SLAC Director's Status Review of LCLS-II HE Project

Close-Out Presentation

October 22, 2020

Charge Questions

1. **Design Maturity: Is the overall design maturity adequate for this stage of the project?**

2. **Technical: Is there adequate technical progress on the LLPs? Is the overall technical progress to date appropriate at this stage of the project? Is the scope properly defined to meet the preliminary KPPs? Are the plans for the proposed injector facility and SRF gun adequately defined and justified? Is the additional XES instrument scope adequately defined and justified?**

3. **Management: Is the project being appropriately managed to advance the design effort and deliver the long lead procurements? Does the project have the necessary resources to succeed? Does the project team have sufficient expertise and experience to successfully execute the project? Are the multi-laboratory partnerships functioning effectively?**

Charge Questions (cont)

4. Cost and Schedule: Is the LLP cost and schedule performance, including contingency utilization, reasonable and properly managed based upon project performance to date? Are cost and schedule estimates progressing adequately to support proposed CD-2 and CD-3 decisions as early as 2QFY2022? Is the TPC preliminary point estimate adequately justified and credible for this stage in the project?

5. Risk Management: Are risks being properly managed? Are the risks associated with the long lead procurement scope being properly managed? Have the COVID-19 risk been appropriately identified and managed? Is the overall risk registry sufficiently developed for this phase of the project?

Charge Questions (cont)

6. ES&H: Are ES&H aspects properly addressed and are future plans sufficient given the project's current stage of development? Has the project considered COVID-19 related safety protocols in their plans?

7. Lessons Learned: Has the project adequately addressed LCLS-II lessons learned?

8. Recommendations: Has the project responded appropriately to recommendations from the last DOE review?

Subcommittee 1: Accelerator Physics

- **Subcommittee Chair –** N. Moody (LANL)

- **Subcommittee Members --** L. Duffy (LANL)

SC-1: Accelerator Physics

- **Observations/Concerns (1/4)**
  - The SLAC accelerator physics team has again demonstrated their expertise in developing innovative solutions to provide new capabilities, enhance performance, and optimize accelerator beamlines.
  - We affirm the proposed beamline revisions, which retire significant risks from LCLS-II HE. This includes removal of the LEX, which caused significant emittance growth of the beam going to the SXR undulators, and increase in the SXR undulator period, to provide soft x-rays at 8 GeV, instead of from the original 4 GeV low-energy beam.
  - Start-to-end (S2E) simulations of the revised beamline design support the expectation that the LCLS-II HE revised beamline will meet the KPPs for electron energy, charge per bunch, and photon energy range and quantity per bunch.

SC-1: Accelerator Physics

- **Observations/Concerns (2/4)**
  - S2E simulations use a flat-top laser profile on the cathode, the baseline for LCLS-II HE. LCLS-II as-built has a Gaussian longitudinal profile. Some simulations with the Gaussian profile indicate that the KPPs could still be met with a Gaussian laser profile on the cathode.
  - A study on tolerances would be useful to determine the error range within which the KPPs will still be met. In particular, what variability in the laser profile is allowed to still meet the KPPs?
  - Significant dark current has been measured at the location of the first cavity after the LCLS-II injector. This current is well separated from the main electron beam, and likely can be removed by collimation. The observed increasing APEX dark current over time is a concern for the LCLS-II injector.

SC-1: Accelerator Physics

- **Observations/Concerns (3/4)**
  - An additional, superconducting rf (SRF) gun, with a new low emittance injector tunnel (LEIT) is being proposed. This injector would retire the risk of failure of the LCLS-II gun, and the associated low emittance would extend the energy reach of LCLS-II beyond the current baseline KPPs. R&D is required to support development of this SRF gun.
  - The upper limit of gradient on APEX gun (and subsequently LCLS-II APEX type gun) is not known. It may be possible to improve the XFEL performance beyond what is currently expected if this limit is determined.
  - Independent verification of simulation predictions would be helpful, via both simulation and experiment. Machine development time, either on LCLS or the European XFEL is a candidate to assist in verification.

SC-1: Accelerator Physics

- **Observations/Concerns (4/4)**
  - The revised design has focused the many excellent ideas from the accelerator physics team, and this focus means that staffing levels now seem adequate to meet the project needs. There is an appropriate staffing plan in place.
  - The accelerator physics presentations focused on the revised beamline, and proposed SRF injector.
  - Demonstration of hard x-ray self-seeding is currently being constructed, and will be tested by CD-2.

SC-1: Accelerator Physics

- **Recommendations**

1. **Improve the clarity of the motivation for the SRF gun (by next DOE review)**
2. **Consider obtaining independent verification of S2E, including modeling and experiment (by CD-2)**
3. **Include a presentation describing the sensitivity deviations in beam profiles and distributions to KPPs (complete study by CD-2)**
4. **Update the status of hard x-ray self-seeding at the next review**

SC-1: Accelerator Physics: Response to Charge Questions

1. **Design Maturity: Is the overall design maturity adequate for this stage of the project?**
   Conditional yes. The *proposed* baseline changes are derived from a robust physics design and S2E studies show self-consistency and agreement with experiment.

2. **Technical:**
   a. **Is there adequate technical progress on the LLPs? (N/A)**
   b. **Is the overall technical progress to date appropriate at this stage of the project? Yes.**
      i. **The proposed design changes (e.g., LEX removal) are well documented with supporting simulation**
      ii. **The consequences of the proposed changes only reduce project risk**
   c. **Is the scope properly defined to meet the preliminary KPPs? Yes.**
   d. **Are the plans for the proposed injector facility and SRF gun adequately defined and justified? No.**
      i. **The argument for SRF scope was not coherent, although the review committee agrees with the approach.**
      ii. **The upper limit in gradient for the APEX gun is not known, which tends to dilute the necessity argument for the SRF injector unless it motivation is further clarified**
      iii. **The purpose of the added tunnel was presented as being tied to that of the SRF injector effort, when it seems that each element serves its own function.**
   e. **Is the additional XES instrument scope adequately defined and justified? Yes.**

SC-1: Accelerator Physics: Response to Charge Questions

3. **Management**:
   a. **Is the project being appropriately managed to advance the design effort and deliver the long lead procurements? Yes.**
   b. **Does the project have the necessary resources to succeed? Yes, for SC-1.**
   c. **Does the project team have sufficient expertise and experience to successfully execute the project? Yes.**
   d. **Are the multi-laboratory partnerships functioning effectively? Yes.**

