, the undulator strong back, undulator magnets, magnet blocks, renovations for Section 20 of the linac, and the magnetic measurement facility (MMF) needed for verification of undulator performance. CD-3a was approved on December 10, 2004, so as not to delay placement of the FY 2005 long-lead

procurements. 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). The limited EIR ultimately resulted in an OECM validation of the LCLS baseline, and Dr. Orbach approved the proposed baseline (CD-2b) on April 11, 2005.

In May 2005, a DOE/SC committee conducted a status review of LCLS. 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 facility modifications for Linac Section 20 and the MMF), and the A/E worked towards completion of Title II design of the CF.

The CM/GC procurement was finally awarded in October 2005 to Turner Construction and its partner for tunneling work, Hatch Mott McDonald. The CM/GC reviewed and provided input to the Title II CF design, and the A/E 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, Dr. Decker, then Principal Deputy Director for the Office of Science, approved CD-3b, Approve Start of Construction.

Since then, the project received bids for Turner subcontracts in civil construction that grossly exceeded estimates (due in part to the escalated costs in the San Francisco Bay Area for construction materials and labor). To proceed within available resources, project management sought to replace the new CLO building construction with less expensive renovated space elsewhere at SLAC, and used available contingency to make awards for the other construction activities.

FY 2007 was the project's peak year of spending, with a Presidential budget request of approximately $122 million. However, a lengthy CR prevented the project from receiving funds prior to about February 2007, and appropriated funds were approximately $8 million less than the full request. As a consequence, not all of the originally scheduled FY 2007 project activities could be undertaken, within available resources. Mid-fiscal year project indicators (e.g., the schedule performance index, cost performance index, and available contingency) showed significant cost and schedule overruns to the baseline plan for progress to date. Planning exercises in value engineering led to some concepts for rebaselining the project. The purpose of rebaselining would be to facilitate completion of the LCLS project, thereby meeting its mission

need, in a better management approach (e.g., with more realistic cost and schedule parameters) than the current baseline plan offered. This rebaseline was then pursed, using an EIR site visit in October 2007 and its follow-on report, and was formally accomplished by a memorandum from the DOE Deputy Secretary dated January 24, 2008, and a memorandum from the Office of Science dated February 7, 2008. The revised baseline set the project's TPC at $420 million, with a Level 2 milestone for LCLS' readiness to support early science by September 2009, and a CD-4 project completion date of July 2010.

1.2 Charges to the DOE/SC Review Committee

In a March 7, 2008 memorandum (see Appendix A), Dr. Harriet Kung, Associate Director of Science (Acting), Office of Basic Energy Sciences, requested that Daniel R. Lehman, Director of the Office of Project Assessment, organize and lead a review to evaluate progress of all aspects of the LCLS project, including technical, cost, schedule, management, and environment, safety, and health (ES&H) issues. The purpose of this review was to assess the project's status.

1.3 Membership of the Committee

The Office of Project Assessment formed a Committee composed of members (see Appendix B) selected based on their independence from the project, as well as for their technical and management expertise, and experience with building large and complex scientific research facilities. The Committee was organized into nine subcommittees, each assigned to evaluate a particular aspect of the project corresponding to members' areas of expertise. Daniel Lehman of the Office of Project Assessment chaired the Committee.

1.4 The Review Process

Prior to the review meeting, the LCLS project team provided project documents and other project information to the Committee as downloadable for early study. A review meeting was held at SLAC in Menlo Park, California, during May 13-15, 2008. Representatives from SLAC, the DOE Stanford Site Office (SSO), DOE/SC, and the DOE Office of Project Assessment jointly developed the meeting agenda (see Appendix C).

The first day of the review consisted of presentations given by SLAC staff and discussions to answer detailed questions from the Committee. The LCLS project managers and other principals overviewed project activities, civil construction status, and developments to date on major technical systems and components. A site tour was held to view the BTH (in the

"research yard"), the UH tunnel entrance and exit, the construction site of the NEH, and the injector at Section 20 of the linac.

Breakout sessions were held on the second day for additional follow-up on questions and issues of interest to the Committee. The Executive sessions at the end of the first and second days, and the morning of the third day, were devoted to Committee deliberations, report writing, and drafting a closeout report. Preliminary results were discussed with LCLS staff at a closeout session on the last day.

Experience on projects with similar features was the primary method used by Committee members for assessing technical designs, cost estimates, schedules, and adequacy of the management structure. Although the LCLS project requires some technical extrapolations to address its technical challenges, similarities exist with other scientific facility construction projects and related technical systems in the United States and abroad, and these similarities provide a relevant basis for comparison.

2. TECHNICAL SYSTEMS

2.1 Accelerator Physics

2.1.1 Findings

Progress in commissioning the injector, linac, and bunch compressors has been outstanding. The commissioning team has demonstrated great physical insight and technical skill in achieving such excellent results. Beam quality at the end of the linac meets the requirements for commissioning the undulator systems. Plans for commissioning the undulator systems and for early SASE operation at 15 Angstroms are well developed. Safety is integrated into all planning for the accelerator systems.

The MatLab based control has made it possible to write powerful applications that have greatly facilitated commissioning. The sophistication of these applications, written very quickly by the physics group, is impressive.

Optical transition radiation screens are not presently usable due to coherent optical transition radiation. This is believed to be due to microbunching in the electron beam. This microbunching may result from longitudinal space charge or from coherent synchrotron radiation in the bunch compressors. The laser heater that will be installed in FY 2009 should provide sufficient energy spread in the electron beam to solve this problem.

2.1.2 Comments

Budget constraints have resulted in the delay of the wire scanner diagnostics in the linac sector 24, upstream of the second bunch compressor. These diagnostics may be very valuable in characterizing the quality of the electron beam and will be necessary if the problem with the optical transition radiation monitors is not resolved by the laser heater.

It would be very desirable if the wire scanners could be implemented.

Integration of the control of the old linac hardware with the new LCLS control system is of great importance. The project recognizes this and is working to determine a path to carry out the upgrade without introducing a delay in the commissioning.

The old beam position monitors (BPM) in the linac do not have the resolution desired for LCLS commissioning. It would be very desirable to upgrade these monitors as soon as possible.

The output SASE depends on a great many beam and system parameters. Developing a start-to-end simulation model and placing it in correspondence with the experimental observations will be of great value in understanding and optimizing the free electron laser (FEL) system behavior. At present, the work toward implementing start-to-end simulations available on-line for commissioning is not proceeding.

2.1.3 Recommendation

1. Begin work to implement start-to-end simulations available on-line for commissioning by July 2008.

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

2.2.1 Findings

The injector/accelerator team has obtained impressive results since the July 2007 DOE/SC review. The Committee cannot overstate the significant technical progress that was accomplished. As of September 7, 2007, the injector commissioning was completed. As of March 31, 2008, the beam to end-of-the-linac has the required quality to support LCLS operation at 15 Angstroms. The photocathode laser availability is greater than 99 percent, and the details of integrating the drive laser into accelerator operations was resolved, addressing one of the concerns raised at the July 2007 DOE/SC review. The gun is now running smoothly and with very low dark current. Attaining the CD-4 milestone should be readily achievable.

The project rebaseline made two of the recommendations of the 2007 review moot. The second recommendation: “Determine cost/schedule/risk impact of removal of beam diagnostics with respect to the FEL commissioning.” was not addressed. The downstream BPM and wire scanner diagnostics were removed from the project scope and are having an anticipated effect on the commissioning.

2.2.2 Comments

With the extensive set of diagnostics and reliable systems before BC2, excellent beam performance through the first buncher has been attained. Most all of the technical issues presented at the July 2007 DOE/SC review were satisfactorily addressed.

