

## **Response to the Comments and Recommendations of the 7-8 April 2005 Meeting of the LCLS Facility Advisory Committee\***

Committee Membership: H. Carter, A. Chargin, J. Cleary, J. Corlett, M. Cornacchia, R. Falcone, J. Feldhaus, P. Fuoss, T. Himel, A. Kugler, J. Pflueger, T. Rabedeau, K. Robinson (Chair), K. Schuh, P. Siddons, T. Tschentscher, K. White

### **1.0 General**

#### ***Introduction and Charge***

The Linear Coherent Light Source (LCLS) Facility Advisory Committee (FAC) met with the LCLS project team on 7, 8 April 2005. J. Galayda specifically charged the Committee 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

The Committee was divided into four subgroups: the Electrons Subgroup that covered the accelerator and undulator systems design and construction, the X-Ray Subgroup that covered x-ray transport, optics, diagnostics and experiment station systems design and construction, the Controls Subgroup, and the Conventional Facilities Subgroup. The X-ray Subgroup was also briefed on the fast x-ray detector development plan and the MIE project that has been separately funded by Basic Energy Sciences Program (BES) within the Office of Science (SC) of the Department of Energy (DOE). Appendix A is a listing of the members of the Facilities Advisory Committee that were present at this meeting and their respective subgroup assignments. Appendix B is the Agenda of the 7, 8 April 2005 FAC meeting.

The following sections address the specific points of the charge through the summary reports of the subgroups. General comments and recommendations precede these summary reports in this section.

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\* Meeting was held at SLAC on the 7-8 April 2005. This report contains the committee's final report. Additional text in bold (red) contains the responses from the LCLS management team.

## **General Comments and Recommendations**

The LCLS project appears to be doing very well based on the progress since the last FAC meeting. Many technical challenges and project challenges were addressed and are cited in the subgroup summary reports.

Members of the FAC had minor concerns about the organization chart as having a *baroque* appearance in that on the surface, lines of authority don't appear to be that clear. However, throughout the course of the FAC meeting clear lines of responsibility and authority were in evidence and only a few issues on communication (notably between the physics requirements on the conventional facilities and the operations configurations and approaches) were apparent. **Response: The LCLS organization chart has been revised to clarify roles and responsibilities.**

The management of the LCLS project appears quite strong and as the execution of the project progresses the FAC expects to see this strength fully manifest itself and begin to show up in transition to operations planning as well. The risk registry for the project is in good shape. The project updates the risk registry on a monthly basis and is using the registry as a management tool and not merely a data request to pass an external independent review.

An example of effective management within the project is that a lot of x-band hardware has been obtained from the Next Linear Collider Test Accelerator (NLCTA) at virtually no cost representing a significant savings and effective reuse of available infrastructure.

The LCLS project should incorporate additional items that are still in trade off into the risk registry:

1. Undulator tunnel floor stability in trade-off with the required timeframes for the various types of beam-based alignment (BBA);
2. The trade-offs of the operational and commissioning approaches being explored as these trades present a schedule and/or cost risk to the project and commissioning of the facility; and
3. The project should incorporate those risk or trade-off items identified in this and previous FAC meetings into the Project Risk Registry to ensure adequate tracking and resolution. The project may wish to also incorporate any such risk items cited in official DOE reviews as well.

**Response: The LCLS organization continues to use the Risk Registry on a monthly basis as a key management tool to proactively address its known risks. The undulator floor stability risk has now been retired as it has now been shown that expected stability issues can be addressed with the alignment systems and BBA at acceptable intervals.**

The project is entering into its *boost phase* where it is undergoing its maximum gradient: staffing, effort and procurement. During this phase, the timeliness of decisions often

becomes critical and delays can quickly accumulate that can impact the overall progress of the project without specific attention. This is a concern to the FAC as the decision making process is not transparent and may need to accelerate to ensure avoiding unnecessary delays. Often *position papers* (risk assessments) can assist in arriving at a timely decision.

**Response: The decision making process has been made more transparent with the Change Control Board (CCB). With the CD-2b (Approve Performance Baseline), LCLS has enacted the CCB to deal with technical, cost and schedule issues on a timely basis. The CCB forum ensures that decisions are communicated uniformly across the project and formally documented in a manner consistent with good configuration control. Since CD-2b (April 2005), LCLS has approved 77 changes to the project and allocated ~\$7M of contingency to the baseline cost of the LCLS.**

Also, during this *boost phase* of the project particular care should be exercised in that inefficiencies from rapid staff increases can stall progress and burn funds without gaining attendant earned value. The *critical path* of the project, likewise, may be extremely fluid during this phase and near critical paths can quickly become critical paths, and so those efforts which at present are not on the critical path, must understand that they can quickly become the pacing activities.

**Response: The LCLS has significantly increased its staffing since April 2005 and with that some time for assimilation of new staff into the project is required. The LCLS is now nearly complete on its staffing plan so the inefficiencies due to assimilation can be expected to drop off. Critical path is monitored regularly and has not shown any appreciable degradation since established at 215 days.**

The earned value integrated baseline plots (related to BCWS) do not show contingency use or the options available to the Project in managing project float and fiscal budgets. This is consistent with the ANSI/EIA standard to which all large DOE projects are being held. However, an insightful planning exercise is to evaluate all activities for early starts up to the point where all of the budget authorization (BA) in each fiscal year would be used. In addition, exceeding this optimistic BA plan by 5 to 10% would also be helpful in evaluating potential resource demands. This planning assures that there are “swing items” identified in order to accomplish other work if planned activities are delayed. If the project doesn’t have swing items identified to work in the available time and with the available BA, the CD-4 milestone may be at greater risk than necessary. The level of effort and indirect costs to a project often continue even if no direct earned value is realized, so not performing alternate work in the time available will increase costs. However, care must be taken to assure that substitution of activities with float for scheduled work not performed is both productive and efficient.

**Response: “Swing procurements” are procurements that can be advanced should budget become available due to delays in other areas. This is of primary importance between FY06 and FY07. Since civil construction sets the critical path,**

**LCLS will plan to use its budget flexibility in this area to best advantage, based on advice from the Construction Manager.**

In addition, a planning exercise that addresses the project resources needed to productively expend the entire BA in each year provides insights on a more demanding resource plan. A useful plot that can illustrate this phenomenon, and serve as both a leading and lagging indicator, is the contingency as a percent of the estimate to complete (ETC) budget as a function of the percent of the project complete. Generally, this should be roughly a horizontal line above 20%. Early in the project life it would likely start out at a higher number and depending upon the remaining risks within a project, the percentage can also be less than 20%.

**Response: Currently, the LCLS holds ~32% contingency on work remaining. This number may fall lower as the conventional facilities estimates become more mature and LCLS approaches the start of construction.**

There is a need for a central database containing and controlling the complete configuration of the LCLS project. This is not just a controls effort. This need remains from previous FAC meetings and is greater than ever. A hire is supposedly in progress, however if such a controlling database doesn't happen soon, many parts of the project (controls in particular) will likely develop their own disjointed workarounds that will make coordination difficult. Then, when a central database is finally added natural resistance will hamper adoption and effectiveness.

