

# Report of the 12, 13 October 2006 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 on 12 and 13 October 2006. In addition, the X-Ray Subgroup of the FAC met with the LCLS Ultrafast Science Instruments (LUSI) project on 11 October 2006 to review its conceptual design. 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

The FAC was also asked to additionally concentrate on the systems integration/installation planning strategy, the XRTOD diagnostics, the undulator prototype results, and to give advice for an upcoming Department of Energy (DOE) review of the LCLS project (Lehman Review).

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 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 12, 13 October 2006 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*

This meeting of the FAC began on a rather somber note with the announcement that the Central Laboratory Office Complex (CLOC) has been stopped and removed from the active scope of the project. This results from escalating conventional facilities costs consuming too much contingency to prudently continue the CLOC as part of the project. SLAC management is looking where existing space can be used that is best suited for the LCLS. “Buildings within buildings” are being looked at for specific specialty space and facilities such as laser labs associated with activities and research at the LCLS could be deployed. The removal of the CLOC from the scope of the project does not compromise the ability of the project to meet its scientific goals. The sample preparation laboratory contained within the CLOC is the only aspect that directly impacts LCLS scientific operations, but alternatives are being aggressively pursued. SLAC and LCLS management have examined a number of alternatives including a Level-0 Baseline change to retain the CLOC, but none have proven feasible.

It is possible that an office building could be included in the scope of the project if contingency usage is slowed with a final decision point scheduled for October 2007.

Groundbreaking ceremonies for the LCLS are scheduled for 20 October 2006 with tunnel excavation beginning the end of October 2006.

The LCLS Project safety record to date is worthy of note. As of the end of August 2006 the LCLS Collaboration had worked more than 700,000 hours with only 2 lost-day cases (a shoulder and a back strain injuries) and the subcontractors had worked nearly 50,000 hours without any injuries. The current LCLS lost time injury rate is more than 3.5 times *less* than DOE construction rates. The LCLS Project is encouraged to take credit for its safety achievements, but at the same time admonished not to let vigilance slip.

The LCLS FAC meeting interactions remain strong and the Project actively engaged with the FAC during this meeting. The quality of this interaction continues to be high. Significant progress in integration and installation preparedness was much in evidence and a notable change in the focus of both the meeting and project concerns was in evidence. The concentration on installation, integration, interfaces, and items ignored (I<sup>5</sup>) during the FAC was viewed as essential and should be beneficial to the project. Although the project is in full construction and fabrication, installation and integration tasks are starting to dominate many technical systems. As noted, the focus of the project is beginning to evolve, but the FAC remained unconvinced that installation and integration of the project as a whole was completely under control. The LCLS Project is making strong strides in this area and the FAC is optimistic about successful integration and installation, but considerable work remains to be done to ensure that success.

The LCLS Project, in response to a recommendation from the previous FAC meeting, has begun to adapt and strengthen the use of the Risk Registry to a more tactical document approaching that of a *punch list* with each of the System Managers to identifying risks. This will give greater uniformity, stronger ownership, and authority to execute the tactical risk plan. However, at the time of the FAC meeting there was still considerable variability between the degree of effectiveness and timeliness of the Risk Registry across the systems. For example, the entries for the Undulator System were incomplete and hadn't been updated in some time.

As evidenced during this meeting of the FAC, while costs are of a particular concern in the conventional facilities, the schedule is the major concern for the project as a whole and the technical systems. Because of the integrating nature of project tasks at this point (an activity having a strong dependence on several parallel activities feeding into it) delays can quickly accumulate. One example of this concern was reported by members of the FAC that had attended a review just days early concerning commissioning. Within the space of a few days the schedule had slipped by nearly two months. Such slips cause the FAC concern and are the basis for our opinion that the installation schedule may not yet be under control at this time.

There continued to be evidence of too many members of the project team viewing float time in their particular subsystem areas as available buffer. A day of float, regardless of how far from the critical path a particular activity is, should only grudgingly be surrendered. The listing of activities or items as *just in time* gives cause for concern. In one-off single development projects *just in time* can quickly become *just too late*. Dogged attention to progress and details is necessary at this point of the project as well as driving to an early finish to minimize to the extent possible delays.

The LCLS Project, since the previous FAC meeting, has taken several notable steps to strengthen its organization. Of particular note is the innovative Integration Management Team with R. Boyce serving as both the Integration/Installation Manager and responsible for SLAC Division Interfaces. This approach maintains the line manager responsibility but should ensure integration across the entire project. Other organizational additions include an associate director for civil construction, a field procurement officer supporting conventional facilities, Jacobs Engineering Contract Administration, and accelerator diagnostics lead. With these project strengthening additions some attention to carefully identifying roles and responsibilities in anticipation of the Lehman Review is in order.

Communication appears to be very strong in the project, but the biggest risk will continue to be items, interfaces, or issues not being heeded in a timely fashion. The Project has taken several steps as indicated previously to minimize this risk, but it is still present.

As was the case at the time of the previous FAC meeting, the persistent growth of conventional facilities costs, as a result in large part to forces beyond the control of the project, will continue to exert strong pressure on contingency. The FAC still believes it is unlikely that any *spare* contingency will remain to be allocated items previously removed from the active scope of the project. Consequently, LCLS project management should insure that thorough processes related to scope management are meticulously followed. Otherwise, any transfer of scope between LCLS cost accounts, or interfaces concerning scope in external projects such as LUSI or on-going operations could result in costly oversights or delays as integration continues. The recent estimate to complete (ETC) has caught many of those items of scope that may have been transferred without full concurrence (see April 2006 FAC Report). However, it is a tactic that is after the fact and a vigilant and continuous scope management process is a more forward looking and effective approach.

Finally, as we in the FAC have stated previously, the comments and recommendations of the FAC are made with the desire to further improve an already strong and well functioning project. These comments and recommendations are made in the context of the numerous and considerable accomplishments of the project. The quality and quantity of the work accomplished since the previous FAC meeting is apparent in all areas.

## **2.0 Electron Systems Subgroup Summary**

J. Corlett, M. Cornacchia, W. Leemans, P. O'Shea, J. Rossbach

### **2.1 Management**

As in previous meetings, the committee thanks the LCLS accelerator systems teams for excellent presentations and discussions during the meeting. The teams continue to produce impressive work in accelerator physics, hardware development and installation, and technology development.

