Report of the April 2004 Meeting of the LCLS Facility Advisory Committee

H. Carter, J. Feldhaus, P. Fuoss, T. Himel, W. Leemans, J. Pflueger, T.Rabedeau, K. Robinson (chair), J.Rossbach, K. Schuh, P. Siddons, and K.White

1.0 General

This report assembles the findings, comments, and recommendations of the Linear Coherent Light Source (LCLS) Facility Advisory Committee (FAC). . The FAC was charged with examining the project efforts from the perspective of an integrated facility. In order to accomplish this charge, the FAC is divided into four major subcommittees with emphasis on particular technical areas of the project and facility. The first of the four subcommittees is the Electron Subcommittee (including injector/electron gun and laser system, linear accelerator, and undulator system). The second subcommittee is the X-ray Subcommittee (including the front end, the near and far experimental halls and experimental support). The third subcommittee is Controls, and the fourth subcommittee is Conventional Facilities (including global Environmental, Health and Safety).

Appendix A is a list of the members of the LCLS Facility Advisory Committee and Appendix B is the Agenda of the April 2004 Meeting of the FAC.

General Comments

The Linear Coherent Light Source (LCLS) is an exciting project with strong project preparation and a great team. The quality of the work presented was excellent work. Project preparation appears in relatively good shape and the project team is to be commended.

<u>Integrated project and process:</u> There is evidence of complete integration within the project in regards to the facility, but much work remains. Consequently, there are attendant risks to technical performance, cost and schedule. These risks are likely both explicit and hidden and may not be fully appreciated by the project at this time.

<u>Comment:</u> It may be advantageous to focus future FAC meetings on pre-defined issues, that is, spend only about half of the available time on general project progress and half on the special subjects such as tolerance budgets, reliability issues, failure management, electron and photon diagnostics. Otherwise, it may be difficult for the Committee to delve sufficiently into detail to provide substantial benefit to the project.

Recommendation: The LCLS team is encouraged to continue to concentrate on the development of an integrated installation and commissioning plan that focuses on links between subsystems.

2.0 Electrons Subcommittee Summary

W. Leemans, J. Pflueger, K. Robinson, J. Rossbach

2.1 Injector / Electron Gun

Electron gun

The overall design of the electron gun is based on years of experience by world-leading experts. The design is well justified and computer-modeled in terms of mechanical and electrical behavior with respect to electron beam dynamics. Still it is important to realize that at present no prototype exists fulfilling the design performance. Consequently, the FAC, based on experience in this technical area, recommends that the project perform early tests of the main components, and perform failure safety analysis of both components and entire system. The project should also develop concepts for failure handling. Associated with this is that redundancy should be implemented from the start into the design and that in addition to the failure analysis, reliability studies should be conducted as soon as possible.

Associated with the electron gun it was not clear that the specifications on profile uniformity are consistent with experience at BNL in regard to emission. This is something that should be tested soon and the FAC wonders if this could be done at the Gun Test Facility (GTF).

It is suggested that LCLS find a laser research institute ready to commit for injector laser R&D. Further progress on drive laser performance in terms of longitudinal and transverse profile, stability and reliability will be critical for the entire LCLS project.

In order to reduce integration issues, the FAC suggests that within the laser system that orders for the IR and UV parts not be split between companies. The danger in separating out the bids to different vendors is that should a problem develop each supplier will point to the other and LCLS will most likely be left with the liability. Consequently, specifications to "vendor" should include entire system needs:-Danger in separating out bids to different vendors--it will be the other guy’s problem.

The proposed timeline calls for bids to go out by June 2004. The FAC suggests the involvement external reviews be employed in defining request for proposal, not merely proposal evaluation.

LCLS should consider installing a full-scale duplicate of electron injector as a quick back up in case of a gun failure. LCLS should even consider a third branch for testing new gun versions during dedicated machine shifts.

LCLS should perform tests of performance and reliability of components and system as soon as possible. To this end, a test stand should be available (not necessarily at SLAC, but somewhere) by mid of 2006. Likewise, the project may wish to seek input from laser developers at LLNL and other labs on system designs for maximum reliability.

