

*Department of Energy  
Review Committee Report*

on the

Technical, Cost, Schedule, and  
Management Review

of the

**LINAC COHERENT  
LIGHT SOURCE  
(LCLS) PROJECT**

April 2002



## EXECUTIVE SUMMARY

A Department of Energy (DOE) Office of Science project review of the Conceptual Design Report (CDR) and documentation for Critical Decision 1, Approve Preliminary Baseline Range, for the Linac Coherent Light Source (LCLS) project located at Stanford Linear Accelerator Center (SLAC) was conducted on April 23-25, 2002. The purpose of the review was to assess all aspects of the project's conceptual design and associated plans to determine its readiness for Critical Decision 1.

The Committee found that the project's CDR was sound, the management leadership of the highest quality, and the associated documentation adequate. However, the funding profile and schedule needed more development, and additional work on the design of the conventional facilities will be necessary to bring it up to the level of technical systems.

The LCLS project will be an X-ray source of unprecedented brightness and coherence, located at SLAC. The LCLS project consists of an injector, linac, undulator, and experimental hall. The project's preliminary Total Estimated Cost is approximately \$216 million, and the Total Project Cost is approximately \$233 million (based on funding assumptions that were determined to be overly optimistic). The lead laboratory is SLAC, and the other major collaborators are the Lawrence Livermore National Laboratory and the Argonne National Laboratory.

The Committee made 52 recommendations including: establish a spare parts list; perform validation tests on the Gun Test Facility test stand; designate a senior team leader for the Undulator Systems; build a complete undulator prototype subsystem; incorporate an injector commissioning plan with installation of other subsystems; increase materials damage R&D for the optical components of the Photo Beam Handling Systems; consolidate the Control Systems efforts under one entity; augment the Conventional Facilities Team with more experienced individuals; perform a geotechnical survey now; re-evaluate the Total Estimated Cost, the Total Project Cost, and contingency; complete the Acquisition Execution Plan and Preliminary Project Execution Plan; define the advisory process for scientific input; and, define the criteria for Critical Decision 4, Start of Operations.

The Committee also developed four action items including: DOE Office of Basic Energy Sciences will provide funding guidance; and LCLS management will provide a project schedule, complete the draft Acquisition Execution Plan, and submit all other documentation by July 1, 2002.

In summary, the Committee found the LCLS conceptual design to be sound, and the scope was adequately defined to support the cost and schedule estimates, which were judged to be credible. The LCLS management team is experienced and capable of leading the project to a successful conclusion. The LCLS project, after completing a number of refinements to the Preliminary Project Execution Plan, is judged to be ready for CD-1, Approve Preliminary Baseline Range.

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# 1. INTRODUCTION

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

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

The LCLS will have properties vastly exceeding those of current X-ray sources (both synchrotron radiation light sources and so-called "table-top" X-ray lasers) in three key areas: peak brightness, coherence (i.e., laser like properties), and ultrashort pulses. The peak brightness of the LCLS is ten billion times greater than current synchrotrons, providing  $10^{12}$ - $10^{13}$  X-ray photons in a pulse with duration of 230 femtoseconds. These characteristics of the LCLS will open new realms of scientific applications in the chemical, material, and biological sciences. The LCLS Scientific Advisory Committee, working in coordination with the broad scientific

community, identified high priority initial experiments that are summarized in the document, *LCLS: The First Experiments*. These first five areas of experimentation are: fundamental studies of the interaction of intense X-ray pulses with simple atomic systems; use of the LCLS to create warm dense matter and plasmas; structural studies on single nanoscale particles and biomolecules; ultrafast dynamics in chemistry and solid-state physics; and studies of nanoscale structure and dynamics in condensed matter.

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

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

The Mission Need, Critical Decision 0, was approved by the Office of Science in June 2001. The LCLS preliminary Total Project Cost range was \$180-240 million, during the conceptual design stage, with Project Engineering and Design (PED) funds beginning in FY 2003 and construction starting in FY 2005.



Subsequent to the DOE Conceptual Design Review, the Office of Basic Energy Sciences provided SLAC with additional guidance that resulted in a revised TPC range of \$245 million to \$295 million and delayed the construction start to FY 2006. Under this scenario, long-lead procurements would be initiated in FY 2005.

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## **2. TECHNICAL SYSTEMS EVALUATIONS**

### **2.1 Accelerator Physics**

#### **2.1.1 Findings**

The teamwork carrying out the analysis of the accelerator physics for the LCLS is of the highest quality, and indicates that the conceptual design of the accelerator systems is sound and likely to meet the technical performance requirements. As presented, the project scope and specifications are clearly defined and provide a proper basis to support the preliminary cost and schedule estimates. Credible bottoms-up cost estimates were presented based on careful analysis by the responsible engineers. Significant effort has been made to assign contingencies based on risk. Schedules for individual systems have been developed that are credible and realistic for this stage of the project. However, the Committee was not given an overall schedule showing proper project milestones correlated with available resources. The accelerator physics design is being very well managed and has reached a stage appropriate for the start of Title I design. Environmental Safety and Health (ES&H) aspects have been addressed to the extent required for this stage of the project.

Experimental investigations of self-amplified spontaneous emission (SASE) carried out at Los Alamos National Laboratory (LANL), Argonne National Laboratory (ANL), Brookhaven National Laboratory (BNL) and DESY have demonstrated agreement with theory in the infrared, visible, and ultraviolet regions of the spectrum. The basic physics of SASE are expected to be the same for the generation of X-rays. The success of these experiments has provided an important foundation for the LCLS.

Start-to-end simulations have been developed describing the generation of the electron beam in the photo-injector, its transport, compression, and acceleration. Calculations of the SASE output have been made using the simulation results for the electron beam at the undulator entrance. These start-to-end simulations have been used to characterize the performance of the SASE source and used to develop the required tolerances on the electron beam and the accelerator hardware systems.

Important work has been done characterizing the effects of wake fields in the linear accelerator and undulator, as well as the effect of coherent synchrotron radiation in the bunch compressors. This has placed the design on a much more secure foundation.

Critical progress has been made in obtaining agreement between the results of simulations of photo-injector performance with experimental measurements.

Analysis of using beam-based alignment to correct the trajectory of the electron beam in the undulator indicates that the extremely tight tolerance of 1 micron is achievable.

### **2.1.2 Comment**

The source of funds for future experimental R&D on photo-injectors and bunch compressors was not clearly defined.

### **2.1.3 Recommendations**

1. Continue to give high priority to experimental benchmarking of the computer codes used to model the photo-injector.
2. Pursue the experimental investigation of bunch compression and its comparison to theory.
3. Continue to develop tolerance budgets and optimize performance by use of start-to-end simulations.
4. Study self-amplified spontaneous emission (SASE) output versus electron bunch charge to investigate the possibility that LCLS performance goals can be achieved for charges lower than 1 nano Coulomb.