The beam diagnostics (the Sector 24 wire scanners and the linac BPMs after BC2) previously removed from the project scope may not significantly affect meeting the CD-4 milestone but could have a significant negative impact on the FEL commissioning schedule. The remaining linac has the old wire scanners with 50 micron resolution. The peak-to-peak motion of the beam centroid at the linac end is on the order of the beam radius. The lack of accurate position measurement monitors after BC2 does not allow determination of the source. This can have a serious impact on the FEL commissioning. Replacing some of the older BPMs with the newer sub-5 micron design should allow finding the source of the variations.

The Optical Transition Radiation (OTR) screens have exhibited significant variations in light output unrelated to the beam parameters of interest. This is attributed to Coherent Optical Transmission Radiation (COTR). Although COTR is the most likely explanation for the observed variation in signal from the OTR screens, other explanations are possible. The COTR is an interesting physics experiment, should be studied, but is not the point of the LCLS program. The project should not let the commissioning be delayed by allocating too much time to this activity.

The overall system availability can be severely affected by legacy accelerator components, such as the RF systems, that are near end-of-life and have an over-sensitivity to environmental and infrastructure conditions. At some point the availability of the overall LCLS operations could be limited by these legacy components.

The new beam interface software is very well done and will make future operations much more convenient and not so expert driven.

The schedule has slipped one month due to getting appropriate approval for the paperwork after submission, but this is well within contingency and will not affect meeting milestones. The contingency to complete the given scope is adequate.

One minor note, laser lock is monitored with a web camera because the oscilloscope interface cannot handle the fast data rates. A faster interface should be integrated into the system when resources allow.

The project did a very nice job on beam software user interface, and this effort will reduce significantly the commissioning time and reduce the time required for future problem resolution. The end-to-end modeling is not in existing Work Breakdown Structure (WBS) structure. Although this is not an issue now, when FEL operations begin this will be a serious impediment to understanding performance.

2.2.3 Recommendation

1. Establish the schedule for early implementation of wire scanners in sector 24 and more higher-resolution BPMs in the remaining linac.

2.3 Undulator System (WBS 1.4, 2.4)

2.3.1 Findings

The scope of the LCLS Undulator System includes undulator magnets and supports, undulator diagnostics, vacuum systems, controls for the undulator equipment, and the magnet measurement facility. Integration and installation are also included within this area. The project 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 operational undulator spares, including three prepared for installation 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 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 has made significant progress since the July 2007 DOE/SC review. Overall the production phase of the undulator is nearing completion. Several categories of major hardware delivered to SLAC from ANL (since the review) constitute completion of the production runs including:

- 39 Undulator Magnetic Structures (July 2007)
- 37 Girder and Motion Structures (March 2008)
- 36 Quads and Correctors (April 2008)
- 40 Undulator Vacuum Chambers (May2008)

This is particularly noteworthy, since at the time of the July 2007 DOE/SC review the vacuum chamber design was not resolved and there was significant concern over the delivery of the RF BPMs. In addition, given these pressures the beam loss monitors (BLM) was placed on the back burner.

Ongoing production activities include completion of the RF BPMs, the beam finder wires, quad spools, bellows modules, and the long-break spool. All of these production runs are slated for completion by the middle of July 2008, which supports the overall project schedule.

The Committee found that the LCLS Undulator Systems Team was responsive to the July 2007 DOE/SC review recommendations. The specific recommendations included:

1. Fabricate prototypes of each back-up option by end of August 2007 ,
2. Select 'best' option to move into production by mid-September 2007, and
3. Evaluate potential impact of any anticipated sub-specification performance. Include in risk registry with any mitigation strategies and potential costs as soon as feasible; in no case later than the next DOE review.

   From that point to the current review, the team delivered the complete set of vacuum chambers to SLAC that meets the slope error specification. To accomplish this they extended the range of the slurry polishing technique for aluminum extrusions, a development of interest to other accelerator projects around the world. This has been a remarkable achievement for the project team.

4. Provide adequate support to ensure placement of orders for RF BPMS on or before the end of September 2007.

   Fabrication of the RF BPMs has overcome significant manufacturing problems and they are now in full production. Eight were delivered to SLAC and production of the remaining BPMs should support the assembly/installation of undulators as planned.

5. Develop Physics Requirements Documents for beam loss monitors to meet project needs by end of August 2007.

   Undulator BLM PRD 1.4-005-r0 was completed and signed off.

6. Develop revised estimate for BLM system as soon as feasible; In no case later than the next DOE review.

   A prototype run of five BLMs is planned. These devices will certainly be adequate for detecting beam loss and may even be suitable for measuring dose to the undulator sections. Controls for these monitors have been integrated into the Machine

Protection System and they will be available to support commissioning activities. If tests of these initial devices are successful, their design could form the basis for a production run of 30 monitors in FY 2009.

7. At the next DOE Review Present Installation and Commissioning plans.

   Plans were presented in several breakout sessions that seemed methodical and well thought out. The magnitude of risks to the project are diminishing, but there is little schedule contingency to CD-4. However, the Committee felt that the team can reasonably be expected to support the installation and commissioning schedule.

Taken together the Committee recognized these accomplishments as extraordinary and commended the team for their outstanding effort. The Committee examined the Undulator System portion of the project with respect to the questions posed and made the following conclusions:

At the time of the review the Undulator System (WBS 1.4 and 2.4) cost, schedule and technical status were being reported against the recently revised LCLS Baseline and Project Execution Plan. As presented, the Undulator Systems TEC budgeted cost of work performed (BCWP) was $42.2 million, with actual costs of work performed (ACWP) at $42.7 million within a budget at completion of $49.6 million. The cost performance index (CPI) was 0.99 and the schedule performance index (SPI) was 0.99 (three months after rebaselining the project). The work to go (WTG) was $6.4 million and the project is reserving contingency of $1.9 million or 30 percent of the WTG for the Undulator System.

The Undulator System's cost, schedule, and technical baselines are consistent with those in the FY 2009 LCLS Construction Project Data Sheet. Adequate progress was demonstrated to meet the baseline objectives and the information reported from the Undulator System to the DOE Project Assessment Reporting System (PARS) is consistent with physical progress. Contingency allocation is appropriate for this stage of the project.

The Committee found that the Undulator System technical systems were sufficiently mature to support the planned hardware procurements. Progress in addressing integration tasks and deliverables was notable. The Committee judged that satisfactory progress in this area will continue. Plans for installation and commissioning are in development and appear to be on track to support the project objectives.

2.3.2 Comments

The Committee was concerned with respect to the undulator tuning work ahead. Some of the completed undulator modules had been stored in an area where the winter temperature was 'too-cold' for an extended period of time. Measurements on three of the devices that received this exposure have shown a reduction in gap of approximately 1 micron. The trajectory and field integral changes resulting from this 'frost bite' are within acceptable limits as are the phase changes of about two degrees. This does have, however, the effect of shifting the magnetic center of the undulator, so the devices must be re-feducialized. In response to concerns over these temperature excursions the project acquired storage space in the GLAST cleanroom that experienced a short period of high temperature due to an HVAC failure. These 'heat-stressed' undulators may also require re-measurement and re-fiducialization as well. In all, perhaps 24 devices need to be re-feducialized, a process of approximately three days duration for each.

In addition, eight of the production run undulator magnets proved to be more difficult to tune than the others. In one case, a pole is high (possibly riding on a burr)—this must be disassembled to be repaired. Another had a bad magnet block and was shipped back to ANL for repairs. The other six were manufactured within specification with respect to minimum chamber gap, but had more pole height variation than the others, and proved to be more difficult to shim. These were set aside to move on with the bulk of the production, but must now be re-measured and shimmed to obtain the same (larger) minimum gap achieved on the other modules.

There was also development in the design of the shims such that the good field region can be extended from ±2.5 mm to ±6 mm. This would extend the K adjustment range but it requires modification of the limit switches for the magnet movers, as well as installation of new shims. Existing X-trajectory shims must also be modified (by removing some material) to allow the -6 mm "in" motion required to realize the full extended K range.