**Response: Work has begun on defining the detailed needs of the central database effort for the LCLS project. An IT Manager (Andrea Chan from the SLAC SCS group) has been hired into the LCLS Division and bringing significant experience in setting up databases in a project environment. At the same time Sergei Chevtsov in the LCLS Controls Group has been looking at the relational database needs for the control system, in particular the RDB requirements for online modeling for the accelerator. LCLS is comparing several database schemes, including those from SNS which work with the XAL online model, and those from PEP II for which there is a larger amount of in-house expertise.**

The matrix memoranda of understanding (MOUs) that the project has put in place are very good and provide some measure of protection during this period of maximum gradient.

The LCLS Project should consider giving the FAC access to the LCLS internal website. This would allow the FAC to view other reviews and important work that can have an impact on the scope and details of FAC meetings. It will also allow the LCLS Project to exploit the full potential of the FAC.

**Response: Presently, access to internal project data requires a SLAC computer account, which in-turn requires the individual to become a SLAC user. The process requires a significant amount of paper work. LCLS is in the process of exploring a different data management system, which would make access control but the system is not likely to become operational in this calendar year. At present, LCLS is working with Kem Robinson to do it the hard way now or wait until the simpler solution is in place.**

## 2.0 Electron Systems Subgroup Summary

### ***Management***

The committee once again recognizes the excellent accelerator team supporting the LCLS project. In particular, the appointment of Paul Emma (SLAC) to lead the Accelerator Team is applauded.

### ***Photoinjector***

#### Laser systems

The selection of a vendor is a significant step and the choice appears to have been made on sound technical grounds. Laser pulse shaping remains an R&D item, and activities at LLNL and ANL in pulse shaping and third harmonic generation (THG) should continue. Care should be taken in the coordination of the laser R&D activities to avoid conflicting demands on the sub-systems. The details of operational stability of the system remain to be determined.

**Response: Coordination of the efforts of LLNL and ANL is centralized in the LCLS Laser Group. As design elements are completed at LLNL and ANL, they are incorporated into the final design which is then reviewed by all interested parties.**

The purchase of a second laser has been postponed until after experience has been gained with the first system. The Committee recommends that this not be forgotten and remains in the plan. A decision on a new gun test facility (GTF, see later) may influence this timescale.

**Response: The purchase of a second laser is not in the current baseline but has not been forgotten.**

The strengthening of the laser team remains an important goal. The Committee recommends that LCLS management address the issue of building up this team.

**Response: The LCLS Laser Group leader (Bill White) started in May and a long term staffing plan for the group has been developed and is currently being reviewed and synchronized with the other groups within LCLS**

### RF gun

The in-house fabrication of the rf structure will begin soon, based on the completed physics design. The first gun is expected to be completed in April 2006. The prompt completion of a second gun is encouraged.

**Response: A second gun will be fabricated along with the first and will be integrated into a complete backup gun system. The gun assembly includes the dual feed gun, solenoid and vacuum isolation valve on a common support structure. The entire assembly can be tested separately and be a fast replacement of the first gun assembly at Sector 20 if needed.**

While the physics design is very thorough, the Committee recommends that gun wake field effects be investigated.

**Response: The concern of wakefield in the gun had been raised when too large energy spread had been measured on the GTF which could not be identified. This large energy spread cannot be explained by applying the well-assessed longitudinal wake formula to 1½ cells. However, the  $\pi$ -0 mode beating seems to explain the large energy spread. In the LCLS gun, the  $\pi$  and 0 modes are separated by 15 MHz instead of 3.5 MHz, so this effect should not be present. Also, physicists from the ACD group plan to perform full PIC simulations with the exact LCLS parameters, which should confirm this statement. The PIC simulation cannot be completed before the next FAC meeting given the limited manpower, but will be done in the coming year.**

H<sup>-</sup> cleaning of the cathode surface shows promise in improving quantum efficiency (QE), and continued study of this process is expected to prove it to be a useful technique.

**Response: Modifications in the budget have been incorporated to pursue this effort and test the technique on the second gun assembly.**

### Beam dynamics

The 3-D ellipsoidal electron distribution presented during the FAC meeting is a novel approach for photoinjectors and has promising capabilities. We encourage the continued study of the practical aspects for producing such beams.

**Response: This type of shaping should be pursued once the basic process is understood of shaping and frequency-converting the laser pulse to achieve the nominal 'square pulse'. Thus the square pulse shape remains the LCLS baseline, but techniques for producing the ellipsoidal shape are being discussed.**

### GTF

While recognizing that results from GTF have provided useful guidance in improving the gun design for LCLS, and have given confidence in gun performance parameters, the Committee understands the management decision to phase-out GTF activities.

Nonetheless, we strongly encourage the development of a new permanent facility for gun testing and development.

**Response: Due to delays in identifying a location and funding for a new gun test facility, GTF will be funded through FY2006.**

### **Linac**

Physics studies of a low charge configuration with 0.2 nC per bunch indicate an emittance of 0.8  $\mu\text{m}$  and peak current of 2 kA. This presents an operating regime with several advantages including more uniform current and FEL output distribution, and reduced wake fields in the linac and undulator vacuum chambers. Operation in this mode is achieved through adjustment of accelerator component settings, and does not impact engineering designs. The Committee applauds this initiative that increases confidence in performance and flexibility in choice of operational parameters.

### **Collimators**

Continued comprehensive studies of dark current, beam loss, and collimation are providing a significantly deeper understanding of the radiation levels along the linac and the undulator. The proposed collimation systems appear to be suitable in providing protection to the undulators.

The radiation produced by scattering from OTR foils in the undulator is a concern. The Committee recommends that a plan be developed to minimize risk of damage to undulators from OTR screen use.

**Response: With regards to the undulator, Radiation Physics simulations have shown that OTR foils are not likely to cause a problem if designed and used properly. A foil of 10 microns thickness or less used for a few shots at a time will not cause a problem. The use of the foil will be interlocked to the MPS system. Also, bunches will not be allowed to enter the undulator area while the OTR foil is performing an insert or remove motion (indeterminate position).**

**Presently, the plan for the undulator OTR foils is being reduced down to an R&D project. We are removing the funds for actually building and installing OTR foils in the undulator area from the base line. We will still have the ability to measure the x and y beam sizes at every undulator break by using the secondary function of the Beam Finder Wire (BFW).**

**Although this comment addresses screens in the undulator, it is worth pointing out that undulator protection from radiation due to inserted screens in the linac and LTU is accomplished using the beam abort kicker with the MPS logic, and the insertable stopper upstream of the undulator. Any screen inserted in the linac will fire the abort kicker for all pulses until the screen is removed. As for the two screens downstream of the kicker, but upstream of the undulator, the driver laser**

**will be used to inhibit the electron beam when these screens are inserted (or indeterminate) unless the undulator entrance stopper is inserted.**

## ***FEL Physics***

Since the last FAC meeting there has been major progress in understanding and alleviating the effects of the ac resistive wall impedance. Resistive wall wake fields have been thoroughly analyzed by theoretical and computational studies, and by experimental measurement of relevant materials properties. These studies have significant impact on the design of the facility, including selection of a rectangular aluminum coated stainless steel undulator vacuum chamber, and support the desirability of the low-charge option in further reducing wake fields. Undulator tapering may be an additional tool in improving performance in the low-charge regime.