Installation priorities are based on hardware required for installation within the linac tunnel during the current shutdown. Installation of components not inside the linac tunnel (i.e. in the injector vault) may be accomplished after the shutdown, with minimal impact on operations. While the prioritization introduces some delay in readiness of the injector upstream components, the overall philosophy appears to be sound. Provision for access to the main linac for installation of remaining items should be negotiated with SLAC management to integrate with commissioning needs where possible.

The committee encourages the LCLS management to provide sufficient resources to avoid compromising injector readiness for commissioning, e.g. the contract for installation of LCW in the

injector region is not yet awarded, and there is potential for problems that may be encountered to cause delays. Also, the photocathode laser installation schedule is tight and attention should be given to readiness with at least the minimal required laser systems performance for initial gun tests with beam.

As installation proceeds and pressure on resources is strong, the committee recommends that priorities be carefully assessed and discussed with SLAC management when necessary to ensure optimal response to schedule-related activities such as work in the SLAC machine shops. There may be some opportunities to make use of other resources to help with meeting schedule, such as engineering and fabrication of selected components and subsystems. Other Laboratories, vendors, or even different departments within SLAC, may be able to respond well to requests to take responsibility for well-defined items, particularly in preparation for the 2007 shutdown and installation period,

The schedule for installation of components in the injector vault was not clearly articulated, and delays appear to be likely. The committee recommends that a definitive schedule for completion of all injector components required to begin commissioning be developed as soon as possible. Any delays will reduce the much-needed time for accelerator commissioning, and should be strongly resisted.

The commissioning schedule is well developed and the committee supports the approach. Care must be taken in prioritizing activities should installation delays result in a shorter commissioning period before the 2007 shutdown. If not carefully planned and managed, the impact could ultimately be felt in the delivery of first light from the undulator in August 2008

## **2.2 Photoinjector**

### **2.2.1 Laser**

The laser group is highly talented and has progressed well with installation and initial commissioning of the hardware. The photocathode drive laser system is both critical to LCLS performance and a large and complex optical system. It may be expected to fail at some point and availability of system spares needs to be secure. The committee recommends that critical components be defined and a plan for spares to maintain operational up-time be developed. The committee also encourages that LCLS management continue to explore means to fund development of a complete second system, to be used for both R&D and as source of spares that have an immediate availability for operations.

Several key areas of the laser system are yet to be fully demonstrated to design specification, and the committee encourages the team to continue to address these issues and resolve them in the most timely fashion possible:

- Stability of the spot position on the cathode: The pointing system, using a pair of controlled mirrors in a feedback system, allowing angle and position control of the spot, has been tested with a CW laser. Performance needs to be verified with the UV signal from the mode-locked Ti-sapphire source that will be used in the final system.
- Spatial shaping of the spot on the cathode: Aspheric optics will be used to produce a uniform illumination on the cathode surface. The existing optics, however, have significant aberrations and do not meet specification. Intensity variations within the spot on the cathode will likely lead to local charge enhancement and emittance growth from space-charge forces. The manufacturer is aware of the performance limitations of the optics and is making another set to meet requirements. In the meantime, the existing optics will be used.

- Temporal shaping of the laser pulse: A Dazzler is integrated into the laser system built by Thales, and provides temporal shaping of the IR beam. At the time of the review the Dazzler was being commissioned and was not meeting specifications. As a backup, an alternate approach of stacking two pulses has been developed, and if the Dazzler does not work the Thales laser will be set up to provide Gaussian pulses for the stacking technique. Responsibility for delivery of a functioning temporal shaping system belongs with Thales, and the LCLS project should ensure satisfactory delivery of a system meeting specifications.

The interactions between the laser group and accelerator physics group have been excellent in studying the impact on the electron beam of laser systems imperfections.

### **2.2.2 RF gun**

Fabrication of the first gun is complete, and RF power conditioning is under way. The second gun is being fabricated. The committee congratulates the design team for development of this gun, and recognizes the hard work that has gone into the physics and engineering design of this critical piece of hardware. The performance of the LCLS will in great part be determined by the functioning of the gun, and the committee is pleased to see that good progress is being made in bringing the gun up to operational capability.

Since the gun is such a critical and long-lead item – and simulations suggest that accelerating gradients of 100 MV/m will be acceptable for commissioning purposes – the committee recommends that great care be taken in conditioning the gun, and that less aggressive goals be considered. The second gun should be completed as soon as possible.

The committee recognizes the importance of R&D in support of gun operations, and encourages LCLS management to pursue a gun test capability, and development of a mode-lock system for in-situ cathode replacement.

## **2.3 Gun to Linac**

Accelerating sections to be installed in the GTL were measured using a coordinate mapping machine, and found to be curved with a displacement of up to 1.5 mm in the center. These deviations have been corrected. The committee recommends that the straightness of other accelerating sections be assessed, and the impact of similar displacements in other accelerating sections in the LCLS be analyzed.

The LCW system required in the injector vault is complex and the contract for installation has not yet been awarded. As mentioned previously, the committee considers this a risk and that the system should be installed as expeditiously as possible.

## **2.4 Diagnostics**

Plans for implementing beam-induced coherent radiation measurement systems, to be used in a feedback system controlling bunch-length, were presented. Two systems are to be installed in the region immediately downstream of BC1, one using coherent synchrotron radiation from the last dipole magnet of the BC1 chicane, the other using radiation from a gap in the conducting beam pipe. A third system based on fluctuations in the synchrotron radiation spectrum is also being studied, and if successful could provide an absolute measurement of bunch length. Developments of these systems appear to be in hand now, and the committee applauds these developments.

## 3.0 Undulator Subgroup Summary

J. Pflüger, K. Robinson

The Undulator System within the LCLS Project continues to make very strong and notable progress. The main magnetic structures are in full production and 7 production undulators have been delivered to SLAC with an additional production undulator at Argonne National Laboratory (ANL). The mu-metal magnetic shield has adequately demonstrated performance and is being fabricated in the ANL shops, but its delivery has been delayed and so is presently holding up the beginning of production measurements. The last of the production undulators are slated for delivery in April 2007.

