

# Report of the June 16<sup>th</sup> through 18<sup>th</sup>, 2008 Meeting of the LCLS Facility Advisory Committee

## 1.0 General

### 1.1 *Introduction and Charge*

The Linear Coherent Light Source (LCLS) Facility Advisory Committee (FAC) met with the LCLS project team and the LCLS Ultrafast Science Instruments (LUSI) project team on the 16<sup>th</sup> through the 18<sup>th</sup> of June 2008. The charge of the Facility Advisory Committee continues to advise SLAC, SSRL, and LCLS management on the continued execution of the LCLS Project and Facility development throughout its several phases and systems:

- Accelerator systems design and construction
- Undulator systems design and construction
- X-ray transport, optics and diagnostics design and construction
- Experiment station systems design and construction
- Conventional facilities design and construction
- Planning and execution of commissioning and early operations

As the project has evolved the emphasis of the charge to the LCLS-FAC has evolved as well, and in meeting the FAC was specifically charged to

- Assess installation planning;
- Identify technical risks remaining in the photon beam systems and LUSI;
- Assess the controls applications strategy with specific comments on risks and priorities being sought;
- Assess commissioning plans; and
- Advise on how to best integrate LUSI into the FAC mission.

The FAC was divided into five subgroups: the Electron Systems Subgroup that covered the accelerator systems design and construction; the Undulator Subgroup that covered all parts of the undulator and its ancillary systems; the X-ray Subgroup that covered x-ray transport, optics, diagnostics and experiment station systems and the LUSI project design and construction; the Controls Subgroup; and the Conventional Facilities Subgroup. Appendix A is a listing of the members of the Facilities Advisory Committee and their respective subgroup assignments. Appendix B is the Agenda of the June 16–18, 2008, FAC meeting.

The following sections address the aspects of the charge through individual reports of the subgroups. General comments and recommendations precede these individual reports and follow in the next subsection.

## 1.2 General Comments and Recommendations

Progress on the LCLS Project continues to accelerate and continues strong. Since the previous FAC meeting (October 2007) the LCLS project baseline was revised to a total estimated cost (TEC) of \$352M and a total project cost (TPC) of \$420M. As part of this revised baseline the Department of Energy (DOE) Critical Decision 4 (CD-4), the official project completion milestone, has been set to July 2010. An additional global project milestone has been added as well *Early Finish* in July 2009. This *Early Finish – Start Near Hall Operations* includes characterizing x-ray flux at 0.15 nm in the front-end enclosure and detecting x-rays in the Near Experimental Hall. Overall project construction was listed as being 82% complete. The injection is 100% complete. The Linac was reported at 86%, the Undulator System at >89% complete (ANL workscope at 95%). The Conventional Facilities was reported as being more than 84% complete and Turner Construction activities at more than 89% complete. The emphasis of the project has moved towards the installation and integration, X-Ray Transport/Optics/Diagnostics at more than 76% complete, the XR End Stations at ~30% (the most significantly delayed as a result of the continuing resolution) and LUSI has been scheduled for a CD-2 review in August 2008 which will baseline three major instrumentation efforts.

To date, commissioning and injector results are impressive. The Project team is functioning well, working very closely together in a unified effort with no obvious difficulties. Implementation of the integration and installation processes is progressing very well. The switch to the operating organization is well underway in the areas of Accelerator Systems Division, LCLS Experimental Facilities and LCLS System Engineering. There has been a strong emphasis on accomplishing tasks correctly which demonstrates the cohesiveness of a unified, mature team. This team is appropriately focused paying attention on the deliverables and end goals.

During the transition phase to a facility, the Project must focus on the deliverables and SLAC must focus on the facility. SLAC should pursue the facility aspects that are not *on-project* (e.g. monitoring of floor motions throughout new construction). Complete understanding of the interplay of all aspects of SLAC, the Facility and the Project is imperative. As the LCLS Project is heading toward completion, the LCLS Facility is striving to become established and the SLAC is evolving to single entity with a multipurpose mission. A healthy tension naturally exists and it is important that to understand.

Installation in several areas has proceeded as far as possible due to the challenges presented by co-occupancy. This may cause further schedule delays in the technical systems installation. A suitable environment and controls are necessary before many systems can be attempted. The emphasis at this time is to not unwittingly assume a greater risk while attempting to mitigate or transfer other risk.

The commissioning plan has gone well but great care must be exercised not to allow the desire for the early science milestone to compromise aspects of the facility. Free-electron lasers have demonstrated over more than thirty years that they can be quite challenging in commissioning. The LCLS Project is encouraged not to promise a usable x-ray beam by a given date. More advisable is stating that an x-ray beam of a given quality will be

available no earlier than a given date. This will make it incumbent upon the LCLS Facility to inform and select *first users* that have sufficient flexibility to start experiments with relatively short notice once x-ray beam characteristics and stability have advanced sufficiently experiments to be conducted without undue frustration.

As the emphasis of the project changes, the FAC should evolve to meet the needs of the LCLS. The Electron and Undulator subcommittees should be merged into a Commissioning subcommittee. Conventional Facilities should remain intact through one additional review process. It is likely advisable to expand and subdivide the x-ray subcommittee so that the instrumentation efforts of LUSI project can be adequately supported. There should be comprehensive coordination with the SAC to ensure complementary roles.

The LCLS project continues to be an exciting project. SLAC and LCLS should not lose any opportunity to preserve and provide valuable lessons learned throughout the entire evolution of the project. This is extremely important for the benefit of this project and for future projects that follow at SLAC and elsewhere.

As always, the FAC is very appreciative and would like to extend their sincere thanks to Helen O'Donnell, Siony Matni and the LCLS staff for all of their hard work and efforts in organizing these meetings.

## **2.0 Electron Systems Subgroup Summary**

John Corlett, Max Cornacchia

### **2.1 Commissioning**

Commissioning of the accelerator systems has progressed very well. The injector commissioning was completed in the fall of 2007, and those systems have been handed over to operations. The injector produces excellent beam quality, with measured projected emittance less than 1  $\mu\text{m}$  at 0.25 nC, at 135 MeV and before bunch compression. Beam commissioning to design energy of 13.6 GeV was completed in March 2008. Projected emittances are 1.36 mm-mrad horizontal and 0.90 mm-mrad vertical, measured at 9.2 GeV with 0.25 nC, 75 fs bunches. With these parameters the FEL is expected to saturate in 100 m and produce  $10^{12}$  photons per pulse at 8 keV, achieving the design goals for the LCLS. The horizontal emittance is observed to be sensitive to charge, probably due to CSR effects, whereas vertical emittance remains approximately 1 mm-mrad at 0.50 nC.