The committee was pleased to see the comprehensive wake field budget.

## ***Undulator***

### Alignment

The undulator system is well instrumented and the depth of studies bodes well for achieving the required tolerances. The procedure to align the undulator appears to be feasible and offers additional redundancy; however, the justification for an upstream beam monitor was not made clear.

**Response: The need for the upstream beam monitor, *i.e.* the Beam Finder Wire (BFW), comes from the tight tolerances for positioning the electron beam on the undulator axis as defined during the tuning procedure. While this alignment can be achieved using a portable wire position monitor system, using such a system requires extended tunnel access during the commissioning process after a straight electron beam trajectory has been established with the beam-based alignment procedure. The BFW will provide a beam-based measurement, and allow this alignment task to be accomplished from the control room without the need for tunnel access. The portable wire position monitor system will serve as a backup.**

Concern remains about the ground settlement and stability of the undulator hall floor. The Committee recommends that LCLS project physicists quantify the allowable ground motion given the range of instrumentation available, and provide specifications on ground motion based on realistic day-to-day alignment and periodic beam-based alignment. The physics analysis should include study of the extent to which the systems can accommodate movements beyond the survey tolerances.

**Response: LCLS has studied more carefully the tolerances for alignment variations over both short and long term time-scales, and have devised an escalating series of beam-based correction levels, each with an associated time-scale and tolerable FEL power loss, as was suggested by the FAC in April 2005. The ‘bulls-eye’ diagram proposed by the FAC has been tagged “Kem’s Zones” and will be described in some**



**detail in the presentations. Briefly, the correction levels extend from shot-to-shot trajectory feedback systems, to hourly ‘micado’ steering algorithms, to daily weighted steering or ‘BBA-light’, to weekly BBA, and finally to semi-annual conventional alignment. The outcome of these studies has also served to define the tolerable trajectory drift errors over short term (BBA execution duration: 1 hr) and longer term (diurnal variations: 1 day). These tolerances are incorporated into the undulator Physics Requirements Document (PRD) 1.4-001 and serve as a guideline for the design of supports, temperature regulation, and BPM systems.**

### 3.0 X-Ray Subgroup Summary

#### ***Presentations to the Committee***

The x-ray subgroup heard presentations from three members of the LCLS management team on five different topics: 1) x-ray transport and diagnostics, 2) the addition of a low-pass mirror system to the project, 3) scope and plans for end station development, 4) x-ray detector development activities, and 5) the instrument MIE project. Each of these areas will be summarized below.

#### X-Ray Transport, Optics and Diagnostic Systems (XTOD)

Plans for XTOD were discussed by Rich Bionta (LLNL). XTOD requirements were also reviewed. Work on the design of the various x-ray transport and diagnostic systems has resumed after the end of the Congressional fiscal 2005 year continuing resolution. Twenty-two people work on the project, but only at a rate of 6.8 FTE.

**Response: The FTE rate at LLNL for LCLS activities was 6.9 in Feb., 8.4 in March, 10.82 in April, 13.26 in May, 12.97 in June, 15.16 in July and 13.45 in August.**

There has been a significant amount of work done on conceptual design of detectors. Monte Carlo simulations of the response of the wide field of view direct imager (WFOVDI) were presented. It appears that the WFOVDI will have the required sensitivity to separate the spontaneous radiation from the FEL radiation, and will be a useful diagnostic. The current plan is to fabricate a prototype by September 2005.

**Response: The Direct Imager prototype has been slightly delayed by work on concepts and layouts for the new FEE that includes the FEL offset mirror system.**

Similar simulations of the indirect imager were presented. A conceptual design and Monte Carlo simulations of an x-ray bolometer array were presented. This detector appears very promising for total energy measurement and detection of the FEL radiation.

**Response: LCLS has continued to push the development of the bolometer detector. We funded researchers at Townsend University who have prepared CMR sensor elements now under test at LLNL. Further heat transfer modeling has confirmed our design assumptions.**

There has been some investigation of spectrometers and monochromators to monitor the energy profile of the FEL beam and these efforts were summarized. However, there needs to be a more systematic investigation of the various options.

**Response: Measurement of the spectrum of LCLS radiation, both spontaneous and FEL, will be an important diagnostic tool. Much work was done this summer on defining the requirements for spectral measurements. A workshop will be held in early November 2005 to compare calculations by different groups and form a consensus about the optimal measurement strategy for using the spontaneous spectrum to measure undulator k values to the precision needed for FEL lasing. Several LCLS groups (XTOD, XES, and Undulator) have been involved in this effort.**

Damage experiments are planned for October 2005 at the TTF. These are very important experiments to confirm the LLNL damage codes.

Finally, Rich Bionta reviewed the FAC findings from Oct. 2004 that relate to XTOD systems. Staff has been added in key areas but they lacked time to fully resolve any other earlier issues.

#### X-Ray Low Pass Mirror System:

John Arthur (SLAC) presented conceptual plans for a new x-ray low-pass mirror system which will move the x-ray beam 25 mm off of the FEL centerline. Scientific and safety concerns both drive this addition. These concerns arise from the significant background of very high energy ( $E_c \approx 150$  keV) spontaneous radiation and bremsstrahlung from scattered electrons. The mirror system will use a pair of SiC mirrors in a parallel setting. The FAC X-ray Subgroup (Paul Fuoss in particular) pointed out that there were many other possible mirror configurations and some of these could also perform additional necessary functions as well. An extensive discussion over the desirability to maintain the capability to see the unmodified synchrotron spectrum also occurred.

#### X-Ray Endstation Systems:

Stephan Moeller (SLAC) described the current plans for LCLS development of endstation systems. Many of the original objectives of this portion of the project have been transferred from the LCLS project to the ~\$50M instrumentation major item of equipment (MIE) project (referred to as PIXEL during the FAC and now known as LUSI [July 2005]). This portion of the LCLS work breakdown structure (WBS) will now focus on providing personnel protection systems (PPS), machine protection systems (MPS), network and computer support, and prototype detectors for the experimental project; and

instrumentation for the first Atomic Physics (AMOP) experiments. There was extensive discussion of the layout of the XTOD and AMOP instrumentation. The plans at this stage are still very schematic and there are important issues to be resolved about space allocations.

#### LCLS Detector Development:

John Arthur presented an overview of the LCLS detector development plans. The issue confronting LCLS is that FEL data comes in very large, ultra-fast pulses and current x-ray area detectors are too slow and too noisy for LCLS experiments. LCLS has formed a Detector Advisory Committee (LDAC) with a very strong, international membership. LCLS will continue to develop a pixel array detector with researchers from Cornell University. It is expected that the MIE project will develop a detector in collaboration with BNL using silicon drift technology. In addition to these high performance 2-d x-ray detectors, LCLS is also participating in the development of streak cameras, beam imaging cameras and intensity monitors.