The Undulator System team has exploited the single undulator test (SUT) to the extent possible and has demonstrated the feasibility and viability of most all of the systems. SUT has been used to firmly demonstrate the considerable progress and functioning of the support and mover systems. The final design review of the mover system was completed in September 2006 and its prototype has demonstrated performance at specification or very close to specification. The Undulator Team carefully instrumented the entire SUT and was able to use it to iterate and perfect aspects of the support and mover systems. With the addition of feedback the cam mover system is reported to be capable of repeatability within 2  $\mu\text{m}$ . The kinematic replacement of central undulator modules has been demonstrated to the level of 10  $\mu\text{m}$  vertically and 40  $\mu\text{m}$  horizontally worst case.

The Magnetic Measurement Facility (MMF) at SLAC, although behind schedule with respect to the original plan as a result of issues with compressed air and other commissioning issues, has been occupied and is now fully operational. The MMF has demonstrated good temperature stability and a new magnetic measurements bench is fully commissioned. Impressive progress has been made since the previous FAC meeting (April 2006). Alignment techniques based on capacitive sensors have been perfected. New  $B_x$  magnetic shims have been developed that generate considerably less transverse stray fields. Complete rough and fine tuning measurement plans are being detailed. Software automation and some fixturing for the fine tuning measurement system remains to be completed before full production measurement rates can be achieved. The serial production measurement campaign is about to begin with the schedule goal of completing all 33 undulator sections by September 2007. While this is ambitious and represents throughput of 1 device/week at sustained rate for 28 weeks, it should be achievable. It is planned that each undulator section will spend 4 weeks in the MMF. It is planned that a *reference undulator* that will remain in the MMF and will be measured after every fourth device to ensure that no errors are creeping into the system. At the present time the magnetic measurements of the undulator sections are not the pacing activity for completely integrating the undulator systems and this activity has upwards of six months of float available.

The area of largest concern for both the FAC and the Undulator Systems Team remains the undulator vacuum chamber. The physics requirements are demanding and have been difficult to fully identify. Surface finish and conductivity are all demanding requirements derived from wakefield effect calculations. A considerable amount of very good engineering development and design tradeoffs have gone into the vacuum chamber. As a result of the requirements, Undulator Systems Team converged on a stainless steel chamber with an aluminum inner coating to improve conductivity. At the previous FAC meeting (April 2006) the baseline approach was to use a stainless steel sheet polished, given an aluminum coating, and then bent into a u-shape and welded to a stainless steel piece. This is referred to as *Plan A* and was to have been prototyped in July 2006. Surface roughness tolerances could not be maintained in the corners of the bent structure and this approach was completely abandoned.

A new vacuum chamber design, *Plan B*, is being pursued at present that consists of two flat polished stainless steel sheets laser-welded to long stainless blocks forming a rectangular cross section vacuum chamber. The assembly is then machined down, thinning the sheet thicknesses, to the final outside vertical dimensions. The inner wall of the chamber is then plasma coated with aluminum to increase the conductivity. This design is only pumped at the ends of the chamber. There are no fundamental technical issues with the proposed design, but there is significant technical, design, and fabrication development to be completed. The *Plan B* design and the undulator vacuum system were reviewed by subject matter experts on 27, 28 September 2006. The FAC agrees with the conclusions of that review. The vacuum chamber is the pacing item of the undulator system and it is very late in the project for a subsystem to still require this level of development. A 42" 4-weld vacuum prototype shows good mechanical results. As presently scheduled, this prototype will not be vacuum tested until after it has been coated and so the FAC is concerned that the design may present higher than calculated outgassing rates from virtual leaks. Vacuum testing of the 42" Prototype was not shown on the development schedule. A full length first-article vacuum chamber will not be completed until the end of January 2007 which is also the *gate-point* at which time any additional developments or changes to the chamber fabrication approach will begin to impact the overall project schedule. It is the opinion of the FAC that there is still a very high risk of schedule failure inherent in *Plan B*. The FAC is not convinced that full length prototype / first article will be completed by the deadline, but the FAC would love to be proven wrong on this point.

This concern for successfully achieving the full length prototype of *Plan B* is shared by the Undulator Systems Team and fall back alternatives are being investigated at this time. The FAC was given a status update of the *Undulator Chamber Task Force*. This taskforce has been charged with developing a fall back alternative design should the *Plan B* design fail to meet either performance or development schedule requirements. A concept review of the alternatives has been scheduled for 20 October 2006. There are two alternatives: an aluminum extrusion with the capability of distributed pumping and a welded aluminum *clam shell* structure. (These alternatives have been referred to as *Plan C* and *Plan C'* or *D* respectively.) There has been some preliminary work on these alternatives and basic concepts were presented to the FAC, but they clearly were not well advanced.

The FAC strongly recommends that effort on *Plan B* not be diluted and it should be vigorously pursued as the baseline. However, because of the high schedule risk, the LCLS Project must develop a fallback alternative design that can quickly be put into production if *Plan B* fails to meet the end of January 2007 milestone and avoid additional delays.

Additionally, the 42" prototype should be vacuum tested as soon as possible; even prior to it being aluminum coated. This prototype lends itself easily to vacuum gauge instrumentation being placed on one end and vacuum pumping being applied at the other. This test would give some idea of what level of vacuum would be achieved in the middle of a ~2-meter chamber. While a ~2-meter effective length chamber is shorter than a final production length, the vacuum calculations presented indicate that it would be expected to have only a slightly better vacuum one would find in the center of a full length vacuum chamber ( $\sim 2.1 \times 10^{-7}$  vs.  $\sim 2.5 \times 10^{-7}$  torr). The chamber once aluminum coated will probably not achieve a vacuum better than the uncoated version and so such a test will begin to bound the vacuum limits that might be achieved.

The beam-loss monitors for the undulator (beam protection system) have gotten off to a late start, but they were reported as being "significantly off of the critical path" (implying considerable float). The Undulator System Team heeded previous recommendations of the FAC and design work has begun in this area. The approach follows that of DESY with a multiple levels including scintillators/Cerenkov

detectors coupled to photomultiplier tubes, Cerenkov detectors, and long fiber optics. The FAC commends this effort and serious attention that the team is giving to this area.