4. **Cost and Schedule: Is the LLP cost and schedule performance, including contingency utilization, reasonable and properly managed based upon project performance to date? Are cost and schedule estimates progressing adequately to support proposed CD-2 and CD-3 decisions as early as 2QFY2022? Is the TPC preliminary point estimate adequately justified and credible for this stage in the project? Yes, proposed accelerator physics design is clearly linked to the cost and schedule estimate.**

SC-1: Accelerator Physics: Response to Charge Questions

5. Risk Management:
   a. Are risks being properly managed? Are the risks associated with the long lead procurement scope being properly managed? Yes, simulation and modeling are guiding the reduction of risk in the accelerator design.
   b. Have the COVID-19 risk been appropriately identified and managed? Is the overall risk registry sufficiently developed for this phase of the project? N/A: Accelerator physics does not own risks in the registry, and modeling can continue remotely.

6. ES&H: Are ES&H aspects properly addressed and are future plans sufficient given the project's current stage of development? Has the project considered COVID-19 related safety protocols in their plans? N/A

7. Lessons Learned: Has the project adequately addressed LCLS-II lessons learned? Yes, within SC-1 scope.

8. Recommendations: Has the project responded appropriately to recommendations from the last DOE review? Yes, within SC-1 scope.

Subcommittee 2: Injector

- **Subcommittee Chair –** J. Lewellen (LANL)

- **Subcommittee Members --** D. Nguyen (SLAC)
  J. Schmerge (SLAC)

- **Observer -** D. Gorelov (LANL)

SC 2: Injector

- **Observations/concerns (1/4)**
  - The modeling and simulation effort related to development of enhanced injector capabilities is impressive and is to be commended. The program has accomplished a notable amount of work in a limited time.
  - Much of the initial work performed by LCLS-II on injector optimization – for instance, an external multicell booster, techniques to mitigate RF power coupler effects, etc. – may be directly applicable to the second injector line design.
  - Addition of a second low-emittance injector in a separate tunnel (LEIT) would be of significant benefit to the project in several key respects: operational redundancy and downtime minimization; tune-up for ultra-low emittance operation; and injector R&D. However, messaging of those benefits could be improved.

SC 2: Injector

- **Observations/concerns (2/4)**
  - The new injector line posits either an extended LCLS-II type cryomodule, or a 9-cell SC buncher plus an LCLS-II type CM, in addition to the gun. No plans were presented regarding integration of the new injector beamline (L0bis) design into plans for cryomodule requirement specification, design, and procurement.
  - The maximum operable gradient of the LCLS-II photoinjector has not been determined. The nominal field at the cathode is 20 MV/m, but dark current has increased to ~1uA, already above LCLS-II nominal limits if accelerated to 100 MeV. Mitigation (interception at low energy) is expected to be possible but has not been demonstrated.
  - The gradual rise in the LCLS-II gun's dark current is cause for concern. The spare gun incorporates features intended to help mitigate dark current generation, but these have not yet been tested.

SC 2: Injector

- **Observations/concerns (3/4)**
  - Performance of QW-type photoinjectors in general, SRF or normal-conducting, appears to be very sensitive to the placement of the emittance compensation solenoid.
  - Initial modeling efforts of a QW-type SRF gun as an LCLS-II injector are quite promising, but do not yet incorporate 3d field effects, e.g. from RF power couplers. These are expected to be increasingly important, given the emittance and charge regimes in which the new injector line is expected to operate.
  - S2E simulations have not yet been done with the new LEIT concept.
  - Historically, SRF gun development has been a high-risk endeavor, and will likely require an extended, committed effort to achieve its full promise.

SC 2: Injector

- **Observations/concerns (4/4)**
  - The project is embarking on an ambitious QW-type SRF gun development effort. The development time is tight, and some of the proposed activities need additional refinement (rationale, planning, scope, target goals, etc.)
  - The Wisconsin SRF photoinjector has demonstrated 29 MV/m operation without cathode stalk inserted, and low (pA-range) dark current; but was limited to 20 MV/m with the cathode stalk inserted.
  - The R&D plan for the SRF injector does not, at this time, include generation and characterization of an electron beam.
  - An evaluation of the cost/benefits of an independent cryoplant for the new injector line (L0bis) would be worthwhile.
  - Robust engagement with the broader photocathode R&D community could provide additional performance benefits, in particular by supporting development of reduced-MTE (mean thermal energy) photocathodes.

SC-2: Injector

- **Recommendations - present all at December ‘20 OPA review**
  - Refine R&D plans for SRF injector, breaking out clear plans and objectives, including cavity testing, particulate testing and cathode development.
  - Clearly and succinctly delineate the benefits of a second injector vs. a spare gun - improved performance, tune-up, and redundancy for operations.
  - Clearly and succinctly delineate reasons for pursuing an SRF injector versus an upgraded LCLS-II gun, e.g. dark current, emittance, and improved solenoid placement.
  - Develop plans for specifying requirements, designing, and procuring cryomodule(s) and cryo distribution system for the L0bis injector line; present status of planning.

SC-2: Injector

- **Response to Charge Questions (Injector)**

1. Design Maturity: Is the overall design maturity adequate for this stage of the project? **Yes, for original scope; Conditional Yes for proposed new scope. If new scope is adopted, documentation and specifications need to be developed and defined.**

2. Technical: Is there adequate technical progress on the LLPs? **n/a** Is the overall technical progress to date appropriate at this stage of the project? **Yes.** Is the scope properly defined to meet the preliminary KPPs? **Unable to determine - depends on KPP finalization for photon energy, revised scope, etc.** Are the plans for the proposed injector facility and SRF gun adequately defined and justified? **No - see recommendations.**

SC-2: Injector

Response to Charge Questions (Injector) (cont'd)

3. Management: Is the project being appropriately managed to advance the design effort and deliver the long lead procurements? **Yes.** Does the project have the necessary resources to succeed? **Unable to determine.** Does the project team have sufficient expertise and experience to successfully execute the project? **Yes for current baseline.** Are the multi-laboratory partnerships functioning effectively? **SRF gun partnership not established yet, cannot evaluate.**

