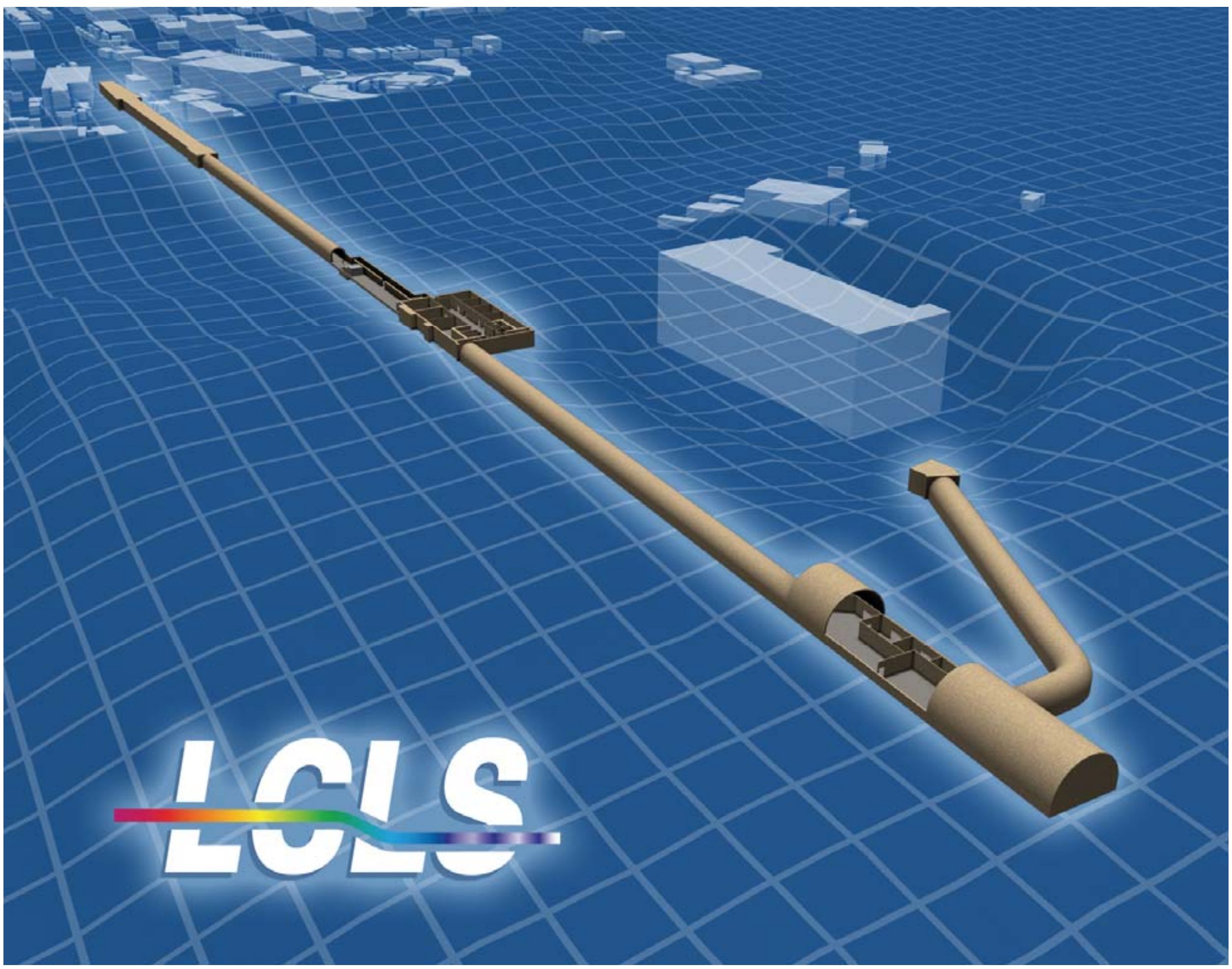
SLAC National Accelerator Laboratory

Linac Coherent Light Source (LCLS) Lessons Learned Report

PMD 1.1-056-R0



April 2009

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1.0 PURPOSE

The purpose of the Linac Coherent Light Source (LCLS) Lessons Learned Report is to share experiences and lessons learned among Department of Energy (DOE) projects, DOE Headquarters and Site Office program managers, and SLAC National Accelerator Laboratory project and project support personnel to ensure that projects are completed safely, within costs and schedule, and meet or exceed their performance objectives. LCLS project participants were allowed to share ideas and information regarding all aspects of the LCLS construction project by identifying and resolving common issues, learning methods that work and those that do not work, exploiting opportunities for improvement, and in general, helping one other.