## **2.2 Injector and Linac**

### **2.2.1 Findings**

The LCLS team has performed extensive analysis and design of the required systems. The team was very appreciative of the support that was given during the review of the design and costing methodology. The work to date is world-class, but much development remains to be done. This is essentially an R&D effort to achieve the required beam specifications at the wiggler. While the Committee believes that the design goals will ultimately be met, success cannot be assured at this point and continuing development is required. The best demonstrated

performance of an injector system is around a factor of two less than the requirement. Codes predict that appropriate modification of the beam profiles will lead to an achievement of the required performance. Research in this area needs to continue.

1. Is the conceptual design sound and likely to meet the technical performance requirements?

Yes. It meets a satisfactory level for Critical Decision 1, Approve Preliminary Baseline Range

2. Are the project's scope and specifications sufficiently defined to support preliminary cost and schedule estimates?

Yes, but there are some items that are not completely covered at this time. The overall performance specification for project deliverables is not fully defined. The project does not yet have a resource-loaded schedule. In the Committee's estimation, the resources are insufficient to meet Critical Decision 2, Approve Performance Baseline, in less than a year.

3. Are the cost and schedule estimates credible and realistic for this stage of the project? Do they include adequate contingency margins?

The contingency is adequate, but it is unclear that personnel for the commissioning process have been completely included. Some prototyping efforts are lacking in the plan. There is no funding for running the gun test stand. There is no funding for support of the injector crew during commissioning. Cost for spare components were not included in all estimates.

4. Is the project being managed (i.e., properly organized, adequately staffed) as needed to begin Title I design?

Yes

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

Yes

### **2.2.2 Comments**

The beam quality is an important driver for overall system performance. Even though the Committee believes that the project has a path to attaining the required performance, the required performance has not been met, and the injector system design is still evolving. The major concern was related to ensuring that enough of the injector issues are resolved so that final commissioning focuses on the FEL performance, and not the injector linac. This implies that the injector systems should all be brought into operation as soon as possible. This could be done on the Gun Test Facility (GTF) with subsystems implemented as soon as possible to ensure that performance improvements meet expectations.

Because of the lack of spares in the proposed plan, there could be significant schedule risk.

Injector through undulator-to-beam dump error simulations are needed to confirm the present error budgets and their resulting impact on the FEL performance. Non-uniform cathode emission should be included.

### **2.2.3 Recommendations**

1. Establish a resource-loaded schedule for the Project Engineering and Design phase by September 2002.
2. Establish a realistic spares list and include in Other Project Costs or other appropriate place by September 2002.
3. Include support for the required injector scientist activity in the commissioning plan by September 2002.
4. Move forward with laser prototyping as early as budget permits. Include in planning by next review.
5. Move forward with prototyping the gun as early as budget permits. Include in planning by next review.

6. Perform prototyping and design validation tests on the GTF test stand, integrating as many of the injector components as possible before final integration on the injector linac. Tests are to continue during FY 2002-2003. Include in the Total Project Cost by next review.

## **2.3 Undulator**

### **2.3.1 Findings**

The undulator subsystem includes 33 undulator magnetic structures, the vacuum chamber, permanent magnet quadrupoles, electron beam diagnostics, and X-ray diagnostics that are deployed within the undulator length. The Experimental Facilities Division of the Advanced Photon Source at ANL leads the effort. The Undulator system is at, or beyond, a CD-1 maturity level and the conceptual design is complete as stands. The conceptual design is sound and work to date has either demonstrated, or will likely demonstrate, the technical performance requirements.

The undulator system has been well managed during the conceptual design phase. The ES&H aspects of the undulator are being properly addressed given the project's current stage of development.

A full-length prototype has been partially assembled and has provided verification of the tuning stub range, field strength, and a test of the passive thermal compensation. The passive thermal compensation of the magnetic field by counteracting materials with differing coefficients of expansion has been judged as insufficient by the Advanced Photon Source to avoid some other means of field strength control.

The scope and specifications of the undulator systems are sufficiently defined to support preliminary cost and schedule estimates. The contingency margins assigned to the undulator subsystem have been properly assessed based on the tools provided by the central project office. However, as presented, the schedule for the design is aggressive and there are not enough resources within the Advanced Photon Source at ANL to accomplish Critical Decision 2, Approve Performance Baseline by March 2003. The organization and staff necessary to start Title I design are not yet defined. The preliminary engineering design phase requires approximately 16 full-time equivalents (FTEs) according to estimates.

### 2.3.2 Comments

A number of diverse technologies must be implemented in the undulator system to achieve success. The Advanced Photon Source and SLAC have a good grasp of what these technologies entail. The application of beam based alignment evidences a strong collaboration between the LCLS and the Next Linear Collider groups. This is very encouraging.

The cost estimate appears credible and realistic for this stage of the project, however, active temperature stabilization, which was not part of the original concept, has not been included in the costs.

In developing the undulator procurement strategy the Advanced Photon Source should consider procuring all of the magnets to be used in the undulators and drop ship them at the undulator subcontractor site. Additionally, if the procurement choice uses high-level industry involvement for the undulator system, prospective suppliers need to be involved early enough through letters of interest and/or intent. Necessary actions should be initiated to allow full value engineering and production optimization. Another option, if the goal is to go with industry, would be multiple first-article suppliers with the option to pick single or multiple suppliers for the final deliveries. In any event, care should be exercised to ensure that competition is maintained for as long as possible. This will ensure that the potential suppliers remain responsive and have the potential of achieving a better overall value.

The Advanced Photon Source should consider the development of a long-term assessment strategy of the stability of the undulator magnetic fields by characterizing the undulator sections of the Advanced Photon Source Low Energy Undulator Test Line when removed and compare their present magnetic configuration with characterization measurements made prior to installation.

With the incomplete success of passive temperature stabilization, and the need for a degree of remote magnetic field adjustment (for phase), the need and benefit of temperature stabilization of each segment needs to be clarified.

During the next design phase, the preferred approach for phase adjustment of successive undulator sections needs to be determined. The options presented at the review included piezoelectric actuators, vertical alignment, or thermal control. Other options may warrant consideration as well. It may also be advisable to develop a means of following the long-term magnetic field stability of each undulator segment once installed in the tunnel.



It will be very advantageous if both the prototype electron beam position monitors and the X-ray diagnostics tested with an electron beam as soon as possible.