#### The Instrumentation MIE (PIXEL) Project:

A summary of the proposed PIXEL project was presented by John Arthur. The PIXEL project is envisaged to support 1) pump-probe diffraction, 2) nano-particle and single-molecule imaging, 3) x-ray coherent scattering, and 4) soft x-ray coherent imaging. It is expected that experiments 1 and 2 will be finished by 2009 and that 3 and 4 will be operational in 2012. The remaining LCLS thrust area, high-energy density science is deemed outside the mission of BES and will require funding from another source. The physical infrastructure, particularly the experimental areas in the Near Experimental Hall (NEH) and Far Experimental Hall (FEH), developed by LCLS will have a strong impact on the PIXEL project. There was an extensive discussion of different hutch layouts and their strengths and weaknesses.

#### **Concerns of the FAC**

The Committee must reiterate that the main concern continues to be the lack of detail concerning specifications and needs resulting from a comprehensive analysis of the proposed experiments.

**Response: The process of working with the LCLS Science groups and defining the specifications and requirements for the experiments has started. We expect this situation to improve rapidly as this process is optimized with the hiring of the LCLS instrument scientists.**

This situation is improving, but there is urgent need for convergence on the physical layout of the experimental halls. The most pressing need is to finalize the hutch layout in the FEH. At the previous FAC meeting, one design for the FEH was presented. At this FAC meeting there are three competing designs for the FEH. Since these different hutch layouts dictate different building designs, this uncertainty negatively impacts the civil design and construction part of the project.

**Response: The physical layout of both the NEH and FEH have now been defined, and approved by the LCLS SAC and the LCLS Science Team Leaders.**

In addition, the FAC is concerned about the layout of optics and experiments in the front end enclosure and the near experimental hall. It appears that both the diagnostics effort and the experimental program expect to use the same space. It is crucial that the space be used efficiently yet there is poor coordination between the affected parties.

**Response: LCLS has increased the length of the FEE so that the critical diagnostics formally located in the NEH Hutch 1 could be moved to the FEE upstream of the offset mirror system.**

The Committee also remains concerned that there are no conceptual solutions to the non-destructive characterization of each pulse of the FEL. We reiterate that, since both the nominal photon energy and the total energy per pulse will vary significantly from pulse-to-pulse, such characterization may be crucial to the scientific program of the LCLS. Such measurements are unique to FELs and it is difficult to extrapolate existing synchrotron technologies for their solution.

**Response: LCLS has put back the ion chamber diagnostics into the WBS (it was eliminated due to budget considerations.) Two concepts are under study, both employ windowless, differentially pumped gas chambers, but differ in their readout scheme.**

We have expressed concern in the past regarding the stability of optics, particularly those used to steer the beam to the FEH experiments (see report from Oct. 2004). The addition of numerous additional mirrors amplifies this concern. In addition, we are concerned about the degradation of the proposed mirrors from high peak FEL flux, high energy photons from the spontaneous radiation, and high energy particles from the accelerator.

### ***Endorsements of the FAC***

1. There is a good staffing plan in place and a great deal of progress has been made on hiring appropriate staff.
2. The Committee believes that there is a good plan for detector development.
3. The workshops and periodic meetings with the scientific teams is improving communications.
4. There is good alignment between the administrative structure and staff efforts with the important scientific and technical problems.

### ***Recommendations of the FAC***

1. Efforts of the x-ray group should focus on problems which are unique to LCLS.

**Response: The X-Ray group is expanding and the relationships between XTOD, XES and the LUSI project are becoming much clearer. LCLS is working to further define these roles and relationships with the above recommendation foremost in mind.**

2. The hutch layout in the FEH needs to be quickly finalized. The FAC specifically recommends:
  - That all hutch and assembly areas should have same height
  - The “Stephenson” staggered hutch arrangement
  - That the on-axis hutch has provision for “white” beam

**Response: The final layout has been chosen and follows these recommendations.**

3. The optics, and particularly mirror, design needs to:
  - Preserve option for straight through (white) beam operation.
  - Deal with personnel protection issues now as they will not become easier later.
  - Investigate the impact long-term damage to mirrors and coherence preservation.
  - Include stability and alignment issues in design.
  - Generate holistic design that preserves future flexibility

**Response: LCLS intends to follow all of these recommendations as optics are designed. Specifically, though use of white light is not anticipated in the NEH of FEH, the design does not exclude this possibility. The FEE has been lengthened and access has been upgraded so that white-light experiments can take place there.**

4. The project should design a revised beam transport, optics and hutch layout which:
  - Optimizes space usage in the FEE and NEH.
  - Reconciles competing demands of the diagnostic and experimental efforts.

**Response: The revised design for the FEE and NEH follows the recommendations.**

## 4.0 Controls Subgroup Summary

### ***Concerns from last review that have been well addressed***

There has been a lot of progress made since the last FAC meeting in October 2004. Many of the suggestions we made at the last meeting have been implemented. It was very convenient that each presenter made sure to list the suggestions from the last meeting stating the progress that had been made. We encourage a continuation of this presentation style.

Here are a few specific places where good progress was made along with comments about further work that is needed.

1. The WBS structure has been changed to put virtually all the design effort in a central controls element. Only the costs of mass production of components are left under the individual systems.
2. Great progress has been made in selecting global standards for the hardware. There was particularly great progress with the integration of the x-ray beamline. This has been helped greatly by the addition of Steve Lewis.
3. There is now a much better definition of the x-ray beamline controls.
4. It has been decided to lock the BPM to the quadrupole. This is a good decision that should help with alignment.

**Response: The locking of the BPM to the quadrupole will be achieved by mounting the two devices to the same supporting girder structure.**

5. The engineering process is improving. There are now coding standards, requirements documents and reviews.
6. There was a concern that it was unknown how to design a feedback system that would control the x-band phase (which has very tight tolerances). It was shown that the bunch length and energy feedback which is implemented by adjusting the S-band phase and amplitude effectively solves this problem.

### ***Concerns from last review that have not been fully addressed.***

1. The control interface for the injection laser is still a concern. Vendors have bid on the laser and there is no obligation to provide an EPICS interface or even enough documentation to allow SLAC to implement an EPICS interface. There was a plan presented to have an EPICS person work with the company so that the laser controls would be implemented in EPICS by that person with the help of the vendor. It could be a win-win situation in that the vendor gets free help from our EPICS person and learns EPICS and we get a laser with EPICS built into the low level controls. The vendor is not obligated to accept this, so they should be urged to accept it.