4. Cost and Schedule: Is the LLP cost and schedule performance, including contingency utilization, reasonable and properly managed based upon project performance to date? **n/a** Are cost and schedule estimates progressing adequately to support proposed CD-2 and CD-3 decisions as early as 2QFY2022? **Not presented - unable to evaluate**. Is the TPC preliminary point estimate adequately justified and credible for this stage in the project? **Not presented - unable to evaluate**

SC-2: Injector

Response to Charge Questions (Injector) (cont'd)

5. Risk Management: Are risks being properly managed? **Yes for current baseline. No risk analysis presented for proposed scope changes; past experience with SRF guns suggests schedule risk may be high.** Are the risks associated with the long lead procurement scope being properly managed? **n/a.** Have the COVID-19 risk been appropriately identified and managed? **Not presented.** Is the overall risk registry sufficiently developed for this phase of the project? **Risk registry for proposed scope not presented.**

8. Recommendations: Has the project responded appropriately to recommendations from the last DOE review? **n/a - no recommendations relevant to injector subsystems.**

Subcommittee 3: Cryomodules

- **Subcommittee Chair –** M. Kelly (ANL)
- **Subcommittee Member –** J. Mammosser (ORNL)

SC-3: Cryomodules

Observations/Concerns

- Technical design maturity is high for this stage of the project due to reuse of LCLS-II designs
- Long lead procurements (CD-3A) for cryomodules are underway
  - Power couplers by JLab
  - Vacuum vessel and cold mass by FNAL
  - SRF cavities procured by SLAC
- HE plans 23 cryomodules at 20.8 MV/m for the new linac segment, one new cryomodule is needed for the second injector
- Verification cryomodule cavities (10) all exceed the LCLS-II-HE specification in terms of quality factor and gradient in vertical testing
- Assembly of the verification cryomodule is well underway and expected to finished by February 2021

SC-3: Cryomodules

Observations/Concerns

- Presently HE cryomodule work finishes at JLab in Q2 FY24
  - JLab plans simultaneous production lines for three different projects (CEBAF refurbishment, SNS-PPU and LCLS-II-HE)
- JLab is attempting to accelerate the production cryomodule assembly so that between JLab and Fermilab, all 24 modules are assembled within the existing schedule
- The project baseline for cavity nitrogen doping recipe for HE is the so-called “2N0” recipe. The 3N60 recipe continues as an R&D effort and a plan for determining its viability is established for this change to be considered.

SC-3: Cryomodules

Observations/Concerns

- The LCLS-II superconducting linac is planned to be shut down for one year during HE installation
- No low energy extraction means only 1 LCLS-II cryomodule needs to be removed to install HE
- Production cryomodule work for CD-3A (WBS 1.2) is approximately 10% complete and on schedule and budget
- Non CD-3A cryogenic systems (WBS 1.02) is 28% complete and also on schedule and budget
- HE Cryogenic systems have carried out a detailed and thoughtful analysis of technical risks

SC-3: Cryomodules

Observations/Concerns

- It was determined that a extended range tuner would allow for increased flexibility for off crest operation and therefore is a technical design change to HE cryomodule. A program is underway for the development and testing and is planned to be complete by May/June 2020
- The present plan is to use single cell cavities to verify the flux expulsion properties for each batch of niobium used to fabricate new nine cell cavities
- R&D at JLab on flux expulsion in niobium tubes is being undertaken as a possible cost savings technique

SC-3: Cryomodules

Observations/Concerns

- An HE cavity R&D program was undertaken in order to demonstrate the higher cavity gradient planned for HE
  - The method is to improve the doping process to maintain high Q while extending the cavity gradient
  - The key lesson learned was that cold electropolishing with nitrided cavities produces smoother cavity surfaces and reproducibly higher gradients
- These reviewers are supportive of the continuing R&D on the 3N60 recipe. We suggest caution on discussion of future HE operation at 9 GeV and note that 3N60 may also provide additional margin and reliability for 8 GeV operation

SC-3: Cryomodules

Observations/Concerns

- HE has a plan to refurbish and reuse cavities and niobium material from the LCLS-II
  - It was indicated that as many as 25 cavities from LCLS-II are likely recoverable for HE
- The cavity reuse plan appears to be well planned and realistic.
- Fermilab plans to use the same infrastructure for HE as for LCLS-II
- The Fermilab production cryomodule plan indicates that no rework is assumed for HE; the reviewers believe some rework, such as opening and repairing an internal component after testing, is likely.

SC-3: Cryomodules

Observations/Concerns

- Technical issues including multipacting and microphonics are not academic points, but have potentially important operational impacts
- Speakers highlighted multipacting as more critical for HE, as compared to LCLS-II, since cavities will run within the intrinsic multipacting bands
- The HE cavity qualification strategy is well thought out and does require complete processing of multipacting as one of the qualification steps
  - We suggest multipacting be carefully studied in long-term testing of the verification cryomodule
  - Testing of production cryomodules for longer than the planned one day at full gradient by the partner labs should be performed when the schedule permits

SC-3: Cryomodules

Observations/Concerns

- The reviewers encourage the stated intention to measure cryomodule microphonics at the full operating gradients and over extended periods
- The reviewers also strongly support detailed measurements of the effects of flux trapping on the cavity quality factors, especially during the verification cryomodule testing
- On cavity fabrication, discussions with the cavity vendor on possible cavity performance incentives are underway; the start of fabrication is imminent, and the project should finish discussions as soon as possible

SC-3: Cryomodules

Observations/Concerns

- Plenary and breakout talks did not clearly present assumed cryomodule performance for LS1-LS4 (number of cavities at each gradient, number of cavities assumed turned down), but this was provided in follow up discussions. We suggest to clarify this in the future.
- The reviewers concur that the addition of three cryomodules to HE combined with a lower operating gradient for LCLS-II is less aggressive than the previous plan, but would suggest to avoid characterizing this as ‘conservative’
- Fabrication and assembly of the additional four cryomodules are not formally integrated into the project schedule

SC-3: Cryomodules

Recommendations

- **Include the three new cryomodules for Linac segment 4 and the new cryomodule for the injector into the formal project plan. Complete changes to the plan as soon as possible and preferably before the December 2020 OPA review**

- **Consider and document the impact of potential cryomodule re-work on the assembly schedule. Update the plan if necessary and complete before the December 2020 OPA review**

SC-3: Cryomodules

Recommendations

- **Implement a plan for onsite monitoring of cavity fabrication by an LCLS-II-HE project representative as soon as reasonably possible**