The committee applauds the excellent progress in beam commissioning, which reflects excellent planning and execution, and strong contributions from the LCLS team involved in the many areas needed to bring a concept to practical realization.

The committee recommends beam test at higher repetition rate, ideally up to 120 Hz where possible, to allow early identification of potential problems in hardware, diagnostics, and in software needs.

### **2.1.1 BC1**

The central dipole magnets in the first bunch compressor were removed and field flatness improved by mounting caps onto the pole pieces. Magnetic measurements were performed before re-installation, and the magnets are now of sufficient field quality.

### **2.1.2 Main Linac**

BC2 was installed to a very tight schedule, and the committee applauds the careful planning and continued attention that resulted in this success.

The tight RF tolerances are being met, using RF feedback for short-period control, and beam-based feedback for longer timescales, resulting in very good energy stability measured to be 0.03% RMS at 14 GeV, transverse phase-space jitter typically less than 12% of beamsize, and bunch arrival time jitter of ~46 fs (with respect to the transverse deflecting cavity RF). Bunch charge jitter is measured to be ~1.5%. A 10  $\mu\text{m}$  bunch length is measured after BC2, limited by the resolution of the bunch length monitor screen.

### **2.1.3 Controls**

Powerful high-level application tools have been generated in Matlab by physicists, and have proven essential in the success of commissioning and operations. Feedback systems implemented in Matlab are essential in meeting specifications for peak current, charge, bunch length, etc. Not all feedback systems will be able to function at 120 Hz, and the necessity for such bandwidth is not yet determined and would be investigated at higher repetition rate operations (see earlier recommendation to pursue this).

New BPM electronics, read directly by EPICS, have high readout speed and have proven very useful in commissioning, for example the shot-to-shot transverse phase-space measurements. Old SLC BPMs readout rate is low in EPICS, ~1 Hz

The software group will migrate code from Matlab and implement features for improved reliability and maintainability (see comments in Controls section). Have EPICS BPMs in critical areas (high dispersion, etc.).

## **2.2 *Photoinjector***

Performance of the photoinjector has been very good. The gun, laser systems, and diagnostics are now fully functional and highly reliable.

The committee reiterates its recommendation that the LCLS project pursue means to build a gun test facility, for the testing and development of components for LCLS applications without disruption of operations.

### **2.2.1 Laser**

The photoinjector laser systems have proven to be highly reliable, and 99.9% availability was reported. The systems are typically operating at 10-30 Hz, although they have been tested at 120 Hz. A Dazzler is used to generate the laser

beam temporal profile, and the spatial profile provided by an iris imaged onto the cathode plane. Fused silica windows have been replaced, the laser room to injector enclosure transport tube cleaned, and pointing stability and energy adjustment systems improved. Stability of the systems, and safety, has been enhanced by enclosing all laser tables with opaque screens.

The daily operation of the photoinjector laser is now controlled by operators in the main control room. Operators log laser system parameters daily, allowing engineers to analyze data for predictive maintenance. Operators do not go into laser room.

### **2.2.2 RF gun**

A change in staff responsible for the gun appears to have been smoothly implemented.

RF field probes have been replaced with ones that are less tightly coupled to the cavity, and can be operated at 120 Hz with design gradient at the cathode.

The second gun has been built and RF conditioned at 125 MV/m, 120 Hz, 2 ms pulses.

Cathode quantum efficiency has been improved by laser cleaning, although with some resulting non-uniformity in emission, and with reduced quantum efficiency following venting to install the new field probes. A less aggressive laser cleaning technique is under development. The committee recommends that the cathode not be replaced at this time, since the performance has been demonstrated to meet the needs of the FEL, and a new cathode may bring fresh challenges as yet unanticipated.

### **2.2.3 GTL Diagnostics**

GTL diagnostics have been repaired and re-aligned where necessary, with the Faraday cup and YAG screen, IM01 toroid, in-vacuum laser mirror and window, and laser alignment window now fully functional.

## **2.3 *Coherent optical transition radiation***

Strong signal from coherent optical transition radiation (COTR) saturates the OTR monitors designed as beam diagnostics, and makes them unusable downstream of the first bunch compressor. As a result, the emittance cannot be measured until downstream at a beam energy of 9.2 GeV, where scanning wires are installed for this purpose.

Studies of the COTR have improved understanding, although the detailed structure of the beam giving rise to coherent radiation in the optical region is not yet fully understood. The solution to the COTR problem is believed to be the laser heater, which is designed to introduce an incoherent spread in the beam energy, smearing out micro-structure in a bunch that gives rise to COTR.

### **2.3.1 Laser Heater**

The laser heater design packages are being completed, and the system is planned to be installed September 2008, with beam commissioning no later than January 2009.

Since COTR significantly impacts the usefulness of OTR diagnostics, and the micro-structure in charge distribution that gives rise to COTR may affect lasing in the FEL, the committee strongly supports continued attention to installation and commissioning of the laser heater.

## **2.4 *Plans for FEL Commissioning***

The committee thanks the LCLS team for their responsiveness to our request for a detailed description of FEL commissioning plans.

Beam commissioning in the from the LTU to the beam dump will begin without the undulators installed, in order to minimize potential damage to the magnetic material while the beam is steered through the transport line. RF cavity BPMS and beam finder wires, with mechanical girder movement systems, will be used to steer the beam through the quadrupoles in a straight line. Undulator sections will then be installed at a rate of approximately 3 segments per day, taking about 2 weeks to install all sections. An alignment diagnostic system (ADS), consisting of a stretched wire and hydrostatic level measurement systems allows for compensation of long-term ground motion, providing feedback signals for the girder mechanical movement. The undulator hall temperature is to be maintained at a constant temperature  $\pm 2.5^\circ\text{C}$ , and installation of undulator sections will not begin until the HVAC system is fully functional.