**Response: The laser vendor has been chosen and has agreed to supply all source code for their control software to the LCLS controls group. The vendor was not interested in developing in house EPICS experience but has agreed to provide access to their software engineer during the development of the control software.**

**The vendor-supplied controls with a LabView™ interface will be used during the first year of laser commissioning in order to not void the warranty. Additional controls for laser transport and diagnostics will be implemented in EPICS. A full EPICS interface to the laser controls will be implemented after the first year of operation. Sheng Peng has been hired from SNS to implement these controls.**

2. There has been a lot of progress on the SLC-aware IOC. Unfortunately, this progress has been confined to the database and communications utilities. It is urgent that the actual applications (magnet, BPM, and timing jobs) be implemented. It is making the functionality of these jobs close enough to that of the SLC micros so that the high level applications work that is the big concern. Not even functional requirements have been written yet. This is a non-trivial step as the people doing the work are not the authors of the SLC code. The plan presented showed that the SLC-aware micro will be completely done by the next FAC. We look forward to seeing this significant milestone achieved.

**Response: The SLC-aware IOC milestone has indeed been achieved. The major applications for Beam Synchronous Acquisition and Control (BSAC) and Magnet Device Monitor and Control will be implemented by October this year and are documented along with the general requirements at [http://www.slac.stanford.edu/grp/lcls/controls/global/facilities/slc\\_ioc/index.html](http://www.slac.stanford.edu/grp/lcls/controls/global/facilities/slc_ioc/index.html)**

### **New Concerns**

1. The PPS system will be implemented with PLCs. This is the first time this will be done at SLAC. We are glad you are helping bring SLAC PPS into the present century. There is a relatively new standard for *safety* certified PLCs. Consider using only PLCs that meet this new standard.

**Response: LCLS is working together with SPEAR3 to develop a common approach based on the work at J-Lab and SNS using the SIL3 Cat4 safety certified Pilz PLCs. The LCS injector PPS plans are scheduled for presentation to the SLAC safety committee this November.**

2. The magnet power supplies have only one current read-back. This is used both in the feedback loop of the power supply and in the read-out by the control system. While many accelerators operate like this, it has the problem that if the current readout (shunt or transducer) breaks such that it gives the wrong reading by a few percent, there will be no indication in the control system, but the beam will misbehave. While such failures may not happen too often, they can take many days (suffering with poor beam) to track down. The use of redundant current read-backs would solve this problem. One is used in the supply feedback circuit while the second is used for the control system read-back. If either fails, the control system will show that the current is out of tolerance. Please consider using redundant read-backs.

**Response: The orders for the powers supplies for the injector have now been placed. The small, corrector supplies use the COTS Bira™ MCOR supplies with only one current readback. The intermediate supplies for the injector solenoids and bend magnets will use a SLAC design ethernet controller, used at SPEAR3, which does have the capability for redundant readback. We are also further**

**investigating the power supply controllers for the rest of the project with redundant readback and better integration into the control system in general.**

3. The MPS system needs to be defined soon. It is unknown if it is a big job or a little job. Until it is defined well enough to know, it will remain a concern. Reasons to be worried that it might be a big job is that its actions are mode dependent, it must stop the beam before the next pulse, and it may need to interface with the master pattern generator of the SLC control system. It is complicated enough that it may need to be programmable, yet as an MPS system, great care must be taken to make sure it keeps things safe. A similar project on the SLC took several man years to implement. At least the functional requirements and top level design should be done and presented at the next FAC so it will be know how big a job it is.

**Response: The functional requirements for the MPS have now been defined including both the range of fault sensing devices and the beam shut off systems to be used, along with the necessary response time.**

4. While SLAC is using a CVS system at SLAC as a controlled software repository, the other labs are doing their own things. There needs to be a common repository that all the developers use.

**Response: It is a good idea and we need a manager to set such a thing up. Until then, we plan to receive updates from the other labs (i.e., in tar format), import into the SLAC CVS repository, build, and release to production as needed. We also provide SLAC AFS accounts to external engineers and allow those accounts to update the SLAC repository.**

5. The present plan is to move the undulators in and out of the beamline by using two stepping motors (one at each end). This may cause problems of keeping them synchronized to avoid the jamming that would occur if the undulator gets crooked. Consider using a single motor with gears and chains connecting the two ends or air cylinders to move them instead of the two-motor solution.

**Response: LCLS will test a fail-safe motor controller software system in the next year. This would sense the position of both motors to avoid jamming. We believe this is preferable to the additional mechanical complexity of gears and chains linking each end of the undulator.**

6. The very tight temperature tolerances in the undulator tunnel (+/- 0.2 C) have severe implications on controls. There are plans to put electronics in the ceiling air return duct where it will be difficult to maintain and concerns that the stepping motors will give off more heat than allowed. The air conditioning system necessary to maintain that temperature stability is also very expensive. The accelerator physicists should have a hard look to see if there is a way to increase this tolerance.



**Response:** The temperature stability tolerances for the undulator tunnel have been re-examined both with respect to their influences on the undulator magnetic field as well as to the positional stability of the quadrupoles and BPMs. GENESIS simulations of the effects of errors of the average  $K$  values for each undulator segment, both random and systematic, show that temperature errors from a uniform distribution with a width of  $\pm 1$  degree F ( $\pm 0.56$  degrees C) are consistent with a total overall error budget for a 25% reduction in FEL power (but not taking credit for simple undulator  $x$ -position adjustments to compensate temperature variations). In parallel, a thermal expansion study was carried out at the APS with the result that for temperature changes of  $\pm 0.5$  degree C the critical components will stay within the position tolerances ( $\pm 5$  microns over 24 hours). Based on these analyses, which will be presented during the next FAC meeting, the temperature tolerances for the undulator tunnel have been relaxed. The requirement specification says now: "The absolute temperature along the Undulator will stay within a range of  $20 \pm 0.6$  °C at all times."

### ***New progress and things we particularly liked***

1. The project is making good use of commercial hardware solutions. This will help keep the engineering costs down.

**Response:** We are continuing with this policy and are now exploring COTS small processors that can run RTEMS and EPICS to support small, standalone controls applications without the use of a full VME crate. However, in order to expedite the injector installation we have opted to use a small number of SLAC built power supply controllers for the medium sized magnets while we further explore other commercial solutions.

2. The power distribution system is being planned with extra capacity. This will allow upgrades to the linac to be conveniently done by implementing the new hardware using the new power distribution system. The old hardware can then just be turned off when it comes time to switch over.

**Response:** Electrical power load tests have been scheduled for the linac klystron gallery and after evaluation the Conventional Facilities group will begin planning any upgrades necessary to support the new equipment.

3. A fiber solution for distributing the RF phase reference was presented as a future upgrade to the planned distribution via cable. This looks very promising. We encourage actively pursuing this R&D with the hope that the fiber system could be used from day one.

**Response:** LCLS is carefully following the progress of two groups at present, who are pursuing fiber distribution of RF. The MIT/DESY collaboration uses interferometry at the RF wavelength to stabilize the fiber, while LBL uses a

**method developed for astronomy based on interferometry at optical wavelengths. We have not yet built a test stand of our own for LCLS R&D.**

## 5.0 Conventional Facilities Subgroup Summary

### ***Areas Requiring Priority***

#### Undulator Tunnel

As presented at the meeting, it appeared that the Conventional Facilities team (CF) by itself had no workable solution to meet the undulator tunnel physics criteria. The floor designs being considered would require both a proof of principle and constructability demonstrations. We expected that part of the solution might be in an active alignment system for the machine, and discussions with beam alignment specialists on the second day of the FAC review confirmed that there were alignment solutions available.