Even though a detailed design is available, construction of the LCLS injector should be considered as having research project aspects rather than merely just a construction job. The reason for this is simple – an expert team must be available to react on problems (which will almost certainly happen) during construction, commissioning, and long-term operation. This expert team is also indispensable to help define a strategy towards further gun performance improvements beyond baseline design values. These performance improvements will very likely become clearly desirable based on operational experience and evolving user demands.

Within the laser system itself the design indicates that all colors will be used, but the specific requirements for the laser heater were not obvious. Experience at LBNL indicate that laser mode characteristics will be critical. LCLS should consult with the physicists at LBNL involved in the ultrafast slicing experiments.

The laser synchronization experience at SPPS is very positive and has produced some very impressive results. Some care needs to be exercised in the extrapolation of the SPPS work to LCLS. For example, LCLS should study impact of implementing timing system on facility needs (e.g. temp stabilized cables, penetration through shield walls, etc.).

2.2 Accelerator

Linac System

The linac system is well developed and understood. The FAC was pleased to see that the superconducting wiggler and its attendant complications were no longer part of the baseline. The initial diagnostic suite seems adequate, but care should be exercised to understand the effective “dynamic range”. In the words of one member of the FAC: “How good do the diagnostics work when things are really messed up?”

LCLS should look into the possible use of the laser heater as a diagnostic tool for both e-beam and FEL characteristics. The collimator scheme and protection of the undulator seems well thought out and the FAC looks forward to shower calculations being completed.

2.3 Undulator System

Undulator Magnet

LCLS should replace the permanent magnet quadrupoles with electromagnetic quads. This will increase flexibility for optimization of SASE gain, which is important because precise parameters of electron beam are not known yet, and may change over the years. It will also simplify the beam based alignment procedure. Note here the experience from TTF1. TTF1 had to use permanent magnet quads which were superimposed to the undulator fields because a betatron function ~1 meter was required. The DESY experience with beam-based alignment by energy variation has not been favorable, as predicted, by the way, by SLAC experts. For LCLS the optimum betatron function is ~20m, so it is suitable to use separate quadrupole magnets. With separate quadrupole magnets electromagnets are much better.

The presented commissioning procedure of the undulator and of SASE assumes saturation at the undulator exit. This is not commissioning. For commissioning, LCLS should assume there is initially very little gain (that is only factors of 100-1000 above noise), or even no gain whatsoever. Based on this initial assumption procedures must be developed to improve gain. This will identify what tools are needed. LCLS must then verify that those tools will be available and have adequate capability.

LCLS should complete working out an over-all wake-field budget for the undulator vacuum chamber (This work is already under way).

The Undulator has seen some major improvements during the past 6 months:

Canted poles: The Canted pole design now offers the way to: Precision adjust the K-Value of an undulator segment, to introduce a taper, if needed, and reduce requirements on thermal stabilization.

Roll away option: This was introduced to retract an undulator segment from the beam, thus reducing provision of a means of effectively “switching it off”, and protect it against radiation exposure. For this option, the segment has to be mounted on horizontal precision linear slides. This option will open new optical diagnostic modes and ease commissioning. Presently, only a manual is planned.

Quadrupole mounts: A quadrupole is still rigidly connected to the corresponding undulator segment. Thus, quadrupole and undulator segment can only be moved together via the micro mover system.

Granite girders: Granite girder length and undulator segment should coincide. Presently, every third segment’s bridges over two granite girders. Moreover, the present design of the undulator segments does not make the need for granite girders evident.

Optical diagnostics between undulator segments: There are still short and long intersections between undulator segments. However, any beam intercepting optical diagnostics has been removed. Instead optical diagnostics have been foreseen after the undulator system.

Comments, recommendations

All of the items cited above, quadrupole mounts, Roll away option and canted poles are intrinsically connected to each other. Unfortunately, the present configuration does not make use of the full potential.

Recommendations:

1. Quadrupole and undulator segments should be separated. Careful analysis of which components need to be moved, and which do not, is recommended.
2. The roll away option should be available from remote and controlled via length encoders, etc.

This would allow for the following options:

1. Local K-Parameter variation of a segment, i.e. optimization of taper/output power; the exact K-parameter is then adjusted via the horizontal position. This is not possible with the present system.
2. Removal of segments for the beam for purposes of optical diagnostics or to reduce radiation exposure of the magnet material during commissioning

For the horizontal movement of the undulator segment a moderate accuracy of only 300µm, or less, is required. In the vertical direction, no movement is needed for the undulator segments, but the alignment tolerance is only 50 µm.

