

**CD-1, Approval of Preliminary Baseline Range  
for the  
Linac Coherent Light Source  
at the Stanford Linear Accelerator Center**

**Office of Basic Energy Sciences  
Office of Science**

**A. Purpose**

The purpose of this paper is to document the review by the Office of Science Energy Systems Acquisition Advisory Board-equivalent for the Critical Decision “Approval of Preliminary Baseline Range (CD-1)” for the Linac Coherent Light Source (LCLS) project at the Stanford Linear Accelerator Center (SLAC). The review certifies that all of the CD-1 requirements prescribed by DOE Order 413.3 (Program and Project Management for the Acquisition of Capital Assets) have been satisfied.

**B. Mission Need**

The mission of the Office of Science is “To advance basic research and the instruments of science that are the foundations for DOE’s applied missions, a base for U.S. technology innovation, and a source of remarkable insights into our physical and biological world and the nature of matter and energy.” The Linac Coherent Light Source (LCLS) project is a unique opportunity for a major advance in carrying out that mission.

The LCLS will be the world’s first x-ray free electron laser (XFEL), serving as a research and development center for XFEL physics in the hard x-ray regime and as a facility for the application of XFEL radiation to experimental science.

The LCLS will provide coherent radiation of unprecedented intensity and pulse duration in the wavelength range 1.5 - 15 Å. It is based on the SLAC linac, which can accelerate electrons or positrons to 50 billion electron Volts (GeV).

The LCLS will be the first XFEL in the world operating in the 1.5 - 15 Å wavelength range utilizing the first harmonic of the undulator (shorter wavelengths are possible using higher harmonics). The emitted coherent x-rays will have unprecedented brightness with  $10^{12}$  -  $10^{13}$  photons/pulse in a 0.2 - 0.4% energy bandpass and an unprecedented time structure with a design pulse length of 230 femtoseconds.

The unique characteristics of the LCLS will open new realms of scientific applications in the chemical, materials, and biological sciences.

The first five areas of experimentation currently envisaged for the LCLS are: (1) fundamental studies of the interaction of intense x-ray pulses with simple atomic systems; (2) use of the LCLS

as a pump source to create warm dense matter and plasmas; (3) structural studies on single nanoscale particles and biomolecules; (4) ultrafast dynamics in chemistry and solid-state physics; and (5) 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.

### **C. Project Preliminary Scope Baseline**

The LCLS project will build an x-ray FEL facility at SLAC based on their existing linac. The LCLS requires a new 150 MeV injector to be built at Sector 20 of the 30-sector SLAC Linac to create the high brightness electron beam required for the FEL. The last kilometer of the linac will be modified by adding two magnetic bunch compressors. Most of the linac, and its infrastructure, will not be changed. 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 halls (50,000 – 70,000 gross square feet total) will be constructed. The Near Hall will be built approximately 40 meters downstream of the Undulator Hall. The single-story near hall will be 30 meters wide by 55 meters long. The Far Hall will be built approximately 322 meters downstream of the Undulator Hall. The two-story far hall will be 35 meters wide by 57 meters long and will accommodate office and laboratory areas on the second floor. Provisions will be made for housing instrumentation and controls for the initial experiments.

The LCLS project will be a collaboration between SLAC, Argonne National Laboratory (ANL), and Lawrence Livermore National Laboratory (LLNL). SLAC will provide overall management of the project along with technical responsibilities delineated in the work breakdown structure (WBS), ANL will be responsible for the Undulator and LLNL will be responsible for the x-ray transport, optics and diagnostics. The scope of work of these two collaborating laboratories will be controlled by the LCLS Project Execution Plan (PEP) and associated Memoranda of Understanding.

#### Key Design Operating Parameters

0.8 – 8 KeV Self-Amplified Spontaneous Emission (SASE) Free Electron Laser  
Electron Beam Energy 4.54 – 14.35 GeV, from SLAC Linac  
Peak Power in SASE bandwidth 8 Giga Watts  
Peak Brightness  $1 \times 10^{33}$  photons/(mm<sup>2</sup> mrad<sup>2</sup> 0.1%BW)  
Pulse Duration 230 femtoseconds  
Pulse Repetition Rate 120 Hertz

### **D. Project Preliminary Cost and Schedule Baseline**

Based on the completed conceptual design, the preliminary Total Estimated Cost (TEC) range is \$200 million - \$240 million and the preliminary Total Project Cost (TPC) range is \$245 million - \$295 million. The performance cost and schedule baselines will be established at CD-2b

(Approval of Performance Baseline). Project Engineering and Design (PED) funds for the LCLS are in the FY 2003 budget request. The PED funding profile follows:

Fiscal Year	Project Engineering and Design	Other Project Costs	Total Project Funding
2002		1,500	1,500
2003	6,000		6,000
2004	15,000	4,000	19,000
2005	10,000	4,000	14,000
2006	2,500		2,500
Total	33,500	9,500	43,000

The preliminary schedule baseline is as follows:

CD-0	Mission Need Approval	June 13, 2001
CD-1	Preliminary Baseline Range Approval	September 2002
CD-2a	Long-Lead Procurement Budget Approval	February 2003
CD-2b	Performance Baseline Approval	April 2004
CD-3a	Long-Lead Procurements Approval	August 2004
	Authorize Long-Lead Procurement Funds	October 2004
CD-3b	Start Construction Approval	August 2005
	Authorize Construction Funds	October 2005
CD-4	Start Operations Approval	2008

### E. Acquisition Execution Plan

The acquisition of the LCLS will be conducted through Stanford University - SLAC as a prime contractor. The project is similar in scope to the recently completed B-Factory at SLAC, which was conducted successfully by SLAC management. SLAC is capable of directing this project, and together with the resources of its collaborators (ANL and LLNL), it also has the means to execute the project.