### **2.3.3 Recommendations**

1. Designate a senior team leader for the LCLS Undulator system from within the Advanced Photon Source before September 2002, whose primary responsibility is to carry the system forward to successful completion.
2. Develop a resource-staffing plan prior to starting Title I design, to meet requirements during the Project Engineering and Design phase by July 2002.
3. Decide upon the Undulator procurement approach by September 2002. This must address whether a national laboratory or industry will be responsible for individual portions of the design, fabrication, measurements, etc. The design development during the preliminary design phase is different depending upon the chosen approach.
4. Complete a thorough value engineering and production analysis of the undulator mechanical design. Trade-offs on the choice of strongback materials, thermal compensation and phasing control, physical tolerances, and relationship between stringent tolerances and post assembly tuning must be completed. This should be completed prior to submitting any long-lead procurements for bid.
5. Focus the second undulator prototype on addressing mass production issues. The design and technical approaches have been sufficiently advanced that production issues are the most critical. If a second prototype is pursued, this recommendation must be completed prior to Critical Decision 3, Approve Start of Construction. If industrial production is selected, the second prototype should be produced in industry.
6. Build and deploy a complete prototype subsystem consisting of an undulator (the existing prototype is adequate), vacuum chamber, a short diagnostic/focus section, and a long diagnostic/focus section. This should include the electron beam diagnostics and X-ray beam diagnostics. This is to be completed prior to Critical Decision 3, Approve Start of Construction.

7. Assess and ensure that the allocation of the total impedance budget throughout the undulator is complete before Critical Decision 2, Approve Performance Baseline. Specifically, the cavity beam position monitors, X-ray diagnostics, and Cerenkov detector disruptions will impact the allocated impedance of the system.

## **2.4 Installation and Alignment**

### **2.4.1 Findings and Comments**

At several junctures there will be interference with the operation of the linac system for other programs. The project is aware of this and has incorporated it in their planning. As the installation time approaches, this will require further detailing to ensure that schedule interferences are minimized. It is particularly important to incorporate time for injector testing and commissioning in parallel with linac installation and operation for other programs.

The cost estimates for installation are at a reasonable level of development for this stage of the project. It appears adequate funding has been provided for activities associated with the smoothing of the linac required to meet the alignment tolerances. Operational methodologies have been established to deal with the remaining alignment errors.

Technical risk for this activity is expected to be minimal since the major part of the effort is similar to activities regularly performed at SLAC by the same personnel. One activity that is somewhat outside their scope of experience is the installation of the undulator modules. These are relatively fragile devices with tight tolerances. Careful procedures for transporting and installing the modules must be established. Training of the crews in the proper procedures will also be required.

1. Is the conceptual design sound and likely to meet technical performance requirements?

Yes. It is a satisfactory level for Critical Decision 1.

2. Are the project's scope and specifications sufficiently defined to support preliminary cost and schedule estimates?

Yes, but the project does not yet have a resource-loaded schedule. The details of how the installation schedule will be incorporated into linac operations are yet to be fully established, but the plan is adequate for cost and schedule estimates.

3. Are the cost and schedule estimates credible and realistic for this stage of the project? Do they include adequate contingency margins?

Yes. This area includes reasonable contingency because the experience base is well established.

4. Is the project being managed (i.e., properly organized, adequately staffed) as needed to begin Title I design?

Yes

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

Yes. There will be Personnel Safety System aspects involved in the installation and alignment activities of the injector and linac systems in the side tunnel. The project is aware of this and will incorporate the requirements in the safety system.

#### **2.4.2 Recommendation**

1. Continue to optimize the approach for minimizing installation interference with linac operations for other programs. Incorporate the plan for injector commissioning with installation of other subsystems by the next review.

### **2.5 Photon Beam Handling Systems**

#### **2.5.1 Findings**

The diagnostics and end stations component of this project will be completed later than many of the other subassemblies of the LCLS. Given this point in time, the conceptual design is at a reasonable level and likely to meet the required technical performance. The LLNL and LCLS staff members have done a very thorough job to date exploring a variety of possible approaches to solve the extremely challenging technical problems associated with the X-ray FEL. Excellent progress has been made by the team to define what will be needed for the photon handling and how to develop the necessary optics and diagnostic tools. The partnership between LLNL and SLAC is effective and productive, and many excellent people are working on this part of the project.

Clearly one of the more interesting challenges is the survivability of optical components placed in the direct beam. The team members working in this area are well aware that this is a critical, and largely unexplored area, and have already begun to put resources in this direction. Work is essential on both theoretical and experimental aspects of materials damaged by the FEL beam.

The scope, conceptual design, timeline, management plan, and costing are all satisfactory for CD-1, with a few reservations concerning the costing and timeline for some R&D and procurements noted in specific places. The Photon Beam Handling Systems are also on track for the Critical Decision 2, Approve Performance Baseline in March 2003. The costing was thorough and often based on recent experience. In some cases, the cost analysis arrived at a reasonable total for a particular component, but with more for engineering and less for procurement than past experience suggests.

Implementing the diagnostics and photon beam aspects does represent a very challenging and crucial aspect. This is because very little is known about how the intense, short pulse X-ray radiation will interact with materials, for example, whether there will be unforeseen damage mechanisms or multiphoton processes. There are many challenging questions that remain with regard to the materials that will be used for the optics, apertures, and slits, although much is now satisfactorily planned. Also, it is not known how short the pulses from the LCLS will be or how to measure such short pulses, although some new ideas are being considered. A careful assessment of how the PED funds are distributed and whether it is possible to reallocate some of these resources to address some of these issues may be desirable.

The Conceptual Design Report presents many sound and clever ideas about how to measure the pulses and to perform post-processing for timing jitter. The depth of planning was apparent throughout the breakout session, where many more details were presented and new ideas discussed. The plans to provide diagnostics for several aspects of the pulse on a pulse-to-pulse basis are excellent. This includes pulse energy, shape, and centroid. In separate experiments, bandwidth, coherence, and temporal information will be obtained. It may be possible to obtain pulse chirp information through some of the newer atomic physics methods of temporal pulse measurement that are being considered. In addition, the current planning of the user halls and endstation areas provides a flexible and thorough base for future work by users, as well as for the diagnostics effort. The detector development contained in the plan is crucial and must be maintained. This is the one area where the timeline is critical for this group to develop the high repetition rate two-dimensional acquisition.

The LCLS will become a unique coupling of lasers and accelerator physics that will ultimately be crucial for many of the diagnostics and endstation work. None of the planned diagnostics presently consider the merger of short pulse lasers with the LCLS beam. While much laser expertise resides in LLNL, by the time of commissioning it will be desirable to have additional in-house staff with expertise and interest in short pulsed lasers at SLAC. Similarly, the machine advisory committee should be constituted with a more general name, such as facility advisory committee, and should have a strong component of laser experts as an integral part.

