Department of Energy
Review Committee Report

on the

Technical, Cost, Schedule, and
Management Review

of the

LCLS ULTRAFAST SCIENCE INSTRUMENTS (LUSI) PROJECT

July 2007

EXECUTIVE SUMMARY

A Department of Energy Office of Science review of the Linac Coherent Light Source (LCLS) Ultrafast Science Instruments (LUSI) project, to be located at the Stanford Linear Accelerator Center (SLAC), was conducted in Gaithersburg, Maryland on July 23-24, 2007. The review was conducted at the request of Dr. Patricia Dehmer, Director, Office of Basic Energy Sciences (BES), and chaired by Mr. Steve Tkaczyk, Office of Project Assessment. The purpose of the review was to assess all aspects of the project—technical, cost, schedule, management, and ES&H. This information would subsequently help in the evaluation of the project's readiness for Critical Decision (CD) 1, Approve Alternative Selection and Cost Range, which is a prerequisite for proceeding with preliminary design.

The Committee concluded that the project should proceed with CD-1 approval.

The project constructs three specialized instrument stations that will complement the initial instrument included in the LCLS construction. The three LUSI instrument stations are X-ray Pump Probe Diffraction, Coherent X-Ray Imaging, and X-Ray Photon Correlation Spectroscopy. Each instrument station is designed to support scientific studies of a certain type, and was identified as a high-priority need by the scientific community, as documented in the LUSI Mission Needs Statement (MNS), CD-0, that was approved in August 2005. These instrument stations are designed to use "hard" X-rays (i.e., those at the shorter wavelengths, or higher energies, of the LCLS output spectrum, specifically between 4-25 keV). As noted in the project's Acquisition Strategy (AS), the original MNS called for a fourth station tailored for "soft" X-rays (i.e., those at the longer wavelengths, or lower energies of the LCLS output spectrum), but the LUSI project has since been de-scoped to remove this soft X-ray instrument.

The Total Project Cost is $60.0 million with a Total Estimated Cost of $55.1 million, which includes a total contingency of $13.2 million. Other Project Costs are $4.9 million.

The overall schedule for LUSI is approximately seven years, starting with CD-0, Approve Mission Need, approved in August 2005 and ending with CD-4b, Approve Start of Operations, scheduled for March 2012.

The LUSI project responded adequately to the recommendations from the previous review. The project was integrated within the LCLS organization: the LUSI project director now reports to the LCLS project director. This enables the LUSI team to take advantage of the systems and expertise already available at LCLS, in particular project controls, procurement services, controls and data management, and safety.

The project is managed per the SLAC Integrated Safety and Environmental Management System (ISEMS) consistent with the project's current state of development.

The Committee made 17 recommendations including LUSI project readiness to receive CD-1 approval. There was one Action Item—to plan and execute a CD-2a Independent Project Review in December 2007.

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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 X-ray Free Electron Laser. Its goal 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 United States and abroad to apply this new X-ray tool to the study of phenomena in ultrafast chemical reaction dynamics, precision imaging of macromolecules, novel physical effects (of atoms, molecules, and condensed matter), and other material systems.

Current plans call for this X-ray beam to be delivered to several end station locations that will contain instrumentation to enable experiments of different types to be performed. To maximize the use of LCLS for scientific studies, it is desirable to develop these specialized instrument stations in a timely manner – by constructing them over the next several years, for use as soon as practicable when the LCLS X-ray beam becomes available.

The project under review here, known as the LCLS Ultrafast Science Instruments (LUSI), constructs three such specialized instrument stations as its scope. Each instrument station is designed to support scientific studies of a certain type, and has been identified as a high-priority need by the scientific community, as documented in the LUSI Mission Needs Statement (MNS), and references therein, that was approved in August 2005 as Critical Decision (CD) 0 for this project. These instrument stations are designed to use "hard" X-rays (i.e., those at the shorter wavelengths, or higher energies, of the LCLS output spectrum, specifically between 4-25 keV). As noted in the project's Acquisition Strategy (AS), the original MNS called for a fourth station tailored for "soft" X-rays (i.e., those at the longer wavelengths, or lower energies of the LCLS output spectrum), but, in order to remain within the cost range, at the direction of Office of Basic Energy Sciences the LUSI project has since been de-scoped to remove this soft X-ray instrument.

The technical objective of the LUSI project is to design, build, and install at LCLS Experimental Halls three X-ray instruments that will complement the initial instrument included in the LCLS construction. This initial LCLS instrument is designed for atomic, molecular, and optical physics studies. The three LUSI instrument stations are X-ray Pump Probe Diffraction, Coherent X-Ray Imaging, and X-Ray Photon Correlation Spectroscopy. The purposes, functions, technical performance parameters, and a more complete description of these instruments and stations are described in the Conceptual Design Report (CDR) and other project documents. Below is a brief summary of each LUSI instrument station.

X-ray Pump Probe (XPP) Diffraction Instrument. This station is designed to probe dynamics of a sample system at ultrafast timescales (e.g., reactions or relaxation processes with sub-picosecond time constants) using X-rays (i.e., on systems for which X-ray scattering constitutes a useful and informative signal). In this setup, a short pulse of an optical laser creates excitations in a sample, which is then probed by an X-ray pulse that interrogates the sample as it evolves over time after the initial laser excitation. The timing between the optical laser pulse and the X-ray probe pulse is experimentally measured and tuned as a parameter that is varied. The X-ray pump probe incident upon the sample generates scattered X-rays that are detected in order to measure properties of the excited, transient system and its dynamical evolution. Use of the ultrashort intense LCLS X-ray pulse enables a separate image of the system to be created via the scattered X-ray intensity pattern from each pulse, with sub-picosecond time resolution.

Coherent X-Ray Imaging (CXI) Instrument. This station is designed to conduct experiments that use the X-ray beam to image: a) molecules that are free-standing targets (e.g., not periodic or bound in a lattice), and/or b) systems that are susceptible to radiation damage (because the scattered signal from each pulse is generated prior to any sample degradation from the X-ray power). In this setup, an intense X-ray pulse is incident upon a sample molecule (e.g., a large protein), to create a detectable diffraction pattern that is dependent upon the molecule's structure and spatial orientation. This process is repeated several times, with successive X-ray pulses incident upon molecules of varying orientations, each time producing a diffraction pattern with features that depend upon the sample's molecular structure and orientation. All of these diffraction images, produced by the same molecule but with different orientations, are then analyzed with computational algorithms to calculate a three-dimensional structural image of the sample molecule. The brightness, energy, and coherence of LCLS X-ray pulses could create images of single molecules at close to atomic resolution.

X-Ray Photon Correlation Spectroscopy Instrument (XCS, a.k.a. XPCS). This station is designed to conduct correlation spectroscopy using X-rays. In this setup, an X-ray pulse is directed onto a sample, creating a scattered intensity pattern characteristic of the location of scattering centers within the sample. After an experimentally controlled time delay, a second X-ray pulse re-interrogates the sample, creating a second scattered intensity pattern. The difference in the two scattered intensity patterns is telling of time scales of motions within the sample. The two intensity patterns are compared quantitatively by calculating the degree of correlation (e.g., the contrast in intensity in each detector pixel) for that time delay. These intensity correlations are measured as a function of the time delay in order to map out characteristic time scales at which disorder occurs in the sample. Using the short, intense, and coherent LCLS X-ray pulses, X-ray correlation spectroscopy can be applied to several scientific problems, and in particular can probe condensed matter sample dynamics in regimes of imparted energy and momentum transfer that other experimental techniques cannot attain.

All of these experiments require X-ray optics to guide the beam, X-ray beam diagnostics to measure beam properties, control systems, two-dimensional pixilated detectors with fast read-out capability, a data acquisition architecture that includes fast signal processing algorithms, and significant data storage and handling requirements. Therefore, these technical features are also part of the LUSI project scope.