There is still no calculation predicting the undulator tunnel foundation system deflection for either near term or long term creep. The undulator floor/tunnel design remains a critical issue that needs to be addressed as soon as possible, so that Title II work can proceed in this area of the project. The Conventional Facilities Subgroup suggests that a cost/benefit analysis could be conducted utilizing a range of settlement specifications for the tunnel floor, such as:

- 0.04 mm RMS/year/10m separations
- 0.2 mm RMS/year/10m separations
- 1.0 mm RMS/year/10m separations

Once this analysis has been performed, the Project can then decide how much of the problem should be solved with civil construction and how much should be resolved using Beam Based Alignment and other alignment techniques.

To improve the design criteria, the Project should engage soil modeling experts to perform settlement calculations. The existing empirical data from the SLAC tunnel and the geotechnical data now available for the Site can be used to make a reliable analytical model of the expected performance of the soil foundation. These experts in soil mechanics can be hired by the architecture and engineering firm (AE) if it does not possess the in-house capability. Given the above calculations, the AE can design the optimum structural configuration to minimize long term creep.

There were two sketches presented showing the proposed tunnel cross-section: circular shape with a flat floor and a semicircular top with vertical sides anchored on a flat floor, that is, an inverted *U*. In the circular version, the proposed separation of the floor from the tunnel structure may be an expensive complication not necessarily contributing to the needed solution. If the Project were to consider unconventional tunnel designs to meet otherwise unachievable alignment requirements, there are additional tunnel design concepts to evaluate. One is the *moment-free* tunnel shape, which is not a circle but

rather resembles a flattened pear shape. A better solution for a predictable conventional facility construction cost and duration is to build a tunnel of a practiced and proven configuration. The inverted *U*-shape with a connection to the base floor capable of carrying shear loads structurally resembles the original SLAC linac tunnel. The linac tunnel configuration would give an acceptable performance, but it is impractical to replicate it in the undulator location. Assuming that the soil mechanics calculation will yield the expected results, the inverted *U*-shape could be an acceptable substitute.

**Response: The design approach to the Undulator Hall floor was modified June 23, after a meeting with Jacobs. We decided to move away from the Tri-Tee isolated invert concept and pursue a more conventional slab design. The shape of the tunnel was also revised to an inverted U shaped tunnel. These concepts were developed and included in the 30% design drawings. Implied by these changes is the decision to rely more heavily on the global straightness reference provided by the HLS and the WPS systems, and the active alignment system to correct the effect of ground motion. By moving to a more conventional tunnel design and relying more on the technical systems, we judged that overall risk is reduced. Jacobs stated that the fact that the slab will not be isolated from the tunnel invert will eliminate Jacob's ability to reduce the movements of the tunnel invert from geological effects that the tunnel will experience, but that it was their intention to try to reduce the effects of this movement by structurally connecting the slab to the tunnel lining. Subsequently Jacobs analyzed the PEP data, especially where the PEP tunnel is mined and in the same sandstone soil as the Undulator tunnel. Based on that analysis they designed the Undulator tunnel structure to be stiffer than either the PEP or Linac tunnels and estimated the differential settlement rate will be between 0.3 - 0.5 microns/day rms @ 10 m separation, which is within the LCLS requirement.**

#### LCLS Construction Safety Program

The CF Subcommittee recommends implementation of a construction safety program specific to the LCLS Project with an approach similar to successful programs implemented on other DOE construction projects.

The importance of safety in the conduct of work is accepted by the LCLS group. Continuous improvement is, of course, a core function of the Integrated Safety Management System and needs to be pursued.

The Project safety expectations and requirements must be clearly presented to subcontractors with Requests for Bid. The LCLS Project is awaiting direction from ES&H management regarding subcontractor safety program implementation. New construction designs are currently at the Title II level and cost and scheduling need to be developed that incorporate construction safety program requirements. The CF schedule has Title II design being complete by November, 2005. Outside firms that are at times unfamiliar with SLAC practices, requirements and infrastructure will need to have a clear understanding as to exactly what their ES&H responsibilities will be. The LCLS project has indicated that these SLAC ES&H requirements are in the process of being revised

and the program is in a state of frequent change. It will not be possible for subcontractors to provide accurate cost and scheduling estimates if they do not have a full understanding of their responsibilities. Deficiencies in subcontractor work control planning and implementation, and failure of subcontractors to fully embrace and implement the safety program would exacerbate an already strained safety culture and place the Project at risk.

The LCLS has taken very proactive steps to improve the level of construction safety expertise on the project, including the addition of a fulltime ES&H person with a construction safety background to lead the process of developing a construction safety program for the project. The model chosen to develop this program has been proven to work at other DOE laboratory construction sites and meets industry standards including DOE expectations. The LCLS Facilities Advisory Committee fully supports and encourages completion of this construction safety program as soon as possible.

The construction safety program requirements for conventional facility work already out for bids, such as Sector 20, remains in a state of flux. Though the value of these early construction scopes is small, the cost to the Project of a failure to perform satisfactorily on the initial conventional facility construction could be very damaging.

To enhance Project safety performance as discussed, the LCLS project team must obtain SLAC management approval to implement a Project Site specific construction safety program already proven by application on other DOE construction sites. This subgroup recommends and supports this approach and the effort in progress.

**Response: As recommended, LCLS has implemented a construction safety program unique to the LCLS project has been developed and approved by the Project Director, (Environment, Safety and Health Plan - LCLS Document Number: PMD 1.1-011). This document has been modeled after other successful DOE projects using Integrated Safety Management System measures. Clear roles and responsibilities have been delineated within LCLS Management, Line Organization, ES&H Coordinator and the subcontractor workers. Responsibilities and expectations have been given developed for various work activities including hazardous work requirements. It is intended that this approved document will become a part of all subcontractor activities through the RFP process.**

**General conditions and special requirements have been developed in an effort to establish the required parameters that are unique to the SLAC site and the LCLS project. This data has been given to the AE firm and has been reflected into the most recent cost estimate.**

### Construction Management

The award of a CM contract is time critical, and the earliest selection date is still months away. The LCLS Project needs the experienced resources of a CM for design reviews, management of construction safety programs, site management, procurement support, and for project continuity. The Committee recommends and supports the effort in

progress as essential to successful performance of conventional facility construction, including construction safety.

**Response: A Construction Manager/General Contractor (CM/GC) contract has been awarded. Included in their Phase I effort will include such tasks as development of an approved safety program, constructability reviews, value engineering reviews, cost estimates, preparation of bid packages, etc. Meetings between Owner, Architect, Contractor (OAC) are conducted on a weekly basis to maintain continuity through design and construction between the AE firm and the CMGC.**

### Jacobs Design Management

The turnover in staff at Jacobs since the Title I design effort places the Title II design at increased risk. With start of Title II design immediately following this FAC meeting, the Project needs assurance from Jacobs that they are assigning their best qualified personnel to the Title II design. This Committee recommends and supports a high priority effort to assure the Jacobs staff assigned to Title II design is the most capable.