Much of the magnetic measurement work (and rework) was not considered in the original schedule. Care must be exercised to make sure the demand for measurements and time on the CMM is focused on meeting the project goals. It is essential to maintain environmental control over the undulator modules after they have been re-fiducialized to assure that additional measurements will not be required. Some examination of the 'heat-stressed' magnets (in light of the time and range of the temperature excursion they underwent) may provide guidance on the time and magnitude of acceptable temperature excursions the magnets can experience. This might, for example, inform choices about how quickly magnets need to be transported between storage, measurement, and undulator hall locations, and/or what measures are required to avoid

adverse impact from these moves. Also, data from the 'frost bitten' modules could help in formulating response plans for temperature excursions the magnets might experience, even after installation (say in the event of a failure of the undulator hall HVAC system).

2.3.3 Recommendations

1. Complete the re-fiducialization of undulators as necessary and assure that 33 are ready for installation to meet project schedule.

2. Do not proceed with enhancements of the 'good field' region requiring magnetic measurement until recommendation 1 is achieved.

3. Consider developing response plans for the undulators should they experience temperature excursions outside of specification (during storage, transit, or after installation).

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

2.4.1 Findings

Photons Systems

The reviewers were pleased at the considerable progress made in the Photon Systems area since the July 2007 DOE/SC review. Costs, schedule, technical baseline, and contingency are consistent with the LCLS project data sheet and Photon Systems appears to have a realistic schedule to receive X-rays in the summer/fall of 2009. At the July review, there was concern that the orders for the soft and hard mirrors had not yet been placed. The Committee was glad to hear that all orders for X-ray mirrors were placed and soft X-ray mirrors are arriving. Equally pleasing was the fact that the pixel array detector, being developed by Professor Sol Gruner of Cornell University is making very nice progress. It was reported that LCLS staff are already controlling and acquiring data from prototype via LCLS Data Acquisition prototype system and that integration of controls is good to see.

Early science (AMO) experiments in mid-2009 appear to be ambitious; late 2009 are perhaps a more realistic goal. However, early science anytime in 2009 is at risk if approximately $2 million (above expected FY 2009 CR budget) is not available at the beginning of FY 2009 (approximately $800K for AMO and another approximately $1 million for beam transport).

The interface between Photon Systems and LUSI appears to be functional, and the Committee was pleased to hear that Photon Systems and the LUSI project are sharing engineering, controls, and installation staff. However, development of final specifications for the LUSI instruments is required for final Photon Sciences planning and procurements (and for the hutches in the FEH) and is a significant schedule risk.

Transition to Operations and User Access Policy

Although not part of Photon Systems, the Photon System review team sat in on the breakout session covering transition to operations and user access policy. Plans for the transition to LCLS operations appear to be well advanced. The long-range staffing goals for LCLS User Operations provide a good mix of scientific and technical support and should provide scientific opportunities for both LCLS users and the scientific staff. Plans for user operations and access, while still a work in progress, are realistic and should provide the necessary basis for steady-state user access to the facility.

2.4.2 Comments

Photon Systems

Approximately $2 million is needed at the beginning of FY 2009 to complete X-ray transport and AMO instrumentation for early science. SLAC management should do everything in their power to make that happen.

Transition to Operations and User Access Policy

While current project management appears to be on track for finishing construction and installation, facility operations will require a more mission oriented management structure.

Involvement of Jochen Schneider in the development of the User Access Policy was an excellent decision. He brings both considerable experience (from HASYLAB/FLASH) and credibility to the process. The overall User Access Policy and philosophy is similar to that of storage ring facilities, with calls for proposals several times a year and the proposals being scientifically evaluated by a Proposal Review Panel (PRP). It was stated that the PRP would be made up of outside experts plus two members of the LCLS management. The Committee members judged that LCLS management should consider whether members of the LCLS Management on the PRP should be “advisory” or ex officio rather than voting members to

remove any perception of bias in the proposal evaluation process. Close interaction between LCLS management and the LCLS SAC is also encouraged to ensure highest scientific impact of the LCLS (especially the early experiments).

The Committee judged that the sociology of experiments at LCLS will be different than storage ring sources (i.e., the formation of large collaboration of users with similar interests versus small individual groups). Early involvement of the LCLS user community (or LCLS User organization if it has been organized) for input into this process and their education is strongly encouraged. (The recent SPPS experience and the proposed workshops are good steps.)

2.4.3 Recommendations

1. Define the operations management structure in the next six months. This will help to maintain staff morale and provide clear roles and responsibilities for staff as the project evolves into the operations phase.

2. Finalize the User Access Policy in the next three months and make it widely available (including details of the proposal submission processes, criteria for proposal evaluations, etc.).

2.5 Control Systems

2.5.1 Findings and Comments

Organization

There is now a clear separation of responsibilities for LCLS Controls, with different Cost Account Managers (CAM) for electron and photon control systems respectively. The Controls subcommittee met with each of these managers. The working relationship between the CAMs seems excellent and the interfaces between electron and photon systems are supported by appropriate Interface Control Documents. When required, EPICS expertise from the accelerator controls group is made available to the photon controls team. A deputy with specific responsibilities for management of the LCLS controls effort has been appointed in the accelerator controls group. This is a very positive (if late!) development.

Cost and Schedule

The Controls effort has been rebaselined along with the rest of the project and the Committee noted that that the issues and concerns raised at the July 2007 DOE/SC review have been addressed. Performance reports show accelerator controls to be approximately 78 percent complete while photon controls are about 33 percent complete. Overall, there remains about $15 million to be spent, most of which is in WBS 1.6.2 (controls for XES), which is consistent with the status of WBS 1.6 as a whole (26 percent complete.) Contingency is adequate at 22 percent. Both CAMS are able to use the cost reporting data effectively; however, rolling together performance figures for these separate elements is useful to nobody. The Committee saw no issues with the new baseline or with the current performance status.

Protection Systems

A Programmable Logic Controller (PLC)-based system has been deployed for the personnel protection system (PPS) for the first time at SLAC. An operating system failure in a PPS PLC resulted in a two-week curtailment of the injector commissioning run. The safety envelope was not violated and the problem was easily identified and fixed; however recovery from this event revealed a software configuration management issue that was also appropriately addressed with new configuration management procedures. Management is to be commended for its conservative and appropriate response to this event.

The legacy Machine Protection System (MPS) has been adequate for commissioning to date. A new MPS system is under development to support 120Hz operation about a year from now. The new MPS will be deployed in the fall of 2008. Although currently untested, this system represents the only remaining technical risk (small) in planned controls deployments.

Commissioning and Applications

The accelerator controls team is to be congratulated for supporting commissioning to date both successfully and in a timely manner. This included deployment of EPICS-based controls, a new timing system, the first ever PLC-based PPS at SLAC, improved BPMs, a refurbished Main Control Room, and sophisticated laser feedback systems.

Commissioning, to date, has been supported by an impressive suite of physics applications developed in Matlab by the Physics team—about 19 so far with another 7 in progress. MatLab is an excellent rapid prototyping tool and allowed the commissioners to

develop, on their own, exactly the tools they needed. However, there are legitimate concerns about the robustness, performance, and eventual integrability of these applications. Moreover it is not clear that the Physics Group is interested in maintaining them forever. The current suite provides an excellent and already-tested requirements definition but a strategy for integrating, hardening, speeding, and maintaining it is required. At some other accelerator laboratories (APS and SNS are examples) this responsibility has stayed with the Physics Groups, which have been staffed appropriately. The current plan at LCLS appears to be to use operations funds to port these applications to a Java-based framework (XAL) supported by the Accelerator Controls Team. There has been a disappointing lack of progress in this work so far, perhaps due to a lack of available manpower. A physicist assigned to the accelerator controls group was recently given oversight over this effort, and progress is expected to be apparent shortly.