Spontaneous emission will be characterized initially at  $1.5\text{\AA}$ . Setup will then switch to a 4.5 GeV beam energy and SASE optimized at  $15\text{\AA}$ , with a reduced number of undulators, and shorter gain length than with a 14 GeV beam and  $1.5\text{\AA}$  radiation. The undulator beamline lattice is fixed regardless of beam energy (quadrupole settings are unchanged). The SASE radiation will be detected by direct imaging, If not readily observed, then a lock-in detection scheme may be used, using a modulation in energy spread introduced by the laser heater (@ 7 Hz) to effectively switch lasing on and off. Tools and diagnostics will be available for both  $15\text{\AA}$  and  $1.5\text{\AA}$ , allowing flexibility to work at different wavelengths to make best progress.

Initial operations are expected at 60 Hz pulse rate, in October 2009, and at 120 Hz by June 2010.

The committee commends the LCLS team on developing a plan that is thoroughly considered and detailed. Integration between installation, accelerator, undulator, and the x-ray teams is good.

The early science goal, with beam to users in mid-August 2009, drives the commissioning schedule with little room for slippage. The committee notes that

additional pressure may be added to this schedule if beneficial occupancy proves to be later than expected.

### **3.0 Undulator Subgroup Summary**

Joachim Pflüger, Kem Robinson

#### **3.1 General**

The undulator setup is in full progress and was found an impressive effort. All components of the undulator systems are making good progress. Former items of big concerns now run very smoothly, in time and budget. A noticeable change in climate from confrontation towards collaboration partners was observed, which is very beneficial for the project. All items are being addressed, under way, in production or already finished.

There were some changes on the undulator, which came in very late and which need re-measurements.

#### **3.2 Vacuum chamber**

This item, which was subject to many concerns and comments in the past, now is in a very good shape. All Al-extruded vacuum chambers have been produced and are delivered. They fulfill surface roughness/slope requirements. At the excursion the test setup was presented in Hall 750.

#### **3.3 Magnetic Measurements**

There were late changes:

- Slight K changes were observed after storage in winter, where the magnet temperature was low. They are not fully understood where they come from.
- New horizontal shims were developed, which allow a higher good field region of  $\pm 6$  mm to be used.

As a result at least partial re-measurement of the already measured undulator segments is needed. This increased the pressure on undulator time schedule. Time float for undulator measurements consequently has shrunk closed to zero. Therefore no more delays can be tolerated without affecting the project. Some of the already measured segments are on specification limits but can still be used. For mitigation, Zack has made the plan to install those segments, which are within specs and measured, but only good to  $\pm 2.5$  mm and to modify them one after the other as part of the undulator re-measurement plan during operation at a rate of three segments per month.

#### **3.4 System Installation**

The benefit of co-occupation is almost exhausted. There are no more items of the undulator system, which can be installed under the present situation. Installation of the sensitive items can be made only after beneficial occupancy. Depending on the BO there is an additional schedule risk, which requires appropriate planning.

### **3.5 Beam Loss Monitors**

The BLM system has appropriate importance. However, for budget reasons only five BLM systems will be available for commissioning and the rest later. These are considered sufficient for the beginning. Although some workarounds and other protection means such as an orbit control system are foreseen, it was questioned throughout the committee enough protection can be provided by the proposed 5 systems in the delicate commissioning phase. This is considered an additional risk.

## **4.0 X-ray Subgroup Summary**

Lahsen Assoufid, Paul Fuoss, Tom Rabedeau, Peter Takacs, *Thomas Tschentscher (not present at the review)*

### **4.1 Overview**

The x-ray efforts of the LCLS project are progressing rapidly but are being severely squeezed by the current spending profile. As was discussed in our last report, procurement of the AMO scientific instrument is being delayed until the beginning of FY09. This delay results in a significant risk that no functioning scientific instrument will be ready when x-rays are first available at the LCLS. The project is actively working to mitigate this risk and we believe that these efforts will be successful.

There has been significant restructuring of the LUSI MEI effort since the FAC last met in October, 2007. Tom Fornek has taken over responsibility for the LUSI project from Jerry Hastings and the project has been more tightly integrated into the overall LCLS project. LUSI faces severe constraints due to the reduced budget authority, particularly in the near future. The FY08 budget is only 60% of the planned amount, a budget reduction that causes great difficulty to long-range procurements. These constraints are being addressed by rearranging priorities and descoping the project. Significant early scientific opportunities are likely to be lost because of these budget constraints.

An area of significant concern for the committee was the addition of a Soft X-ray Materials beamline to the planning. At a time when the baseline experimental program is under severe stress, the encouragement by senior SLAC management of this new effort aimed at early operation can create uncertainty regarding priorities within the project. For example, much effort is going into restructuring the AMO experiment to move it from Endstation #2 to Endstation #1. While the scientific and technical case for this move may be strong, the potential diversion of staff from a sharp focus on completing the AMO experiment and balancing these competing interests is a significant risk.

LCLS has started a process to evolve from a construction project to an operational x-ray light source and this has led to a much sharper focus on the x-ray scientific infrastructure. A series of proposal workshops are being held. The workshops have already identified areas where the proposed instruments could be refined to support a broader range of scientific programs and a broader user community. This is a very positive development.



## **4.2 Summary of Highlighted Areas**

The x-ray subgroup heard detailed presentations on a key selection of important areas to the LCLS x-ray community. These are summarized below.

### **4.2.1 XTOD Status**

The X-ray Transport, Optics and Diagnostics (XTOD) effort has made significant progress in the last six months but there are still significant areas of concern. Many of the key components for the Front End Enclosure (that are critical of commissioning the FEL) are currently being assembled at LLNL including the Fixed Mask/slit, the Gas Attenuator, Gas Detectors and FEE controls racks. In addition, the components for the thermal sensor and the direct imager are either on order or in house at LLNL. The pop-in monitors are still in the design stage. Of most concern is the K monochromator that is still in the final design stages. This instrument is key to doing the initial calibration and tuning of the FEL undulators during initial commissioning of the FEL. There is not a readily identifiable person with responsibility for the completion of this instrument.

The design and procurement of the x-ray transport system to deliver x-rays to the experimental stations is going well. Preliminary design and prototyping of the x-ray mirror support and movers has been done and a final design review is scheduled for August. The mirror movers meet the stability and pointing requirements for the soft x-ray offset mirrors (SOMS) and, with additional temperature stabilization, meet the hard x-ray offset mirrors (HOMS) requirements. Three of the five mirror blanks for SOMS have been delivered. The first two were just out of spec while the third was comfortably within specification. The first two will be repolished if the final two come in with specification as is anticipated. The HOMS blanks are currently being fabricated but have more stringent specifications than the SOMS. The panel urges a close interaction with the vendor to emphasize these very demanding specifications.