The rf-cavity beam position monitors (rf-BPM) in the Undulator Systems continues to make good progress. There is a strong working design that recently underwent a final design review (FDR) with a complete testing approach on both the Injector Test Stand (ITS) and the Low Energy Undulator Test Line (LEUTL) at ANL. The 3 cavity BPM tests are scheduled to begin on LEUTL during December 2006. The entire effort appears to be on schedule and with strong results overall. The FAC has no specific recommendations on this area other than to keep up the good work.

Since the last FAC meeting there has been a realization that the transverse horizontal good-field region is inadequate to provide completely passive undulator  $K$ -parameter (B-field) tuning. This is evidenced by the fact that the measured change of the total first and second field integrals exceeds tolerance limits while the undulator is exercised through its complete tuning range necessary to accommodate resonant energy tapering. This resonant-energy tapering is needed for synchrotron radiation loss, wakefield losses, and optimal FEL saturation and extraction. The required variability of  $K$  along the length of the undulator is set at 0.6% (PRD 1.4-001). Measurements on the prototype indicate that the total horizontal field integrals remain within tolerance over the entire tuning range (First integral,  $I_1$ , has a total variation of less than 30 G-cm; second integral,  $\Delta I_2 < 5 \text{ kG-cm}^2$ ). However, the total vertical field integrals do remain within tolerance ( $\Delta I_1 \approx 55 \text{ G-cm}$ ;  $\Delta I_2 \approx 15 \text{ kG-cm}^2$ ) and exhibit a strong octupole term for which tuning had not been planned. Three compensation strategies are being explored. The first two strategies center around adjusting the transverse centerline  $K$  parameter of undulator sections to different values along the length of the undulator ranging from a few discrete values (3 *bins* as presented) to a maximum of every undulator section being adjusted in  $K$  parameter to a specific longitudinal location (33 different values) and restricting the tuning range to a transverse adjustment of  $\pm 2 \text{ mm}$ . The third strategy being explored is to use the original complete tuning range, but compensate for  $I_1$  and  $I_2$  variations by dynamic correction (either electromagnetic correction or transverse quadrupole adjustment). The preferred strategy as presented is to individually tailor the  $K$  parameter of each section to achieve the nominal taper configuration. The FAC suggests that LCLS may wish to more strongly consider the use of active compensation as it would avoid the individualization of undulator sections and would reduce the separate bookkeeping, and therefore the risk of error, that will be required as sections are exchanged during operation.

The quadrupoles are near the critical path and have suffered some delays since the previous FAC meeting (April 2006). Some of the issues that have been encountered are hysteresis effects that place the individual quadrupole poles at different operating points as a result of different  $B$ - $H$  excursions that each pole will see from the applied dipole and quadrupole moments. The Undulator Systems Team is working with the supplier to move from the present *build to specification* configuration to more of a *build to performance* configuration that will allow the supplier to employ techniques for which it is more familiar.

Considerable work in the undulator controls area has been realized, but there are concerns that with the division of labor between SLAC and ANL additional opportunities for items and issues to be overlooked exist. The Undulator Systems Team Leader indicated that there is a need to set up a detailed compilation of all controls items and responsibilities. This, of course should be handled by the overall LCLS controls so that everyone, at SLAC and ANL, understands what is required of whom. This requires an in depth discussion between the LCLS Controls and the LCLS Undulator as to what is included and implied in the schedule. LCLS may wish to consider designating a SLAC/ANL controls



liaison in a manner similar to those covering mechanical areas. This should be an area of concern for both LCLS Controls and the Integration Management Team.

## **4.0 X-Ray Subgroup Summary**

R. Falcone, J. Feldhaus, P. Fuoss, T. Rabedeau, T. Tschentscher

### **4.1 Presentations and Progress**

The attention of the x-ray subgroup is primarily focused on evaluating the development of x-ray systems and conventional infrastructure to support the experimental program of the LCLS, both current and future. The current program consists of six distinct experiments (the acronyms are local to this document for convenience):

- 1) AMO experiments in the soft x-ray region (AMOP),
- 2) soft x-ray pump-probe measurements and coherent imaging (SXP),
- 3) hard x-ray pump-probe measurements (XPP),
- 4) hard x-ray photon correlation spectroscopy (XPCS),
- 5) hard x-ray coherent imaging (XCI), and
- 6) high energy density physics (HED)

The first of these experiments is included as part of the LCLS project, experiments 2-5 are supported by the LCLS Ultrafast Science Instrumentation (LUSI) project and the final item will be separately funded. This review focused on progress, challenges and opportunities in the first five of these projects.

On Wednesday, Oct. 11 the sub-group met with the LUSI project team and discussed the project status. On Thursday and Friday, Oct. 12-13, the sub-group met with the LCLS X-Ray Endstation (XES) and the X-ray Transport, Optics and Diagnostics (XTOD) team.

The meeting with the LUSI project team was split into two main discussions. First, Jerry Hastings presented a detailed overview of the entire LUSI project and the challenges it faces. Due to budget guidance, the support for the Correlation Spectroscopy and Pump-Probe infrastructure has been reduced. Further reductions to all experiments will probably be required as a balance is sought to provide x-ray beam to all projects as early as possible.

A major technical challenge faced by LUSI is the transport of x-ray beams over hundreds of meters and through many optical elements without significant degradation of their unprecedented brightness. Between the LCLS and LUSI projects, a complex optical design has been developed to both provide separation from the high energy background radiation coming from the linac and to share the beam between several simultaneous experiments. The current optical design is a great improvement over what had been presented to the FAC in earlier meetings and has great potential for enabling highly productive science programs at the LCLS.

During the afternoon the committee looked into a few of the sub-tasks in much more detail, particularly the development of x-ray splitting monochromators, the beam transport system to the far hall, and data acquisition infrastructure for the experiments. The committee felt that the project was being overly optimistic regarding the fabrication of the x-ray optics, dynamic alignment of the x-ray optics, development of a computing infrastructure, and installation costs for the conventional aspects of the x-ray transport system. However, these areas were not chosen at random for review but were areas identified by the LUSI project or the committee as areas where problems seemed likely. Thus, the implication of this statement should not be extended to the entire project.