The gas attenuator appears to be relatively complex and costly. It would be valuable to check the designs of other gas filters implemented at synchrotrons before finalizing the design of the gas attenuator.

All end stations seem to be of a “generic” design, which is appropriate at this time. Shielding seems excessive on the walls of the end stations, and additional calculations are needed to ensure there can be no radiation issues on the connecting tubes.

The level of contingency did not seem commensurate with the level of technical risk and difficulty. Optics under the extreme conditions of the LCLS X-ray beam will be in a completely new regime of incident instantaneous power density and the contingency for these components seemed low. Budgets should be configured to include special process spare items for some of the crucial optical elements because of the potential for damage by the high-power beam.

## **2.5.2 Comments**

Several broad areas will require more understanding of important physics. These include the topics of coherence preservation on optics, multiphoton processes in materials as they relate to possible damage, and pulse duration and timing measurements. By the time of commissioning, it will be necessary to obtain better synchronization of the LCLS pulses with short pulse laser sources. These are discussed further below.

Although the current effort by LLNL has focused primarily on the issue of damage, optical performance is really the bottom line. For example, coherence/brilliance preservation of the beam is critical for many experiments. With a radiation opening angle of 1 microradian, mirror slope errors need to be a small fraction of this to not dilute the brilliance. This requirement is at the state-of-the-art for polishers and metrology. Developing partnerships and collaborations with existing synchrotron radiation facilities, in particular with the third generations sources that already require such specifications, is a good approach to gain expertise in this important area.

Multiphoton processes are largely unknown, but afford an excellent means of obtaining autocorrelations of two X-ray pulses. More theoretical work in this area would be valuable.

Synchronization with short pulse lasers, pulse timing, and pulse duration measurements are going to be the key areas for future experiments. Several new methods are being considered and others have been suggested. Split pulse methods together with frequency downconversion methods in gaseous or solid media may provide temporally linked pulses with much smaller timing jitter than currently contemplated. Additional methods to measure chirp may be possible and necessary in the future, using processes in atoms. These should be pursued vigorously.

The Committee is pleased to see that the project seems to be taking advantage of established designs from existing synchrotron radiation sources and not starting from scratch in the design of components. Considerable effort and expense has gone into optical component development and fabrication at existing facilities, and the project should take advantage of this expertise.

Concerning suitable materials for optical components, it should be pointed out that the authors stated that continued R&D into X-ray photon-materials interactions should be further explored. The Committee commends this action.

### **2.5.3 Recommendations**

1. Increase R&D in the optics damage area as much in advance as possible before experiments take place. At the same time, calculations of optical component performance must also be pursued.
2. Increase communication with the undulator X-ray diagnostics group.
3. Increase R&D to measure temporal resolution, achieve pulse timing, and measure pulse chirp.
4. Ramp-up additional staff with laser expertise on the project at SLAC for commissioning.
5. Include laser specialists and experienced synchrotron radiation users/beamline designer as an integral part of the advisory committee. Consider renaming the Machine Advisory Committee to Facility Advisory Committee.

6. Integrate the Scientific Advisory Committee and potential users immediately with the Optical Systems team in the design of the end stations to ensure compatibility of end stations with planned experiments. If necessary, a specific liaison should be appointed.
7. Evaluate the shielding requirements for the connecting tubes and other elements.
8. Assess contingencies based on individual component risk analysis.
9. Incorporate lessons learned from third generation light sources for developing optical component specifications and beamline component design.

## **2.6 Control Systems**

### **2.6.1 Findings and Comments**

Considerable effort has gone into the preparation of the Conceptual Design Report by a very cooperative, experienced, enthusiastic, and informed team. Controls for major LCLS subsystems are delivered with those subsystems, for example the Undulator controls are to be delivered by ANL as a part of the Undulator. As a consequence of this approach, the controls effort is spread around the WBS at Level 4 and below. In general, the control system design appears to be at the CD-1 level of maturity.

The control systems will use a combination of SLAC controls and Experimental Physics and Industrial Control System (EPICS), with a preference for the use of EPICS where practical constraints do not dictate otherwise. The SLAC team knows how to do this, based upon experience at PEP-II. The design of the linac controls is in good shape and well understood. The same appears to be true for the undulator and X-ray parts of the facility, but these were developed at the partner laboratories and the SLAC team is less familiar with the details. The major technical concern has to do with subsystem integration. “Global” systems, such as timing, machine protection and network must be common and should follow the SLAC model. (For example—at present the undulator cost estimate assumes an Advanced Photon Source-type timing system—probably acceptable for cost estimating, but not for technical implementation.) Feedback between subsystems may be unnecessarily difficult if the Control Systems are different. A standard naming convention (SLAC’s) should be imposed. A common technical database needs to be used. A more complete understanding of requirements for the integration of the various and complex diagnostics is also required. The present SLAC Timing System is capable of achieving the advertised required timing precision for the LCLS. However, there are

concerns that better timing precision may be necessary, and technical investigations into this issue are ongoing. If improved timing precision turns out to be necessary, achieving that precision will be the most interesting technical challenge in the controls area. However, based upon developments already done for Next Linear Collider, the SLAC team is confident this can be achieved. Altogether there appears to be a great deal of work required to bring the design to Critical Decision 2, Approve Performance Baseline, but this ought to be achievable by March 2003 with available resources.

Cost data has been assembled from the various distributed WBS elements into one comprehensive cost book. The distribution of controls costs throughout the WBS makes it difficult to make comparisons with rules of thumb such as cost/channel, hardware/labor, etc. All elements are presented in a uniform way, however, the controls team at SLAC needs to understand the cost estimate for the non-SLAC elements well enough to “own” them. Overall, the estimates have been developed by experienced people and appear credible. Management may be light and care must be taken to include special process spares. A very rough estimate of time phasing has been done, and the proposed project schedule appears supportable. Risk (and therefore contingency) has been reasonably estimated—the highest risk is in the integration of subsystems. Some value engineering (combination of input/output crates based upon a better understanding of geographic component distribution) has already begun.

A detailed schedule for Control Systems was not presented, however, the schedule is entirely derivative and depends upon the schedule for the individual subsystems. A schedule for the global subsystems is required. There should be no problem meeting these schedules—even for the early subsystems.

The intent is to have a controls project manager in the LCLS Division, following the PEP-II model. Details of this organization need clarification, as this is the mechanism for addressing the integration issues noted above. The Control Systems manager’s scope should include control over all controls WBS elements.

Independent of where they are designed, all LCLS subsystems must be tightly integrated and be operated from the SLAC control room. There can be one and only one timing system, naming convention, Machine Protection System, database scheme, etc.