The committee was given a tour of the near experimental hall (NEH) and the far experimental hall (FEH) and shown the endstation rooms in the NEH. These are progressing well although there was concern about the configuration of the air handling system and temperature stability across the room since ventilation air is only being introduced on one side of the very large rooms. A preliminary design review for the laser and transport system for the NEH has been completed although it cannot be ordered until FY09.

There appears to be excellent progress on the 2D Pixel project lead by Cornell University.

### **4.2.2 AMO Instrument**

The AMO instrument is on schedule for completion by the time x-rays are available from the LCLS but there is no float in the schedule and timely procurement is essential. Thus, the recent proposal to relocate the instrument from Endstation #2 to Endstation #1 is worrisome since staff effort and resources could easily get diverted into dealing with unforeseen problems and not expediting the crucial procurements.

The AMO project also faces some stress from the outcome of the recent Proposal Workshop that revealed that most outside investigators wish to bring specialized chambers to attach to the basic AMO instrument. This requires straightforward but potentially time consuming redesign of portions of the AMO instrument. Nevertheless, the design of the AMO instrument is excellent and the team should be commended for their work to this point.

#### **4.2.3 XPP Instrument**

Excellent progress continues on the design of the x-ray pump-probe (XPP) instrument. There was an extensive discussion of the merits of using industrial robot technology to move the x-ray detector and how to specify tolerances and reproducibility of motions. The committee believes that the robot approach is very promising and recommends the design team determine whether there are standards (e.g. ANSI) for robot design that will make specification easier.

The design of the sample orientation system (goniometer) is still at an early stage. The committee is concerned that the design is being done without clearly defined reference loads and moments. It would be beneficial to have several conceptual sample chambers (e.g. a cryostat) that could be used to get realistic performance numbers from standard commercial instruments. The mechanical stability of the instrument could be improved by limiting the vertical range of motion, a distance that is currently quite large.

The design team has adopted the philosophy that the incident slits and beam conditioning hardware should be absolutely defined in space. This has led to the use of an extremely large, monolithic block of granite as the support for the incident optics. This appears to be an unnecessarily difficult approach since both the incident beam and the goniometer will have significantly larger motions than the granite block on the relevant time scales. If a large, monolithic block is necessary, it may be possible to find synthetic products that can be poured in place that will approach the performance of the monolithic granite table. The current plan also has the optics being repositioned on top of the monolithic block to reach the direct and offset positions. It may be much more efficient and stable to have a much narrower table top to which the optics are referenced and to move the entire table between the two operating positions.

#### **4.2.4 CXI Instrument**

The presentation and discussion of the coherent x-ray imaging (CXI) instrument mainly concerned the design of the KB mirror focusing systems. Two separate mirror systems are being designed for the project, one to create a 1 micron focus and one to create a 100 nm focus. The project is investigating the use of a bilayer mirror with a 40 nm Rh layer capped with a 30 nm B<sub>4</sub>C layer. The goal would be to get high performance from the B<sub>4</sub>C layer at low photon energy and high performance from the Rh layer at higher photon energy. The committee was not enthusiastic about this approach. The mirrors are required to perform at an extremely high level to meet the design criteria. Whether the required interfacial roughness can be preserved when creating multiple interfaces between materials that have uncertain wetting characteristics and residual stresses is a significant risk. Even if almost ideal interfaces can be created, there will be subtle thickness

variations across the mirror that could lead to complicated interlayer interference and coherence degradation. Finally, the stability of this structure under high instantaneous photon fluxes is uncertain. There appears to be no strong scientific driver that requires rapid switching between low and high energy x-ray operation. The committee felt that a better approach was to concentrate on mirrors optimized for a particular, narrower energy range.

The design of a temporary experimental chamber that supports 1 micron operation but that may not be compatible with 100 nm operation was discussed. The committee felt that this was a good approach to dealing with the experimental uncertainties.

#### **4.2.5 XCS Instrument**

The discussion of the XCS instrument centered on the design of the diffractometer and detector stages. The design effort of this instrument is progressing very smoothly and the committee endorses the decisions that have been made to date. The largest risk appears to be the split and delay line. The committee supports and encourages the team's efforts to construct a prototype instrument and test it at both third generation synchrotrons and the LCLS as soon as possible. The large offset monochromator also requires design attention and carries risk. This has been recognized by the project and appropriate efforts are being made to create a solid design.

#### **4.2.6 X-Ray Diagnostics and Common Optics**

The presentation focused on three areas that the FAC was asked to comment on: 1) an intensity-position monitor, 2) the wavefront monitor and 3) the design of slits. There is a common theme running through the discussions that it is extremely difficult to have solutions that work for both soft x-rays (<4 keV) and hard x-rays. However, it is unclear why the LUSI team is expending large amounts of effort on soft x-ray problems since there is no scientific program in the LUSI scope using soft x-rays. Thus, we would encourage the program to find robust, reliable solutions that function in the hard x-ray regime above 4 keV. If that decision is made, it appears that suitable solutions are available for most of the diagnostic and beam definition instruments.

The design of the wavefront sensor is promising. This is a device that can easily be tested on an existing source and we would encourage a prototype to be quickly constructed and tested. Demonstration of a robust reconstruction with a computation time consistent with dynamic feedback to the experiment would eliminate substantial uncertainty in experimental and data acquisition design.

The lack of any completed designs for these key components causes concern.

#### **4.2.7 X-Ray Commissioning**

Hal Tompkins presented detailed planning for the x-ray commissioning of LCLS. The overall plans appear reasonable. There is a need to retain a great deal of flexibility in the scheduling since it is likely that some operations will take considerably less time than allocated and some considerably more than anticipated. Also, contingency plans for the failure of components to reach design

performance are not included. A plan for “on call” technical support to respond rapidly to surprises in the performance of the instruments, should be developed.