The Thursday discussions with the XTOD and XES teams focused on the plans for the first half of FY07. Donn McMahon (LLNL) presented a comprehensive plan for XTOD activities and milestones. It appears that all of the XTOD activities are on schedule. However, the FEL offset mirror systems are critical for LCLS experimental operations and have long lead times. Stefan Moeller discussed the plans for the XES efforts with a supplemental presentation by John Bozek on the experimental plans for the AMO experiments. There have once again been significant reductions in scope for the project with various items either deleted or transferred to other efforts. This trend continues to concern the committee. There has been significant progress in defining the physics requirements for the AMO experiment and developing its conceptual design. While a great deal of design and bid preparation is scheduled for early FY07, it appears that these efforts are on a reasonable schedule.

The committee has expressed concern over the lack of real-time, non-destructive beam characterization and monitoring tools, and had requested a presentation of plans for these important items. Richard Bionta presented a comprehensive discussion of the LLNL plans for a suite of diagnostic tools for the commissioning and periodic tune-up of the FEL. The committee believes that this suite of instruments should be capable of performing the required measurements. However, this presentation did not address the committee's concern that the project lacks an effort to provide the experimental programs with a data feed of beam parameters such as total photon energy, beam location and beam energy on a pulse-by-pulse basis. These are difficult technical issues that the project should address.

The committee has also been very concerned about the project's reliance on mirrors to separate the photon beam from the radiation background of the FEL. Peter Stefan presented a detailed discussion of the new beam transport system that relies on a combination of mirrors and monochromators to deliver FEL pulses to a variety of experiments with the possibility of simultaneous operation of multiple experiments. He also presented an analysis of mirror figure errors, intrinsic limits on pointing stability from a vibration analysis of the site, and the impact of bending induced focus errors associated with the mirrors. This presentation led to a long discussion of the limits of mirror performance. The committee believes that the use of informal specifications quoted by vendors is problematic and that the desired mirror performance remains at or slightly beyond the state of the art. The committee also felt that the control of gravity-induced bending of the "periscope" mirrors would be a significant challenge and encouraged the exploration of using a horizontal beam deflection rather than a vertical beam deflection to minimize this problem. Finally, while the intrinsic pointing limitations are well within the physics requirements, actual point performance is heavily dependent on careful design of the complete mirror, mirror holder, and mirror mover. Design of this critical component should be a priority.

There were extensive discussions during the three-day meeting regarding the relationship between LCLS and LUSI.

## **4.2 Observations**

Note that some of these observations (in italics) are repeated from earlier reports for emphasis.

- *Given the revolutionary nature of the LCLS source it is difficult to predict with certainty the requirements that future experiments will place on the optics, detectors, and conventional facilities infrastructure. Thus, flexibility and adaptability are keys to a successful design.*
- *Delaying the design and construction of components to the operational phase and relying on the experimental groups may cause difficulties. In particular, it is important for the experimental programs (mainly LUSI) to define their controls and diagnostic requirements quickly so that they can be incorporated into LCLS planning.*

- *The definition of the physics requirements for the various components is a crucial process. While much progress is being made on this issue, it is not clear that sufficient staff is available for this important activity to be completed in a timely manner that doesn't delay design and procurement.*
- *Communications within the project and with the experimental teams continue to improve. Yet there still seems to be inadequate attention paid to critical path items. In particular, there seems to be no appreciation that the critical path to commissioning may be significantly different than the critical path to successful experiments. Both should be optimized.*
- *Great progress has been made on the conceptual design of the AMOP experiment.*
- *The SPPS experience demonstrates that incorporation of shot-by-shot diagnostic and performance information from the RF, the electrons and the photons will be important to the success of the LCLS experimental program. Suitable x-ray diagnostics are apparently not being developed.*
- *Real-time x-ray performance information will be important for developing suitable metrics for accelerator performance. The lack of such metrics greatly hindered the SPPS program.*
- *The basic XTOD systems appear on track for initial LCLS commissioning. However, more sophisticated systems like the x-ray mirrors risk being late.*
- *The proposed staffing levels for the operational phase appear too low. Basing them on the much different operating environment of a storage-ring based synchrotron source is inappropriate since a much broader skill set will be required to effectively use an FEL.*
- The design, testing and acquisition of the mirror system is likely to be an extended process since the optic elements are near state of the art, unique alignment techniques will need to be developed for use with low repetition LCLS beams, and the lower operational stability (at least in the short term) may result in drift problems. The design of these systems needs to be advanced rapidly.
- The budget pressure is continual and items identified as scope contingency are not being pursued. Many of these items are still critical to the experimental programs and will need to be provided from some source eventually.
- Further down scoping of x-ray instrumentation will negatively impact the scientific output of LCLS.
- The coordination between LCLS and LUSI is complicated and yet remains dominated by relatively informal agreements.

### **4.3 Recommendations**

- Mirrors are crucial in the current concept
  - Mechanical and optical design concepts efforts can and should move ahead semi-independently.
  - The performance of both the mirrors and their mechanical mounts are at the state of the art. A panel of independent experts should be asked to provide early input into physics requirements and design.
- LUSI should obtain expert advice on design and fabrication of thin monochromator crystals since they appear critical to the future operation of the facility.

- LCLS and LUSI should define critical paths for commissioning and for the experimental program
- The FAC should provide advice that spans LCLS and LUSI.
  - LCLS and LUSI should bring problems at an early stage to the FAC.

## 5.0 Controls Subgroup Summary

T. Himel, K. White

There has been a lot of progress made since the last FAC meeting in April 2006. Many of the suggestions we made at the last meeting have been implemented.