## 2.6.2 Recommendations

1. Consolidate the Control Systems effort under one organizational entity within the LCLS Division. Consider consolidation of the controls WBS elements as well.
2. Centralize at SLAC the design and development of the “global” systems, including timing, the Machine Protection System and network. Establish standards for naming, technical database, and appropriate hardware and software to be applied across the project.
3. Initiate discussions with LLNL to understand interface requirements between the X-ray control systems and the accelerator control systems. (Communication with the Undulator controls team at ANL has already been initiated.)

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## **3. CONVENTIONAL FACILITIES**

### **3.1 Findings**

The conceptual design for the Conventional Facility (CF) work is not fully developed; the System Design Requirements are not defined to adequately scope the CF. This includes the detailed shielding requirements for the hutches and beam dump.

The cost estimate for the CF work is of concern; the estimate was developed using a detailed quantity take-off method with the source document being sketches. Upon review, the Committee found the basis of the construction estimate is variable in detail and is in some cases difficult to substantiate; furthermore, the basis for the engineering estimate is unclear.

Given the status of the design and the estimating approach, the contingency estimated (19.3 percent) for the CF work is low; this can be adjusted to account for the lack of System Design Requirements, detailed shielding requirements, and geotechnical/biotechnical reports.

The proposed schedule and funding profile delays the Title I design of CF until FY 2004. The project will have neither adequate CF design information nor a conceptual estimate in order to baseline the costs for Critical Decision 2, Approve Performance Baseline in March 2003.

### **3.2 Comments**

The project team, as currently assembled, is dedicated and conscientious; however, they would benefit from individuals with experience in managing a CF project in the \$35 million to \$50 million range.

The geotechnical/biotechnical report is scheduled for preparation in FY 2003. The required information for the foundation designs, soil remediation, and cost estimates of the CF may be late as a result of this schedule; additionally, National Environmental Policy Act (NEPA) documentation could also be impacted.

Means and methods for the tunnel construction, as well as risk assessment for this work, need to be reviewed and managed by individuals with specific experience in this area. Existing SLAC resources from prior projects should be used to augment this activity wherever possible.

Timing of shut-downs for critical path activities on the front-end of the CF schedule should be carefully managed to ensure there are no impacts to the overall schedule. The Integrated Project Schedule must reflect the inter-relationships of the CF schedule with the special equipment installation.

### **3.3 Recommendations**

1. Develop, document, and control the top-level System Design Requirements for the Conventional Facilities to ensure that the Conceptual Design Report and estimate are adequate by July 1, 2002.
2. Further define System Design Requirements by the completion of Title I.
3. Augment the Conventional Facilities team with more experienced individuals; assign the Conventional Facilities team directly to the LCLS Project Team prior to the start of Title I development. Engage additional consultants as required to augment the Conventional Facilities Project Manager to develop cost estimates, schedules, and other plans during Title I.
4. Develop a Procurement Plan for the Conventional Facilities work and identify approaches and schedules for civil construction facilities prior to Title I.
5. Perform the geotechnical/biotechnical survey now, with the final report due no later than September 1, 2002.
6. Revise the project schedule to perform Title I design of the Conventional Facilities in concert with the rest of the project, but not later than Critical Decision 2, Approve Performance Baseline.
7. Revise the allocation of contingency to approximately 30 percent; this is due to the lack of detail in the Conceptual Design Report. As more detail is developed, the contingency should be reduced commensurately.

## **4. COST and SCHEDULE**

### **4.1 Findings**

It is recognized that the project can access good cost and schedule capabilities.

A complete project critical path schedule has not been developed. All dates and milestones are based on local experience from somewhat similar projects. This may create a perception that demands contingency in amounts other than what may be appropriate.

The detail cost estimate provided a by-element breakdown and the application of contingency dollars to the sixth level of the WBS. Details in support of that estimate have also been provided. For this stage of the project, the process used to establish the estimates seem to be sufficiently creditable.

### **4.2 Comments**

Good Project Management Control System (PMCS) capabilities are only one part of good project management. These capabilities however are only as good as the level of commitment project management puts on this data as well as their willingness to hold participants to their respective plans.

In the absence of a critical path schedule, staffing requirements are not tied to nor integrated with the critical path leaving a questions about capability to staff the project as needed.

Control of contingency should be addressed in more detail in the PEP. All project participants need to understand how changes will be approved and who controls the use of contingency.

Cost Account Managers (CAMs) need to be assigned for each WBS element. These CAM assignments will ensure that an individual is responsible for the scope, schedule, and budget of each WBS element.

The Committee has a general concern that management is not planning to implement a PMCS to a level of rigor necessary in the PED phase to insure a smooth transition to the construction phase.

The Committee reviewed project contingency to identify areas of concern, however the Committee is not recommending an increase in the TEC

### **4.3 Recommendations**

1. Cost estimates need to be consistent with recommendations made by the other Committee members.
2. Develop a TPC that includes an updated TEC and details OPC. The OPC should include R&D, Capital Equipment, Commissioning, etc
3. Provide a schedule with a critical path including resources, to support and verify that assumptions made relative to cost estimates, staffing levels, and funding levels are appropriate and can be achieved.

## 5. PROJECT MANAGEMENT

### 5.1 Management Overview

#### 5.1.1 Findings

The LCLS will be designed and built by a three-laboratory consortium (SLAC, Livermore and Argonne) with SLAC as lead laboratory and central management organization. SLAC described its plans to manage LCLS utilizing the successful PEP-II project as a management model.

The scope of the project does not include experiments and their associated data acquisition and computing needs. The key elements of the PEP-II management model would be:

- Creation of a separate division at SLAC with the LCLS Project Director heading this division as a SLAC Associate Director to ensure that the LCLS project has appropriate authority and control of resources at SLAC.
- Creation of and meaningful links to the other laboratories in the consortium at the highest levels and working levels.
- Institutionalizing experienced oversight through advisory committees, periodic DOE project reviews and a weekly meeting between the Project Director and the Laboratory Director to assure that the project is receiving the proper support from SLAC.
- Establishment of an active process for resource management within and between the Laboratory Collaboration Council.

A set of preliminary documentation has been developed which seeks to address the significant management issues and requirements that are appropriate for this stage in the development of the project. These documents include the Conceptual Design Report, a Preliminary Project Execution Plan (PEP), Draft Acquisition Execution Plan (AEP), NEPA strategy, and Preliminary Hazards Analysis Report. Additional documentation includes the Baseline Range Estimate for Total Project Cost, and Draft Memorandum of Agreement for Partner Laboratories.