The LUSI is a Major Item of Equipment (MIE) project of the U.S. Department of Energy (DOE) Office of Science (SC). The Project Execution Plan (PEP) shows each instrument to be a deliverable that is organized and managed as a separate element of the project’s Work Breakdown Structure (WBS). The PEP and the AS show the project’s $50-60 million Total Project Cost (TPC) range (in as-spent dollars) through Fiscal Year (FY) 2012. The AS describes the Analysis of Alternatives. The technical alternatives were devised in a process that began with Science Teams who developed the concept for each instrument. A subsequent peer review step was conduced by the LCLS Scientific Advisory Committee (SAC) to assess the compatibility of each instrument with LCLS, and the scientific merit of potential studies using that instrument. The AS also summarizes the acquisition and business approach. Technical staff at SLAC will finish conceptual design work by engaging user community members for that instrument. The Instrument Scientists and other SLAC staff will finish the engineering design at SLAC, tapping relevant technical expertise elsewhere as needed. The SLAC staff will procure individual components and subsystems to be assembled into complete instrument stations, to be installed in buildings that are now under construction as part of LCLS, and in coordination with LCLS construction and operations. In summary, because of the need for integration and compatibility with LCLS, the business approach is to build the LUSI instrument stations at SLAC, using on-site technical staff to interact with outside experts and to procure components needed for final assembly into completed instrument stations.

1.2 Charge to the DOE Review Committee

In a May 21, 2007 memorandum (see Appendix A), Dr. Patricia M. Dehmer, Associate Director for Science, Office of Basic Energy Sciences, requested that Daniel R. Lehman, Director of the Office of Project Assessment, organize and conduct a review to assess several aspects of the LUSI project – including technical, cost, schedule, management, and environment, safety, and health (ES&H) issues. The purpose of this assessment is to inform a decision of whether the project is ready for CD-1.

1.3 Membership of the Committee

The Office of Project Assessment formed a review 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, complex, and highly specialized scientific instruments. Stephen Tkaczyk from the Office of Project Assessment chaired this review committee.

1.4 The Review Process

The LUSI project team provided documents such as the CDR, PEP, and AS to the review Committee as downloadable read-aheads prior to the review meeting. A review meeting was held in Gaithersburg, Maryland, during July 23-24, 2007. 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 and LUSI project directors and other principals overviewed LUSI information and the context offered by LCLS. Each LUSI instrument scientist then presented more detailed material on each subproject instrument, including its specific plans, schedules, and cost estimates, in order to status the conceptual design work to date for that instrument.

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

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

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2. TECHNICAL SYSTEMS EVALUATIONS

2.1 X-ray Pump/Probe Diffraction (WBS 1.2)

2.1.1 Findings

This LUSI element, the X-ray Pump-Probe beam line (XPP), is being constructed to enable pump-probe experiments in a number of physical systems with the most likely emphasis on study of strong excitation in condensed matter systems. By using the ultrafast X-ray pulse from LCLS in conjunction with an ultrafast laser pump pulse, the structural changes that accompany fast electronic transitions induced by the laser can be probed. In principal, the time resolution of these experiments is limited by the pulse duration of the laser pump pulse and the LCLS X-ray pulse. In practice, the timing jitter between the laser and X-ray pulse, which will be approximately 1 ps, can deleteriously affect the ultimate time resolution of experiments performed on this beamline if not properly remedied or measured. Given the capabilities of this beamline, it promises to service a very wide variety of users and user interests. As such, it will represent a backbone of the LCLS capability when it is complete.

Overall, the Committee found that the present conceptual design of this element is technically sound. The team has developed a well thought-out plan that has led to a flexible beamline design. The beamline will utilize two interchangeable diffractometers. It will also include, ultimately, a femtosecond laser capable of producing pulses over a wavelength ranging from 11,000 to approximately 300 nm. The beamline design will enable an enormous range of cutting edge pump-probe experiments. The new evolving baseline design employs an electro-optic sampler on the electron beam that will enable shot-by-shot measurement of the relative timing between the LCLS electron pulse and the XPP laser pulse.

Furthermore, the Committee found that most other aspects of this WBS element are well developed and without major issues given the early stage of the project. The R&D plan required for successful accomplishment of this beam is straightforward. The Committee did not find any major technical challenges that represent a significant barrier to the successful completion of this element's performance milestones. The most significant hurdle still requiring R&D is the development of thin Si crystals for the offset monochrometer. This technology will ultimately determine if simultaneous operation of all beamlines will become part of the baseline plan.

The budget of $10.1 million for this element is reasonable. The Committee judged that the contingency levels proposed are appropriate for the moderate level of risk of this element. Some items my be slightly over budgeted at this time, such as the ultrafast laser. The schedule outlined for this element is also quite credible. Element designs are mature for CD-1. The schedule includes early deployment of most of the beamline hardware but a later deployment of the pump laser.

The staffing of this element has improved dramatically since the January 2007 DOE review. The hiring of David Fritz as the lead scientist for this element was an excellent move on the part of the LUSI management. Dr. Fritz has done an excellent job of organizing this element so far. The Committee felt, however, that additional assistance will likely be necessary in the near future. Finally, the Committee found that the strategy for acquiring the principal hardware is reasonable. Acquisition of the long-lead time diffractometers represent the principal schedule risk but these items should not be a major issue.

2.1.2 Comments

In short, the Committee is impressed with the progress on the conceptual design of this LUSI end station. Of the three beamlines in the latest incarnation of the LUSI project the XPP beamline appears to be the most straightforward of the three beamlines with the least technical risk. Given the advances in ultrafast X-ray science world wide, it is likely that X-ray pump probe experiments performed on XPP will likely be a core capability for the LCLS. Because of this the LUSI team has designed a beamline which is very flexible. Clearly this beamline is benefiting from the experience at SPPS and other ultrafast X-ray experiments. The Committee was very impressed with the thoroughness of the design, and the compromises that were necessary seem to be well planned.

The Committee would like to add that progress made on the design is due in no small part to the competence and experience of beamline scientsist David Fritz. LUSI and LCLS management is to be commended for this appointment, as well as for the appointment of an overall strong team of beamline scientists on all three endstations. This move addresses very well one of the primary concerns of the XPP station by the January 2007 DOE review. It should be noted though, that as the project develops, the demands of fielding this and the other beamlines will probably require that a deputy beamline scientist be hired to help out Dr. Fritz. This deputy could in fact be a post doc who could grow into the position with experience.

During this review, the Committee found that the early concerns about picosecond time jitter were allayed with the inclusion in the new baseline plan of the in-situ electro-optic sampling diagnostic. Given the positive experience of the SPPS team with a similar diagnostic, it was surprising to the Committee that this was not presented in the original conceptual baseline plan when it was rolled out last fall. The Committee strongly urged LUSI management to retain this crucial diagnostic as a high priority.

Furthermore, the Committee found that the plan to use the AMO laser early in the project for experiments and to field the XPP-specific laser later in the project is a wise plan. At this point in the project, the ultimate laser specifications seem well motivated scientifically. However, the Committee urged the LUSI team to remain flexible in the design of this laser and to work with potential users to further hone the specifications. The team may find that a lower repetition rate, higher energy arm to be a low cost addition to the laser, which will expand its capability greatly. Other improvements may arise as potential users become more involved.

Finally, the Committee noted that, as outlined in the January report, technical risk still exists in the offset monochrometer if thin Si crystals are to be employed. This technology has a good R&D, but the possibility of not being able to deploy these crystals needs to be considered.

2.1.3 Recommendations

1. Consider hiring a deputy beamline leader.

2. Work with a broad range of potential users to develop more thoroughly the specifications for the pump laser.

3. Work with industry on laser development and work toward procuring this system as a complete system from a laser vendor.

4. Develop a detailed plan for the offset monochrometer to deal with the possibility that the thin Si crystal technology does not develop fast enough.