### **4.3 Summary**

The x-ray instrumentation program is under severe stress due to budget constraints and late starts on many key design issues. The staff should be commended for their very positive response to this difficult environment. The project is encouraged to develop plans that identify the minimum capabilities needed for scientific programs to take advantage of the unique x-ray beams the LCLS is expected to produce, and to focus on making sure that those capabilities are provided as soon as practicable. There appears to be an implicit assumption in planning for LCLS beamlines that the LCLS will not reliably produce hard x-rays for a significant period of time (i.e. over a year) in the planning for infrastructure development. This assumption does not appear consistent with the other presentations to the FAC and the project is encouraged to have contingency plans to exploit early success with pioneering hard x-ray experiments. The current proposal workshops appear to be a good mechanism to facilitate the development of such plans.

## **5.0 Controls Subgroup Summary**

T. Himel, K

There has been a lot of great progress made since the last FAC meeting in October 2007. The installation and commissioning of BC2 went very smoothly with the tight schedules being met. The MPS system which has been a schedule concern for two years has its first modules working in the field with a test database. There is still considerable work to do on this system but this is a significant milestone and reduces the level of concern. Finally (at last), Hamid has the deputy that both he and the FAC have wanted for several years. Welcome aboard Enzo Carrone! It looks like you have rapidly come up to speed.

The hardware and low level software for the electron beamline are either satisfactorily done or ballistic, so there are no major remaining concerns. Some minor comments:

- There is not yet an adequate plan for setting the thresholds of the Beam Loss Monitors (BLMs). Setting them to the lowest setting where they don't trip and having no idea of the calibration is likely to lead to problems. We suggest combining data on the radiation damage rate of the undulators with EGS modeling of beam losses with source or beam calibrations of the loss monitors to arrive at an initial threshold setting. This can later be adjusted by comparing undulator deterioration with TLDs with the BLM readings.
- We are concerned that the reduction from 33 BLMs to only 5 for budgetary reasons may compromise the safety of the undulators.
- Presently feedbacks are implemented in Matlab and due to this architecture are limited to running at 5 Hz. They are working quite well and are providing adequate stabilization at present. It is a fairly big job to implement the architecture

that allows high rate (120 Hz) running and since the project is not sure it is needed, its implementation is low priority. There are 3 feedbacks in the linac using the legacy control system that do run at full rate. With the planned modernization of that control system, these loops will no longer run at full rate. The experience at SLC was that some of the loops needed to run at 120 Hz. Considerable effort was put into increasing the rates of some loops from 20 Hz to 120 Hz. We strongly suspect that since the FEL is supposed to be as fussy about its beam as the SLC was that full rate feedback will be needed to obtain stable operation. Consideration should be given to accelerating (from zero speed) the development of higher rate feedbacks. At minimum, some early 120 Hz testing should be done to see what problems occur not only for feedback, but for other systems.

- Without doubt, when the linac is run at 120 Hz, there will be timeslot separation where every other pulse has a different energy and trajectory. To solve this does not require 120 Hz feedback. It only requires controls and actuators that can switch at 120 Hz (such as a PAU and a solid state phase shifter). The plan for how to compensate for timeslot separation should be developed soon so it can be implemented and tested before production 120 Hz running starts.

In the push to get a new control system operational, emphasis is properly given to getting needed new hardware and features implemented and hence the fixing of minor operational problems are given low priority and essentially ignored. If not fixed, these minor problems increase in number and operation of the accelerator becomes difficult and frustrating. Things are going well enough (rumor has it that some controls people are even being allowed to sleep at night) that it is time to devote more attention to finding and fixing these problems. Finding them may only involve encouraging the operators to complain or sitting in on shift for a few hours. An example of such a problem (which is minor enough we're embarrassed to mention it here, but nevertheless if there are several others like it they add up to a significant problem) is that the drag and drop of a PV from one place to another (e.g. data archive viewer) does not always work.

Progress has been good on the photon and experimental controls since the last review. It is pretty clear something will be up and running for the early experiments. We are concerned that the high data rates needed for later phases of the experiments will require considerable lead time to develop the DAQ, online and especially offline computing power and software. This is complicated by the fact that these are new types of experiments and people are not sure how or if the data can be zero suppressed or how it will be processed. It is complicated still more by the fact that different experimental groups will be using the facility each week and each may have its own unique requirements and we cannot afford the lost beam time of multiday transitions. Some planning involving the experimenters and controls people and then explaining of how these concerns will be addressed would be helpful.

High level applications (HLA) remain a significant concern. They are now suffering from the (proper) choice of delaying work on them in favor of more urgent matters. Concentrated work started only a year ago and the management and plan of what tools to use was changed only a few months ago. The plan has changed from taking

most applications from XAL (the SNS HLA suite) and using Eclipse to taking only the model calculation from XAL and writing everything else from scratch in Java and Swing. This may well be the right thing to do, but it leaves us with several concerns:

- Writing things from scratch will take longer than adapting an existing HLA suite (on the uncertain assumption that such a suite exists that is good enough and adaptable enough).
- The resulting applications will not be easily modifiable by the physicists so changes they will certainly decide they want at the last minute will be slow in coming.
- There will be difficulties weaning the physicists away from the Matlab codes they have developed and grown accustomed to.

On the positive side, the functional requirements are being based on the existing Matlab applications and input from the physicists and operators. On the negative side, this committee is too ignorant to know if the best path has been taken. We certainly cannot say that the planned path will not work. In fact, it certainly can work. With all this considered, we renew our recommendation from the last FAC review that an *external* review should be held to go over the plans for HLA implementation. We would suggest having a reviewer representing each of the major HLA suites including SPEAR III, SNS and a couple of others.

## **6.0 Conventional Facilities Subgroup Summary**

H. Carter, T. Chargin, J. Cleary, A. Kugler, K. Schuh

### **6.1 General**

#### **6.1.1 Oct. 2007 Review Recommendations & LCLS Responses**

Design: Four recommendations resulted from the October 2007 review. All have been satisfactorily addressed.

Construction: Three recommendations were made. All have been satisfactorily addressed. However, the issue of construction delays due to budgetary reasons should be revisited for the remaining CF work.

Installation and Commissioning: One recommendation which was satisfactorily addressed.