The Preliminary PEP for the LCLS defines the responsibilities of the three laboratories and their Directors, the Project Director, and the advisory committees (Machine Advisory Committee and Inter-Laboratory Collaboration Council). ANL would be responsible for the Undulator

(WBS 1.2.3) with an estimated cost of about \$55 million and LLNL would be responsible for X-ray transport optics and associated diagnostics (WBS 1.3.1) with an estimated construction cost of about \$29 million. Memoranda of Understanding between SLAC and LLNL and between SLAC and ANL would formalize responsibilities and resource commitments of these laboratories.

SLAC presented plans for how the LCLS management organization will evolve from its present R&D stage through the PED and then construction stages.

A major goal of the LCLS and SLAC management is to have Critical Decision 2, Approve Performance Baseline, in March 2003. In support of this goal, the Laboratory identified January 2003 for an External Independent Review.

### **5.1.2 Comments**

LCLS involves achieving cutting edge performance in an accelerator driven FEL. The technical performance achieved at the completion of the formal construction project will likely not be at the level needed for the most challenging aspects of the scientific program that would use the facility. This is completely reasonable for a project of this level of challenge. The definition of the performance capabilities achieved following construction completion should reflect this expectation. This definition should be such to assure that major systems are shown to operate successfully and that the underlying beam physics is proven at a level of performance that guarantees that LCLS will ultimately achieve its required performance for science.

The PEP-II project provides an excellent management model for LCLS that should be utilized. However, there are some aspects of the PEP-II model that may not work as well for LCLS. As a result, the LCLS project must be managed with cognizance of the differences between LCLS and PEP-II, especially in regard to priorities within the laboratory.

The lead management personnel on the LCLS project, the Project Director and the Chief Engineer are very experienced and are excellent choices to lead the project in the PED phase and in construction.

SLAC is primarily a high energy physics laboratory. It has managed Stanford Synchrotron Radiation Laboratory (SSRL) for many years and has shown its commitment to successfully meeting its commitments to DOE/Office of Basic Energy Sciences and to its user community. Although



there is the potential for some conflicts with the laboratory's energy physics program (assignment of technical personnel, access to the linac tunnel for construction, etc.) the SLAC Director's support of LCLS should ensure that such potential conflict should not be a significant problem.

The advisory committees described by SLAC are very appropriate to a project of this type and scale. Laboratory management should consider one additional advisory committee reporting to the Laboratory Director to provide oversight and advice concerning the project's management activities.

The plans for the evolution of the LCLS management organization throughout the PED and construction stages are reasonable and appropriate.

The project management tools and processes that would be used in the PED and construction stages are based on the PEP-II experience and are reasonable and appropriate for a project of this scale and complexity.

In order to bring documentation to the point where it can support a Critical Decision 1, Approve Preliminary Baseline Range, the shortcomings in the draft AEP described in this report must be remedied. The Preliminary PEP also needs some additional work. The Conventional Facilities section of the Conceptual Design Report also needs to be fleshed out with additional detail, and the Preliminary Hazards Analysis must be completed.

The goal of a Critical Decision 2, Approve Performance Baseline, in one year is extremely challenging at best. It is suggested that LCLS management carefully track progress of the needed deliverables so that the Critical Decision 2 process is planned to take place at a time when it would be successful.

The management costs projected for the project appear reasonable for a project of this scale. However, the assigned contingency of two percent appears too low to account for the uncertainties at this stage.

LCLS experiments (e.g., crystallography) could produce megabytes/second of data. This is in the realm of forefront high energy physics experiments where computing costs are at the multi-million dollar level. DOE should be aware of the need to provide funding for this need in their downstream planning for LCLS science.

### **5.1.3 Recommendations**

1. Adopt a project complete milestone that confirms the completion of construction and the verification of the basic functionality of the facility. Therefore, LCLS should adopt a performance capability to be reached at the completion of construction that will assure that major systems operate successfully and that the underlying beam physics is proven at a level to guarantee that LCLS will ultimately achieve its required performance for science. This should be accomplished before Critical Decision 1, Approve Preliminary Baseline Range.
2. Make improvements and corrections in the documents needed for CD-1 so that a decision could be made in the July 2002 time frame.

## **5.2 Documentation**

### **5.2.1 Findings and Comments**

#### ***Conceptual Design Report***

The Conceptual Design Report is generally of high quality. The scientific and technical sections are well done and are at a level of detail needed to support a Critical Decision 1, Approve Preliminary Baseline Range decision. Reflecting the clear focus on technical systems, the Conventional Facilities sections require additional detail to reach the needed quality.

#### ***Project Execution Plan***

A Preliminary PEP has been drafted, and this was provided to the Committee for evaluation. It contains most of the elements required by DOE Order 413.3, however, there are several omissions (e.g., value engineering, life cycle costs) and refinements needed before the document will be ready for Critical Decision 1, Approve Preliminary Baseline Range. The schedule and Budget Authority funding profile assume that construction funding will be available starting in FY 2005, with project completion at the end of FY 2007 and a Total Project Cost in the range of \$180-\$240 million.

An inter-laboratory Memorandum of Understanding has been drafted and is under review by SLAC management. The Memorandum of Understanding is to be signed by the Directors of the three collaborating laboratories (SLAC, ANL, and LLNL).

The draft Preliminary Project Execution Plan should more thoroughly explain how the multi-laboratory collaboration will operate, including: staff assignments, funding allocations and contingency management, and performance supervision and evaluation. There must also be mechanisms identified for resolving issues that require top-level management attention at the three laboratories.

Although the project plans to develop a separate Project Management Plan, this is unnecessary. The additional information should simply be incorporated into the PEP, perhaps as an appendix under the control of the LCLS Project Director. The PEP should be a comprehensive, stand alone document. It should also contain the AEP as an appendix.

One particular area of the PEP where more attention will be needed is in defining the criteria for Project Completion (Critical Decision 4) and in describing the plan for transitioning to operations.

### ***Acquisition Execution Plan***

The AEP is a draft plan and by its nature is incomplete and needs further work with more details in a few months. It fails to define clearly who is going to perform the design work and the civil construction management and under what conditions (i.e., procurement strategy, review process, etc.) The plan also lacks a discussion of the Advanced Procurement Plan process with specifics of when and under what conditions they will be required and who will be required to approve these. It does not discuss the controls that will or may be exercised by the LCLS project management in reviewing partner laboratories acquisition strategy and award processes. The AEP does not adequately discuss the range of procurement strategies that are available and might be utilized under specific conditions (i.e., Sole Source procurements, Fixed Price, low bid Commercial Off the Shelf items, evaluated procurements and Costs Contracts.)

The plan envisions that there will be revisions to the plan in the future and thus defers decisions critical to the project until some time in the future. There are other administrative issues within the plan that can be corrected during the near term revision.