2.2 Coherent X-ray Imaging (WBS 1.3)

2.2.1 Findings

The team addressed all major comments made at previous LUSI review, LCLS scientific advisory committee and instrument design review. Making these reviews available is very helpful.

The experience at FLASH facility in Germany has been very helpful. Damaging issues related to optics is understood.

The conceptual design of the instrument, including focusing optics, monochromator, diagnostics, particle injector, sample environment and X-ray detector is sound for the proposed initial scientific programs.

The addition of a new scientific staff as the lead of the Coherent X-ray Imaging (CXI) instrument is very positive. The new staff brought with him significant experience in coherent X-ray imaging and instrument design.

With the exception of a few components, in particular K-B mirrors and injector, which are the state-of-the-art or need further development, most of the components are either commercially available or within reach with the proposed research program.

The cost of the instrument, risk assessment, contingency allocation as well as schedule seems adequate.

2.2.2 Comments

R&D plan to ensure coherence preservation is sound, in particular the proposed development of wavefront sensing technique.

The use of refractive lens as an alternative to K-B mirrors should be investigated. It might provide a higher flux density then K-B mirrors for single molecule imaging.

Detector development is not part of LUSI project. It is on-track so far. Close interactions between instrument scientist and instrument team, and the detector development group and LUSI control group is very important. The project management should encourage this interaction.

Development of protective layer for single molecule to extend the length X-ray pulse needed is promising.

Particle injector is a critical component of the instrument, in particular for the single molecule experiment. Further development is needed.

Some of the proposed fixed target experiments do not require the ultra-short pulse provided by LCLS.

2.2.3 Recommendations

1. Ensure the particle injector MOU with Lawrence Livermore National Laboratory (LLNL) is managed carefully since it is the key component of the CXI instrument.

2. Evaluate the use of refractive lens for focusing as an alternative to mirrors.

2.3 X-ray Photon Correlation Spectroscopy (WBS 1.4)

2.3.1 Findings

The plan presented in this review included all the optics, covering: a) the monochromator, b)*"split-and-delay line"*, c) focusing optics, d) two instruments, small and wide angle scattering diffractometers, and e) 2-dimensional detectors. The costs included support and engineering, installation, beam transport over 200m from Near Experimental Hall (NEH) to Far Experimental Hall (FEH), diagnostics, and control and data acquisition.

The *"split-and-delay line"* is an in-kind contribution from DESY at no cost. Also, at no cost, it is likely that some of the prototype two-dimensional detectors developed for XFEL and PETRA II may be tested at the LCLS. The fact that these two critical items are not included in the cost is of concern to the Committee.

Technically, what was presented was sound and innovative.

The risks involved are the splitting monochromator performance, and pulse-to-pulse beam stability, both in terms of position and intensity.

The incorporation of the *"split-and-delay line"* system from the beginning will allow extension of the time range to nano-second regime, albeit a limited range of 0-2.8 nsec. The limitation is the vertical travel in the delay line. The fact that *"split-and-delay line"* system is not part of the cost has a down side, and that is that they will not have the advantage of developing a better system for themselves.

Also, no provision is made for sample environment.

The cost of the system, at first glance, looks reasonable. However, after the detailed engineering plans are prepared, it seems there is room for value engineering, and it should be done in FY 2009.

The schedule is a concern. The CDR is not due until July 2009. The XPCS beamline is due at the same time as the XPP and CXI beam lines, but they have a head start of two years. It may be advisable to move the CDR for XPCS beamline to July 2008, one year earlier.

2.3.2 Comments

Under Dr. Aymeric Robert's leadership, this part of the LUSI project is functioning effectively. He seems to be well connected with his American, European, and Japanese counterparts, and that will be advantageous for the project.

Timing of the start-up of LCLS also plays favorably for XPCS beamline in the sense that XFEL staff may consider bringing up their prototype instruments like the new detectors, or *"split-and-delay line"* system to LCLS-LUSI-XPCS beamline.

The beam-splitter monochromator, which was said to be 2 micrometer thick, has problems. The extinction depth of Si (111) at 8 keV is about 0.7 microns, and reflectivity of Si (111) will drop to 70 percent levels in an ideal scenario, or even further due to inevitable bending. So this concept should be tested at SSRL or any other synchrotron source or an X-ray machine early to firm up the preliminary design report. This issue not only affects the XPCS but all other split beam lines as well.

The beamline will need a second instrument scientist, and also a post-doctoral associate, as well as one or two graduate students, perhaps each associated with different aspects of the science at XPCS.

The physical dimensions of the station are also of some concern. To accommodate the two spectrometers, a minimum of 20 m length between sample to detector distance should be accommodated. This is in addition to the mirror and sample chamber space.

2.3.3 Recommendations

1. Develop a strategy to deal with pulse-to-pulse stability.

2. Plan an early test of the 2 micrometer thick silicon beam-splitting monochromator, before firming up the optical layout of the beamline.

3. Address the issue of beam-stability after a 200 m long monochromator arm, and consider developing a feed-forward system to anticipate the position change and correct for it before the beam comes to the second monochromator crystal.

4. Make provisions to develop *"split-and-delay line"* system in-house.

5. Make provisions for sample chamber environment, perhaps through MOU's with the Design Team Leaders.

2.4 Diagnostics (WBS 1.5)

2.4.1 Findings

The conceptual design for diagnostics presented for the LUSI MIE project includes five different types of diagnostic beam monitors: position monitors, intensity monitors, high and low energy transmission intensity monitors, and wave front sensors. The conceptual design includes a beam position and intensity monitor proceeding and following each reflective optical element in the LUSI beamlines. In addition, the long-beam transport sections have periodic beam position monitors.

Synchronization of the LCLS X-ray pulses and lasers in the LUSI experiments is provided by LCLS through the use of commercial phase locking hardware to be purchased as a part of the LUSI laser systems. Jitter limits this system to a synchronization level of 1 ps.

The development of a hard X-ray wave front sensor is required for successful operation of the coherent X-ray imaging station.

The schedule for design and acquisition of beam diagnostics calls for delivery of the first beam diagnostics before the time of the first delivery of beam from LCLS.

2.4.2 Comments

The conceptual design for diagnostics is technically sound and meets the requirements for accurate beam delivery to the LUSI experimental stations and gives the possibility of feedback at start of LCLS operations. The number, type, placement, installation schedule and cost estimates for diagnostic components presented are reasonable. Contingencies are adequate and consistent with risk.

Significant progress has been made in the development of a wavefront sensor for 8 keV X-rays. Development of electronics (detector) for 120 Hz operation of this sensor remains a concern.

Synchronization of the LCLS X-ray pulses and lasers in the LUSI and LCLS experimental stations at the level of the LCLS pulse length (approximately 200 fsec) will be provided by the use of an electro-optic timing diagnostic. The schedule presented has this diagnostic available at the start of LCLS operations.

LUSI diagnostics staff and the controls group appear to have established a good working relationship. These groups are working closely together to integrate diagnostics into LUSI controls and data systems. The use of pulse-to-pulse diagnostics information for real-time data reduction, for example information from the wave front sensor at 120 Hz for coherent X-ray imaging, will require substantial computing infrastructure and staff support for controls and data systems.

2.4.3 Recommendations

None.

2.5 Controls (WBS 1.6)

2.5.1 Findings

The LUSI CDR presented a control and data system that has the maximum capability to interoperate with existing hardware and software infrastructure at the LCLS control system and the SLAC SCCS (Scientific Computing and Computing Services) system.

The proposed control and data system is scalable and upgradeable to take advantage of the fast moving technological advances in data system. It will have a considerable amount of hardware and software design copied and imported from existing high energy physics control and data systems, such as SSRL, LCLS, and SLAC BaBar.

To implement the timing and synchronization with short pulse lasers, the LCLS project will provide each end station with a timing trigger system. Additional fiber and microwave timing methods are being considered for the ultra short laser pulse of LUSI's pump-probe instruments.