The quadrupoles, on the other hand, need to be moved for the beam based alignment (BBA) by a moderate amount in both directions (±50 µm). It was not clear to the FAC whether or not there is any need to move the undulator segments at all via the micromovers. It may be worth considering that the quadrupoles are moved alone on the micromovers while the undulator segments stay fixed. The undulator segments, however, remain movable on horizontal translation stages. The FAC proposes having a granite girder length properly synchronized to the segment length so that the undulator is on its horizontal translation with the quadrupoles separate. A revised mechanical design, with undulator segment and quadrupole separated, could thereby profit from the stability provided by the granite girder.

The quadrupole in the present proposals are a fixed Permanent Magnet. BBA then only works via electron beam variation. This proved to be unfavorable and inaccurate in TTF, due to Linac instabilities. BBA is much superiorly implemented if the quadrupole strengths can be altered. Electo-magnets or adjustable PM one are recommended for this purpose.

Radiation Damage

Significant progress has been made in planning for collimators, dog legs and radiation detection systems to passively and actively protect the undulator system during operation. Additional reduction of radiations exposures will be provided by the 'Roll away option'

Although no hard data are available, the choice for NdFeB material under these conditions seems acceptable.

Long lead procurement

It is planned to start procurement of long lead items in October 2004. For the undulator system, this relates to Poles, NdFeB magnets and Ti strongbacks only. It is planned to procure these items for the whole undulator system beginning in Oct 2004. Then, a different supplier will be used for the assembly of the undulator segments. This approach, however, maximizes production risks to ANL. It distributes production over different vendors and requires additional logistics for supplying poles, magnets, and strongbacks, etc. Also quality and liability issues might become important if clear roles and responsibilities are not strongly evident.

One main contractor is recommended. This contractor organizes production and takes care of all liability issues. For the undulator segments this might be, but need not be, the magnet manufacturer. Many synchrotron radiation sources have had good experience building undulators in this way.

Of course, one should make the best choice for the project and find creative ways of fitting a procurement, which minimizes production risks, into the available funding profile.

Optical Diagnostics

Included in the scope of work for the undulator system are dedicated optical diagnostics for the undulator system located in the Near Hall after the undulators. These diagnostics may include: Photon Beam Based Alignment (PBBA), and exact spectral diagnostics for individual undulator segments, if the remote roll away option is exercised. No details of these diagnostics were presented at the meeting.

Integration:

Temperature Stability:

If isolated, the natural temperature for the undulator tunnel hall would be at ~59° F in the absence of any heating or cooling. People generally prefer to have an ambient temperature of ~72° F. The question that LCLS should ask then is "What would be the appropriate temperature for running the undulator system, and are insulating jackets needed to surround the granite blocks, the undulator system, or people accessing the tunnel during maintenance?" This question should be examined from a systems perspective with regards to temperature control, stability, set point and a total project/lifecycle cost and benefit analysis.

Granite, Cradle, Support:

Again, the FAC feels that systems and engineering resources should be added to look at optimizing the total approach. Bridging gaps by undulator system sections compromises the value of the granite blocks. The project should consider from a system standpoint that if it is acceptable to bridge between granite blocks with every third undulator section, would it be acceptable to have all undulator sections bridge between smaller blocks? A complete commissioning approach and scheme is required. All parameters will undoubtedly be completely awry at the start commissioning. A well developed plan could significantly accelerate the process in obtaining a true optimization.

3.0 X-Ray Subcommittee Summary

Paul Fuoss, Pete Siddons, Tom Rabedeau, Josef Feldhaus

The following are the major subsystems covered by the X-ray Subcommittee of the FAC:

- ☐ Front End
- ☐ Near Experimental Hall
    - o Hutch layout
    - o Diagnostics
    - o Experiments
- ☐ Far Experimental Hall
    - o Hutch layout
    - o Beam distribution system
    - o Conventional infrastructure
- ☐ Experimental Support
    - o Detectors
    - o Computer infrastructure

Issues

The details presented to the FAC were very sparse. This is appropriate at this stage, but rapid progress needs to be made as soon as LOIs arrive.