2.0 PROJECT OVERVIEW

The LCLS project is a multi-laboratory partnership (with partners at Argonne National Laboratory and Lawrence Livermore National Laboratory) led by the LCLS Project Office at SLAC. When completed, the LCLS will be a world-class scientific user facility to provide laser like radiation in the hard X-ray region of the spectrum that is ten billion times greater in peak power and peak brightness than any existing coherent hard X-ray light source. The LCLS project will provide the first demonstration of an X-ray free-electron-laser in the 1.5-15 Angstrom range and will apply these extraordinary, high-brightness X-rays to an initial set of scientific problems in disciplines ranging from atomic physics to structural biology.

The baseline Total Project Cost (TPC) is $420 million and project completion is scheduled for July 2010.

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

- an “injector” (laser light pulses impinging upon a photocathode to produce electrons in a radiofrequency (RF) “gun” that are accelerated and steered into Section 20 of the Linac);
- modifications to the last kilometer of the Linac system, including installation of magnetic bunch compressors and beam diagnostics for the electron beam;
- a Beam Transfer Hall (BTH) to direct the energetic electron beam to the undulator;
- an Undulator Hall (UH, built under a hill to aid in temperature stability), containing an undulator magnet assembly composed of sections of rare earth magnets that when aligned produce a magnetic field to oscillate and bunch the electron beam (producing X-rays), and a vacuum system whose chamber vessel is compatible with the electron and X-ray beams;
- construction of a Front End Enclosure (FEE), Near Experiment Hall (NEH), X-ray transport tunnel, and Far Experiment Hall (FEH), all below grade; and
- X-ray beam optics, diagnostics, and controls systems.

3.0 LESSONS LEARNED/BEST PRACTICES

Management & Communication

Best Practices

An essential ingredient in all major project acquisitions is a compelling science case. This provides strong support both politically and scientifically. Political support from DOE-SC never wavered. The science community support of LCLS was engaged throughout the construction project, providing excellent feedback on design and construction choices.

Senior laboratory management must have the appropriate experience necessary to construct large projects, particularly in the centralized functions (i.e., procurement, finance, legal, ES&H) which are necessary to execute the project. Laboratory Division and Department heads need to feel ownership of the project outcomes. Lab management musts be committed and accept institutional ownership and accountability.

Senior laboratory management and the project management must work closely to ensure adequate resources are provided to ensure the project success. Examples are these are priority access to key influential lab talent, adequate co-located space to house the project team, direct access and reporting to the Lab Director.

Local Site Office management must also be staffed with experienced project-savvy professionals in all functions in order to act as a conduit for major project approval and reporting requirements to DOE authorities (OMB, OECM, DOE). Site Office managers need to feel ownership of the project outcomes.

LCLS was designed and constructed as an extension to the SLAC linac, requiring significant integration with the existing SLAC infrastructure. Recognizing this, LCLS management made a conscious effort to not use a stand-alone organization but to matrix managers, physicists and engineers from the Lab that would have the necessary institutional knowledge to manage the integration of existing equipment and new systems and components.

Technical risk management (RF Gun development, undulator and RF BPM R&D) was essential to staying to schedule and meeting commissioning goals. Looking at organizational risks, it is essential that the project team perform a careful comparison of the project's requirements and the management team's capabilities. Make key hires well in advance to allow for assimilation with the project team.

A stand-alone procurement "cell", co-located with the technical team dedicated to the project is a best practice for large capital projects.

Opportunities for Improvement

Multi-lab partnerships require good coordination and communication. Care should be used in developing MOU's, SOW's and Technical Addenda that document budget transfers to ensure the documents meet the needs of the project and Laboratories.

Adequate funding, particularly early on in the project is essential to building a solid design (with supporting cost estimates) in order to support a Performance Baseline.

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Environment Safety & Health

Best Practices

Recognizing outstanding performance during the work is an important aspect of motivating contractors to work safely. An example of a program implemented on the LCLS project was called 'The Safety Star Program'. This program allowed real time in field recognition of safe work practice by giving a safety star to be applied to a workers hard hat in the moment. In addition, rewarding, or penalizing, groups leads to peer pressure for superior individual performance.

The LCLS Project formed a Safety Stewardship Committee comprised of Project and General Contractor executives, superintendents and safety representatives to address issues and more importantly to establish a look-ahead-process. The issues addressed included analysis of incidents for lessons learned and how to communicate the lessons to the workers. This process included identification of planned activities with high hazard components such as work at heights or work to energize newly built systems. Another purpose of the committee was it allowed the Laboratory and DOE to communicate directly and often to the General Contractor and subcontractors our high expectations for Environment, Safety and Health.

A full time on-site Nurse with occupational medicine expertise has been highly beneficial on large DOE project where one has been included, including the LCLS. The nurse provides immediate response to injuries and is designated to aggressively manage injuries to ensure that first aid cases and the like do not unnecessarily become recordable cases.