The technical challenges in data subsystem are related to the extremely high raw data rates and potentially huge volume of accumulated data generated by two-dimensional megapixel detectors with high intensity resolution and unique tagging of beam diagnostics information for each image on a pulse-by-pulse basis.

The LUSI control and data system design team included experts from LCLS, and SLAC PPA and SCCS group.

2.5.2 Comments

The conceptual design is technically sound. The project's scope, cost and schedule are all satisfactory for CD-1.

The Committee was pleased to see that the project team is taking advantage of established designs from existing LCLS and other existing SLAC projects. It is a very cost effective decision to have a considerable amount of hardware and software design copied and imported from existing SSRL, LCLS, and BaBar control and data systems.

The CDR presented a sound analysis for possible vibration or drifting sources and concept feedback control method to stabilize the beam at the point of the experiment. Considering the complication of the possible vibration or drifting sources involved to the feedback control system, the Committee noted that R&D effort in this area should be further explored.

Since beam diagnostics information for each experimental data set is critical on a pulse-by-pulse basis, it is very important to have a strong technical collaboration between diagnostics physicist and control system design engineer.

2.5.3 Recommendations

1. Increase R&D effort to improve the position stability of the photon beam at the point of the experiment:

   - Solidify beam position feedback and/or feed forward control for beam slow drifting control.
   - Optimize the beamline optics design to reduce the system sensitivity to the beam position jitter on a pulse-by-pulse basis.

2. Optimize the system design and procurement schedule to take advantage of the fast moving technological advances in data acquisition and management.

2.6 Installation

2.6.1 Findings

The LUSI project team is to be commended for a detailed breakdown of cost and effort for the assembly and installation activities. As suggested during the January 2007 DOE review the LUSI project has integrated the installation as part of the respective instrument WBS. The sections 1.x.8 of the WBS are for the installation activities.

The management structure clearly outlines engineering oversight for the installation activities. Each instrument was assigned an engineer as a system manger to coordinate and track the WBS activities.

2.6.2 Comments

The new management structure clearly highlights the roles of the engineering staff from design to assembly to installation. Each instrument has a system manger to track the cost and schedule. The system manager is also the lead engineer for the specific instrument. Assignment of specific staff so early on in the project is very important as it will enhance a good communication between the engineering staff and the instrument team leaders. The LUSI project has provided a good working model for the instrument installation activities.

The LUSI project has used the risk matrix similar to SNS to determine the contingencies. The contingency of 31 percent for most of the installation is very reasonable. For optical components like monochromators and mirrors where the risks are higher a contingency of 39 percent was assigned. Overall the contingency used for the installation is appropriate.

The LUSI project is now under the LCLS management. There seems to be better integration of activities between the LUSI and LCLS projects. LCLS has a photon beam system manager to coordinate the installation of FEE and also the AMO experiment setups. The LUSI project will be fully integrated into the LCLS once it reaches operational phase.

2.6.3 Recommendation

1. Utilize the LCLS photon beam System Manager and his team to also coordinate the rest of the installations for LUSI.

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3. ENVIRONMENT, SAFETY and HEALTH

3.1 Findings and Comments

The Environmental, Safety and Health (ES&H) recommendation from the January 2007 DOE review of the LUSI was satisfactorily completed.

The LUSI project Preliminary Hazards Analysis Report (PHAR), which identified the potential breath of hazards to be evaluated in detail as the project moves forward, was updated. The revisions reflect changes in the project scope, comments from reviews, as well as tailoring based on the LCLS PHAR. The revised document was reviewed by the DOE Stanford Site Office (SSO) and their comments were incorporated consistent with the current evolution of the project.

ES&H related Lessons Learned from the LCLS project are being reviewed and incorporated into the LUSI project as appropriate.

The Project Manager presented the LUSI project to the SLAC Safety Overview Committee (SOC), which consists of a number of safety subcommittees of topical areas. The SOC identified several subjects for the project to report on in more detail at the appropriate time as the design proceeds. This process is part of the SLAC oversight mechanism to identify potential hazards and encourage that they be designed out where possible or to ensure that effective controls are going to be in place.

Equipment safety interfaces between LUSI and LCLS were defined to be consistent with the current level of design. These interfaces are managed by a LUSI/LCLS Interface Working Group and an Interface Control document is in draft form.

The current level of ES&H support provided to LUSI is adequate and consistent with the work being performed.

The project is being managed per the SLAC Integrated Safety and Environmental Management System (ISEMS) and is consistent with the project's current state of development.

3.2 Recommendations

None.

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4. COST and SCHEDULE

4.1 Findings

The LUSI Mission Need Statement (MNS) was approved at CD-0 in August 2005. The project's technical goal, as stated in the MNS, was to augment the LCLS construction project with a suite of four X-ray instruments, to be built over a period of six fiscal years. At CD-0 the preliminary range for the Total Project Cost (TPC) was set at $50-60 million, and CD-4, Approve Start of Operations, was planned to be phased from 2010-2012.

The initial cost estimate provided by the project for this scope in August 2006 significantly exceeded the cost range set at CD-0. As a result, at the January 2007 review, the project proposed a revised scope that would meet the CD-0 cost range target, but only deliver two instruments (the XPP and the CXI) and beam delivery for the other two instruments (the XPCS and Soft X-ray Scattering). The details for a $60 million maximum cost were presented with a proposed Total Estimated Cost (TEC) of $43.0 million, $3.6 million of Other Project Cost (OPC), and a contingency of $13.4 million (31.2 percent on TEC and 28.8 percent on TPC). Escalation rates were based on the published DOE rates. Numerous recommendations were made by the review committee and documented in their report.

In March 2007, as directed by the office of Basic Energy Sciences, another plan was put forth that committed LUSI to produce science when LCLS becomes operational and settled on three instruments with priority given to CXI. Accordingly, for this review, the project team presented the project scope that will deliver three instruments (the XPP, CXI, and XPCS). Two of these instruments (XPP and CXI) will be ready to produce science when the LCLS is operational in FY 2010. The XPCS will follow a later schedule due to a constrained funding profile. The project plan includes CD-2a/3a/4a and CD-2b/3b/4b dates to establish separate milestones for obtaining approvals and for completion of the XPCS instrument. The TEC of $55.10 million includes a contingency of $13.18 million. The OPC of $4.9 million result in a TPC of $60.0 million.

The project now has a resource-loaded P3 schedule with milestones indicated, and the critical path is identified for the first two instruments. Approximately 16 weeks of schedule contingency are indicated for the CD-4a and CD-4b milestones. Cobra will be used as the cost processor to support earned value management reporting. The LUSI Project Management Cost and Schedule system was created to implement earned value management processes for this project. This system is based on other SLAC projects including the LCLS project. The project team has plans to work with their partner laboratories to coordinate earned value reporting on their activities.

The project presented a Risk Registry that documented 19 open risks. Two of these risks are rated as a HIGH risk (delay in DOE yearly funding and delays in staffing). The risk registry will be evaluated monthly and updated at least quarterly.

4.2 Comments

The LUSI project plan for staffing and procurements conforms to the program funding profile. However, receipt of FY 2008 funding is critical to the project schedule as there is minimal carryover from the FY 2007 funding. A Continuing Resolution is a strong possibility in FY 2008, therefore, the project team must work with the DOE program to obtain sufficient funding needed to avoid impacting their ability to prepare the necessary CD-2a documentation. Failure to obtain this funding would result in delays in the project schedule.

The project funding plan includes $4.6 million in FY 2012, and there is a possibility that this number will increase by $0.5 million with a reduction in FY 2011 funding. Scheduled activities in FY 2012 include procurements such as purchase of a laser system. The CD-4b date of March 2012 may not allow sufficient time for the required spending plan and completion of these procurements, particularly if a continuing resolution limits available funding. The CD-4b date should be evaluated by reviewing the scheduled work that is dependent on receipt of the FY 2012 funding, to confirm that the date can be met.