<u>Mis-steered beams</u>: Questions that need to be considered by LCLS include: How are optical components protected in case of component failure? Where does beam from reflective slits get absorbed?

<u>Per shot beam characterization</u>; Each pulse needs to be characterized nondestructively if single shot experiments are being performed. The may result in significant computational and/or network demands. Additionally, LCLS may wish to consider as to whether analysis of higher order spontaneous radiation can be used to help alignment, find gain signal or optimize the FEL beam.

Stability of optics: Very long lever arms and small beams make stable operations and optimization difficult and should considered carefully.

Ergonomics (workflow): The LCLS needs to consider the ramifications of having the laser room upstairs from the experiments.

Detector development: Detector development needs to be driven by performing a high-priority experiment uniquely needing the LCLS capabilities. Included in the detector development suite should be an energy-analyzing detector.

Positive Developments

Far Experimental Hall layout is a big improvement over earlier designs; moving the Near Experimental Hall downstream should also help with optics design. Also, with the LCLS facility having support services close to experiments is very good.

The overall design appears very flexible and capable of incorporating future upgrades.

4.0 Controls Subcommittee Summary

Tom Himel and Karen White

Background

The control system for the LCLS will be developed as a collaborative effort by the partner labs, SLAC, ANL and LLNL. Each laboratory is responsible for delivery of the controls associated with their respective machine segments. In keeping with this model, the controls work and budget has been distributed to the various WBS organizations. A wide variety of devices must be supported across different hardware platforms. However, the pieces of the control system provided by the partner labs must be integrated together in a way that provides an easily operable machine. Additionally, the new LCLS controls must be integrated with the existing SLC control system.

Status

A basis for establishing some consistency between the controls provided by the partner labs has been provided by the selection of a single toolkit, EPICS, for controls system development. The LCLS group has also taken steps to identify preferred hardware platforms to avoid the complexity associated with the proliferation of multiple types of devices to accomplish the same function. It has also been correctly recognized that the integration between the LCLS EPICS system and the SLC control system is a unique and critical element, which must be developed. A small global controls effort has been identified to handle some functions, which are unquestionably global in nature (e.g. network infrastructure, timing and synchronization, machine protection).

Concerns

<u>Details are sparse:</u> Although a lot of excellent work has been accomplished and was presented, the controls design is at an early stage of development, and it is difficult for the FAC to make detailed comments at this point. It appears that the definition of the needed hardware modules is proceeding well. The definition of needed software components is not as far along and some areas such as global tools have not been addressed yet other than the selection of the EPICS toolkit. In particular, the details of the X-ray beamline controls are not defined and need careful attention from management to ensure the design follows the standards established for the overall control system.

<u>Distributed organization of the controls work and budget</u>: Despite recommendations of previous reviews, the LCLS project appears to be committed to the horizontal distribution of the controls work and budget. While there are clear advantages to this approach, management should be aware of the corresponding disadvantages and prepare to minimize the potential associated problems.

These disadvantages include:

- Difficult to define and enforce standards
- Difficult to integrate non-standardized pieces into a coherent system
- No central budget accountability; risk of controls budget erosion due to system specific problems

While EPICS has been selected as a common toolkit for control system development, EPICS can, and has been utilized in a myriad of ways with widely different results. It is important for management to take steps that ensure standardized usage of EPICS in order to secure a consistent and well-integrated product. This can be accomplished by strengthening the role of the global controls group. The scope of the work for the global controls group is not yet well defined. Management should have this group set standards for controls development across the project and provide common controls development project infrastructure by providing:

- Central control system database
- Element naming convention
- Code management system
- Standardized system tools (e.g. display manager, archiver, alarms, error handler, e-log)
- Standards for controls development
    - User interface design guidelines
    - Common error handling
- Standards for supported controls infrastructure
    - Operating systems
    - Hardware platforms
    - Devices and electronic modules

- Tools (programming and scripting languages, libraries, middleware)

Without a strong compelling reason, all controls development, regardless of position in the organization, should operate according to the specified standards. Setting and enforcing such standards will reduce the overall cost of development and maintenance. It will also provide a more operable system for the operations staff by providing a common look, feel and behavior. We strongly emphasize this point because there is evidence that early developments are going in different directions, perhaps due to a lack of specified standards. This can be directly related to the earlier lack of a central controls group. It appears that the current management agrees with this philosophy and we encourage these efforts.