- **Maintain the verification cryomodule in such a state that it is available as an investigative tool to address production issues as they arise**

SC-3: Cryomodules

Response to Charge Questions (Cryomodules)

1. Design Maturity: Is the overall design maturity adequate for this stage of the project? **Yes**.

2. Technical: Is there adequate technical progress on the LLPs? Is the overall technical progress to date appropriate at this stage of the project? Is the scope properly defined to meet the preliminary KPPs? **Yes to all, see first recommendation.**

SC-3: Cryomodules

Response to Charge Questions (Cryomodules) (cont'd)

3. Management: Is the project being appropriately managed to advance the design effort and deliver the long lead procurements? Does the project have the necessary resources to succeed? Does the project team have sufficient expertise and experience to successfully execute the project? Are the multi-laboratory partnerships functioning effectively? **Yes to all four.**

5. Risk Management: Are risks being properly managed? Are the risks associated with the long lead procurement scope being properly managed? Have the COVID-19 risk been appropriately identified and managed? Is the overall risk registry sufficiently developed for this phase of the project? **Yes, see third recommendation.**

8. Recommendations: Has the project responded appropriately to recommendations from the last DOE review? **Yes.**

Subcommittee 4: Linac & RF Power Systems

- **Subcommittee Chair –** R. Geng (JLAB)

- **Subcommittee Members --** E. Harms (FNAL)
  D. Sun (FNAL)

SC-4: Linac & RF Power Systems

- **Observations/concerns (1/5)**
  - Linac and RF power system scope is well defined in CD1 and continues to evolve. Added scope after CD1 includes among others, Installation of 3 additional cryomodules and 27 SSAs in L4 segment.
  - The committee affirms the current design scope.
  - The baseline scope change has a large impact to Accelerator Systems.
  - The team should be commended for making progress in advancing the design of long lead time items despite the pandemic slow-down and rapidly evolving scope.
  - The management team is rapidly taking shape, with years of experience in the field they are managing, and is aware of the need for further strengthening the team in key expertise areas.
  - The team reports Accelerator System design maturity at 67% for CD1 scope and adjustment is being made to reflect recent scope change, appropriate for the current stage of the project.

SC-4: Linac & RF Power Systems

- **Observations/concerns (2/5)**
  - A new 3-D design method introduced for linac layout, capturing the existing systems and new systems, seems to be very helpful in revealing interface conflicts and increase design flexibility, could be very valuable in dealing with potential linac and RF power system schedule interruptions caused by uncertainties or surprises in design inputs.
  - Linac installation of cryomodules in L4 follows the procedures developed and executed for LCLS-II, giving confidence in critical particulate control. It is important to maintain the institutional knowledge and skills over ~ 4-year gap between LCLS-II and LCLS-II-HE linac installations, critical for reaching project KPP and future long-term operations.
  - Much of the design effort is 'cut & paste' from LCLS-II. This will help to increase design efficiency and assure rapid assembly. Care should be taken to not overly rely on this design path which could lead to possible design oversights given the higher SSA power and beam energy. NIRP and Radiation protection requirements of RF penetrations, for example, should be re-evaluated for LCLS-II HE.

SC-4: Linac & RF Power Systems

- **Observations/concerns (3/5)**
  - Design inputs and assumptions of L4 linac and cryogenic distribution layout, and correspondingly the interface between L4 and L3 segments, are dependent on the actual performance of cryomodules in L0-L3 segments, but this will not be known before LCLS-II-HE CD2.
  - This leads the team to face uncertainty in producing a correct design for the project to deliver on KPP's. Linac and cryogenic distribution layout options are proposed for mitigating various risk scenarios.

SC-4: Linac & RF Power Systems

- **Observations/concerns (4/5)**
  - 10 out of 18 First Article units of 7kW SSA's are built, factory acceptance tested and shipped to US in September, permitting testing in FY21.
  - The addition of front panel controls to the 7 kW SSA's as compared to the 3.8 kW series is a fine example of incorporating Lessons Learnt.
  - The relationship with the SSA vendor is very strong. The team is to be commended for working out the procurement contract with deliverables including controls source code and all drawings, which the vendor accepted. The committee is concerned with the limited scope of the proposed high power testing plan of the isolators. Suggest high power tests of every circulator with shorting plate at output port to create two separate conditions: maximum H & E field at ferrite disk.
  - The committee notes and endorses assignment of a dedicated safety controls engineer for Non-ionizing Radiation Protection (NIRP).
  - Joint Breakout sessions e.g. HRPR and LLRF would have been beneficial; consider for future reviews

SC-4: Linac & RF Power Systems

- **Observations/concerns (5/5)**
  - Overall the HPRF system design is very similar to the LCLS-II one with only minor modification and space adjustments.
  - Standard WR650 waveguide components are used for both LCLS-II and HE. Those components can carry RF power up to several MW, more than adequate for LCLS-II HE need of 7 kW.
  - Two critical RF components are SSAs and Isolators. Both are specified for 7 kW, which can maintain cavity gradient up to 26 MV/m with a 31 uA beam current.
  - The cost and the schedule of those two critical components are well understood. Vendors are reported to be able to deliver SSAs at 14 units per month and Isolators at 24 units per month.
  - An acceptance test program for total 18 units of SSAs (and isolators) is currently being performed at SLAC and partner labs. Two SSAs have been power tested at SLAC.
  - The LLRF system has been proven reliable for LCLS-II cryomodule testing at the partner labs and has proven effective at achieving design gradient and controlling microphonics to specification.

SC-4: Linac & RF Power Systems

- **Recommendations**
  - Prior to December IPR, develop a criterion for selecting current options toward a baseline linac and cryogenic distribution layout for L4 segment and the interface between L4 and L3 segments. Prior to CD-2, evaluate the design tolerance of the variation in loads between CP1 and CP2.
  - Consider quantifying the impact of LCLS-II completion on LCLS-II HE design. Ensure adequate dedicated resources are allocated to LCLS-II-HE Accelerator System design effort; adjust cost (staffing needs and M&S) and schedule accordingly.
  - Prior to the OPA review ensure that the installation costs associated with all additional scope is integrated into the cost estimate.