The level of detail and basis behind the cost estimate are very good for this CD-1 stage of the project. The cost estimate is well detailed to WBS Levels 4 or 5 with PED, construction labor, and material costs shown for all items. Appropriate burdens were applied and are shown in the estimate at the task level. Quotes were obtained for approximately 50 percent of procurements, these quotes will be updated and additional quotes obtained prior to CD-2a. An independent cost review was conducted prior to the first CD-1 review to validate WBS elements, activity durations and material costs. Since the cost estimate has changed significantly since this review, a similar cost validation review should be conducted prior to submittal of the CD-2a documents.

Escalation rates of 4.0 percent for labor and 2.3 percent for materials are reasonable and compare well with the rates used for LCLS. The project team should continue to monitor market conditions that could affect these rates, and adjust them if necessary prior to establishing the project baseline.

The project contingency was calculated at each task level of the cost estimate by using the risk registry. Risks are well defined using technical, cost, and schedule categories. Risks were appropriately weighted based on design or manufacturing requirements, material and labor cost certainty, and schedule impact. The overall project contingency of approximately 31 percent is reasonable for the work scope and stage of this project.

A separate schedule was provided for the detector work performed at Brookhaven National Laboratory, with a completion/delivery milestone shown in the LUSI project schedule. Integration of these two schedules is suggested, as it would allow for accurate identification of the critical path for this instrument, highlight potential schedule delays, and simplify earned value reporting. Schedule dates for the injector work at LLNL are not currently shown in the master schedule and need to be added.

The project schedule includes contract award activities for major procurements. It was observed that some of these contract awards precede the CD-3a or CD-3b milestones. These contract award activities should be linked to the CD-3 approvals to correctly reflect their dependency on these approvals.

The XPCS instrument is shown in the project schedule as a milestone and in the cost estimate as a work package allowance. Prior to CD-2b, detailed schedule activities for the XPCS should be added to the schedule and the critical path identified for this instrument. Detailed costs for each task level associated with the XPCS should be shown in the cost estimate.

The project schedule includes a milestone for beneficial occupancy of the Near Experimental Hall. In order to identify potential schedule impacts, consideration should be given to including additional LCLS schedule milestones in the LUSI schedule.

4.3 Recommendations

1. Evaluate CD-4b date of March 2012 to confirm it allows sufficient time for completion of the planned FY 2012 procurements.

2. Add activities and dates for the LLNL injector work to the project schedule

3. Link all contract awards in the project schedule (except “first article” procurements) to the CD-3a or CD-3b milestones.

5. PROJECT MANAGEMENT (WBS 1.1)

5.1 Findings

The LUSI project responded adequately to the recommendations from the previous review. The project was integrated within the LCLS organization: the LUSI project manager now reports to the LCLS project director. This enables the LUSI team to take advantage of the systems and expertise already available at LCLS, in particular project controls, procurement services, controls and data management, and safety.

The LUSI project management team consists of a project director (full time laboratory employee), project manager (part time contract employee), and a chief engineer (full time laboratory employee). A clear organization structure is in place. System engineers rather than instrument scientists were designated as CAM's reporting (all except Controls and Data Systems) to the Chief Engineer. This is a reasonable approach.

Following the recommendations from the January 2007 DOE review the scope of the LUSI project was modified to emphasize the unique hard X-ray capabilities of the LCLS and be ready for initial science when the LCLS comes on line. Three instruments will be constructed with two of these (CXI, XPP) ready for early science but not complete (CD-4a) in February 2010. The first two instruments will be completed and the third instrument (XPCS) will be delivered at the end of the LUSI project (CD4b) in March 2012.

The project plans to achieve CD-2a for all WBS elements except WBS 1.4 XPCS in December 2007. Considering the present state of the project, this is feasible. All instrument teams must be aware at this stage that the diagnostics and controls and data management scope will be baselined.

A formal value management (VM) process was in place and being implemented.

Memorandums of Understanding were being finalized for critical components that are being managed outside the LUSI project (2D detector for XPP [BNL]; Single Particle Injector for CXI [LLNL]; Split and Delay system for XPCS [SLAC/DESY]). The schedules for these components will be integrated into the LUSI schedule at top level and will be reported through the LUSI EVMS system.

An external Advisory Committee was established to review the detector systems.

The required documentation for CD-1 approval is in place.

5.2 Comments

Although 0.5 full-time equivalents were budgeted for a Project Manager throughout the life of the project the contract for the present project manager will terminate in March 2008. By CD-2a the project must have definite plans in place to continue this role.

Diagnostics are critical to the success of the LUSI instruments and the conceptual designs are well advanced. Although there is some limited overlap with the diagnostics required for the AMO experiment, and LUSI engineers are working with LCLS staff to develop some initial standards, these activities were not formally integrated. It should be noted that LLNL provides diagnostics for the FEL. Standardization of diagnostics across all LCLS instruments will be important in the future and should be taken account as the operations organization is developed.

Initial planning for instrument installation work is on-going and it is clear that the project management team is giving some thought to the means of achieving the installation. It would be advisable to manage LCLS installation and LUSI installation in one installation team under a single installation manager.

The cost estimates were made using a detailed evaluation of the contingency. As the project progresses the management team should develop a plan to use remaining contingency including decision processes and dates, which take into account schedule and budget restrictions.

5.3 Recommendations

1. Develop a plan for instrument installation that fully integrates with LCLS by CD-2a.

2. Approve CD-1.

APPENDIX A

CHARGE MEMORANDUM

DOE F 1325.8
(08-93)

United States Government
Department of Energy

memorandum

DATE: May 21, 2007

REPLY TO
ATTN OF: SC-22

SUBJECT: DOE REVIEW OF THE LINAC COHERENT LIGHT SOURCE (LCLS) ULTRAVAST SCIENCE INSTRUMENTS (LUSI) PROJECT

TO: Daniel R. Lehman, Director, SC-1.3

I request that your office organize and conduct an Office of Science (SC) Conceptual Design Review of the Linac Coherent Light Source (LCLS) Ultrafast Science Instruments (LUSI), Major Item of Equipment (MIE) project located at Stanford Linear Accelerator Center (SLAC) in Menlo Park, California, during July 23-24, 2007. This review is to be conducted at the Hilton Washington DC/North Gaithersburg Hotel, located at 620 Perry Parkway, Gaithersburg, Maryland, 20877. The Scientific User Facilities Division will assist with the meeting site logistics.

Your office reviewed this project in January 2007 and did not recommend going forward with CD-1, Approve Alternative Selection and Cost Range. The project has completed the action item and presented a plan that reduces the technical scope and ensures that LUSI produces science at CD-4 and the LCLS project. The purpose of this review is to re-assess all aspects of the project – technical, cost, scheduled, and management, and ES&H. This information will subsequently help SC evaluate the projects readiness for CD-1, which is a prerequisite for proceeding with preliminary design.

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

1. Is the modified conceptual design technically sound and likely to meet the performance expectations identified in the LUSI Mission Need Statement approved by DOE?

2. Is there a Research & Development plan that adequately supports the design effort and mitigates the technical risks?

3. Are the cost and schedule estimate ranges credible and reasonable for this stage of the project based on the funding guidance from BES? Do these estimates include adequate contingency margins that are based on a project-wide risk analysis? Are any changes recommended?

4. Does the project have a credible plan, as reflected in a Preliminary Project Execution Plan, to staff and manage the LUSI? Is the management team in place to carry out preliminary design, and is the project organized for its effective execution?

5. Is the Acquisition Strategy appropriate considering the project’s scope and the attendant cost and schedule risks?

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

Thomas M. Brown, the LUSI Construction 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.