The need for a central database: Ideally, the project would begin with a central database to be used as a repository for commonly shared information such as hardware layout. The lack of such a database early in the project will inevitably lead to each developer or group creating individual solutions. This wastes manpower, ensures there is not one common authoritative source of information, and creates maintenance nightmares. Management has indicated their intention to hire a database person and this should proceed as soon as possible.

The developers at APS stated their intention to use an APS developed database, IRMIS, for documentation of controls hardware and software. This system clearly has not been adopted for the project and may in fact be the wrong choice. This system relies on the EPICS IOC databases as the source of hardware configuration information. This is understandable in trying to understand an existing system, however, seems backwards as a way to begin a new project. Hardware configuration information should originate in the relational database and the online database should be generated based on this information.

SLC aware IOC: The need for a link integrating the existing SLC controls with the new LCLS controls was properly identified as an important controls task. Such a link is critical to the success of the LCLS control system. The design and prototype of this work should proceed as soon as possible to assess the feasibility of the presented plan and minimize potential risks. Providing this link will allow LCLS to take advantage of existing SLAC high-level applications. However, there seems to be some uncertainty regarding which SLC applications should be used as they currently exist, and which should be converted to the new system. Such details need to be addressed in order to truly assess the scope and cost of the controls work.

Machine Protection System: The scope of the requirements for the MPS system is not clear. There is some indication it may be a significant new system. There are MPS requirements that the beam be stopped on the next pulse. The "old MPS" system (relays and current loops) does this, but lacks good diagnostics. The "new MPS" system (CPU based) is said to have a 3-pulse delay. If this is the case, a completely new system called the Hazard Avoidance

Logic (HAL) may be needed. The situation is further complicated by the desire to use BPM and mover readings within the MPS system. These readings are typically provided within the EPICS IOC, which may not be robust enough for this use. This area needs more thought and definition to ensure the proper resources are allocated.

Tools for commissioning Injector

Tools for commissioning injector: The Injector commissioning is scheduled relatively early in the project. Attention must be paid to the schedule for delivery of common controls tools in order to ensure those needed for Injector commissioning are available.

BPMs: The following issues should be addressed with regard to the BPM system:

- The BPM electronics in the linac are being designed to handle e+ and e- beams on the same pulse, 60 ns apart. This complicates the design considerably. Management should assess the need for this capability (it is not for LCLS, but rather for the 3 months a year when LCLS doesn't run).
- Consider putting BPM immediately next to, and attached to, quad as is usually done to have them solidly locked together for beam-based alignment.
- The initial alignment plus electrical offset specification of 100 microns for the undulator BPMS is very tight. Is there data to support this requirement? Can the beam based alignment process be improved to ease this tolerance?

5.0 Conventional Facilities

Harry Carter and Keith Schuh

5.1 Response to Charge:

If one considers the LCLS as an integrated facility, will it support the range of possibilities for the presently envisioned experiments?

Yes, the proposed facilities will support the present envisioned experiments.

Are we [the LCLS] making design choices that foreclose important potential capabilities?

No, the present plan with three adequately sized experimental hutches in the Near Experimental Hall (NEH) provide the means to maximize the physics program by permitting one experiment to be taking data while two others are being installed and debugged. The hutch size planned in the Far Experimental Hall (FEH) appears adequate for future experiments.

Consider the LCLS commissioning challenges; do the design and diagnostics properly address the challenges of commissioning?

Yes, the conventional facilities design appears to adequately address the commissioning challenges.

5.2 Concerns and Recommendations

Schedule:

Concern #1: FFTB and Sector 20 decommissioning

Recommendation: Decommissioning of the FFTB and the linac sector 20 must not be delayed. Project schedule impact is essentially 1 day/1 day.

Concern#2: Procurement Process for Construction Contracts

Recommendation: Construction management needs to work closely with procurement to assure that the procurement process is streamlined to avoid unnecessary delays. Example: the prequalification of contractors and subcontractors should begin as soon as facility designs are finalized.