A strategy for model development is also required. A model is required both for end-to-end simulations and for some of the on-line control applications discussed above. An integrated end-to-end model is a daunting and very manpower-intensive task, in part because different modeling codes and models are currently in use for different parts of the machine. This task should be sensibly scoped and planned carefully, including realistic and prioritized deliverables. An XAL-based model is currently under development for the electron portions of the machine and is being verified against the MAD-based model used by the Matlab applications.

Relatively slow (5 Hz) Matlab-based feedback loops have also been used in various places and to date have proven effective. The current architecture would not, however, be capable of supporting dramatically increased loop bandwidth should that prove necessary.

Upgrade of Legacy Systems

The LCLS currently depends upon the use of many SLAC legacy systems, including parts of the control system such as linac BPMs, Multibus-based controllers, VAX/VMX servers and many high-level applications. Operation and maintenance of these legacy systems poses a risk to reliable operation of LCLS. Parts are scarce and expertise is diminishing. A number of SLAC AIPs have been proposed to replace these legacy systems with LCLS standard hardware and software technology. The “SLC-aware IOC” turned out not to be a complete solution for access to legacy applications as hoped. A major upgrade of the control system is therefore proposed for January 2009. This is an extremely aggressive schedule and the Committee is concerned that any serious problem in deployment could have a negative impact on LCLS commissioning. Testing without beam is not a complete test; testing with beam could be disruptive. Every effort should be made to devise a strategy that includes the ability for rapid-

rollback and to operate with both the old and new systems in parallel during the transition period. Such a strategy would almost certainly require more work, and possibly some "throw-away" intermediate software, but would minimize the risks. The Committee was pleased to note that a technical review of this proposal with both internal and external experts is planned for June 2008. This review should include both a technical review and an assessment of the potential impact on LCLS and possible mitigation strategies.

Miscellaneous

The Committee heard about the inefficiencies in the LLNL collaboration due to security restrictions on direct observation of LLNL systems—either remotely or by non-citizens. It would be helpful if LLNL could find ways of decreasing reliance on SLAC staff, either by acquiring the necessary expertise in-house or by moving some systems to SLAC for testing and debugging.

The Committee was pleased to note two excellent practices: the routine scheduling of software developers for one-week shifts in the control room in order to better appreciate operator issues and requirements, and the scheduling of "software days" to allow for unimpeded testing of new software on a regular basis.

2.5.2 Recommendation

None.

2.6 Transition to Operations

2.6.1 Findings

The injector and accelerator groups have made excellent progress toward demonstrating the sort of beam capability needed for initial operations of the FEL. In particular, the performance of the injector/linac at 0.2 nC has greatly relieved the risk of failure in technical performance to CD-4. Reliability of new systems is very good although some legacy equipment is exhibiting symptoms of increased failure rates at end of life.

The Committee found plans for transition to operations in development at an appropriate level of detail for this stage. As this is a cutting edge facility with capabilities never before achieved it is expected that some learning curve will be required. The LCLS team is quite aware

of that and is well-positioned with the expertise and analysis tools should it be necessary to adopt backups and alternative approaches to achieve required performance of the linac or FEL.

The lack of some diagnostics in the baseline will hamper handover to operations and may delay schedule since without core diagnostics in all areas the validation of proper performance of many systems is left in an ambiguous state and the ability to trouble shoot off-normal states is hampered, especially by non-experts.

The Committee was shown many examples of excellent high-level software programs developed by the physicists. These are well founded in the machine physics but not necessarily sufficiently user friendly, automated, fast or robust enough for use by non-experts. The process for transition of these applications to the Controls Group is not well defined and not happening at a reasonable rate due to lack of personnel. An example of this situation is the high-level simulation with integrated settings and tracking required to tie together many of the other applications.

The performance of the linac to date puts the program in an excellent position to proceed to commissioning with beam the wiggler chambers followed by the addition of the wiggler itself. The schedule for initial commissioning of the wiggler and FEE next spring is aggressive and success oriented; a slip would endanger early physics but not CD-4.

In terms of longer-term operational needs, the capability for generation and transport of 1 nC at the required brightness is a work in progress with many uncertainties in the physics at this time. However, such capability is not required for initial operation and lasing and should not delay transition to operations.

Likewise the gun load lock is not in present budget or contingency allocation. The inclusion of a gun test stand in the overall program would bring significant long-term benefits through improved injector performance and possibly higher brightness beams, which would ease lasing at 1.5 Angstroms.

The Committee was comfortable with the cost contingency; it reflects risks as presently understood. In many areas the project funded effort has been completed. The Committee also observed that Integrated Safety Management is being appropriately addressed at all stages of the planning. It was obvious that safety is being taken seriously by staff.

2.6.2 Comments

The Committee offered the LCLS Injector and Linac team congratulations on terrific work to accomplish the required performance at 0.2 nC in the injector and linac. This success (which was not assured at the beginning of the project) has eliminated a major potential technical risk for performance of the FEL.

The reliability of the drive laser has been (surprisingly) very good and is ready to support operations. However, failure data on older RF and other legacy systems was of some concern and may limit transition progress and operations availability. Longer-term, the project is going to have to come to terms with replacement and upgrades of such hardware. An example where such replacement is needed near term is in replacement BPMs. The older systems do not have enough resolution to determine what is causing jitter in the beam.

Another example where key diagnostics do not exist is Sector 24 wire scanners. They are on the AIP list but need to be moved up in priority so that the machine operation can be sufficiently defined and automated in setup to hand over to operations. Good diagnostics will save both time and money.

The existing high-level control programs are outstanding and provide confidence in the understanding of the physics. They will serve as a great basis for the more robust tools needed by operators in the future.

2.6.3 Recommendations

1. Re-consider prioritization of AIP diagnostic items and establish schedule to provide required new and upgraded diagnostics by October 2008.

2. Establish a plan and support for transition of high-level software to Controls Group by July 2008.

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3. CONVENTIONAL FACILITIES (WBS 1.9, 2.9)

3.1 Findings

The LCLS Conventional Facilities (CF) scope represents a significant fraction (over 40 percent) of the LCLS TEC. The current CF baseline estimate is now $135.9 million, this is up from $128.8 million in July 2007. The total work accomplished through February 2008 is reported at $108.6 million—76 percent of the estimated CF work. The majority of the work is contained in a contract with the CM/GC, Turner Construction. At the end of February, the Turner contract construction was approximately 85 percent complete. Tunneling activities were completed without technical issues. Utilities are being installed and LCLS co-occupancy activities are progressing well. Commissioning of the facilities has just begun. Approximately $2,521K in Field Change Orders have been negotiated and approved, which is less than four percent of construction progress to date.

Substantial progress has been made in the last ten months with the Conventional Facilities construction. The Undulator Hall tunnel, NEH, and FEH have been constructed, as well as the Front End Hall from the linac to the Undulator Hall. All tunneling has been completed and the tunneling subcontractor has demobilized and left the site. An early occupancy arrangement that allows joint usage by the LCLS technical groups with Turner was started in January. The Front End Hall and Undulator Hall are under "joint occupancy" with the LCLS installation proceeding, under the schedule control of Turner. The new Central Utility Building (CUB) is powered and nearing acceptance tests. Beneficial Occupancy for the Beam Transfer Hall is expected in May, and also for the new CUB. The NEH and X-ray Hall will follow in June and/or July. Beneficial Occupancy of the FEH is expected by the end of August 2008. As of the date of the review, the final floor was placed from the Front End Hall and Undulator Hall to the upstream end of the X-Ray-Transport Hall. Electrical conduit and utility piping are being installed everywhere upstream of the X-ray transport. In the NEH hutch and control room, partitions are in place and much work on utility installation has occurred. Overall, the Turner contract schedule as of mid-May was within 120 days of completion for most areas upstream of the FEH.