/signed/

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

cc:
S. Tkaczyk, SC-1.3
K. Chao, SC-1.3
P. Montano, SC-22.3
T. Brown, SC-22.3
A. Richards, SSO
H. Lee, SSO
H. Joma, SSO
J. Hastings, SLAC

APPENDIX B

REVIEW PARTICIPANTS

Department of Energy Review of the
LCLS Ultrafast Science Instruments (LUSI) Project

REVIEW COMMITTEE PARTICIPANTS

Department of Energy

Steve Tkaczyk, DOE/SC

Committee Members

Esen Alp, ANL
Ian Anderson, ORNL
Mark Beno, ANL
Arnold Clobes, LLNL
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Thomas Brown, DOE/SC
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Hanley Lee, DOE/SSO
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APPENDIX C

REVIEW AGENDA

Department of Energy Review of the
LCLS Ultrafast Science Instruments (LUSI) Project

AGENDA

<u>Monday, July 23, 2007</u>

8:00 am	DOE Executive Session	P. Dehmer, H. Lee, S.Tkaczyk
8:30 am	LCLS Overview	J. Galayda
8:50 am	LUSI Overview	J. Hastings
9:35 am	LUSI Project Management Overview	W. Foyt
10:00 am	Break	
10:20 am	Coherent X-ray Imaging (WBS 1.3)	S. Boutet
10:45 am	Pump Probe (WBS 1.2)	D. Fritz
11:10 am	X-ray Correlation Spectroscopy (WBS 1.4)	A. Robert
11:35 am	BNL Detector Program	N. van Bakel
12:00 pm	Working Lunch	
1:00 pm	Diagnostics (WBS 1.5)	Y. Feng
1:25 pm	Controls (WBS 1.6)	G. Haller
1:50 pm	LUSI Engineering Overview	N. Kurita
2:20 pm	LCLS-LUSI interface	J. Arthur
2:40 pm	Break	
2:55 pm	Breakout Sessions	
5:00 pm	Executive Session	Committee
6:30 pm	Adjourn	

<u>Tuesday, July 24, 2007</u>

8:00 am	Breakout Sessions/Report Writing (agenda attached)	
11:00 am	Executive session	
12:00 pm	Working Lunch	Committee
1:00 pm	Closeout Dry Run	Committee
4:00 pm	Closeout Presentation to LUSI Management	All
5:00 pm	Adjourn	

APPENDIX D

COST
TABLE

LUSI PROJECT
CD-1 COST ESTIMATE
(DOLLARS x 1000)

LEVEL L1	L2	L3	DESCRIPTION	TOTAL	FY 2007 DIRECT $	INDIRECT	ESCALATION
LUSI - TOTAL PROJECT COST (TPC)				**$60,000.0**	**$46,479.6**	**$9,314.0**	**$4,206.4**
1.0			LUSI PROJECT (MIE)	55,100.0	42,773.6	8,120.0	4,206.4
2.0			LUSI - OTHER PROJECT COSTS (OPC)*	4,900.0	3,706.0	1,194.0	
1.0			**LUSI PROJECT (MIE)**	**$55,100.0**	**$42,773.6**	**$8,120.0**	**$4,206.4**
	1		**PROJECT MANAGEMENT**	**$5,611.7**	**$3,264.7**	**$1,873.7**	**$473.4**
		1	ES&H	208.5	101.1	86.4	21.0
		2	Project Management	4,905.0	2,799.9	1,680.7	424.4
		3	Technical Support	498.2	363.6	106.5	28.1
	2		**X-RAY PUMP/PROBE DIFFRACTION**	**$10,066.9**	**$7,914.6**	**$1,388.7**	**$763.6**
		1	Physics Support & Engrg Integration	878.5	516.4	306.7	55.5
		2	X-ray Optics	1,574.0	1,200.6	216.7	156.7
		3	Laser System	2,122.4	1,746.7	179.1	196.7
		4	Detector System	2,605.9	2,234.0	227.8	144.1
		5	Sample Environment	1,520.2	1,228.3	199.5	92.4
		6	Lab Facilities	122.2	72.8	31.8	17.7
		7	Vacuum	619.2	481.7	99.4	38.1
		8	Installation	624.5	434.1	127.9	62.5
	3		**COHERENT X-RAY IMAGING**	**$8,596.1**	**$6,714.6**	**$1,356.3**	**$525.2**
		1	Physics Support & Engrg Integ	1,225.1	669.4	456.8	99.0
		2	X-ray Optics	1,776.3	1,422.0	218.0	136.2
		3	Sample Environment	1,467.6	1,134.9	271.6	61.1
		4	Lab Facilities	118.7	71.6	31.3	15.7
		5	Vacuum	547.1	427.3	85.7	34.0
		6	Injector	2,927.8	2,621.6	178.3	127.9
		7	Installation	533.7	367.9	114.6	51.2

	4		**X-RAY CORRELATION SPECTROSCOPY**	**$7,691.4**	**$5,826.6**	**$1,129.2**	**$735.6**
		1	Physics Support & Engrg Integration	896.8	481.6	318.6	96.7
		2	X-ray Optics	1,383.5	1,045.7	187.7	150.1
		3	Detector System	2,258.0	1,938.1	167.7	152.2
		4	Lab Facilities	154.9	88.0	40.3	26.6
		5	Vacuum	1,012.2	794.0	122.6	95.6
		6	Sample Environment	1,449.3	1,120.9	187.4	141.1
		7	Installation	536.6	358.4	104.9	73.4

	5		**DIAGNOSTICS**	**$3,166.2**	**$2,329.7**	**$625.7**	**$210.8**
		1	Physics Development	788.5	407.7	314.2	66.7
		2	Position Monitor	237.3	184.8	38.5	14.0
		3	IO Pop-In Monitor	292.3	212.8	61.7	17.7
		4	Hard X-ray Intensity Leave-In Monitor	404.0	290.9	89.5	23.6
		5	Wavefront Sensor	416.3	346.5	51.7	18.1
		6	EO Monitor	379.5	321.7	38.9	19.0
		7	XCS Planning Package	648.3	565.4	31.2	51.7

	6		**CONTROLS**	**$6,792.4**	**$4,535.8**	**$1,746.3**	**$510.3**
		1	Physics Development	1,295.4	653.0	525.4	117.0
		2	In Station Cabling	469.3	287.8	148.0	33.6
		3	Computer Hardware/Admin	963.3	620.7	276.0	66.5
		4	Experimental Control (EPICS)	420.8	250.6	139.5	30.7
		5	Data Acquisition HW/FW	482.3	299.2	148.9	34.2
		6	Timing & Triggering	160.0	114.9	35.0	10.1
		7	Laser Control & Laser PPS	140.7	94.5	36.8	9.4
		8	Vacuum Controls	408.8	256.1	123.9	28.8
		9	Diagnostics, Optics, Sample Environment	922.2	674.6	188.1	59.5
		10	PPS/MPS/PLC	219.9	134.6	69.6	15.8
		11	XCS Planning Package	1,309.7	1,150.0	55.2	104.5

CONTINGENCY @ 31.4%				**$13,175.2**	**$12,187.6**		**$987.7**
		1.1	Project Management	1,010.1	924.9		85.2
		1.2	X-ray Pump/Probe Diffraction	3,061.9	2,839.7		222.2
		1.3	Coherent X-ray Imaging	2,904.8	2,730.1		174.7
		1.4	X-ray Correlation Spectroscopy	2,766.3	2,509.0		257.3
		1.5	Diagnostics	1,111.9	1,040.8		71.1
		1.6	Controls	2,320.3	2,143.2		177.1

2.0	**OTHER PROJECT COSTS**		**$4,900.0**	**$3,706.0**	**$1,194.0**	
	1	Project Planning & Development	3,053.0	1,955.0	1,098.0	
	2	Detectors	1,847.0	1,751.0	96.0	

* OPC is in FY 05 - 07 dollars.