Safety: Two recommendations were made. The first was accepted and implemented; the second consisted of a Report on LCLS Safety Performance containing six sections, each of which contained additional recommendations. The initial response from the Project Team was that some FAC safety comments weren't being addressed because LCLS safety had to be consistent with SLAC safety as a whole. Additional feedback from LCLS was that some FAC safety comments weren't being addressed because there was only a short time remaining to completion of the CF construction. FAC expects more. SLAC's own internal reviews have identified systemic safety problems at SLAC that still must be corrected and the Laboratory Director is pursuing solutions. Further, the LCLS project safety program needs to continue through construction of technical

systems, testing and commissioning, and into operations although it will likely feature different emphasis than during CF construction since the participants will have changed."

## **6.2 Design**

### **6.2.1 Findings:**

The Conventional Facilities has experienced low change order rates during construction, reflecting positively on the quality of the Jacobs design issued for construction. There were significant problems during design with construction bids exceeding the engineer's cost estimates. Construction contract awards exceeded estimates and budgets by ~50%. Other DOE projects were experiencing similar problems.

The LCLS Project reports good performance from Jacobs on Title III engineering support during construction, and has extended the duration of the Jacobs contract through the first quarter of CY 2009. Some of the testing to demonstrate the design function of Jacobs designed operating systems will not be completed during conventional facility construction because the Laboratory technical systems and equipment will not yet be in place. Jacobs has a limited role in Conventional Facility commissioning and testing, but will participate in reviewing selected test results such as for fire protection and vibration testing. Jacobs prepared the Commissioning Plan document issued with construction bid documents. This Plan specifies the selection and award of a contract for a Commissioning Agent. That contractor has been selected and is on-Site: Engineering Economics Inc (EEI).

The Project Office declined to accelerate design of Buildings 028 and 751 improvements because of other project priorities. Modifications to these building are slated to replace the function of the \$25 Million LCLS Support Buildings (CLOC) that were deleted from the Project during earlier budget cuts. The CLOC buildings were to accommodate 176 users. The design of Buildings 028 and 751 modifications will start in September, 2008, under a new design contract awarded by LCLS. The LCLS Conventional Facilities staff will also perform the construction management of these building modifications. The construction scope is estimated at ~ \$5 Million and the space will accommodate 171 users.

### **6.2.2 Recommendations:**

None

## **6.3 Construction**

### **6.3.1 Findings:**

The site tour on the first day of FAC review confirmed the Conventional Facility construction status, reported to be ~85% completed overall (the Turner scope is ~90% completed). The visual quality of the Conventional Facility concrete and utility installations is impressive; however, there are some dimensional problems with concrete placed.

The tunnel walls at the location of the beam dump are 1" from where the beam designers expected them to be. The construction location of the embed for the beam dump will have to be evaluated for serviceability. There is no construction nonconformance identified, construction tolerance is  $\pm 1/4"$ . Survey coordinates and benchmarks used for beam line and for CF construction should be cross checked for conformance.

The floor plane elevation variations in the undulator hall required grinding of concrete in order to place technical equipment. The surface variations exceed construction specifications and exceed the adjustment range of technical equipment pedestals.

The usual cleanliness problems in most remaining Conventional Facility construction areas will preclude use of co-occupancy to install sensitive Laboratory technical equipment until Turner has completed construction. Installation of temporary barriers to prevent migration of particulates could allow a progressive cleanup, but presents ventilation problems.

Conventional Facility construction is behind schedule, but Turner is expected to complete construction in less than the 28 months provided by contract. There is a net delay of 3-4 months in the scheduled completion of the conventional facility construction due primarily to late Turner contract award. To date, co-occupancy with Turner has lessened the impact of construction delays on the installation of LCLS technical systems.

The Conventional Facility project staff reports significant progress on negotiating a resolution to an early Turner claim. The CF staff also reports that Turner accepted the concept of co-occupancy as a no cost change order and has not submitted delay claims to date.

An accrual system has been implemented, so the progress payment schedule for Turner matches the construction completion quantities measured by field walkdowns. This was recommended by FAC to resolve conflicting progress reports.

Conventional Facilities contingency on remaining work is ~28%, broken down into three parts: Contracts Underway, Contracts To Be Placed, and Expected



Claims. Resolution of pending claims should allow a significant reduction in CF contingency.

### **6.3.2 Recommendations:**

If post-project beam line equipment is installed in tunnel areas where concrete surfaces out of spec have been accepted as-is, consideration should be given to increasing the adjustment ranges of new equipment to avoid concrete grinding and associated concrete dust.

The beam dump embed must be evaluated for serviceability. The survey coordinates for the CF construction and for the beam line should be cross-checked for conformity. If the survey coordinates for CF and beam line are different, there may be other ramifications than the beam dump embed location.

## **6.4 *Installation and Commissioning***

### **6.4.1 Findings:**

The conventional facilities commissioning appears to be progressing as planned. A third party Commissioning Agent was selected by competitive bid and the contract awarded to Engineering Economics Inc. The Commissioning Agent is charged with preparing a detailed Commissioning Plan and Report.

Jacobs prepared an initial Commissioning Plan that was issued with the construction bid documents. This plan specifies a limited role for Jacobs during Commissioning. Jacobs will review test results for Fire Protection Systems and Vibration, but will not review all test procedures and test results. Further, some of the Jacobs designed systems will not be tested until after CF construction contractors have been demobilized.

The FAC was not provided with a clear description of where responsibility has been placed for establishing testing configurations and engineering acceptance criteria in the absence of Jacob's participation in the testing of all Jacob's engineered systems. Further, there was no clear recognition that some Conventional Facility designed and constructed systems cannot be fully tested until well after completion of CF construction and demobilization of CF contractors because technical systems are not complete.

During the design phase, Conventional Facilities asked for a relaxation in tunnel floor settlement criteria, so a conventional tunnel cross-section and structural configuration could be built in the interest of cost and schedule. Though tunnels have been completed for several months in areas critical to beam alignment such as the undulator hall, only one set of data has been taken to date, so no settlement trends are yet available. Settlement is an identified risk to beam alignment and alignment frequency. Further, there is an expected settlement profile that cannot be verified without periodic data points.

### **6.4.2 Recommendations:**

Clear lines of custody need to be established for equipment handoff to operations following testing.

The commissioning sequence should consider operational needs, including the required safety systems.

Allow sufficient time in the commissioning schedule for documentation preparation and approval process associated with partial or full operational readiness reviews.

Verify that Jacobs has provided engineered acceptance criteria for planned test configurations on the systems designed by Jacobs Engineering.