The construction workforce is now averaging 80 construction workers working a normal five-day/eight-hour schedule. Since the start of construction $2.5 million of Field Change Orders have been negotiated and approved. Open change orders and potential claims (before negotiation and resolution) may total several times the amount settled to date.

CF has additional work to perform that is not included in the scope being performed by Turner. The cost that is being carried for this work is without a bottoms-up estimate. Only Conceptual Design cost estimates are available for this work. These areas of work consist of design and construction of: 1) Building 28 renovations for 45 offices, 2) Building 751 renovations for 63 offices, and 3) experimental hutch construction in the FEH. The current estimate is approximately $4.0 million for the building renovations and approximately $4.5 million for the experimental hutch construction.

Several serious safety incidents have occurred during the Turner contract. This has resulted in increased oversight by many parties. Nonetheless, safety continues to be an issue on the civil construction site. SLAC field inspections of the Turner construction site have recently observed unsafe practice of individuals working at heights without appropriate fall protection measures. LCLS has written a formal Safety Notice to Turner Construction requesting immediate corrective action and an analysis describing why these violations continue to re-occur and develop a corrective action plan to eliminate the violations. The focus of all parties is now on completing civil construction without cutting corners that may increase injuries.

3.2 Comments

The BTH is nearing its completion date. Beneficial Occupancy, the formal transfer of the facility from Turner Construction to SLAC, is scheduled for late May 2008 and appears to be on schedule. Magnet stands are being installed in the BTH prior to Beneficial Occupancy to maintain schedule. Beneficial Occupancy of all areas upstream of the FEH by July appears likely if the Turner workforce remains at about the current level of 80. Completion of all the Turner work by the scheduled end of the Turner contract appears reasonable. There are roughly seven and a half months left on Turner's schedule and the review presentations indicated that the testing and commissioning will take six months to complete. LCLS Management and Turner will need to closely plan and schedule the remaining contract work, punch list work and close-out work. The LCLS management needs to make sure that enough retention is being held to ensure that the punch list work will be completed in a timely fashion.

It is still advisable to have as accurate an estimate as possible of the remaining uncontracted work elements. Therefore, it is essential that the specifications of the FEH hutches be completed by the end of June, and the Title II design work for the hutches and the office renovations commence by the end of July as scheduled by LCLS management. Until the designs are completed and contracts awarded for this remaining work, it will not be known whether the estimating has been better than all previous contracts for the LCLS CF, which have run about 50 percent over estimates as contracted.

There is a considerable amount of work to do to negotiate prices for change orders and to settle all claims generated under the Turner contract. Although legal recommendations have been made to both parties to negotiate claim settlements, it is by no means clear that disagreements over claims may not proceed to arbitration and thence to awards unfavorable to the LCLS project. Contingency consideration at this time should include these possibilities.

The Committee was concerned that the current contingency level of $17 million may not be sufficient for all eventualities. The safety incidents that have occurred under the Turner contract are disappointing. The high level of oversight by LCLS management and DOE/SSO should be sufficient to emphasize the commitment to zero further incidents to the end of the Turner contract. LCLS management should track the costs involved in assisting with the Turner safety program and consider presenting a back charge to Turner. It will take a serious commitment by all parties to hold the line and get to the end of the Turner contract without incident. The cleanliness and orderliness of the site during review committee's tour was impressive. The safety record on work outside the Turner contract has been good to date.

3.3 Recommendations

1. Continue to monitor Turner's schedule to completion.

2. Confirm that Turner and the Turner subcontractors are maintaining sufficient staffing to complete the work on schedule

3. Complete the specification for the FEH hutches by June 30, 2008, which is consistent with the schedule presented.

4. Begin the Title II design for the FEH hutches and the two office building renovation projects by July 31, 2008, which is consistent with the schedule presented.

5. Review the cost estimate from the A/E as soon as the Title II work for the FEH hutches and office renovations is complete for this remaining work not under contract.

6. Retain a contingency allowance of between 30 and 50 percent for all Conventional Facilities work for which a final design and an accompanying cost estimate are not in hand today. Retain that level of contingency until contract award.

7. Continue to examine and implement proactively all possible factors necessary to achieve an exemplary safety record on the remaining work.

8. Settle change orders and claims.

4. ENVIRONMENT, SAFETY and HEALTH

4.1 Findings and Comments

LCLS ES&H Program

The LCLS project has given safety strong attention and has staffed the project at a level that is similar to that of other DOE projects of comparable size. The LCLS safety program includes all the program elements found in DOE construction projects.

LCLS ES&H staff assigned to the Technical Systems is adequate. The ES&H staff assigned to construction has been augmented to support the site safety staff. This includes addition of a full-time paramedic and a second shared paramedic/safety representative who support the Turner Site Safety Manager in conducting safety inspections and to provide for on-site robust management of worker injuries. In addition, LCLS has dedicated two University Technical Representatives (UTRs) to monitor contractor safety.

The construction project experienced minor environment discharges in the form of equipment leaks. These were minimal and below notification thresholds. Winter storms on occasion overwhelmed systems in place to prevent soil from entering the storm water system. Corrective actions were taken immediately.

Project safety documentation is current and has been reviewed periodically throughout duration of the project. The Fire Hazard Analysis (FHA) will be reviewed as a part of Mechanical, Electrical, Plumbing (MEP) commissioning to ensure requirements are met. The Atomic Molecular Optics (AMO) Hazard Analysis Report (HAR) will be included as a chapter in the LINAC Safety Analysis Document (SAD).

Technical Systems Safety

The LCLS Conventional Facility (CF) subcontractor work activities and Technical Systems planning and installation activities reflects a systematic integration of safety throughout their respective processes. The activities are well managed with an exceptional safety record. In over 100,000 work hours, no worker has been injured beyond minor first aid. The Total Recordable Rate (TRR) and Days Away and Restricted Time (DART) for these activities is zero.

The project managers, Installation Managers and UTRs overseeing the work execution, supported by the project and SLAC ES&H Team, effectively communicate ES&H expectations, proactively manage the work, provide safety guidance, provide feedback and through work planning and control, aggressively manage to Integrated Safety Management (ISM) core functions and guiding principles.

Job Safety Analysis (JSAs) are completed for each task. Frequent coordination meetings are held between the UTRs, the CF subcontractors, and SLAC workers. These processes and procedures were proven to effectively provide for the safety of installation and commissioning work. Safety performance of each task is reviewed on completion and Lessons Learned integrated into the next cycle for continuous improvement. The Committee considered the LCLS CF sub-contractors and Technical Systems Installation activities to be well managed, consistent with ISM.

Construction Safety

Construction activities during the time of the review consisted of final site grading and mechanical, electrical, and plumbing installation.

Tunneling operation and its associated risks were an initial review concern. This aspect of the project is nearly complete and the Committee considered it to have been effectively managed. Industrial Hygiene assessments were conducted per California OSHA requirements—the Palo Alto Fire Department rescue team (trained in tunnel emergency response and extraction) was available but not utilized.

In spite of this robust presence and very close project management attention, LCLS safety experience during the past year has failed to meet DOE goals or the average construction incident rate within the complex. The LCLS Construction DART rate is roughly twice that of the average U.S. construction experience.

The LCLS management, SLAC, and the DOE/SSO have taken proactive steps to improve safety of the GC managed work. The Committee found excellent cooperation and collaboration in this effort. The Committee assessed that these efforts are starting to show results.

Site presence and visibility by line management and safety support was increased since the July 2007 DOE/SC review. This increased oversight includes joint observations and monitoring of Turner's work by LCLS and DOE/SSO. During the walkthroughs by LCLS and DOE/SSO emphasis is placed on positive safety reinforcement of workers, in addition to the

review of work performance for safety compliance; review of JSAs and Daily Pre-Task planning and execution; and monitoring of specific subcontractor activities for safe work practices.