12-Jun-07

LUSI OBLIGATIONS vs. FUNDING PROFILE
DOLLARS x 1000

WBS	DESCRIPTION	PY	2007	2008	2009	2010	2011	2012	TOTAL
1.1	PROJECT MANAGEMENT	$	$184.6	$1,326.4	$1,374.0	$1,267.2	$955.8	$503.7	$5,611.7
1.2	X-RAY PUMP/PROBE DIFFRACTION		40.2	1,753.0	3,003.5	1,705.2	1,964.6	1,600.3	10,066.9
1.3	COHERENT X-RAY IMAGING		53.3	2,112.2	3,639.9	2,034.1	668.1	88.6	8,596.1
1.4	X-RAY CORRELATION SPECTROSCOPY			112.4	906.4	3,265.8	2,847.4	559.3	7,691.4
1.5	DIAGNOSTICS		22.8	902.1	1,082.7	539.1	393.6	225.9	3,166.2
1.6	CONTROLS		30.4	1,711.8	1,851.2	1,551.9	1,056.9	590.1	6,792.4
	Sub-total		331.4	7,917.9	11,857.9	10,363.3	7,886.4	3,567.9	41,924.8
CONTINGENCY			168.6	2,082.1	3,142.1	4,636.7	2,113.6	1,032.1	13,175.2
1.0	SUB-TOTAL		500.0	10,000.0	15,000.0	15,000.0	10,000.0	4,600.0	55,100.0
2.0	OTHER PROJECT COSTS	3,400.0	1,500.0						4,900.0
TOTAL PROJECT COST		$3,400.0	$2,000.0	$10,000.0	$15,000.0	$15,000.0	$10,000.0	$4,600.0	$60,000.0
FUNDING PROFILE		**$3,400.0**	**$2,000.0**	**$10,000.0**	**$15,000.0**	**$15,000.0**	**$10,000.0**	**$4,600.0**	**$60,000.0**

APPENDIX E

SCHEDULE CHART

Activity Description	Early Finish
1 LUSI Level 1 Milestone	
100 LUSI Critical Decisions	
CD-1 Cost Range Approval	01AUG07*
CD-2a CXI & XPP Performance Baseline Approval	03DEC07*
CD-3a CXI & XPP Construction Start Approval	21JUL08*
CD-2b XCS Performance Baseline Approval	01OCT09*
CD-4a CXI & XPP Start of Operations	08FEB10*
CD-3b XCS Construction Start Approval	31MAR10*
CD-4b CXI, XPP, & XCS Start of Operations	30MAR12*
2 LUSI Level 2 Milestone	
102 XPP (X-ray Pump Probe)	
XPP Phase I Conceptual Design Complete	21SEP07*
Laser Safety Approval	21JUL08
XPP Safety Committee Review	22SEP08
XPP Phase I Final Design Complete	15OCT08
XRPP - Detector Receive (BNL)	04MAY09*
XPP Phase I All Parts Ready For Install	02SEP09
XPP Phase I Installation Complete	30SEP09
103 CXI (Coherent X-ray Imaging)	
CXI Phase I Conceptual Design Complete	03OCT07*
CXI Phase I Final Design Complete	12AUG08*
CXI Phase I All Parts Ready For Install	22JUL09
CXI Phase I Installation Complete	23SEP09
Particle Injector System Receive (LLNL)	02NOV09*
Readiness Review - Particle Injector (LLNL)	01MAR10*
104 XCS (X-ray Correlation Spectroscopy)	
XCS Split and Delay Receive (MOU DESY)	17NOV08*
XCS Conceptual Design Complete	14JUL09*
XCS Final Design Complete	16AUG10*
XCS All Parts Ready For Install	15AUG11*
XCS Detector Receive (BNL)	29SEP11*
XCS Installation Complete	14NOV11*
105 Diagnostic	
Diagnostics Phase I Conceptual Design Complete	24OCT07*
Diagnostics Phase I Final Design Complete	17JUN08*
Diagnostics Phase I All Parts Ready For Install	27MAY09*
Diagnostics Phase I Installation Complete	21AUG09*
106 Controls and Data Systems	
Controls Phase I Conceptual Design Complete	27SEP07*
Controls Phase I Final Design Complete	16JAN09*
Controls Phase I All Parts Reay For Install	18MAY09*
Controls Phase I Installation Complete	07AUG09

Activity Description	Early Finish
3 LUSI Level 3 Milestone	
102 XPP (X-ray Pump Probe)	
Start XPP	
PRD - XPP Instrument Physics Req Doc	22MAY07
Conceptual Design Approved XPP	20AUG07
FDR - Diffractometer Final Design Review	06DEC07
Award 8-Circle Diffractometer	28APR08
FDR - Vacuum Transport Final Design Review	12MAY08
FDR - Optics & Optomechanics	20JUN08
Submit Laser Safety Plan for Approval	20JUN08
EQ Review Hutch Optical Table System	18AUG08
FDR - Laser Containments Final Design Review	15SEP08
RFI - Laser Diagnostic Ready For Installation	18NOV08
RFI - Vacuum Transport Ready For Installation	20JAN09
RFI - Attenuators Ready For Installation	22JAN09
Finalize Installation Plan XPP	29JAN09
RFI - Optical Table Ready For Installation	12FEB09
Receive 8-Circle Diffractometer	19FEB09
RFI - XPP Be Lenses Ready For Installation	27FEB09
RFI - Laser Containments Ready For Installation	17MAR09
RFI - Optics Ready For Installation	18MAR09
RFI - XPP Slit Ready For Installation	28APR09
RFI - Diffractometer Ready For Installation	28MAY09
Complete X-Ray Optics Sub Assy XPP	23JUN09
XPP Readiness Review Phase 1	06JUL09
RFI - Vacuum Subassemblies	03AUG09
Complete XRPP Installation	31AUG09
Complete XRPP Detector Installation	30SEP09*
103 CXI (Coherent X-ray Imaging)	
Start CXI Scientist	
Conceptual Design Approved	03SEP07
PRD - CXI Physics Req Doc	03SEP07
FDR - Be Lenses Final Design Review	18JAN08
FDR - TOF Final Design Review	01FEB08
Start LCLS Injector (LLNL)	
FDR - ION TOF Final Design Review	18APR08
EQ Review Precision Instrument Stand	25APR08
FDR - Precision Stand Final Design Review	25APR08
Conceptual Design Review - LLNL Injector	
FDR - Sample Chamber Final Design Review	16MAY08
FDR - Pulse Picker Final Design Review	23MAY08

Activity Description	Early Finish
Award Sample Chamber Critical	30JUN08
FDR - Slit Final Design Review	11JUL08
Preliminary Design Review - LLNL Injector	01SEP08*
RFI - CXI Electron TOF Ready For Installation	07OCT08
FDR - Vaccum Final Design Review	07OCT08
Receive Sample Chamber Critical	18NOV08
Installation Plan - CXI Instrument	04DEC08
RFI - CXI ION TOF Ready For Installation	08JAN09
RFI - CXI Be Lenses Ready For Installation	26FEB09
RFI - Pulse Picker Ready For Installation	13MAR09
RFI - Sample Chamber Ready For Installation	23APR09
RFI - CXI Slit Ready For Installation	28APR09
Final Design Review - LLNL Injector	01JUN09*
RFI -Vacuum Subassemblies	22JUN09
Complete CXI Installation	26AUG09
105 Diagnostic	
Start Diagnostics	
Conceptual Design Approved	24SEP07
PRD - Diagnostic Instrument Physics Req Doc	24SEP07
FDR & Laser Safety Review - EO Monitor	06MAR08
FDR - Hard X-Ray IO Leave-In Monitor	07MAR08
FDR - Position Monitor Final Design Review	02MAY08
FDR - Position Monitor Final Design Review	13JUN08
Receive Intensified CCD camera	20OCT08
Complete XRPP EO Monitor	20OCT08
Complete Pos. Monitor 1st article Testing	25NOV08
Receive All 1st Article Parts IO Pop-In Mon.	07JAN09
Complete Hard X-Ray IO Leave-1st Article Testing	21JAN09
Complete IO Pop-In Monitor 1st Article Testing	15APR09
106 Controls and Data Systems	
Start Controls and Data Systems	
PRD - Controls: Experiemental (EPICS)	30JUL07
PRD - Controls Diag, Optics, Sample Env.	30JUL07
PRD - Controls Data Acquisition HW/FW	27AUG07
Conceptual Design Approved	28AUG07
PRD - Controls: Vaccum	19NOV07
PRD - Controls In Station Cabling	19NOV07
PRD - Controls Computer HW/Admin	19NOV07
FDR - Controls In-Station Cable Plant	04APR08
FDR - Controls Data Acquisition Final Review	25APR08
FDR - Controls Diag, Optics, Sample Final Review	09MAY08