### 5.1 *Previous Concerns That Have Been Addressed or Are No Longer Relevant*

1. At the April 2006 FAC, Hamid expressed great concern about the cost and schedule for the controls effort which he had just taken over. He has since completed a bottom up estimate of the cost and schedule, and funding issues have been addressed via a considerable increase in the budget. Hamid still feels the budget is *lean* and we did not try to evaluate this at the meeting. There was an earlier internal review and an upcoming Lehman review which examine the new budget and schedule. Hamid has also formed engineering teams in order to improve coordination and address interface issues. The timing team still lacks a technical lead apart from Hamid.
2. We previously expressed concern about the lack of emphasis on using COTS solutions. The controls team now appears to be making good use of COTS and minimizing the number of in-house solutions by using the LLRF modules in several systems. This also effectively addresses the concern about multiple embedded IOC implementations.
3. Controls would benefit from a full time deputy group leader. This position is slated to be posted soon.
4. As of the April 2006 FAC, plans were not in place to provide high level applications for Injector commissioning in January 2007 although it was recognized that the final applications would not be ready. Since then, the controls team has formed a strategy that relies on the use of existing SLC applications and developing a short list of MATLAB applications to support commissioning. Additionally, physicists will be developing MATLAB applications and have been provided a user guide for this purpose.
5. We are sorry to see that developing a central data repository for static machine data is no longer in the scope for LCLS controls. Such a database would be of great benefit over the life of the machine.

### 5.2 *Previous Concerns That Have Not Been Fully Addressed*

1. *MPS* – While the extension of the 1553 MPS system has progressed well and should be ready for the Injector commissioning, the new LCLS MPS system is still early in its design phase and needs significant effort to be ready a year from now for the downstream linac commissioning. The hardware has been selected but not yet evaluated to see if the speed will be sufficient for

the expected data throughput. This evaluation in the form of a back-of-the-envelope calculation should be done before the design review planned for November. The design requirements for this system need further development.

2. **BPMs** – At the April 2006 FAC meeting, we expressed concern at the schedule for the BPMS and the fact that a digitizer had not yet been selected. The digitizer has now been selected; however, the BPM hardware is at high risk of being late for the January 2007 commissioning activities. The resolution meets specifications, but calibration, stability, and thermal testing still need to be done. There also remain some questions regarding what software functions are needed for January 2007 and how to provide them. The basic idea is to link the new BPMs into the SLC software for most purposes. However the timing and BPM software to support the new BPMs in EPICS remain to be implemented. A design review is planned for November.
3. **Schedule** – The tight schedule in some areas was noted at the April 2006 FAC. Significant progress has been made in the purchasing and installation of cables and this activity is now on track to support January 2007 commissioning. Schedule concerns for January 2007 remain for the timing system, BPMs and toroid electronics. It appears that all other systems are on track for January 2007 commissioning.

### **5.3 New Concerns**

1. The emittance and bunch length measurements done in MATLAB on the LCLS side will not be available to the correlation plots on the SLC side as currently planned. Controls should check with the accelerator physicists to see if this is a problem as the reviewers fear it may be.
2. Hamid mentioned a shortage of coordinators which could slow down installation.
3. While the MATLAB applications developed by the Controls Group are under revision control, the ones developed by the physicists are not. These programs also need to be under revision control to prevent accidental lose of source code and ensure a quick return to previous working versions.
4. An interim BCS is planned for January 2007 and the schedule is tight. We agree with the decision to delay the mode switching until next year in order to meet more pressing deadlines.
5. For several systems (e.g. BPMs, timing, high level applications) questions remain regarding what software functionality is needed for January 2007 versus what can wait for later. The “must haves” for January need to be identified as soon as possible so someone will have time for implementation and testing in advance of commissioning.

### **5.4 New Progress and Things We Particularly Liked**

1. There has been great progress on most systems. Many schedule concerns identified at the last FAC have been addressed. Most systems are on track for the January 2007 Injector commissioning with the exceptions noted above.
2. Formation of Engineering Teams: These teams have been put in place to help with integration between the various groups working on installation and development. They are meant to address project lifecycle, interface and coordination issues and are in close communication. This type of interaction is critical with such a tight schedule.

3. The PLC based PPS has passed multiple internal Radiation Safety Committee reviews and is progressing well.
4. Plans to use electronic logbooks already in use at SLAC should provide good continuity.

## **6.0 Conventional Facilities Subgroup Summary**

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

### **6.1 General**

The Conventional Facilities (CF) Subgroup of the LCLS Facility Advisory Committee met with the LCLS CF management personnel in order to review the progress of the CF portion of the project. Progress has been made since the April 2006 review of the project with over 80% of CF contracts awarded, construction in progress and the CF Earned Value reported at 30%. The project director, John Galayda, asked our subgroup assist CF on imminent DOE reviews of LCLS.

### **6.2 Findings**

The earned value for CF is approximately 30%.

The CF bids are in and are ~ 50% over baseline.

The CF design has been stable for several months and over 80% of the bid packages are awarded.

The project is holding 15% contingency for contracts post award and a specific assessment of the CF contingency required post award is in progress.

Due to the 50% cost increase over budget of CF contracts as bid and awarded, the project has removed the CLOC from the CF scope.

The risk registry for CF is being reviewed and updated.

The CF organization has been strengthened with the addition of the APD and staffing.

Procurement/contract administration has been strengthened with the addition of assigned personnel for the construction phase.

An Integrated Management Team (IMT) has been created to address configuration management and interface control. The approach defined maintains overall responsibility for integration with the system managers.

The LCLS construction safety record at this point in the project is excellent.

The LCLS has a documented process for authorizing work; however, the program is not being fully implemented to the level of detail required.

A documentation control system has been implemented; however, the mechanism for notification and distribution of approved field changes (redlines) to users requiring the information is not fully developed.

In general, CF has addressed the concerns and recommendations from the April 2006 FAC meeting. See the Comments section of this report below for specifics.

## **6.3 Comments**

### **6.3.1 Safety**

LCLS continues to improve its safety program. The excellent record achieved by its contractors having worked 136 days without an injury demonstrates this. The creation of the integration management team is a positive path forward that will insure that various subject matter experts are involved in all changes to the project. This will improve overall safety.

Operation of the LCLS facilities will require a new or modified Accelerator Readiness Review (ARR). LCLS should continue to work closely with the accelerator departments to make sure all necessary devices, procedures and environmental issues associated with operating the LCLS are addressed in the ARR.

The use of the *SLAC Today* web page to convey general information about LCLS and publicize safety concerns gets information quickly out to the entire Lab.