Safety Performance Observations are being conducted by both LCLS and Turner. They use their respective systems to track the information. Turner uses the DBO2 system that compares the site experience with Turner's national trends. The LCLS system tracks observations, which are then evaluated internally for trends. Both systems have their merits. Incidentally, SLAC is in the process of adopting the LCLS Safety Performance Observation approach for implementation throughout SLAC.

LCLS and Turner have several regular forums to evaluate and discuss planned work and lessons learned based on the results of the field observations. These include:

- Weekly Owner/Architect/Contractor Meeting
- Weekly LCLS Safety Committee Stewardship Meeting
- Bi-Weekly Subcontractor Safety Committee Meeting
- Scheduled Senior Project Management Team Safety Walks

In addition to the field observations and analysis, the LCLS Director holds a bi-weekly conference call with Turner's Senior Vice President for Operations, dedicated entirely to safety. Turner's Safety Director for their West Coast operations, based in Portland Oregon, is actively involved in safety and is on site three days a week.

Safety Evaluations have been conducted of the LCLS project safety program by several organizations over the past year:

- LCLS ES&H Group January 2008
- An independent former OSHA Compliance Officer
- DOE/ORNL ISC for the DOE- SSO
- BES ES&H Committee July 2007

The conclusions of each of these evaluations has been consistent. They have each identified the problem with the GC/subcontractor project safety performance to be the result of deficiencies in work planning and oversight of the subcontracted work. Serious concerns were expressed at the July 2007 DOE/SC review regarding the GC's weak management of safety (e.g., confusion over a single site safety program or multiple programs; observation of numerous site safety compliance deficiencies; etc).

Work Planning and Execution

In response to the deficiencies in work planning and execution, all subcontractors have been instructed to apply the same work planning process including a JSA for a specific scope of work (30 day review cycle) and a Daily Pre-Task Work Sheet that describe each days activities. Where the contractors have applied this process they have successfully avoided safety occurrences. Contractors that have failed to effectively implement the process have not been successful. The success of the approach is dependent on the strength of the subcontractor's foreman. Where warranted, changes have been made in Turner management and field personnel. Additional steps LCLS has taken include issuing deficiency notices and levy of fines. During the past several months it has become apparent that the GC has not been actively involved in stewarding the process as they assured the project they would.

In the coming months the GC and subcontractors will be demobilizing from the site that can potentially result in accentuated or new safety issues (e.g., loss of focus by the workers and field managers as they think about the next job). The Committee recommended that LCLS develop a safety plan addressing additional measures to ensure safety during the demobilization process.

The project responded appropriately to recommendations from the July 2007 DOE/SC review.

4.2 Recommendations

1. Develop a Post-Project Safety Evaluation addressing the project safety organization and Lessons Learned, for the benefit of future BES projects. To be completed by the next review.

2. Develop and implement an End-of-Construction Safety Plan addressing safety issues unique to GC/subcontractor demobilization from the site. To be completed by June 15, 2008.

5. COST and SCHEDULE

5.1 Findings

The LCLS project cost and schedule rebaselining was complete January 24, 2008 and the Baseline Change Request implementing the new baseline was signed and approved on February 7, 2008. The rebaseline revised the TPC from $379 million to $420 million and extended the completion of the project (CD-4) from March 2009 to July 2010.

The LCLS project reported two months of cost/schedule performance data subsequent to the completion of the rebaseline. The cumulative February 2008 CPI and SPI for the total project is 1.0. The cumulative March 2008 CPI and SPI for the total project is 1.0.

The project planned an aggressive BCWS for the FY 2009 in order to transition to scientific operations as soon as possible. There is currently no planning within the baseline accommodating a likely CR in FY 2009. The project cost/schedule baseline assumes the project will receive full funding in the first quarter of FY 2009. This assumption was used in developing the project baseline to plan for early science in July 2009. This is a Level 2 milestone that is intended to keep pressure on the funding scenarios for FY 2009.

The project's cost, schedule, and technical baselines are consistent with the FY 2009 LCLS Construction Project Data Sheet once the current approved Baseline Change Requests are factored into the analysis.

A reconciliation of the performance values in PARS was compared to the monthly Cost Performance Report for February 2008. The cumulative BCWP and ACWP are consistent with the project performance reported in the project Cost Performance Report (CPR) through February 2008. However, the cumulative BCWS in PARS for February 2008 is $1 million lower than the BCWS reported in the CPR.

The project has a risk management process that is well developed and is utilized by the management team for decision-making. There appears to be adequate cost contingency for the TEC. The cost contingency was based on a bottoms-up estimate by the CAMs when they were re-estimating their work. The CAMs considered Design Maturity based on project guidance and added a factor for technical judgment. During the rebaselining effort the cost contingency estimates and risks in the risk registry were then run through a Monte Carlo analysis to determine the likelihood that the project had estimated enough cost to complete the project within the

available TPC. The results indicated that there was an 85 percent probability that the project would complete within the current funding allowances.

Schedule contingency was applied within the project schedule to Level 3 milestones, as well as at the end of the project in terms of available schedule contingency between early completion and CD-4. The schedule contingency was assessed using Monte Carlo analysis. The result of the Monte Carlo analysis was a 90 percent probability that the project will meet the current cost and schedule objectives. Based on the Monte Carlo analysis performed recently there was a 100 percent probability that the project will meet the CD-4 milestone July 2010.

The project indicated they did not include Other Project Costs (OPC) in the risk registry due to the fact that the work was mostly level of effort.

The renovation of the Office Space and the Hutch space has only been conceptually designed. The cost estimates for these portions of the project have approximately 60 percent contingency on the subcontracted portions of the estimate. This is consistent with the level of design maturity.

Other construction field activities are progressing in a manner consistent with the baseline cost and schedule and significant visible progress was evident. Consistent with this progress there were many outstanding construction contractor claims that have not been closed. The current construction contractor claims have been added to and are identified as a risk items in the risk registry.

The project team has addressed and implemented the recommendations from the July 2007 DOE/SC review.

5.2 Comments

While planning for an early science milestone is a worthwhile objective, additional funding support would be required early in the first quarter of FY 2009. Reviewers agreed that a CR in FY 2009 is inevitable and that it was likely that full FY 2009 funding would not be received in time to support the early science objective.

The project cost/schedule baseline is well developed and planned to a reasonable level of detail. The project controls tools and systems are well integrated and very impressive.

The detailed design of the Hutches and office renovation needs to be initiated as soon as possible in order to integrate this scope into the cost/schedule baseline and to better understand the risks associated with this scope.

Project Management indicated that they did not include the OPC activities in the Risk Registry because the OPC activities were mostly all level of effort. At a minimum, the Committee would expect to see risks associated with commissioning part of the OPC. The commissioning activities include key interfaces and milestones for commissioning of certain systems to be complete before other systems can start or complete commissioning.

The LUSI project needs to baseline the LUSI schedule as soon as possible to determine the impact to the LCLS installation schedule.

5.3 Recommendations

1. Consider utilizing the Risk Management process to its full capability across the entire scope of the project. In addition to generating and evaluating risks on the TEC portion of the project, the management team should consider adding OPC risk items to the risk registry. An example of this is to add the commissioning risks to the risk registry. Add the renovation of the office space to the risk registry to track all risks.

2. Work locally and with other agencies for ways to secure early funding needed to minimize the impact from a probable CR. Work diligently during the next three to four months to secure funding and finalize plans that support the start of FY 2009 activities. Work to finalize all planning required to meet the early science milestone including securing the funds necessary to maintain schedule, and to keep any early FY 2009 procurements on track by pursuing SLAC, the SLAC DOE site office or Oak Ridge Research Office (ORO).