Activity Description	Early Finish
Integration & Implementation Plan - Controls	30MAY08*
PRD - Controls Timing & Triggering	02JUN08*
PRD - Controls: Laser	02JUN08*
PRD - Controls MPS/PLC	02JUN08*
Receive All Parts (XRPP & CXI)	30JUN08
FDR - Vacuum Control Final Review	11JUL08
FDR - Controls Timing & Triggering Final Review	08SEP08
FDR & Safety Review- Laser Controls & PPS	22SEP08
Complete XRPP Data Acquisition HW/FW	21NOV08
FDR - Experimental Control (EPICS)	25NOV08
FDR - MPS/PLC Final Review	03DEC08
RFI - Controls Cable Plant	14JAN09
Complete XRPP Timing & Triggering	30JAN09
Complete XRPP Vacuum Control	01APR09
Complete CXI EPICS	16APR09
Complete XRPP EPICS	16APR09
Complete CXI Data Acquisition HW/FW	16APR09
Complete XRPP Laser Control & PPS	16APR09
Complete CXI Vacuum Control	16APR09
Complete CXI Controls Diag, Optics, Sample Envir	14MAY09
Complete XRPP Controls Diag, Optics, Sample Envi	14MAY09
Complete MPS/PLC	21MAY09

LUSI PROJECT

SCHEDULE OF DOE CRITICAL DECISIONS

LUSI PROJECT CD- 0 Mission Need Approved: August 2005	CD- 1	CD-2	CD-3	CD-4
DESCRIPTION	**Cost Range Approval**	**Performance Baseline Approval**	**Construction Start Approval**	**Start of Operations**
Coherent X-ray Imaging (CXI)	July 2007	(a) December 2007	(a) July 2008	(a) February 2010 (b) March 2012
X-ray Pump/Probe Diffraction (XPP)				
X-ray Correlation Spectroscopy (XCS)		(b) October 2009	(b) March 2010	(b) March 2012
Project Completion				(b) March 2012

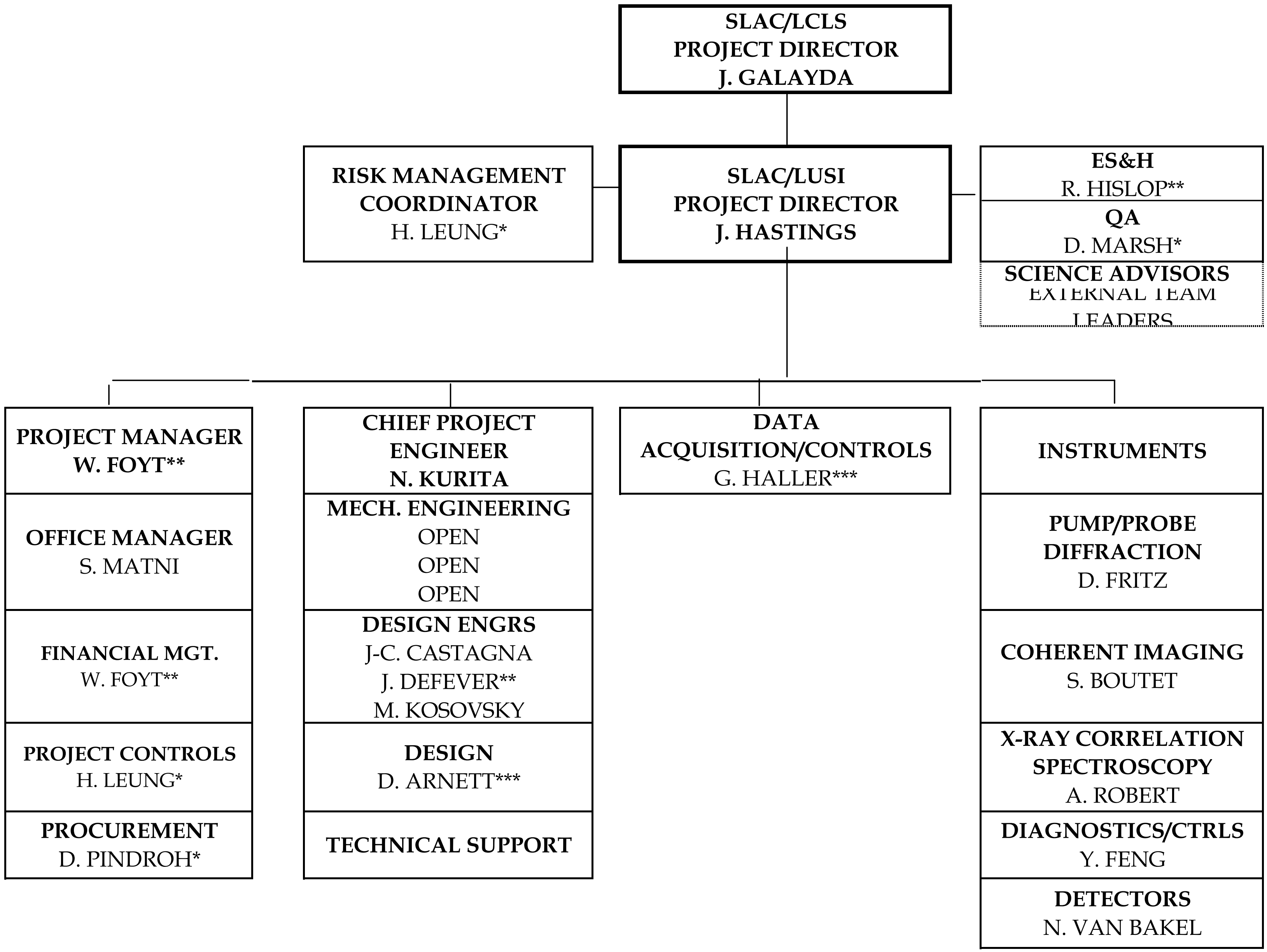
CD-4(a): CXI operational with detector, diagnostics, and controls & data systems.
XPP operational with shared laser, detector (1st article), diagnostics and controls & data systems.

CD-4(b): CXI operational with compressor, detector, particle injector, full diagnostics, and controls & data systems.
XPP operational with dedicated laser, detector, offset monochromator, full diagnostics and controls & data systems.
XCS operational with detector, optics, sample environment, full diagnostics and controls & data systems.

APPENDIX F

MANAGEMENT TABLE

LUSI PROJECT
ORGANIZATION STRUCTURE



*** LCLS Project personnel**
**** Contract personnel**
***** SLAC personnel**

Approved: **DRAFT**
J. B. Hastings

APPENDIX G

ACTION ITEMS

Linac Coherent Light Source (LCLS) Ultrafast Science Instruments (LUSI)
SC Project Review, July 23-24, 2007

Action Item

Action	Responsible Party	Due Date
1. Plan and Execute a CD-2a IPR.	SLAC, SSO, and BES	December 2007

Jerry Hastings
Project Director
LUSI Project
Stanford Linear
Accelerator Center

Hanley Lee
Federal Project Director
DOE Stanford Site Office

Steve Tkaczyk
Chairman, Review
Committee
DOE Office of Science
Office of Project
Assessment

Keith Hodgson
Deputy Director
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Thomas M. Brown
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Patricia M. Dehmer
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