**Response: This is a continuing concern and the highest priority to LCLS management. While LCLS has been assured that the Jacobs effort is competent and well-integrated, the unacceptable growth in the cost of electrical and mechanical systems became a concern to LCLS management well before it was acknowledged by Jacobs. LCLS initiated a parallel design effort for Undulator Hall HVAC, which will result in a more economical system. Cost growth in other areas must now be addressed either by redesign or de-scope of the Project. With cost control a major issue, schedule and quality continue to be key concerns. The Title 2 design is now on the critical path. Senior level management meetings are conducted on a weekly basis between JE and the LCLS Project Office. The SLAC director and LCLS management now conduct regular meetings with JE higher level management to ensure that the LCLS design has the appropriate visibility in the Jacobs organization.**

## **General Comments**

### Conventional Facilities Project Start

The conventional facilities (CF) on the LCLS Project have an excellent opportunity for a very successful project implementation phase. The cost and schedule contingencies are reasonable, the planning and resources are identified, and the CF plan to date has been implemented successfully through Title I design. For CF success, attention must be directed to project risks, to timely actions to mitigate those risks, and to timely decisions to assure the Title II design complies with performance requirements, including the budget and schedule for construction. Some risks have been identified in this report that require prompt action.

### Interaction with DOE/EPA

The CF design has changed from that which was the basis for the original LCLS Finding Of No Significant Impact (FONSI). While no problems are anticipated with the evolved design, the project office should obtain DOE/EPA agreement that the initial FONSI is still in effect.

This Committee was informed at the last review that the design basis for the LCLS Project is UBC1997. We recommend (*again*) that this Code selection be verified with DOE. One concern is the acceptability of partial penetration welds on moment frames that carry seismic loads. More recent Codes require full penetration welds in moment frames because of weld failures observed in the Northridge Earthquake.

**Response: In the construction industry significant work has been accomplished on moment frame design, construction, and inspection techniques since the failures noted in the Northridge earthquake. This issue goes far beyond the limit on partial penetration welding. It does include configuration, materials, welding techniques and inspection.**

**The current standard practice for design of these connections is contained in FEMA 350 for welding and FEMA 353 for inspection of new moment frame connections. Most jurisdictions in seismic areas have adopted these as part of the building code to be used in conjunction with the 1997 UBC or 2001 CBC. Pre-qualified joints or a case by case testing program has been standard practice for several years now for special moment resisting steel connections. Current AISC Seismic Requirements also provides guidance for these types of welded connections.**

**In addition SLAC partially compensates for the deficiencies of the UBC by requiring structures to be built to a higher standard than the UBC minimum. The DOE provides allowances to continue the use of the UBC, but SLAC must provide designs and installations that meet the intent of the IBC or the NEHRP (National Earthquake Hazards Reduction Program) provisions. SLAC also subjects all structural design to a rigorous peer review by licensed California structural engineers. No design is approved by the SLAC Earthquake Safety Committee without all concerns of the peer reviewer completely addressed.**

**SLAC and the DOE should expect adherence to these industry accepted standards. Our Independent Seismic Peer Review team is tasked with looking for this within the project details and specifications should this type of connection be utilized.**

### Contingency and Schedule

The Conventional Facilities schedule durations and contingency have been increased since the last FAC review in response to comments from several independent reviews including this FAC CF Subgroup. Though no detailed assessment was performed by the

FAC subgroup, the conventional facility schedule and budget with contingency now appear to be reasonable.

### HVAC and Vibration

The approach to cooling temperature sensitive components has been defined and, though expensive, appears to be feasible. Detailed calculations on mixing zones and air flow velocities are required, and will be performed in Title II design to verify the concepts proposed in Title I.

A combination of approaches that includes both local isolators and proximity to sensitive components has been defined in Title I design. Detailed calculations against vibration budgets will be required in Title II design to demonstrate compliance to limits.

### Far Hall Layout

The Far Hall Layout needs to be finalized. If the hutch size in the original design is inadequate, the alternate plan should be adopted as the baseline design for Title II.

**Response: The Far Hall layout has been redesigned as part of the baseline design to a more simplified concept. This new version has also improved the constructability and scheduling for the tunneling effort.**

## Appendix A

### “LCLS Facility Advisory Committee Members Present at 7, 8 April 2005 Meeting”

Kem Robinson  
Chair FAC  
Lawrence Berkeley National Laboratory  
(LBNL)  
[KERobinson@lbl.gov](mailto:KERobinson@lbl.gov)

Harry Carter  
Conventional Facilities Subgroup  
Fermi National Accelerator Laboratory  
(FNAL)  
[HFCarter@fnal.gov](mailto:HFCarter@fnal.gov)

Anthony (Tony) Chargin  
Conventional Facilities Subgroup  
Lawrence Livermore National Laboratory  
(LLNL)  
[Chargin@llnl.gov](mailto:Chargin@llnl.gov)

John (Jack) Cleary  
Conventional Facilities Subgroup  
Stanford University (SU)  
[JCleary3@stanford.edu](mailto:JCleary3@stanford.edu)

John Corlett  
Electron Systems Subgroup (Lead)  
Lawrence Berkeley National Laboratory  
(LBNL)  
[JNCorlett@lbl.gov](mailto:JNCorlett@lbl.gov)

Massimo Cornacchia  
Electron Systems Subgroup  
Stanford Linear Accelerator Center (SLAC)  
[Cornacchia@slac.stanford.edu](mailto:Cornacchia@slac.stanford.edu)

Roger Falcone  
X-Ray Subgroup  
UC Berkeley  
[rwf@physics.Berkeley.edu](mailto:rwf@physics.Berkeley.edu)

Josef Feldhaus  
X-Ray Subgroup  
Deutsches Elektronen-Synchrotron (DESY)  
[Josef.feldhaus@desy.de](mailto:Josef.feldhaus@desy.de)

Paul Fouss  
X-Ray Subgroup (Lead)  
Argonne National Laboratory (ANL)

[fuoss@anl.gov](mailto:fuoss@anl.gov)

Thomas Himel  
Controls Subgroup (Lead)  
Stanford Linear Accelerator Center (SLAC)  
[thimel@slac.stanford.edu](mailto:thimel@slac.stanford.edu)

August (Gus) Kugler  
Conventional Facilities Subgroup (Lead)  
BJY  
[kuchleran@astound.net](mailto:kuchleran@astound.net)

Joachim Pflüger  
Electron Systems Subgroup  
Deutsches Elektronen-Synchrotron (DESY)  
[Pflueger@desy.de](mailto:Pflueger@desy.de)

Thomas Rabedeau  
X-Ray Subgroup  
Stanford Linear Accelerator Center (SLAC)  
[Rabedeau@slac.stanford.edu](mailto:Rabedeau@slac.stanford.edu)