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6. PROJECT MANAGEMENT

6.1 Findings

Since the July 2007 DOE/SC review, the LCLS project has demonstrated very impressive progress in site construction, hardware fabrication and installation, and initial commissioning. For example, successful delivery of LCLS quality beam to the end of the linac is a particularly significant achievement. In fact, two of four technical performance parameters that define CD-4, project completion, have already been achieved. The project team responded well to the recommendations from the July 2007 DOE/SC review.

The LCLS project has constructive relationships with both DOE/BES and DOE/SSO. All parties are fully committed to project success.

A number of institutional areas that impact LCLS are in transition. For example, Stanford University has become much more engaged and supportive of SLAC activities. A university Vice President for SLAC has been appointed and is already making a positive impact. The new SLAC Director has initiated changes to the laboratory organizational structure designed to strengthen SLAC effectiveness overall and LCLS as the flagship science facility in particular.

Planning for transition of LCLS from a construction project to an operating facility within the SLAC institutional environment is underway. A vision for restructuring the LCLS organization has been developed and is partly implemented under the Acting Associate Laboratory Director for LCLS.

Work at the two LCLS partner laboratories, ANL and LLNL, is nearing completion and hardware is being delivered to LCLS.

The LUSI Major Item of Equipment (MIE) project remains in the LCLS organizational structure, but with recently restructured scientific and project management roles and responsibilities that match the vision for the new LCLS Directorate.

A March 2007 review of SLAC-wide procurement practices resulted in a dramatic reduction of the laboratories procurement authority. Since then, DOE/SSO has given special attention to LCLS procurements in order to minimize impacts.

A CR at the beginning of FY 2009 is likely. LCLS needs approximately $5 million budget authority in October in addition to the expected CR allocation in order to execute the baseline plans.

6.2 Comments

As an overall assessment, the Committee concluded that LCLS is on track for successful achievement of its technical, cost, and schedule goals.

The LCLS Project Director, John Galayda, and his project team are to be commended for the outstanding progress, especially in the climate of transition and uncertainty at SLAC.

While the cost and schedule status appears to be in satisfactory condition, there is currently no plan to update the estimate-to-complete (ETC) from the rebaseline estimate, which is now approximately six months old. As a general practice in successful SC projects, an ETC is usually conducted at least annually. Such information is essential to guide project assessment and decision making.

The Committee learned that LCLS uses a project specific overhead rate structure for the TEC work but not for the OPC work. This is not consistent with other recent SC projects and is believed to be a carryover from historic SLAC laboratory practices. Application of the project specific rate to the entire TPC would reduce the overhead burden on the project. Continuation of the use of different rates for OPC and TEC is unnecessary should be reevaluated.

As LCLS nears completion, project staff should develop a “lessons-learned” document to capture information that would be useful for future SC projects.

DOE, SLAC, and LCLS itself would be well served by developing an “End Game Plan” that would more fully develop the strategy and plans for completing project activities and the transition to operations. The definition of the completion of the lower-level project activities, for example completion of operations manuals and as-built drawings, should be part of the End Game planning.

LCLS should assure that it has assigned appropriate staff to receive, install and commission ANL and LLNL equipment in cooperation with those laboratories.

So far, the revised management approach for LUSI seems to be on the right track. LCLS management should pay continuing attention to assure that plans for baselining this project are met in a timely fashion.

SLAC and DOE/SSO should work together to resolve the procurement issues and restore a more reasonable authority to SLAC. This is important for LCLS, but especially for LUSI.

With regard to the CR, it should be possible to determine now whether DOE and/or SLAC can provide the necessary funding within the guidelines that apply during a CR.

6.3 Recommendations

1. Complete a bottoms-up ETC in approximately six months.

2. Develop and provide to DOE an “End Game Plan” in approximately six months.

3. Confirm by the end of June that the plan for accommodating the early FY 2009 funding requirements can be met.

Intentionally Blank

APPENDIX A

CHARGE MEMORANDUM

DOE F 1325.8
(08-93)

United States Government
Department of Energy

memorandum

DATE: March 7, 2008

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-28

I request that you organize and lead an Office of Science (SC) status review of the Linac Coherent Light Source (LCLS) project at the Stanford Linear Accelerator Center (SLAC) during May 12-13, 2008. 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).

During the past several months, the project has undergone several reviews and has an approved performance baseline change. The FY 2007 continuing resolution (CR) had many impacts to the projects resulting in a performance baseline deviation (both in cost and schedule). The Office of Engineering and Construction Management (OECM) conducted an External Independent Review (EIR) of the project which concluded successfully. A Performance Baseline Change was approved on January 24, 2008. A Baseline Change Request (BCR) was approved on February 7, 2008. The FY 2008 continuing resolution (CR) had limited impact to the project cost and schedule. The project has continued with civil construction activities and technical hardware procurement and installation. The project was 71% percent complete as of the end of December 2007 against the original baseline. This is the first SC Status review of the project under the revised baseline.

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 the FY 2009 LCLS Construction Project Data Sheet? Is there adequate contingency (cost and schedule) to address the risks inherent in the remaining work and is contingency being properly managed? Is the contingency supported by and consistent with an appropriate project-wide risk analysis? Is the information in the DOE Project Assessment Reporting System consistent with physical progress?

2. Are the construction field activities progressing in a manner consistent with the predicted costs and schedule? Has the renovation of laboratories and office space (Buildings 28 and 750) been integrated into the appropriate project planning and execution documents?

3. Are the designs, procurement and commissioning plans of the technical systems sufficiently mature to support the project schedule? Will preparations for LCLS experiments, (i.e. first delivery of x-rays to the Near Experiment Hall) provide a smooth hand-off and transition to LCLS operations? Are preliminary plans adequate for determining operational readiness?

4. Are preparations for initiation of the LCLS experimental science program progressing appropriately? Assess the effectiveness of LCLS progress and plans for activities such as user outreach and communications, proposal solicitation and review process, policy for access to the facility, goals for commissioning instruments, and plans to support the experiments during facility operations.

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

6. Is the project being managed (e.g., properly organized, adequately staffed) as needed to continue with construction and technical equipment installation and commissioning? Is there an adequate interface activity between LCLS and the LCLS Ultrafast Science Instruments (LUSI) project? Is there adequate support from SLAC in all necessary areas (e.g., contracts, procurement, human resources)? Has the project responded appropriately to recommendations from prior DOE reviews?

Thomas Brown, the LCLS Program Manager, will serve as the Basic Energy Sciences point of contact for this review. I would appreciate receiving your committee's report within 60 days of the review's conclusion.

/S/

Harriet Kung
Associate Director, (Acting)
for the Office of Basic Energy Sciences

cc:
P. Golan, SSO
H. Lee, SSO
H. Joma, SSO
P. Drell, SLAC
J. Galayda, SLAC
M. Reichanadter, SLAC
S. Tkaczyk, SC-28
P. Montano, SC-22.3
T. Brown, SC-22.3
L. Cerrone, SC-22.3
E. Rohlfing, SC-22.1
M. Procario, SC-25.1

APPENDIX B

REVIEW PARTICIPANTS

Department of Energy Review of the Linac Coherent Light Source (LCLS) Project
May 13-15, 2008

Daniel R. Lehman, Chairperson, DOE/SC

SC1

Accelerator Physics

* Sam Krinsky, BNL
George Neil, TJNAF

SC2

Injector/Linac

* Richard Sheffield, LANL

SC3

Undulator

* Erik Johnson, BNL
Steve Marks, LBNL
Kem Robinson, LBNL

SC4

Photon Beam Handing Systems

* Dennis Mills, ANL
Mark Beno, ANL
Chi-Chang Kao, BNL

SC5

Control Systems

* David Gurd, ORNL (ret.)
Larry Hoff, BNL

SC6

Conventional Facilities

* Dixon Bogert, Fermilab
Mike Schaeffer, BNL
Steve Sawch, BNL

SC7

Cost and Schedule

* Cathy Lavelle, BNL
Angus Bampton, PNNL
Steve Tkaczyk, DOE/SC

SC8

Project Management

* Les Price, consultant
Frank Crescenzo, DOE/BHSO
Kurt Fisher, NNSA
Brenna Flaugher, Fermi