Opportunities for Improvement

Unless the Construction Manager (CG) and General Contractor (GC) Key Team Members have worked at a National Laboratory on a DOE project they are unlikely to understand the environment and expectations to be encountered. The short list of prospective bidders should be taken to the site of a project in progress at a laboratory and discuss expectations with the Project Management Team (PMT) on the ground. Initial site description and briefing of the prospective bidders should identify hazards to extent possible and the fact that all existing conditions within the project fence line will be the responsibility of the successful bidder on contract award. These conditions should be specifically pointed out and documented for the GC during the initial site walk.

A CM/GC should be required to produce a comprehensive safety staffing plan for the duration of the project specifically identifying start dates and conditions for end of activity and release of safety personnel. For a major construction project, the CM/GC needs to have a Full-Time Safety Manager, preferably with experience on DOE projects of similar scope and projected manpower levels.

Laboratory Project Personnel should be trained in a common Work Planning & Control process, which includes expectations regarding safety oversight and appropriate interaction with subcontracted personnel. The CM/GC should be engaged in a discussion regarding Work Planning & Control processes and the measures of performance in the Go/No Go reviews of the work packages.

The CM/GC must develop a Site Specific Safety Plan (SSSP) that adequately describes the scope of work to be performed and associated hazards and mitigations. The PMT and has to oversee and ensure that the SSSP is adequate and followed. In addition, a contract clause should state that Project safety requirements are not "frozen" on the date the contract is signed;

as regulations and Laboratory/Project requirements change the contractor will have to comply with the changes in regulations and requirements.

To assist the CM and the GC develop a clear understanding of the Laboratories expectations regarding documentation and work execution a clause in the project contract should be included that requires that all work packages will be subject to a Go/No Go Joint Review by the PMT and CM until the PMT is satisfied with the CM's quality of work planning and execution of the work. A similar Go/No Go Joint Review should be required of the sub-contractors.

Permits and the permitting process should be clearly understood by both the CM/GC and the PMT. It is not sufficient to have a meeting to discuss philosophy. The request for, approval of and execution of the work associated with each type of permit should be choreographed to make sure each party understands the Laboratory expectations involved in processing and expectations regarding execution of each type of permit.

Procurement

Best Practices

The Field Change Order (FCO) process allowed procurement personnel to interact with technical personnel and quickly issue "Not to Exceed" orders to continue work and avoid delay claims. It also reduced administrative costs of completing a requisition each time and going through a procurement pricing process from the start. However, timelier pricing support by contractors and subcontractors must occur along with prompt LCLS technical reviews to make this a more robust and viable process on future projects.

Establishing a maximum pricing form in the contract to handle all changes capping overhead and profit ratios resulted in expediting pricing actions. The fact that these percentages were established for each tier in terms of maximum markups reduced significant layers of costs when changes were processed for lower tier contractors.

Co-location with project staff improved communications with customers and allowed for allocating available procurement resources on critical parts of the project. However, this concept must be embraced by the entire procurement department to avoid presenting conflicting information to stakeholders and laboratory management.

Opportunities for Improvement

Inadequate procurement staffing at the outset of the project created challenges. It is recommended experienced and adequate numbers of procurement staff be aligned at the outset of the project to establish critical procurement processes.

If contract incentives are established for a major contract, they must be meaningful, measureable and governed by a formal process.

Major contracts such as design and construction should be carefully reviewed for ambiguities to ensure bonding costs, progress schedules, as well as terms and conditions are clear. Hold a final pre-award conference going over roles and responsibilities to ensure SLAC and contractor personnel are in complete agreement on fundamental contract requirements.

Procurement estimating support as well as documentation support from technical staff needs to be formalized up front to avoid delays and confusion when processing procurement actions.

Contracts should not be awarded when significant items remain open and unresolved as it can establish a very unproductive atmosphere with contractors.

Conventional Facilities Design & Construction

To be submitted by J. Albino.

Technical System Design, Fabrication, Installation & Integration

Best Practices

The LCLS project is a mixture of complex technical hardware being integrated into a newly designed and constructed conventional facility. As the technical designs matured it required changes to the already designed facility and each technical group began to interface directly to the CF group resulting in multiple and conflicting change requests. The LCLS project office recognized this issue and created the Integrated Management Team (IMT) to provide a conduit from the technical groups to CF. The IMT was made up of members from the project including CF, Electron Beam, Controls, Photon Beam, and the Project Office. The purpose of the IMT is to ensure that all Design Change Requests (DCRs) requests to CF were vetted to be technically viable, understand the impact and costs to CF if implemented, and make recommendations to the Project Office to allocate contingency to this design change if the IMT approved. This process ensured that all groups were informed of the requirements, impact, and schedule of potential changes.