SC-4: Linac & RF Power Systems

- **Response to Charge Questions (Linac & RF Power Systems)**

1. Design Maturity: Is the overall design maturity adequate for this stage of the project? **Yes,** but the team faces unknown design input on actual performance of LCLS-II cryomodules and is studying options for linac and cryogenic distribution layout.

2. Technical: Is there adequate technical progress on the LLPs? **Yes.** Is the overall technical progress to date appropriate at this stage of the project? **Yes.** Is the scope properly defined to meet the preliminary KPPs? **Yes**, with added scope in response to recent additions of 3 cryomodules in L4.

SC-4: Linac & RF Power Systems

- **Response to Charge Questions (Linac & RF Power Systems)**

3. Management: Is the project being appropriately managed to advance the design effort and deliver the long lead procurements? **Yes.** Does the project have the necessary resources to succeed? **Conditional Yes,** see recommendation. Does the project team have sufficient expertise and experience to successfully execute the project? **Yes.** but there is a need for further strengthening the team on key expertise areas.

5. Risk Management: Are risks being properly managed? **Yes.** Are the risks associated with the long lead procurement scope being properly managed? **Yes.**

SC-4: Linac & RF Power Systems

- **Response to Charge Questions (Linac & RF Power Systems)**

8. Recommendations: Has the project responded appropriately to recommendations from the last DOE review? **N/A**. No Accelerator Systems recommendation from Oct 2019 Director's Review for DOE CD-3A.

Subcommittee 5: Cryogenics

- **Subcommittee Chair –** B. Hansen (FNAL)
- **Subcommittee Member –** B. Degraff (ORNL)

SC-5: Cryogenics

- **Observations/concerns**
  - The project team has done a lot of work since CD-1, especially with the recent addition of 3 cryomodules (CMs) to the project scope, and should be commended.
  - LCLS-II is planned to be shut down for one year during LCLS-II HE CM and Cryogenic Distribution System (CDS) installation.
  - Contract durations for individual CDS components range from 11-30 months. Schedule shows total of ~27 months for procurement of CDS, requiring multiple procurements in parallel.
  - The project plans to leverage the LCLS-II CDS contractors by sole-sourcing the LCLS-II HE CDS components. To the extent possible, the committee supports the re-use of LCLS-II designed components as a means of limiting design and procurement risk.
  - The project is currently planning to sub-contract the CDS design. A procurement plan and strategy should be developed with procurement to ensure the project successfully leverages the LCLS-II CDS contractor experience. The BOE and schedule should reflect this approach.

SC-5: Cryogenics

- **Observations/concerns**
  - New surface transfer line (STL) for L4 is ~3-4x longer than the Cryoplant 1 (CP1) STL and further downstream, resulting in larger head losses. Corresponding increase in pressure drop results in reduced Cryoplant 2 (CP2) capacity. The committee supports increasing line B size to 14” provided this does not substantially increase the 2K non-isothermal heat load.
  - The pressure loss due to using the same Heat Exchanger (HX) design for ~2x the flow rate results in significant pressure drop and therefore loss in CP2 capacity. Using the same HX design but increasing the number of channels could improve the pressure drop with minimum risk and impact to existing distribution box (DB) design.
  - The project team did not have design details on the recently added L0bis cryomodule and associated CDS component additions. These L0bis components will add to the CP1 2K heat load.
  - The committee would support an investigation into having L0bis, L0, L1 components cooled from the new gun cryogenic plant. A cryoplant at this location could also be used as an offline cryomodule test facility and/or used to mitigate CP capacity risk.

SC-5: Cryogenics

- **Observations/concerns**
  - The shared resources between LCLS-II and LCLS-II HE provides valuable overlapping experience, however the availability for LCLS-II HE effort is minimal and the project should consider adding dedicated staff to LCLS-II HE.
  - There is no Line B by-pass local to the 2K cold box (CB) that could be used to maintain the Linac at 4K, but the Line D bypass that will be added to the LCLS-II HE endcap for fast cooldown could also be used for this purpose with CP2 only.
  - There are no risks associated with insufficient cryogenic cooling power in CRYO, but MGMT-001 has a risk of LCLS-II HE not performing within specification.
  - 2K operation of CP1 will occur concurrent with LCLS-II-HE CD 2/3 review (+/- a few months). Heat load of full powered LCLS-II LINAC is not expected to be known until well into LCLS-II HE CM production.
  - Based on the CM Q0 results, the LCLS-II LINAC is expected to be supported by only a single cryoplant. However, the HE project should be aware of the risk that CP1 and CP2 may be needed for the LCLS-II if LINAC installed CMs don't perform as expected or CP1 and/or CP2 do not meet capacity specification.

SC-5: Cryogenics

- **Observations/concerns**
  - The design has been changed to add 23 cryomodules instead of 20. The new L4 sector will have a total of 27 CMs, 4 moved from L3 to L4. The L4 section will be split in the upstream and downstream sections, with a vacuum break in between.
  - CP2 will support the new L4 sector and CP1 will support L0, L1, L2 and L3 in all potential design cases. The current design (Case 1) configuration has 2K isothermal capacity margin for CP2 of 6% and a CP1 margin of 23%. The project is aware of the imbalance and is currently investigating different CDS design options.
  - The project team presented several potential viable LINAC configurations for placement of cryomodules with respect to the CDS feedcaps, endcaps, vacuum breaks and tees. However it wasn't clear what configuration will be used for baselining prior to CD2/3. The project should converge on a final LINAC configuration to begin progressing the CDS design and analysis work.

SC-5: Cryogenics

- **Recommendations**
  - For the December IPR, develop a preliminary procurement plan and strategy for the procurement of CDS design and manufacturing.
  - For the December IPR, update the risk registry to address the possibility of inadequate cryogenic cooling capacity at 2K for combined LCLS-II & LCLS-II-HE threshold KPP operation.
  - For the December IPR, include the L0bis (new injector beam line) components into cryoplant heat load margin calculations and clearly present the preferred (baseline) CM locations for 8 GeV operation.