Keith Schuh  
Conventional Facilities Subgroup  
Fermi National Accelerator Laboratory  
(FNAL)  
[Schuh@fnal.gov](mailto:Schuh@fnal.gov)

Peter Siddons  
X-Ray Subgroup  
Brookhaven National Laboratory (BNL)  
[Siddons@bnl.gov](mailto:Siddons@bnl.gov)

Thomas Tschentscher  
X-Ray Subgroup  
Deutsches Elektronen-Synchrotron (DESY)  
[Thomas.tschentscher@desy.de](mailto:Thomas.tschentscher@desy.de)

Karen White  
Controls Subgroup  
Thomas Jefferson National Accelerator  
Facility (TJNAF)  
[Karen.White@jlab.org](mailto:Karen.White@jlab.org)





## Appendix B



### Facility Advisory Committee (FAC) Meeting April 7-8, 2005

## AGENDA

[Printable Agenda](#)

[FAC Closeout Slides](#)

**Thursday, April 7th**

**AM: Plenary Session    PM: Breakout Sessions**

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

| <i>Time</i> | <i>Topic</i>   | <i>Presenter</i>       |
|-------------|--|------------------------|
| 7:30        | Executive Session  |                        |
| 8:00        | Welcome  | J. Dorfan              |
| 8:15        | <a href="#">Project Status Update, Charge to Committee</a> | J. Galayda             |
| 8:30        | <a href="#">Safety</a>                                     | M. Scharfenstein       |
| 9:00        | <a href="#">Project Organization, Executive Status</a>     | M. Reichanadter        |
| 9:30        | <a href="#">Injector/Linac Update</a>                      | E. Bong                |
| 10:00       | <a href="#">Laser Update</a>                               | S. Gilevich            |
| 10:15       | <i>Break</i>   |                        |
| 10:30       | <a href="#">Undulator Systems Update</a>                   | S. Milton              |
| 11:00       | <a href="#">Photon Systems Overview</a>                    | J. Arthur              |
| 11:30       | <a href="#">Conventional Facilities Update</a>             | D. Saenz               |
| 12:00       | <i>Lunch</i>   |                        |
| 1:00        | Breakout Sessions ( <i>see Breakout Session Agenda</i> )   |                        |
| 5:00        | Executive Session ( <i>Redwood C/D</i> )                   |                        |
| 7:00        | Dinner – <i>Ten Fu Chinese Restaurant</i>                  | Committee and Speakers |

**Breakout Session 1 – Design & Construction: Accelerator & Undulator Systems**

**Location: Redwood A**

| <i>Time</i> | <i>Topic</i>  | <i>Presenter</i> |
|-------------|---|------------------|
| 1:00        | <a href="#">Injector Physics</a>  | C. Limborg       |
| 1:25        | <a href="#">Collimation</a>   | J. Wu            |
| 1:50        | <a href="#">Low Charge Working Point</a>  | P. Emma          |
| 2:10        | <a href="#">AC Resistive Wall Wake Field – Measurement, Theory</a>                | K. Bane          |
| 2:30        | <a href="#">Effect of AC Resistive Wall on SASE – Analytic Treatment</a>          | Z. Huang         |
| 2:50        | <a href="#">Effect of Wake Field on SASE – Numerical Results</a>                  | W. Fawley        |
| 3:10        | <a href="#">Undulator Physics Requirements and Alignment</a>                      | H-D. Nuhn        |
| 3:40        | <i>Break</i>  |                  |
| 4:00        | <a href="#">Installation Alignment, Magnetic Measurements and Fiducialization</a> | R. Ruland        |
| 4:30        | <a href="#">Undulator Cell System Integration Test Plan</a>                       | M. White         |
| 5:00        | Executive Session ( <i>Redwood C</i> )  |                  |

**Breakout Session 2 – Design and Construction: XTOD & Experiment Station Systems**

**Location: Redwood B**

| <i>Time</i> | <i>Topic</i>                                       | <i>Presenter</i> |
|-------------|--|------------------|
| 1:00        | <a href="#">XTOD Layout and Diagnostic Systems</a> | R. Bionta        |
| 1:30        | <a href="#">X-Ray Low-Pass Mirror System</a>       | J. Arthur        |
| 2:00        | <a href="#">Revised Endstation Systems Scope</a>   | S. Moeller       |
| 2:30        | <a href="#">X-Ray Detector Development Program</a> | J. Arthur        |
| 3:00        | <i>Break</i>                                       |                  |
| 3:15        | <a href="#">The PIXEL Project</a>                  | J. Arthur        |
| 3:45        | Discussion   |                  |
| 5:00        | Executive Session ( <i>Redwood C</i> )             |                  |

**Breakout Session 3 – Controls**

**Location: Redwood C**

| <i>Time</i> | <i>Topic</i>  | <i>Presenter</i> |
|-------------|---|------------------|
| 1:00        | <a href="#">Controls Overview</a>   | B. Dalesio       |
| 2:00        | <a href="#">Integration with SLC</a>  | S. Allison       |
| 2:30        | <a href="#">Undulator Controls</a>  | J. Stein         |
| 3:00        | <i>Break</i>  |                  |
| 3:15        | <a href="#">X-Ray Transport/Optics/Diagnostics Controls</a>   | S. Lewis         |
| 3:45        | <a href="#">Physics Requirements and Technology Choices for LCLS Instrumentation &amp; Controls</a> | P. Krejcik       |
| 4:15        | Discussion  |                  |
| 5:00        | Executive Session ( <i>Redwood C/D</i> )  |                  |

**Breakout Session 4 – Design and Construction: Conventional Facilities**

**Location: Redwood D**

| <i>Time</i> | <i>Topic</i>   | <i>Presenter</i> |
|-------------|--|------------------|
| 1:00        | <a href="#">Physics Requirements</a>                   | J. Welch         |
| 1:30        | <a href="#">Construction Organization and Schedule</a> | D. Saenz         |
| 2:15        | <a href="#">Sector 20 Design, Status</a>               | J. B. Folger     |
| 2:45        | <a href="#">Magnet Measurement Facility</a>            | J. Sevilla       |
| 3:15        | <a href="#">Construction Safety</a>                    | R. Hislop        |
| 3:45        | <a href="#">Geotechnical Report</a>                    | J. B. Folger     |
| 4:00        | <a href="#">CM/GC</a>                                  | D. Saenz         |
| 5:00        | Executive Session ( <i>Redwood C/D</i> )               |                  |

**Friday, April 8th**

**Location: See listing below**

| <i>Time</i> | <i>Topic</i>                                | <i>Locations</i>   |
|-------------|---|--------------------|
| 7:30        | Executive Session                           | Redwood C/D        |
| 8:00-10:00  | Breakout Sessions, continued (if necessary) |                    |
| 10:00       | Executive Session                           | <b>Redwood C/D</b> |
| 12:00       | <i>Lunch</i>                                |                    |
| 1:30        | Executive Session                           | Redwood Rooms      |
| 2:00        | Closeout – Plenary                          | Redwood Rooms      |