SC9

ES&H

* Arnold Clobes, LLNL

Observers

Jeff Salmon, DOE/SC
Pat Dehmer, DOE/SC
Pedro Montano, DOE/SC
Tom Brown, DOE/SC
Thomas Kiess, DOE/SC
Eric Rohlfing, DOE/SC
Hanley Lee, DOE/SSO
Hannibal Joma, DOE/SSO
Brian Huizenga, DOE/OECM

LEGEND

* Chairperson

Count: 23 (excluding observers)

APPENDIX C

REVIEW AGENDA

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

AGENDA

Tuesday, May 13, 2008—B048/Redwood Room

1:00 pm	DOE Executive Session	D. Lehman
1:30 pm	Welcome	P. Drell
1:45 pm	LCLS Directorate Overview	D. Knutson
2:00 pm	Project Overview and Assessment	J. Galayda
2:45 pm	Project Management	M. Reichanadter
3:15 pm	LCLS Commissioning	P. Emma
3:45 pm	LCLS Tour (B750/Construction Site)	
5:30 pm	DOE Executive Session	D. Lehman
6:30 pm	Adjourn	

Wednesday, May 14, 2008

8:00 am	Breakout Sessions	
12:00 pm	Lunch	
1:00 pm	Breakout Sessions	
3:00 pm	DOE Executive Session	Executive Committee

Thursday, May 15, 2008

8:00 am	DOE Executive Session	
9:00 am	Closeout Dry Run	D. Lehman
10:30 am	Closeout Presentation	
11:30 am	Adjourn	

APPENDIX D

COST TABLE

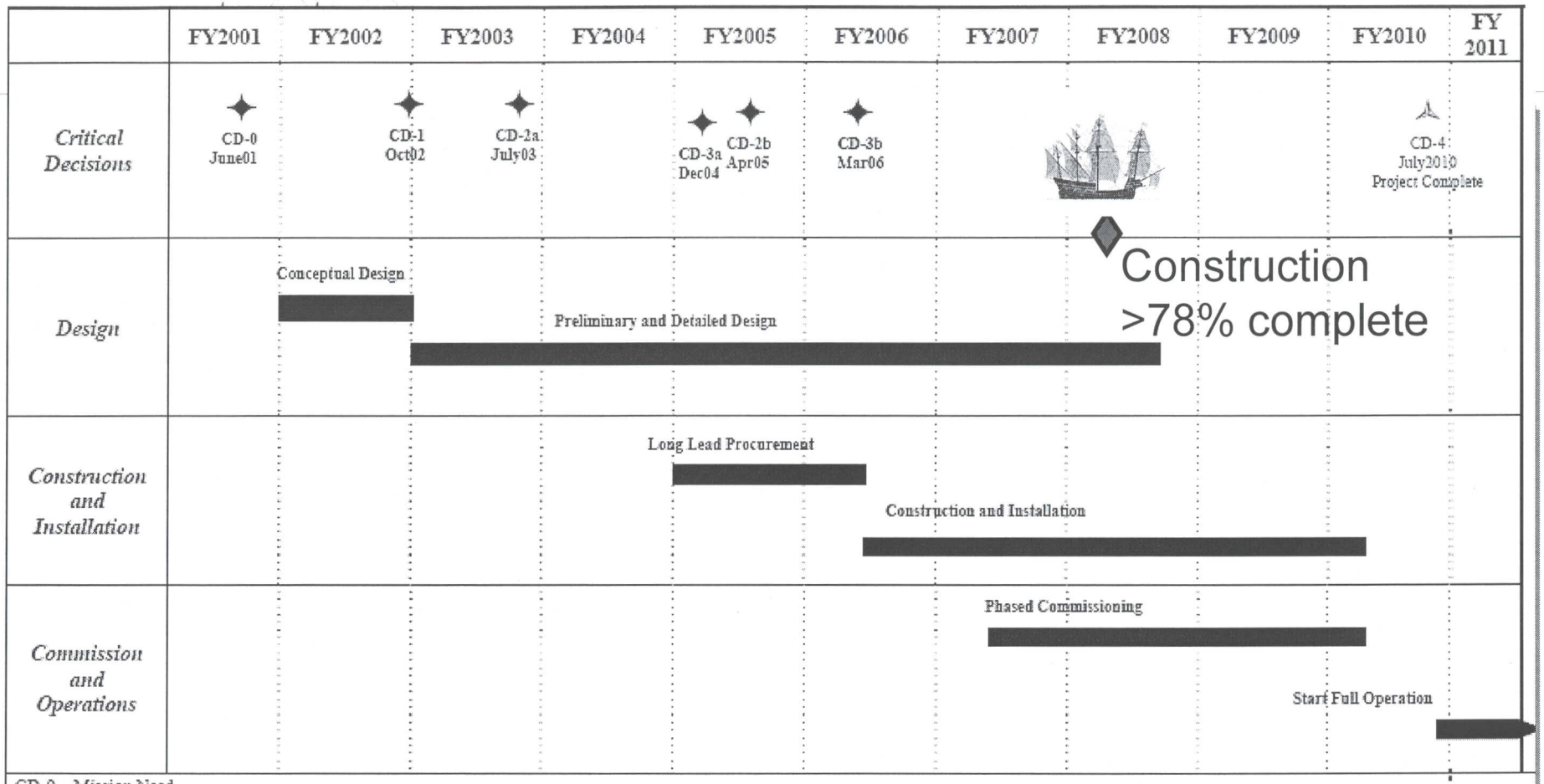
LCLS Project Performance

LCLS Baseline Performance - February 2008 (AYK$)			
WBS	Work Accomplished	% Complete	Total Budget at Completion
1.1 Project Management	18,726	82.1%	22,822
1.2 Injector	20,239	100.0%	20,239
1.3 Linac	22,647	80.1%	28,257
1.4 Undulator	38,724	85.4%	45,355
1.5 X-ray Transport	20,067	73.0%	27,494
1.6 X-ray Endstations	2,437	26.7%	9,115
1.9 Conventional Facilities	108,575	79.9%	135,888
1.X Controls	26,310	63.6%	41,369
1 LCLS Total Base Cost	**257,725**	**78.0%**	**330,539**
		LCLS Total Estimated Cost (TEC)	**352,000**
		Available Contingency	**21,461**
		% Contingency on ETC	**29.5%**
2 LCLS Other Project Cost	**28,065**	**47.8%**	**58,675**
		LCLS Total Other Project Costs (OPC)	**68,000**
		Available Mgmt Reserve	**9,325**
		% Mgmt Reserve on ETC	**30.5%**
LCLS Total Project Cost (TPC)	**285,790**	**73.4%**	**420,000**

M. Reichanadter
reich@slac.stanford.edu

APPENDIX E

SCHEDULE CHART



CD-0 Mission Need
CD-1 Preliminary Baseline
CD-2a Long Lead Procurement Budget
CD-2b Performance Baseline
CD-3a Start Long Lead Procurement
CD-3b Start of Construction (Full scale)
CD-4 Project Complete/Full Operations

	FY02	FY03	FY04	FY05[1]	FY06	FY07[2]	FY08	FY09	FY10	Total
TEC	0	5.93	7.46	49.67	84.69	101.16	51.35	36.50	15.24	352.00
OPC	1.50	0	2.00	4.00	3.50	13.00	15.50	17.00	11.50	68.00
TPC	1.50	5.93	9.46	53.67	88.19	114.16	66.85	53.50	26.74	420.00

[1] *FY2005 TEC funding includes $29,760,000 for long lead procurements.*
[2] *FY07 TPC funding reflects the ~$8M reduction as a result of the FY2007 CR and directed change.*