Identify the CF designed and constructed systems that cannot be fully tested before CF contractors are demobilized. Document and mitigate as appropriate the contractual and technical risks to the Project.

Take settlement data early and periodically to monitor and quantify the risk to beam alignment, and to determine the alignment frequency that will be required during operation.

## **6.5 Safety**

### **6.5.1 Findings:**

Since the last FAC safety review, the Conventional Facilities has again experienced two significant lost time injuries. One was a serious hand injury that resulted from losing control of an improperly rigged hoist load. Rigging intended for incremental loads was attempted on combined loads. The rigging plan did not consider the method of hoisting the combined load.

On the second lost time injury, a backhoe operator lost control of the backhoe, striking his own observer. The operator had placed a roll of tape on a control lever for storage, and inadvertently hit the roll of tape with his leg, rotating the backhoe into his observer. The observer was said to be distracted, speaking to his supervisor at the time, and did not take evasive action.

For the last two months, there have been no lost time injuries reported. The project has implemented the FAC recommendation to assign LCLS CF resources to participate in the implementation of the Turner safety program and process. LCLS Project Management has added three University Technical Representatives (UTRs), an on-site medical professional and two Turner superintendents to improve Turner's safety performance. LCLS Management has identified a clear need to improve pre-task planning and enforcement of LCLS standards.

The project has successfully implemented joint occupancy with Turner to date without reported safety incidents. Though Turner maintains area control, the joint

planning meetings with Turner for work in co-occupied areas provide CF staff another opportunity to participate in Turner safety planning. Attendance at daily planning meetings is required to work in co-occupied areas.

The SLAC Director recognizes the role LCLS plays in the future of the Laboratory and the SLAC safety culture. She has stated her support for initiatives on the LCLS that impact and improve SLAC safety culture. She has stated there is a need for changes and improvements. With the shift from civil construction to commissioning and operations, the LCLS and the SLAC safety culture are expected to become increasingly integral and co-dependent. Future FAC safety reviews will place greater emphasis on commissioning, operations safety, and the safety culture that is evident on-site at SLAC.

The SLAC Job Safety Analysis (JSA) process works when followed. CF has implemented a Safety Stewardship Committee. Turner has increased its presence in the field by meeting with individual work crews daily.

The only indicator of safety performance presented to the LCLS FAC was the DART (Days Away from work, Restricted Time or transfer from job) rate. When the FAC asked to breakout separately and discuss other indicators being tracked to identify the success of the safety program, no time could be found to talk to the committee.

LCLS directly managed construction activities, though not as extensive as Turner's, have a zero DART rate, while Turner's safety performance has been unacceptable. CF Technical Representatives manage by subcontract so the safety performance of the subcontractor is more directly accountable to an individual. In contrast, Turner superintendents manage by construction geographical areas that generally include work performed by multiple subcontractors.

Several of the FAC recommendations for safety program improvement were not implemented by LCLS because of the relatively short time to completion of Turner construction. The LCLS project will continue for two more years, and Conventional Facility construction will continue into CY 2009. There is ample time remaining on the Project duration to improve the LCLS project safety program.

### **6.5.2 Recommendations:**

Continue to support Turner safety practices and initiatives with LCLS resources to reduce the risk of additional safety violations and personnel injuries through the completion of the Turner construction scope.

LCLS should take the lead in establishing the safety culture the Laboratory Director has targeted for the Laboratory as a whole. The LCLS and the Lab safety cultures will become increasingly integral and inseparable as commissioning and operation of LCLS systems progress.

SLAC safety violations identified during LCLS reviews should be addressed and promptly corrected whether specific to the LCLS project, or SLAC generic. The three SLAC safety issues identified and reported to LCLS safety representatives during the June 2008 FAC review of LCLS should be justified or corrected. If LCLS management prefers the FAC safety reviewers deal directly with SLAC's safety department on such issues, they should identify the SLAC interface personnel to be contacted by the FAC.

Track and report the precursors to lost time injuries in order to take corrective actions in time to prevent them. DART statistics are not sufficient if zero lost time injuries is the goal, and it is. To monitor precursors requires monitoring minor injuries, property damage, near misses, non-compliances, and then taking corrective action. Herbert Heinrich wrote in his 1930's book that no safety procedure is complete or satisfactory that does not provide for the correction or elimination of physical hazards. Heinrich found that there was a constant ratio between fatal, light and near-accident of 1:29:300. This conclusion is useful when analyzing the frequent near-accidents (or less severe hazards) to detect organization problems and intervene before a serious or fatal accident happens.

The DOE Lessons Learned database should be utilized as a tool to improve JSA preparation. At the present, this database is only used by reviewers. Further, do not underestimate the time required to prepare safety related documentation and the time it takes for the approval process. As an example, the DOE level 2 milestone for completion of the Injector ARR was 42 days late.

## **6.6 CF Closeout**

### **6.6.1 Findings:**

Conventional facilities is rapidly approaching the beginning of the closeout phase of the project that will include a myriad of new activities including field walkdowns, spare parts and excess materials, contract closeouts, administration of punchlists, preparation of lessons learned, assembly of a CF closeout report, and retaining key personnel to complete work while destaffing unneeded resources.

Inadequate attention has been paid to "lessons learned". The project staff needs to track these. Include in these lessons learned the procurement strategy used in award of the design contract and the CM contract, both of which subsequently presented LCLS management with significant cost, schedule, and safety performance problems. The goal of lessons learned is to repeat the successes on future projects, and to preclude the failures by doing things differently next time.

Conventional Facilities has a detailed plan for destaffing of lab personnel, but Turner does not have an updated destaffing plan approved by LCLS. Turner has not provided a demobilization plan.

Conventional Facilities reports they have started a closeout punchlist, but did not present this list to the FAC for review.

### **6.6.2 Recommendations:**

Develop a detailed, comprehensive CF closeout list and provide that list to FAC for review.

Request Turner submit a detailed de-staffing plan for LCLS review and approval. Update and maintain de-staffing plans so they are always current. Assure that Turner's de-staffing plan best serves the needs of the LCLS project to completion. Anticipate that Turner may have incentive to release key personnel early for their future/on-going projects elsewhere.

Obtain and review Turner's demobilization plan.