SC-5: Cryogenics

- **Response to Charge Questions (Cryogenics)**

1. Design Maturity: Is the overall design maturity adequate for this stage of the project?
- Yes, but the Linac and CDS configuration needs to be finalized

2. Technical: Is the overall technical progress to date appropriate at this stage of the project? **Yes** Is the scope properly defined to meet the preliminary KPPs? **Yes** Are the plans for the proposed injector facility and SRF gun adequately defined and justified? **No, see recommendations**

3. Management: Is the project being appropriately managed to advance the design effort and deliver the long lead procurements? **Yes** Does the project have the necessary resources to succeed? **Yes, but see observations/concerns** Does the project team have sufficient expertise and experience to successfully execute the project? **Yes**

SC-5: Cryogenics

- **Response to Charge Questions (Cryogenics)**

5. Risk Management: Are risks being properly managed? **Yes** Is the overall risk registry sufficiently developed for this phase of the project? **No, see recommendations**

8. Recommendations: Has the project responded appropriately to recommendations from the last DOE review? **None presented**

Subcommittee 6: Undulator

- **Subcommittee Chair –** L. Moog (ANL)

- **Subcommittee Members --** E. Gluskin (ANL)
  P. Den Hartog (ANL)

SC-6: Undulator

- **Observations/concerns**
  - Although the change in period of the SXU is a substantial change since CD-1, the project can build on the positive experience from LCLS-II.
  - An experienced and capable management team is in place at SLAC and at Berkeley to manage the SXU upgrade.
  - Despite the recent addition of the undulators to the project, commendable progress has been made.
  - The cost presented at the review for Accelerator Systems was the outdated CD-1 cost estimate. An updated cost estimate including the new baseline design and incorporating actual LCLS-II costs has been prepared and is now included in Sept's P6 data. An increase of ~10 M$ is expected. Some refinement is needed.

SC-6: Undulator

- **Observations/concerns (2)**
  - LCLSII-HE intends to reuse the SXU gap separation mechanism from LCLS-II. Considerable analysis has been done to show that there is ample margin for handling the increased magnetic force of the longer period LCLS-II-HE undulator.
  - LCLS-II-HE has a well developed installation plan using PAMM days to install the undulators without requiring dedicated shutdowns.

SC-6: Undulator

- **Observations/concerns (3)**
  - The plan for the vacuum chambers for the 9 additional SXUs has not been completely developed. Discussion with ANL (design and construction of LCLS II SXU VCs) has begun. The fabrication schedule, beginning in Q1FY23, is not expected to conflict with the APS Upgrade but communication should continue. A formal MOU will be needed.
  - The high risk and very long procurement time for vanadium permendur for undulator poles is based on experience with the usual single vendor. APS-U was facing similar issues for its conventional magnets and found an alternate and responsive source for equally high-quality Vpermendur. Info has been shared for the project's consideration.

SC-6: Undulator

- **Observations/concerns (4)**
  - LCLS-II-HE will be dependent on the the same Kugler magnetic measurement bench for SXU tuning as is used for LCLS-II. Any problem with the bench or with the LCLS-II undulators during the LCLS-II-HE SXU tuning has the potential to create a major schedule delay. LCLS-II-HE is developing a proposal to acquire a second measurement bench through a cost-sharing agreement with SLAC. This would go a long way toward mitigating this risk.
  - With a second bench, it may be advisable to hire an additional physicist.

SC-6: Undulator

- **Observations/concerns (5)**
  - The SLAC undulator team has comprehensive and successful experience in preparing large numbers of state-of-the-art undulators for an x-ray FEL. For the LCLS-II-HE project, however, the SLAC staff is taking on an even greater role in the construction of the undulator line than they did for the LCLS-II project. Having LBNL as a partner again, as they were for LCLS-II, will partially alleviate this problem, but not entirely. The undulator team should carefully evaluate the need for extra hardware and, most importantly, extra hands for construction and future operations, and prepare a credible staffing plan.

SC-6: Undulator

- **Recommendations**
  - Present the SXU costs for the Dec 2020 DOE Review.

SC-6: Undulator

Response to Charge Questions (Undulator)

•1. Design Maturity: Is the overall design maturity adequate for this stage of the project? **Yes**

• 2. Technical: Is there adequate technical progress on the LLPs? Is the overall technical progress to date appropriate at this stage of the project? Is the scope properly defined to meet the preliminary KPPs? **Yes**

•3. Management: Is the project being appropriately managed to advance the design effort and deliver the long lead procurements? Does the project have the necessary resources to succeed? Does the project team have sufficient expertise and experience to successfully execute the project? Are the multi-laboratory partnerships functioning effectively? **Yes**

•

SC-6: Undulator

Response to Charge Questions (Undulator), 2

•5. Risk Management: Are risks being properly managed? Are the risks associated with the long lead procurement scope being properly managed? Have the COVID-19 risks been appropriately identified and managed? Is the overall risk registry sufficiently developed for this phase of the project? **Yes**

•8. Recommendations: Has the project responded appropriately to recommendations from the last DOE review? **Yes. (There were no prior recommendations.)**

Subcommittee 7: X-Ray Endstations

- **Subcommittee Chair –** D. Haeffner (ANL)

- **Subcommittee Members --** N. Kurita (SLAC)
  D. Harrington (SLAC)
  T. Rabedeau (SLAC)

SC-7: X-Ray Endstations

- **Observations/concerns**
  - The sub-committee endorses the proposed endstation scope expansions to take full advantage of the new capabilities for LCLS-II-HE.
  - The committee appreciates the efforts that were made by the team to prepare the materials and believe that the proposed scope will lead to world class science.
  - Given the late change of scope, the instrument efforts may have difficulty meeting the CD-3 design maturity concurrently with the CD-2 review.
  - The instrument IPR presentations should de-emphasize the scientific motivation and concentrate on project execution elements.

SC-7: X-Ray Endstations

- **Observations/concerns (2)**
  - Presentations did not contain the following in sufficient detail to address the charge :
    - Scope & requirements by instrument
    - Current status, design, and document maturity to validate performance/requirements
    - Risks, impacts, mitigations - use overall project risk tools
    - Hazards
    - Staffing plans and current effort levels
    - Cost and schedule summaries; basis of estimates
    - Response to prior review recommendations
  - A clear plan to reach CD-2/CD-3 readiness was not presented and is required for the IPR.

SC-7: X-Ray Endstations

- **Observations/concerns (3)**
  - Requirement documents were not provided.
  - The project did not clearly present interface points between their entities. Clear hand-off points should be defined early and documented in Interface Control Documents.
  - The majority of the instruments have not held conceptual design reviews.
  - In the presentations the dividing line between on-project scope and off-project scope was often unclear.
  - Current WBS dictionary is high level and lacks detail. It also does not cover the new scope.
  - Presentation of risks was inconsistent and the risk registry is not up-to-date with current concerns.