Technical Concerns:

Concern #1: Undulator movement issues, A/C, vibration, granite, supports, undulator itself. Every third undulator appears to span the gap between adjacent granite blocks. If this is the case, there may be problems with differential displacements between the spanned granite blocks and with thermal gradients across the gap.

Recommendation: Revisit this design and revise if possible. As a minimum, mechanical bump protection should be incorporated and removable thermal barriers to close the gap during normal operations should be incorporated.

Concern #2: QA program initiation.

Recommendation: Work should begin immediately on setting up a QA program. Equipment built at other labs or by subcontractors should have travelers attached. Acceptance-testing procedures should be developed.

Concern #3: Road relocation.

Recommendation: The plan to relocate the access/fire road should be revisited and a location as far from the undulator hall as is reasonable should be considered.

Environmental, Safety & Health

Concern: Delay in Environmental Sampling will Delay Project

Recommendation: Address ES&H issues of Environmental Sampling and waste disposal as soon as possible. Efforts should be made to see if it could be done at the same time as the geological core sampling that is being done. If contamination is found, it will add cost and lengthen scheduling. This issue should be addressed immediately.

Appendix A

“LCLS Facility Advisory Committee Members Present at the April 2004 Meeting

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Appendix B
Facility Advisory Committee (FAC) Meeting
April 29 – 30, 2004
Orange Room, SLAC Bld 40, Rms R140/R150
AGENDA

Thursday April 29, 2004
Plenary

8:00 - 8:30	Executive Session	
8:30 - 8:45	Welcome	J. Dorfan
8:45 - 9:00	Project Overview, Charge to Committee	J. Galayda
9:00 - 9:15	Project Organization, Executive Status	M. Reichanadter
9:15 - 9:45	Injector Overview	D. Dowell
9:45 - 10:15	Linac Overview	E. Bong
10:15 - 11:30	Break	
10:30 - 11:00	Undulator Systems Overview	S. Milton
11:00 - 11:30	Conventional Facilities Overview	D. Saenz
11:30 - 12:00	X-Ray Transport / Optics / Diagnostics Overview	R: Bionta
12:00 - 13:00	Lunch, Executive Session	
13:00 - 13:30	Endstations Overview	J. Arthur
13:30 - 14:00	Controls Overview	D. Kotturi
14:00 - 14:30	Lasers Overview	S. Gilevich
14:30 - 15:00	RF, Phase Stability, SPPS Experience	R. Akre
15:00 - 15:15	Break	

15:15 Breakout Sessions

Breakout Session: Electrons (Alexander Room, Bld 280C, Room 206)

15:15 - 15:45	Injector Physics / Diagnostics / Gun & Linac RF Design	D. Dowell
15:45 - 16:15	Linac Physics, Diagnostics / Commissioning Strategy	P. Emma
16:15 - 16:45	Undulator Physics, Diagnostics / Commissioning Strategy	H.-D. Nuhn
16:45 - 17:15	Undulator Prototype Status	M. White

Breakout Session: X-Rays (Madrone Room, Bld 48, Room 233)

15:15 - 15:45	Hutch Layout, Far Hall Mirrors	J. Hastings
15:45 - 16:15	X-Ray Beam Characterization	R. Bionta
16:15 - 16:45	X-Ray Prototype Optics Specification	J. Arthur
16:45 - 17:15	X-Ray Fast Detector	J. Arthur

Breakout Session: Controls (Orange Room)

15:15 - 15:45	Physics Requirements Overview	P. Krejcik
15:45 - 16:15	Integration with SLC	D. Kotturi
16:15 - 16:45	Injector	D. Kotturi
16:45 - 17:15	Undulator	J. Stein

Breakout Session: Conventional Facilities (Pine Room, Bld 48, Room 232)

15:15 - 15:45	Physics Requirements	J. Welch
15:45 - 16:15	Schedule	D. Saenz
16:15 - 17:15	SiteTour	

Plenary (Orange Room)

17:17 - 17:30	Break
17:30 - 17:45	Wrap-up
17:45	Executive Session
19:00	Dinner

Friday April 30, 2004
Plenary

8:00 - 10:30	Executive Session
10:30 - 12:00	Breakout Discussions
12:00 - 13:00	Lunch
13:00 - 16:00	Executive Session
16:00	Closeout