Identify the lessons learned, both successes and failures, on the CF scope of the project and provide these lessons learned to the FAC for review. In seeking the root causes for successes and failures, consider asking the question "why" several times to converge more precisely on the root cause.

## **Appendix A**

### **LCLS Facility Advisory Committee Members**

## LCLS Facility Advisory Committee Members

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## **Appendix B**

### **Facility Advisory Committee Meeting Agenda**





## LCLS Facility Advisory Committee Meeting Agenda

June 16-18, 2008

### Monday, June 16<sup>th</sup>

#### Plenary Session

**Location:** Redwood Conference Rooms, Building 48

<b>Time</b>	<b>Topic</b>	<b>Presenter</b>
8:00	<i>Executive Session</i>	<i>Committee</i>
9:00	Welcome	P. Drell
9:15	Project Status Update, and Charge to Committee	J. Galayda
9:45	Project Management	M. Reichanadter
<b>10:15</b>	<b><i>Break</i></b>	
10:30	Commissioning Results and Plans	P. Emma
11:00	2009 Commissioning Plans	P. Emma
11:30	Undulator Commissioning Plans	H. D. Nuhn
<b>12:00</b>	<b><i>Lunch (FAC members only)</i></b>	
1:30	FEE Diagnostics & Commissioning	R. Bionta
2:00	X-Ray Commissioning	H. Tompkins
<b>2:30</b>	<b><i>Break</i></b>	
3:00	<i>Construction Site Tour</i>	
4:30	Executive Session	<i>Committee</i>
7:00	<i>Dinner – Compadres, Palo Alto</i>	<i>Committee/Speakers</i>

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### Tuesday, June 17<sup>th</sup>

#### Breakout Sessions

<b>Time</b>	<b>Topic</b>	
7:30	<i>Executive Session</i>	Redwood A
8:00	<i>Breakout Sessions Begin</i>	(see below for listing)
3:30	<i>Executive Session</i>	Redwood A

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### Wednesday, June 18<sup>th</sup>

#### Executive and Closeout Session

**Location:** Redwood Conference Rooms, Building 48

<b>Time</b>	<b>Topic</b>	<b>Presenter</b>
7:30	Executive Session	Redwood C/D
8:00	Executive Session, <i>or More Breakouts if Required</i>	Redwood C/D
9:30	Executive Session	Redwood C/D
11:00	Closeout – Plenary	Redwood Rooms



## Breakout Session Schedule

### Tuesday, June 17<sup>th</sup>

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#### Breakout Session 1 – Accelerator Systems

Location: Redwood C, Bldg 48

Time	Topic	Presenter
8:00	Overview	D. Schultz
8:30	Drive Laser and Hand-Over to Operations	B. White
9:00	RF Gun(s) Status	A. Brachmann
9:30	RF Systems, Diagnostics, and Feedback	J. Frisch
<b>10:00</b>	<b>Break</b>	
10:30	High-Level Applications Software	H. Loos
11:00	TU/Dump Installation Status & Schedule	J. Chan
11:30	LTU Installation Coordination	K. Ratcliffe
<b>12:00</b>	<b>Lunch (FAC members only)</b>	
2:00	Discussion	<i>all</i>
3:30	Executive Session	

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#### Breakout Session 2 – Undulator Systems

Location: Red Slate, Bldg 280C, Room 112

Time	Topic	Presenter
8:00	Undulator System Overview & Fabrication Schedule	G. Pile
8:30	Undulator Vacuum System	D. Walters
9:00	RF BPM Status and Production Test Results	B. Lill
9:30	BFW Production Experience and Test Results	V. Srinivasan
<b>10:00</b>	<b>Break</b>	
10:30	Girder Control Production Status	J. Stein (video)
11:00	WPM/HLS Status and Schedule	F. Peters
11:30	BLM System Design	B. Berg
<b>12:00</b>	<b>Lunch (FAC members only)</b>	
1:30	Undulator Tuning and Fiducialization Schedule	Z. Wolf
2:00	Girder Assembly and Installation Schedule	J. Krebs
2:30	Undulator Controls Status	A. Alarcon
3:00	Discussion	
3:30	Executive Session	

### Breakout Session 3 – X-Ray Systems, Including LUSI

**Location:** Redwood B, Bldg 48

<b>Time</b>	<b>Topic</b>	<b>Presenter</b>
8:00	AMO Instrument	J. Bozek
8:30	LUSI Overview	T. Fornek
9:00	XPP Instrument	D. Fritz
9:45	CXI Instrument	S. Boutet
<b>10:30</b>	<b>Break</b>	
10:45	XCS Instrument	A. Robert
11:30	LUSI Diagnostics and Optics	Y. Feng
<b>12:15</b>	<b>Lunch (FAC members only)</b>	
1:15	XTOD mirrors	T. Mccarville
1:45	Fast imaging detectors	N. van Bakel
2:30	X-ray commissioning	H. Tompkins
3:15	Discussion	<i>all</i>
3:30	<i>Executive Session</i>	

### Breakout Session 4 – Controls

**Location:** Redwood A, Bldg 48

<b>Time</b>	<b>Topic</b>	<b>Presenter</b>
8:00	BC2/Linac commissioning	H. Shoaee
8:30	LCLS MPS	S. Norum., P. Krejcik
9:00	Undulator BLM system	J. Stein
9:30	Undulator Controls	A. Alarcon
<b>10:00</b>	<b>Break</b>	
10:30	Application Software Status and Plans	P. Krejcik, D. Rogind
11:00	Beam-Based Feedback Systems	D. Fairley
11:30	High Level Applications	H. Loos
<b>12:00</b>	<b>Lunch (FAC members only)</b>	
1:30	LTU/Undulator Installation Status	E. Carrone
2:00	Photon Area Control & Data Acquisition	G. Haller
3:00	Discussion	<i>all</i>
3:30	<i>Executive Session</i>	

### Breakout Session 5 – Conventional Facilities

**Location:** Redwood D, Bldg 48

<b>Time</b>	<b>Topic</b>	<b>Presenter</b>
8:00	Status of Construction	J. Albino
8:30	Far Experimental hall Hutches	D. Saenz
9:00	Space Conversion to Offices	D. Saenz
9:30	Commissioning Plan	J. Sevilla
<b>10:00</b>	<b>Break</b>	
10:30	Construction Safety	M. Scharfenstein
11:00	Discussion	<i>all</i>