Recognizing that the plan is an initial draft, it is clear that the elements needed to make it a complete plan do exist. More details are needed to enhance the significance of the past experiences of the laboratory and how they will be utilized to make the project meet its goals.

Discussions with key staff demonstrate that they understand what needs to be done and have the information necessary to accomplish the task. Given the time and resource constraints the draft plan is a good first effort.

### **5.2.2 Recommendations**

1. Complete the Preliminary Project Execution Plan in consultation with the DOE LCLS Federal Project Manager and the LCLS Program Manager in the Office of Basic Energy Sciences. Include as appendices the Acquisition Execution Plan, FY 2003 Construction Project Data Sheet, and if possible the signed inter-laboratory Memorandum of Understanding, as well as any additional management detail at the project's discretion. This document should be ready for approval in July 2002.
2. Review the Acquisition Execution Plan and:
  - a. Include past experiences in handling projects and their related acquisition issues.
  - b. Include in the Acquisition Execution Plan a discussion of the Advanced Procurement Plan Processes for all participants with decision points and LCLS authority lines defined.
  - c. Explain the design and civil construction management process from a procurement strategy point of view and the projects oversight and control process of these activities.
  - d. Discuss, with some examples, the use of the full array of procurement strategies that the project will use in acquiring components, services and civil construction.
  - e. Demonstrate how risk analyses were accomplished to support the choice of procurement strategies in selected procurements and used in the review of all planned procurements.
  - f. Rewrite the "Make-or-Buy" section to clearly demonstrate the process to be used in making these decisions and the LCLS project management's role in these decisions.

## **5.3 Risk Assessment**

### **5.3.1 Findings and Comments**

The LSCS team has identified a number of high-level uncertainties that result in risk associated with technical, cost, or schedule performance.

Identifying major uncertainties early in the development of the project is a positive step. However, it appears that the possible impact of these high-level risks are not explicitly reflected in the contingency analysis and schedule evaluation. The cost contingency is evaluated at Level 6 of the WBS based on the cognizant engineer's understanding of the uncertainties related to the Level 6 item or task. This approach may not fully account for the potential impact of the risk on other parts of the project. Possible actions to mitigate the identified high-level risks were not discussed with the Committee. Such an action plan may not yet exist for the project.

### **5.3.2 Recommendation**

1. During Title I, LSCS should do a more quantified risk analysis, produce a plan that describes actions that could be taking to mitigate the high level risks that have been identified and then reevaluate the contingency and schedule to take account of their potential impact and likelihood.

## **5.4 Commissioning**

### **5.4.1 Findings and Comments**

Commissioning of the LCLS is scheduled to occur in stages. Commissioning of the injector is scheduled to begin in February 2006, the bunch compressor (BC-1) in spring 2006, BC-2 in March 2007, and full LCLS commissioning in summer 2007.

The commissioning will be affected by the running of the linac for PEP II. For instance, access to the injector is allowed during linac operation but no injector operation is allowed during linac access. Access to the linac can only be made between PEP II fills, which are every 45 minutes or so.

Commissioning is scheduled around the installation of the components, consistent with the operating schedule of the SLAC linac.

Access to the injector should be adequate for commissioning. Careful planning and cooperation will be needed with the Technical and Research Divisions to allow commissioning of the Bunch Compressors, BC-1 and BC-2, during PEP-II operation.

#### **5.4.2 Recommendation**

1. LCLS should begin the coordination of commissioning requirements with the Technical and Research Divisions taking into account PEP II running.

### **5.5 Operations**

#### **5.5.1 Findings and Comments**

The startup budget (pre-operations) contains \$5.4 million in FY 2007 for Linac/FEL startup, and \$2.3 million for Photon Systems startup. The project expects continuing operating costs to be approximately \$10 million for the Linac/FEL plus approximately \$10 million for the experimental areas.

Compatibility with the Linac running for high energy physics is included in the planning, including scheduling time well in advance. In particular, up to 25 percent of the roughly 6,000 hours of operation will be used for high energy physics, and the Linac use needs to be compatible with concurrent PEP-II operation.

LCLS needs to allow for test beams at low rates in an arbitrary pulse-stealing mode. This will require careful attention to design of the BC areas and the pulsed quadrupoles. In addition, hours are required to change operational parameters for LCLS.

The experimental laser for pump-probe experiments is planned to be identical to gun laser, and will be built and operated by the same team.

The total pre-operations funding in FY 2007 is less than 40 percent of the expected operating costs. Ramping up to the required operations cost is desired by the Office of Basic Energy Services rather than making a jump from a much lower pre-operations figure. An approach might be to request explicit "Other Project Funding" in FY 2007 for activities related to "preparing for user operations."

Accommodation for the 25 percent high energy physics time will need cooperation among the programs, as well as SLAC management support. Compatibility with PEP-II operation looks to be achievable.

Test beam accommodation will require significant efforts by the LCLS project. Providing test beams may make it difficult for LCLS to change operational parameters concurrently.

Having similar lasers and teams for the gun and pump-probe experiments will be critical to making progress on the timing issues for experiments.

### **5.5.2 Recommendations**

1. Propose a startup budget that covers all technical startup costs and costs for activities related to preparation for utilization of LCLS for science experiments and that ramps up more closely to the estimated operating budget.
2. Reach agreement with the High Energy Physics program on ground rules for compatible operations once the technical feasibility of test beam accommodation is assured.

## **5.6 Management of Science Program**

### **5.6.1 Findings and Comments**

The management structure of the Scientific Advisory Committee has not yet been defined, including its reporting lines. Research teams will develop proposals with SSRL involvement. The proposals will be vetted by an SSRL external review panel, which may or may not be the Scientific Advisory Committee. Once the proposals have been approved, the research teams will secure outside funding with SSRL participation, as appropriate. In return for securing funding, the research team will receive preferred access. The quantity of beam time is undefined at present.

SSRL will manage construction of the experiments, and will operate and maintain the experimental infrastructure, including all experimental stations. It will need scientific advice on the experiments to be supported and the LCLS needs scientific advice on the system design to meet the needs of the experiments. Lastly, SSRL will need to provide construction management as they are upgrading the beamlines of SPEAR-3, and will need to operate and maintain both SPEAR-3 and LCLS.

## **5.6.2 Recommendations**

1. Define the advisory process for scientific input both on experimental proposals and on LCLS design by January 2003. As part of this definition, LCLS, SSRL, and SLAC will need to determine the reporting structure for the Scientific Advisory Committee and/or other scientific advisory committees.
2. Plan for the expanded range of activities at SSRL involved in constructing and operating the experiments for LCLS.