Opportunities for Improvement

LCLS components are complex systems made up of motion systems, hard limits, precision encoders or readouts, limit switches, etc., and if the hardware and controls are not effectively checked out and properly set in the lab prior to installation, then problems are not found until commissioning. To enhance the installation and commissioning of hardware, each component should have a checkout sheet which includes drawings (with sufficient details to enable the technician to verify, with dimensions, that the hardware is set per design), and a data sheet (detailing the system functional aspects and settings - i.e., water flow, air pressure, air cylinder actuation speed, linear stroke distance, controls interconnects, readout values and tolerances, limit switch wiring to connector, etc.). Projects will benefit at the installation phase by maintaining engineering responsibility and oversight though both the installation and checkout phases, right up to the 'turnover' to Operations point.

The successful integration of technical hardware into a newly constructed conventional facility relies upon early review of CF drawings and inclusion of same into technical hardware assembly and/or installation drawings to confirm proper function and fit. This rather simple task becomes extremely difficult if the CF drawings do not have cross sections of the facility which include "all" utilities. When these cross sections drawings were eventually complete and interferences identified, it resulted in change requirements to either the facility construction or the technical hardware design. Facilities designed and built to house technical systems, like the LCLS, require a high level of detail to ensure proper fit and function. It is recommended that CF drawings at the

Title I and II stages include cross sections of the facility showing all utilities to facilitate integration of technical hardware. Technical groups should develop outlines of the facilities in their installation drawings and have these reviewed (by CF as well as tech) and published early to clearly state their assumptions of how the technical hardware interfaces with the new facility.

The installation of technical components in the new LCLS facility was accomplished before substantial completion was achieved leading to integration challenges between the contractor and LCLS. In order to maintain the planned beam schedule it was necessary to begin installation of technical hardware while other subcontractors continued with their work on the facility - LCLS and the GC established Co-Occupancy milestones. This required weekly planning meetings and agreements between the general contractor, technical installation coordinator, and CF managers. Safety was the highest concern, schedule and conflicting work was second; this resulted in creation of a 2 week look-ahead plan to review work. All tasks were discussed, timing and potential interferences had to be reviewed, and a training program developed to ensure all workers who entered the contractor construction zone understood the hazards that might exist.
Definition of Beneficial Occupancy for a new facility needs to be clearly defined and agreed upon between all stakeholders, especially technical and CF groups. It is important to understand what utilities are be in place, what testing is still required, and what access to areas may be restricted upon reaching the Co-Occupancy or Beneficial Occupancy dates. For LCLS, Early Occupancy started in January 2008, Beneficial Occupancy in August 2008, first electron beams delivered in December 2008.

- Define Early/Co-Occupancy and Beneficial Occupancy in terms of utility completion, access conditions, and task priority.
- Define B.O. dates, develop milestones, and use the planning schedule to show how the B.O. dates tie to technical installation start.
- The impact on technical installations that are tied to CF equipment and to contractors needs to be clearly understood and linked in installation schedules.
- Co-occupancy works, but should not be used as a default.

Commissioning & Transition to Operations

Best Practice

The LCLS Project decided early to perform the work on accelerator instrumentation and controls using the existing SLAC departments rather than hire new staff. The SLAC groups had regularly made and installed new equipment in the existing SLAC Linear accelerator. Magnet power supply specification and installation, cable plant organization and installation was performed by the Power Conversion Department. Specification and installation of protection, timing and diagnostics systems was performed by the Controls department. Fabrication testing and installation of beamline components was performed by the Mechanical Fabrication department. In addition to having expert experienced staff, these departments would eventually have the responsibility for the maintenance of those systems. One of the benefits of having these groups responsible for fabrication, installation and checkout is the procedures and documentation necessary for efficient operations was available from the start. The groups were already responsible for accelerator availability and reliability and so the transition from installation to commissioning to operations was seamless.

Opportunities for Improvement

In creating complex instrumentation, especially doing so in collaboration with remote partner laboratories, design reviews are the single best management tool for assuring the ultimate success of the instrument. Yet carrying out and properly responding to design reviews takes time. Review time needs to be explicitly included in the project schedule and realistically estimated. Otherwise the schedule will inevitably slip.

The transition from construction to operations generally requires new or different staff. Funding constraints will tend to push the hiring of new operations staff to the very end of the project. This will create a crisis of hiring and training during the transition to operations. LCLS was pushed into this situation by funding problems in FY07 and FY08, which resulted in a delayed staffing plan. The main problems did not occur until FY09. It may have been inevitable, but the full consequences of the delay in staffing up were not properly appreciated at the time the schedule was prepared.

4.0 CONTACT INFORMATION

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