An area of concern is that documented safety processes are not being fully implemented to the level of detail required. The LCLS has a documented process for authorizing work. The committee was shown two LCLS work authorizations forms both dated August 2006. The first had none of the required ESH review signatures and still the work was approved. The second was missing two ESH review signatures it also had comments attached and none of the boxes that indicated that comments were attached were marked to indicate that they existed. Allowing work to be performed without proper approval must not be an accepted part of the everyday way of doing business.

The committee stresses that this is a very serious concern. LCLS should take aggressive actions to make sure everyone understands that work should not proceed until all necessary signatures are obtained. A similar problem was identified in June of 2006 when a DOE ISMS review of SLAC noted that LCLS contractors did not have all the required signatures on their Job Safety Analysis forms. The consequences for not following proper approval methods could shut down the project. These required signatures act as a barrier that make sure safe work practices are in place prior to starting work. The LCLS managers that are required to sign work authorizations need to be involved in the work planning of these tasks.

### **6.3.2 Contingency**

The project team has needed to react to the bids received that were 50% over budget; therefore the CLOC building was removed from the project, which allowed the Project to maintain a 15% contingency on CF contracts as placed. While we are not aware of a workable scenario that would restore the CLOC building functions to the project scope, it may be possible to help the situation with a multi-prong approach. It seems to us that the 15% contingency for contracts already placed is very conservative. The most difficult portions of the construction, and perhaps construction still subject to some design changes, might need 15% contingency. But there are other contracts that may have little call on the contingency. One might choose half of the currently assigned contingency and keep that as

a stretch goal, i.e. 7.5%, and put 10% in the potential contingency allocation budget. Then the project should keep careful trend of the contracts underway and try to achieve 7.5% goal. If the trend shows the possibility of reaching 7.5% then the potential contingency allocation could be reduced to 7.5%.

This approach may release some of the reserved contingency for the restoration of the CLOC functions in some other on site configuration. Currently the project staff is evaluating a few options and this contingency reduction might help in choosing among the alternatives.

We encourage the project staff to complete the analysis for the CF contracts contingency requirement as soon as practical. While the preliminary result shows about 10% need, with the commensurate tracking in the risk registry and trend analysis, 7.5% could be achievable, per experience in recent DOE projects. This level of contingency can only be achieved through the effort of the whole project team including those that set technical requirements as well as those that execute the CF activities. The Project Management team needs to exercise strong backpressure on any new design changes or improvements, since their cost effectiveness at this stage of the project are dubious.

### **6.3.3 CM and Construction Cost/Quality Performance**

There is more than one philosophy of construction procurement successfully implemented by owners and managers of facilities. One practice is to bring the CM on-board early to help manage the evolution of design and project baselines. This contracting method is sometimes called Construction Management. With this CM dominated approach, the budget and schedule commitments are more readily made a part of a CM contractor performance incentive.

Another approach is to bring the AE on board first to help select a builder, usually a General Contractor (GC). The LCLS Project elected to bring the CM/GC contractor on-board later rather than sooner, so the “CM” has not been a full participant in budget baselines. Consequently, effective incentives on project cost performance are more difficult to place in the CM contract. Recent attempts to reach an agreement on cost incentives with Turner reflect the difficulty inherent in this procurement strategy with regard to CM incentives. Because of the construction procurement strategy implemented by the LCLS, it is now absolutely essential that the CF staff maintain a very direct role in field construction cost controls.

The LCLS CF reports they are inspecting and accepting incremental construction work directly. Turner does not inspect and accept fieldwork before the Owner. Because of the dominant role in field QC now implemented by CF, it is also absolutely essential that the CF staff maintain a highly qualified staff of field construction inspectors. The addition of a highly qualified and very experienced APD for CF should assure the CF staff has and maintains the personnel capabilities necessary. If there is any doubt about this Owner personnel commitment, the CM should be required to inspect and accept construction before the Owner.

## **6.4 Response to Recommendations from the April 2006 FAC**

- **Recommendation #1:** Consider adding cost schedule incentives to the CM/GC contract, either by an explicit formula or indirect means (such as scheduling early completion in 24 months).
  - **Response #1:** Cost incentives were explored in some detail with Turner on two separate occasions, but a mutually agreeable cost number could not be found. It appears that the



remaining incentive for the CM/GC is early project completion. The LCLS CF staff is taking a very direct role in construction cost changes and construction quality control.

- **Recommendation #2:** Reestablish top level management meetings between the CM and SLAC.
  - **Response #2:** Monthly meetings have been reestablished and the APD for CF position strengthens senior level management participation on the Turner interface with newly assigned on-site Turner Project Executive.
- **Recommendation #3:** Continue strengthening the CF staff.
  - **Response #3:** CF management has made good progress in this area. The addition of an APD for CF to the team is an excellent move and care is being taken to not confuse accountabilities. Since this and other organizational changes have been implemented recently, it is imperative that roles and responsibilities are clearly defined and understood by everyone.
- **Recommendation #4:** Ensure that CF is involved in the safety documentation approval process
  - **Response #4:** CF management is included in the approval process and required to sign off on those items both directly and indirectly affecting CF planning and execution.
- **Recommendation #5:** Periodically present field changes above a certain value threshold to representatives of other LCLS systems.
  - **Response #5:** This item will be addressed by the newly formed Integration Management Team (IMT).
- **Recommendation #6:** CF Group staff additions and functional organization is a step in the right direction.
  - **Response #6:** See Response #4 above.
- **Recommendation #7:** In order to handle the anticipated “paper workload” staff specialists will need to be added.
  - **Response #7:** Part time help has been applied to this problem.
- **Recommendation #8:** Little evidence has been presented that the environmental issues have been fully addressed in the LCLS PSAD or the planned SAD.
  - **Response #8:** The project will include additional items in the Operational Safety Program.

## **6.5 Conventional Facility Comments from April 2006 Report with October findings**

- There appears to be a disconnect between CF and technical specifications generated by other organizations that may impact CF work (e.g. CF did not review the general cable specification document).
  - **Oct. 2006 finding:** CF management has been included in the signature chain for approval of changes when those changes may affect the CF portion of the project.
- It appears that the physics staff is not as involved in monitoring the CF activities as previously (such as changes in design and specifications).