## **6. ENVIRONMENT, SAFETY AND HEALTH**

### **6.1 Findings and Comments**

The Environment, Safety, and Health (ES&H) aspects of the LCLS Project are being properly addressed at this stage of the project development. Line management accountability, roles and responsibilities for ES&H are in place, beginning with the Project Director. The SLAC ES&H staff is competent and capable of successfully supporting the project, and ES&H concerns have been thoroughly integrated. Some minor refining of priorities and staffing would significantly reduce cost and schedule uncertainty. Although the LCLS will utilize or require only slight modification to SLAC environmental permits, early discussions with regulators could identify any concerns in time to adequately address the issues.

A determination to prepare an Environmental Assessment (EA) has been made by the Oakland Operations Office, and a preliminary draft EA has been prepared. The draft EA was reviewed by the Committee. While some additional material is required, the preliminary draft document has a reasonable probability of reaching a “Finding of No Significant Impact” by DOE.

The current LCLS FY 2003 ES&H staffing plan cannot support the current schedule. More support for the EA, the development of a Draft Safety Assessment Document, and input to the Commissioning plan is needed.

An approved Finding of No Significant Information is required to support Critical Decision 2, Approve Performance Baseline. Sufficient information exists to develop an acceptable EA. The project should proceed with modifying the preliminary draft EA and submitting the document for review by the Oakland Operations Office as quickly as possible.

Additional geotechnical studies are needed to quantify the soils and groundwater. While the EA can proceed without these analyses, the studies should commence as soon as possible to identify any unforeseen soil and groundwater issues and to quantify the amounts and types of wastes that will be generated in the tunnel construction. When the studies are complete, the EA can be modified as appropriate.

The Preliminary Hazard Analysis Report must be completed prior to Critical Decision 1, Approve Preliminary Baseline Range.

## **6.2 Recommendations**

1. Update and submit the Environmental Assessment to the DOE Oakland Operations Office by October 2002.
2. Ensure that the National Environmental Policy Act documentation is set for the work taking place at ANL and LLNL. This should be verified by the DOE Stanford Site Office.
3. Complete and submit the Preliminary Hazard Analysis Report by July 2002
4. Complete and evaluate the results of the geotechnical study by September 2002.
5. Involve the appropriate regulators in the ES&H aspects of the project as soon as possible.

**DOE Review of the Linac Coherent Light Source Project**

FY02 Dollars (\$K)

April 23-25, 2002

WBS	WBS Title	Cost & Awards thru 3/31/02	LCLS					TEC	LCLS			
			Burdened, escalated \$		Contingency on ETC		Burdened, escalated \$		EAC Variance (calc)	%		
			ETC 3/31/02 Forward	EAC	%	\$	ETC 4/25/02 Forward (calc)				EAC	
1.1	Project Management	-	12,183	12,183	1.6%	190	12,373	12,383	12,383	200	2.1%	
1.1.1	ES&H	-	1,908	1,908	2%	39	1,947	2,108	2,108	200	5.0%	
1.1.2	Construction Project Management	-	10,275	10,275	1%	151	10,426	10,275	10,275	-	1%	
1.2	Electron Beam Handling Sys.	-	79,515	79,515	27.9%	22,151	101,666	79,515	79,515	-	27.9%	
1.2.1	Injector	-	15,912	15,912	28%	4,498	20,410	15,912	15,912	-	28%	
1.2.2	Accelerator	-	18,178	18,178	27%	4,874	23,052	18,178	18,178	-	27%	
1.2.3	Undulator	-	39,118	39,118	28%	10,832	49,950	39,118	39,118	-	28%	
1.2.4	Installation and Alignment	-	6,307	6,307	31%	1,947	8,254	6,307	6,307	-	31%	
1.3	Photon Beam Handling Systems	-	35,506	35,506	25.5%	9,050	44,556	35,506	35,506	-	25.5%	
1.3.1	X-ray Transport & Diagnostics	-	21,992	21,992	21%	4,658	26,650	21,992	21,992	-	21%	
1.3.2	X-ray End Station Systems	-	13,295	13,295	32%	4,316	17,611	13,295	13,295	-	32%	
1.3.3	Installation and Alignment	-	219	219	35%	77	296	219	219	-	35%	
1.4	Conventional Facilities	-	31,778	31,778	19.3%	6,133	37,911	31,778	31,778	-	30.0%	
1.4.1	Injector Facilities	-	989	989	15%	145	1,134	989	989	-		
1.4.2	Accelerator Facilities	-	972	972	23%	223	1,195	972	972	-		
1.4.3	Undulator Facilities	-	924	924	15%	142	1,066	924	924	-		
1.4.4	Near Hall	-	10,395	10,395	23%	2,442	12,837	10,395	10,395	-		
1.4.5	Tunnel	-	2,571	2,571	17%	444	3,015	2,571	2,571	-		
1.4.6	Far Hall	-	15,927	15,927	17%	2,736	18,663	15,927	15,927	-		
<b>Subtotals:</b>		-	<b>158,982</b>	<b>158,982</b>	<b>1</b>	<b>37,523</b>	<b>196,505</b>	<b>159,182</b>	<b>159,182</b>	<b>200</b>	<b>2.6%</b>	
<b>Additional Mgmt Contingency:</b>					<b>0%</b>		<b>-</b>				<b>0%</b>	
<b>Total Contingency:</b>					<b>24%</b>	<b>37,523</b>					<b>2.6%</b>	
<b>Escalation:</b>							<b>19,271</b>					
<b>Total Estimated Cost (TEC):</b>							<b>215,776</b>					
<b>Other Project Cost (OPC):</b>					<b>0%</b>	<b>-</b>	<b>17,100</b>					
<b>Total Project Cost (TPC):</b>							<b>232,876</b>				<b>0%</b>	

**Notes:**

- Project TEC/TPC Used DOE Escalation Rates - FY03 (1.021); FY04 (1.046); FY05 (1.076); FY06 (1.106); FY07 (1.135)
- Burden Rates - ED&I Labor M&S  
 SLAC 20% 6% 6%  
 ANL 30% 24% 13%  
 LLNL 98% 98% 19%
- Other Project Cost (OPC) Breakout - ~\$6M R&D Funding FY99-02; \$11.2M Pre-ops \$3.5M FY06 (Injector) and \$7.7M in FY07 (Injector, linac, exper Using Draft Project Management Manual (Feb. 2002) Definition for OPC - ~\$1.5M for Post CD-0 Preparations; \$11.2M Pre-ops FY06-07
- Due to lack of detail in the CDR, the contingency of 19.3% should be in the 30% range.  
 As more detail is developed, the contingency can be reduced commensurately
- FTE increase needed to support CD-2 & safety/environmental documentation