SC-7: X-Ray Endstations

- **Observations/concerns (4)**
  - 2nd OPCPA system for the far hall laser is currently being proposed for the MEC hutch or the XCS control room. Establish laser system location to avoid negative impacts to cost, performance, and/or off-project dependencies.
  - Radiation shielding requirements driven by the upgraded source remain an open risk and were not discussed.
  - There is a risk that the new scope will require infrastructure upgrades (eg. LN delivery).

SC-7: X-Ray Endstations

- **Recommendations**
  - Ensure IPR presentations address project current status and plans to meet CD-2/CD-3, as well as, address the charge questions.
  - Develop summary schedule or milestone plan for path to CD-2/CD-3 prior to the IPR.
  - Draft requirements document for each instrument and the major systems (laser system, data management, and detectors) prior to IPR. Release in advance of a conceptual design review.
  - Conduct Instrument Conceptual Design Reviews at least 5 months before PDRs.
  - Update the WBS dictionary for the new scope in time for the IPR. To adequately identify scope and track progress, create a detailed product deliverable WBS structure by CD-2.
  - Update the risk registry in time for the IPR.

SC-7: X-Ray Endstations

- **Response to Charge Questions (X-Ray Endstations)**

1. Design Maturity: Is the overall design maturity adequate for this stage of the project?
   - No - requirements and scope documentation has not caught up with scope expansion
2. Technical:
   - Is the overall technical progress to date appropriate at this stage of the project?
     - No - requirements and scope documentation has not caught up with scope expansion
   - Is the scope properly defined to meet the preliminary KPPs?
     - Yes
   - Is the additional XES instrument scope adequately defined and justified?
     - Yes - the additional instrument scope enhancements are justified, but need to be better documented
3. Management:
   - Is the project being appropriately managed to advance the design effort?
     - Yes
   - Does the project have the necessary resources to succeed?
     - Maybe - we were not provided detailed resource plans or current effort level
   - Does the project team have sufficient expertise and experience to successfully execute the project?
     - Conditional yes - see above response regarding resources

SC-7: X-Ray Endstations

•Response to Charge Questions (X-Ray Endstations)

4. Cost and Schedule:
   - Are cost and schedule estimates progressing adequately to support proposed CD-2 and CD-3 decisions as early as 2QFY2022? Is the TPC preliminary point estimate adequately justified and credible for this stage in the project?
     - No - cannot assess based on the information provided

5. Risk Management:
   - Are risks being properly managed? Is the overall risk registry sufficiently developed for this phase of the project?
     - Conditional yes - risk registry needs to catch up with expanded scope. Risks were presented in an inconsistent manner
   - Have the COVID-19 risk been appropriately identified and managed?
     - Yes

8. Recommendations:
   - Has the project responded appropriately to recommendations from the last DOE review?
     - Yes, but communication should be clearer

Subcommittee 8: Controls & Safety Systems

- **Subcommittee Chair –** R. Farnsworth (BNL)

- **Subcommittee Members --** K. Baggett (JLAB)
  B. Drendel (FNAL)

SC-8: Controls & Safety Systems

- **Observations/concerns**
  - Most of the new controls and safety system plans leverage the already existing LCLS-II design, only requiring minor modification or instantiation. Avoiding redesign is very efficient. This may present a tradeoff with obsolescence; however, we don't see any systems where this is a major issue.
  - Presentations were thorough and well detailed. The speakers all spoke well and were able to answer our questions. Careful editing will make the presentations even more concise and deliver the same message.
  - The risk registry identified multiple cable plant risks that should be monitored closely. The cable plant process was outlined in detail. However, any untested process introduced has a higher risk than an established process.
  - While staffing plans were provided, the actual FTE requirements were unclear. Sufficient commitments to dedicated resources are needed. This especially applies to matrixed employees and the areas where we could see that overlapping resources. The addition of deputies could act as a mitigation in areas where resources are stretched.
  - Controls at >10% of the project cost has a greater footprint than usual and needs to be closely monitored.

SC-8: Controls & Safety Systems

- **Recommendations**
  - None

SC-8: Controls & Safety Systems

Response to Charge Questions (Controls & Safety Systems) (1 of 3)

1. Design Maturity: Is the overall design maturity adequate for this stage of the project? **Yes, virtually all of the presented system designs are based on existing LCLS-II designs that require minimal modifications.**

2. Technical: Is there adequate technical progress on the LLPs? **N/A** Is the overall technical progress to date appropriate at this stage of the project? **Yes, Baseline and Final Design happen simultaneously but that is sufficient for this project.** Is the scope properly defined to meet the preliminary KPPs? **Yes, but indirectly, the plans for the controls and safety system should provide the required functionality and diagnostics necessary for other systems to meet the LCLS-II-HE KPPs.** Are the plans for the proposed injector facility and SRF gun adequately defined and justified? **N/A** Is the additional XES instrument scope adequately defined and justified? **Yes**

SC-8: Controls & Safety Systems

Response to Charge Questions (Controls & Safety Systems) (2 of 3)

3. Management: Is the project being appropriately managed to advance the design effort and deliver the long lead procurements? **N/A, no LLPs were identified for controls.** Does the project have the necessary resources to succeed? **Yes, provided full staffing availability. While staffing plans were identified, ties to actual available FTEs were not clear. Dual responsibilities due to matrixed overallocations is a concern.** Does the project team have sufficient expertise and experience to successfully execute the project? **Yes, we are impressed with the technical ability and experience of the controls and safety system team.** Are the multi-laboratory partnerships functioning effectively? **Yes, Fermilab, JLAB and SLAC partnership is working well for SRF and LLRF controls. We encourage any further opportunities for partnerships.**

5. Risk Management: Are risks being properly managed? **Yes, risks are relatively low and well managed for most of controls. There has been significant work to mitigate the higher risk areas.** Are the risks associated with the long lead procurement scope being properly managed? **N/A, No LLPs were identified for controls.** Have the COVID-19 risk been appropriately identified and managed? **Yes, because the designs could efficiently performed remotely the impact has been minimal to this point. The ramp up schedule delays in FY'21 have been calculated based on potential COVID-19 protocol levels.** Is the overall risk registry sufficiently developed for this phase of the project? **Yes, significant details were given for cable plant lessons learned.**

SC-8: Controls & Safety Systems

Response to Charge Questions (Controls & Safety Systems) (3 of 3)

8. Recommendations: Has the project responded appropriately to recommendations from the last DOE review? **Yes, there were no controls or safety system recommendations outside of risk registry updates from the last DOE review. The current risk registry is very well defined.**

Subcommittee 9: Conventional Facilities

- **Subcommittee Chair –** L. Thompson (LLNL)

- **Subcommittee Member -** J. Harkins (SLAC)

SC-9: Conventional Facilities

- **Observations/concerns (1/5)**
  - The infrastructure team is doing an excellent job adapting to the proposed injector tunnel scope change while also coordinating a large number of other supporting infrastructure projects to meet HE's timeline.
  - The Infrastructure team needs to plan the Infrastructure schedule with the proposed change to a 1 year down and short maintenance downs during FY 23 and 24.