- **Oct. 2006 finding:** We have been assured that this is not the case. Jim Welch is the liaison physicist to CF.
- Channels of communications must be maintained to ensure that field changes do not compromise physics interfaces.
  - **Oct. 2006 finding:** There was a mechanism for Field Change Orders (FCOs) described during this review, but it is in its infancy and distributing FCOs (including drawing revisions) to the necessary users appeared cumbersome and possibly insufficient.
- LCLS management must be proactive in assuring that SLAC's contribution to the SAD is completed to meet project milestones.
  - **Oct. 2006 finding:** No specific follow-up on this item in October.

## **6.6 Recommendations**

1. Reevaluate the contingency held for post award CF contracts.
2. Prepare options for CLOC alternatives.
3. Fully execute the planned safety program.
4. Summarize risk registry numerically at the bottom line for CF as a whole as a measure of contingency required for future risks.
5. Fully develop a system for redlined drawing changes and their timely distribution so all users have timely access to changes that impact their areas of responsibility.

## Appendix A

### LCLS Facility Advisory Committee Members

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## Appendix A

# Facility Advisory Committee (FAC) Meeting April 20-21, 2006

## AGENDA

### Thursday, April 20<sup>th</sup> – Plenary

*Location: Orange Conference Room, Building 040*

7:30	Executive Session	
8:00	Welcome	J. Dorfan
8:10	Opening Comments	K. Hodgson
8:20	Project Status Update, and Charge to Committee	J. Galayda
8:50	Safety	M. Scharfenstein
9:00	Project Management	M. Reichanadter
9:20	E-Beam Systems Update	D. Schultz
9:40	Undulator Update	S. Milton
<b>10:00</b>	<b>Break</b>	
10:20	Photon Systems Update	J. Arthur
10:40	Controls Update	H. Shoaee
11:00	Conventional Facilities Update	D. Saenz
11:20	Adjourn to Breakout Sessions (see Breakout Session Agenda)	
5:30	Executive Session (Orange Conference Room, B040)	
7:00	Dinner – <i>Amarin Thai Cuisine</i>	Committee/Speakers

*174 Castro Street, Mountain View, CA*

### **Breakout Session 1: Design & Construction: Accelerator Systems**

*Location: Red Slate Conference Room, Building 280-C*

11:30pm	Injector/Linac System Overview Integration, Installation, & Schedule	E. Bong
12:00pm	Injector Beamline Design & Fabrication	C. Rago
<b>12:30</b>	<b>Lunch</b>	<b>Orange Room</b>
1:30pm	Laser Installation & Commissioning	B. White
2:00pm	RF Gun Fabrication & Testing	D. Dowell
2:30pm	Bunch Length Monitor Development	S. Smith
3:00pm	SAD & ARR for Commissioning	D. Schultz
<b>3:30pm</b>	<b>Break</b>	
4:00pm	Physics Commissioning	P. Emma
4:30pm	Discussion	All

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### **Breakout Session 2: Design & Construction: Undulator Systems**

*Location: SSRL 2<sup>nd</sup> Floor Conference Room, Building 137*

11:30pm	1st Article Report & Undulator Production Status	S. Milton
12:00pm	Undulator Vacuum System	D. Walters
<b>12:30</b>	<b>Lunch</b>	<b>Orange Room</b>
1:30pm	Single Undulator Test Status/Plans	G. Pile
2:00pm	Undulator System Assembly Plans	R. Pope
2:30pm	MMF and Magnetic Measurement	Z. Wolf
3:00pm	Alignment Strategy	H. D. Nuhn
<b>3:30pm</b>	<b>Break</b>	
4:00pm	RF BPM Status and Planning	Morrison/Milton
4:30pm	Discussion	All

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**Breakout Session 3 - Design & Construction: XTOD & Experiment Station Systems**

*Location: Yellow Conference Room, Building 041*

11:30pm	XTOD Planning for 2nd half FY06	D. McMahon
12:00pm	XES Planning for 2nd half FY06	S. Moeller
<b>12:30</b>	<b>Lunch</b>	<b>Orange Room</b>
1:30pm	X-ray Transport System	J. Trent
2:00pm	X-ray Slits	J. Trent
2:30pm	X-ray absorbers	S. Shen
3:00pm	X-ray beamline and experiment layout	J. Arthur
<b>3:30pm</b>	<b>Break</b>	
4:00	Discussion	All

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**Breakout Session 4 - Controls**

*Location: Orange Conference Room, Building 040*

11:30pm	Controls Organization Overview	H. Shoae
12:00pm	Timing Systems Update	D. Kotturi
<b>12:30</b>	<b>Lunch</b>	<b>Orange Room</b>
1:30pm	LLRF Update	R. Akre
2:00pm	Injector/Linac Controls Installation	Shoae for Fuller
2:30pm	PLC-based Personnel Protection Systems	M. Saleski
3:00pm	High-Level Applications and Feedback	Shoae for Fairley
<b>3:30pm</b>	<b>Break</b>	
4:00pm	Network Security	T. Lahey

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**Breakout Session 5 - Design and Construction: Conventional Facilities (Saenz)**

*Location: ES&H Training Room, Building 003*

11:30pm	Construction Organization & Processes	D. Saenz
12:00pm	Construction Procurement Management	D. McGiven
<b>12:30</b>	<b>Lunch</b>	<b>Orange Room</b>
1:30pm	Construction Safety	R. Hislop
2:00pm	Tunneling Safety & Logistics	R. McDonald
2:30pm	Discussion	All
<b>3:30pm</b>	<b>Break</b>	
4:00pm	Discussion	All

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**Friday, April 21<sup>st</sup>**

*Location: See Room Location listings below*

<b><u>Time</u></b>	<b><u>Topic</u></b>	<b><u>Location</u></b>
7:30am	Executive Session	Orange Room, B040
8:00am	Breakout Sessions, <i>continued if necessary</i>	
	Breakout 1: TBD	
	Breakout 2: TBD	
	Breakout 3: TBD	
	Breakout 4: TBD	
	Breakout 5: TBD	
10:00am	Executive Session	Orange Room, B040
<b>12:00</b>	<b>Lunch</b>	<b>Orange Room, B040</b>
1:30pm	Executive Session	Orange Room, B040
4:00pm	Closeout - Plenary	Orange Room, B040