The LCLS project, in close cooperation with SLAC's Technical and Stanford Synchrotron Radiation Laboratory Divisions, will be responsible for accomplishing the project under the terms of Stanford University's M&O contract with the Department of Energy. SLAC will execute those parts of the project associated with conventional facilities and the acceleration and control of the electrons as well as overall system integration and management. The Advanced Photon Source Division at ANL will design and fabricate the undulator and associated systems. The Physics and Advanced Technologies Directorate at LLNL will design, fabricate, qualify, and commission the front-end x-ray optics. Project management at SLAC will control work at these laboratories in accordance with the PEP.

Project activities will be accomplished to the extent feasible using fixed-priced subcontractors selected by SLAC and the collaborating laboratories on the basis of best value, price and other factors.

## **F. Environmental Strategy**

The LCLS will be designed, constructed and operated in compliance with all requirements of the National Environmental Protection Act (NEPA) and its implementing regulations. Construction and operation activities have been evaluated in the NEPA Environmental Assessment (EA) for the LCLS Project. No negative impacts to the environment are anticipated as a result of this project.

## **G. Preliminary Hazard Analysis**

A preliminary hazard screening for the LCLS facility was conducted in June 2002. The purpose was to identify potential hazards associated with the design, fabrication, construction, and testing phases the project. This assessment concluded that the LCLS requirements are well within existing safety and operating envelopes, the risks of all hazards will be similar in nature and magnitude to those already found in the present accelerator and synchrotron radiation programs, and the hazard impact will have only the potential for minor on-site and negligible off-site impacts to people or the environment. The project will evaluate hazards and develop controls for the operation and research activities during the development of the Safety Assessment Document.

## **H. Energy Conservation and Sustainable Design**

Sustainable building design principles will be applied to the siting, design, and construction of the LCLS conventional facilities. Additionally, standard practices, including the use of recycled material, the purchase of energy-efficient and water-efficient equipment, and substitution of less hazardous input materials, will be utilized. Project waste disposal and recycling requirements will be incorporated into the project procurement documents.

The conventional facilities will be designed and constructed to meet energy conservation performance standards. The analysis will be conducted during Titles I and II design phases to comply with California Title 24 and 10 CFR, Part 435.

## **I. Elimination of Excess Facilities**

Starting with new construction projects in FY 2003, Congress is requiring DOE to eliminate an equivalent amount of excess facility space at the site of a proposed project, or go through a Secretarial waiver process to instead allow excess space to be eliminated at another DOE site. In the case of LCLS, there does not appear to be enough excess space at SLAC to offset the amount

of new space constructed for LCLS (50,000 – 70,000 gross square feet). SC therefore intends to pursue a Secretarial waiver to eliminate equivalent space elsewhere in the DOE laboratory complex.

## **J. Risk Assessment**

Risk management for LCLS is based on a graded approach in which levels of risk are assessed for project activities and elements. This assessment is based upon the potential consequences of activity or element failure, as well as the probability of occurrence. The level of formality of the quality assurance requirements is tied to the potential failure consequences. Risk minimization is implemented by conducting research and development activities, prototyping components, and planning alternatives.

A risk assessment was conducted during the conceptual design, which identified technical, cost and schedule risks. At this stage, technical and cost risks appear to be low, and schedule risk is assessed to be low to moderate. Further risk assessment activities will be done as part of the Title I design process and in planning for LCLS acquisitions in compliance with the DOE Order 413.3 and SC project management procedures.

**Submitted by:**

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Date

**Recommendations**

The undersigned “Do Recommend” (Yes) or “Do Not Recommend” (No) approval of CD-1, Approval of Preliminary Baseline Range, for the Linac Coherent Light Source at SLAC as noted below.

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ESAAB Secretariat, Construction Mgmt Support Division      Date      Yes \_\_\_\_ No \_\_\_\_

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Representative, Non-Proponent SC Program Office      Date      Yes \_\_\_\_ No \_\_\_\_

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Representative, Financial Mgmt. Division      Date      Yes \_\_\_\_ No \_\_\_\_

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Representative, Environmental, Safety and Health Division      Date      Yes \_\_\_\_ No \_\_\_\_

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Representative, Security Mgmt. Team      Date      Yes \_\_\_\_ No \_\_\_\_

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Representative, Laboratory Infrastructure Division      Date      Yes \_\_\_\_ No \_\_\_\_

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Representative, Grants and Contracts Division      Date      Yes \_\_\_\_ No \_\_\_\_

**Approval**

Based on the material presented above and at this review, Critical Decision-1, Approve Preliminary Baseline Range, is approved. Therefore, the Office of Basic Energy Sciences is authorized to proceed with expenditure of Project Engineering and Design funds for the design of the Linac Coherent Light Source at the Stanford Linear Accelerator Center.

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Raymond L. Orbach  
Director  
Office of Science

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Date