SC-9: Conventional Facilities

- **Observations/concerns (2/5)**
  - In order to meet the 70% CD-2/3 infrastructure design milestone, the proposed injector tunnel design contract must be awarded around Q2 FY 21. A careful consideration of geotechnical study, soil contamination, noise, settlement requirements (construction and operation), NEPA, and requirements definition must occur to support this compressed timeline, which are all dependent on approval of the baseline change.
  - The infrastructure team is not yet fully staffed.

SC-9: Conventional Facilities

- **Observations/concerns (3/5)**
  - The feasibility study prepared by Arup does not fully consider the cost and schedule impacts of work execution at SLAC, though it is noted the infrastructure team has started increasing injector tunnel design and construction schedules to account for this. It is does not appear that cost has yet been increased in similar fashion. It is suggested that an independent cost and schedule estimate be completed by a Bay Area estimator with experience in the DOE complex.
  - A systems view of all SLAC projects both institutional as well as LCLS-II HE will help to ensure the following:
    - Predecessor infrastructure upgrades are completed in time.
    - Concurrent but unrelated infrastructure projects do not interfere.

SC-9: Conventional Facilities

- **Observations/concerns (4/5)**
  - The K5b substation project is critical to LCLS-II HE operations. Identifying technical requirements, funding and a team to execute this project should be a high priority.
  - The LCLS-II HE project should evaluate impacts to the infrastructure scope of work and obtain input from the infrastructure team for all changes.
  - The recent FAC Committee Review identified the need for Sr. SLAC Management to assign the responsibility for the development, issuance and management of a global Construction Access Plan for all construction activities at SLAC.

SC-9: Conventional Facilities

- **Observations/concerns (5/5)**
  - There is a risk of advancing the injector tunnel infrastructure based on requirements that may change as the gun goes through R&D. Suggest the requirements include headroom for these possible changes.
  - The systems engineering group and the existing Requirements Management Plan should be leveraged to guide process discussions toward overall infrastructure requirements definition. This will ensure infrastructure requirements will flow down from science and/or project requirements.
  - The risk registry should be reviewed to ensure it accurately captures risks that manifest as a result of newly added and existing infrastructure scope. This will ensure appropriate cost and schedule contingency is budgeted and assigned.

SC-9: Conventional Facilities

- **Recommendations**
  - Address the needs for the infrastructure team staffing by Q2 FY 21:
    - CAM (with appropriate experience) for the potential injector tunnel work
    - Backfill for Deputy Infrastructure System Manager (to permit full time HE support)
  - Assess the new injector tunnel infrastructure cost and schedule estimates from the feasibility study to account for the SLAC project environment before committing to this change.
  - Prepare a SLAC global construction access and logistics plan by CD-2.

SC-9: Conventional Facilities

- **Response to Charge Questions (Conventional Facilities)**

1. Design Maturity: Is the overall design maturity adequate for this stage of the project? **Yes, for the baseline scope**

2. Technical: Is the overall technical progress to date appropriate at this stage of the project? **Yes, for baseline scope.** Is the scope properly defined to meet the preliminary KPPs? **Yes, for baseline scope.** Are the plans for the proposed injector facility and SRF gun adequately defined and justified? **No, see recommendations.**

Subcommittee 10: ES&H/QA

- **Subcommittee Chair –** C. Schrof (ORNL)

SC-10: ES&H/QA

- **Observations/concerns**
  - LCLS-II HE ESH&Q staff understand the deliverables that must be met before CD-2 and have a plan to update or complete (e.g., PHAR, update Linac Accelerator Facility FHA, Linac Tunnel ODH Analysis)
  - **A Supplemental Analysis (SA) to the Environmental Assessment for the LEIT Facility is required.** The analysis for the SA cannot begin until a decision is made on the tunnel location and it will take ~ 3-4 months to complete. An approved FONSI is needed before CD-2. This issue has been identified on the Risk Registry.

SC-10: ES&H/QA

- **Observations/concerns**
  - SLAC's Radiation Protection organization has analyzed the changes to the radiological conditions introduced by the LCLS-II HE Project. The new conditions are understood and measures to properly mitigate exposures are being analyzed.
  - The Project has taken measures to mitigate the transmission of COVID-19 by incorporating controls into WPC and JSAs at SLAC and the partner laboratories. The Project needs to remain diligent to focus on all hazards - industrial, radiological and construction hazards. The Project needs to anticipate a distracted workforce because of the implications of the pandemic.

SC-10: ES&H/QA

- **Observations/concerns**

  - **Since the last Director's Review, the Project has focused on developing an integrated Quality Assurance Program (QAP).** The QAP builds on lessons learned from the LCLS-II Project and best practices. The QAP introduces new processes to identify procurement, fabrication and configuration management issues. While the QAP appears robust, it has not been fully implemented and tested. It will take discipline and commitment by the Project Team to not abandon or "cut corners" when schedule and costs becomes tight. It is not clear that the current staff have the bandwidth to fully implement the new processes.

SC-10: ES&H/QA

Recommendations

- Determine if current ESH&Q staffing levels are adequate to meet upcoming deliverables, implementation of the QAP (e.g., participation in reviews for procurement, design, change control, etc.), and maintaining a field presence.
- Obtain the final signatures for the LCLS-II HE Quality Assurance Plan from the partner laboratories.
- Develop an LCLS-II HE Project Assessment Plan to evaluate the implementation and adherence to new processes identified in the Project's QAP. Modify processes as needed.
- Continue to drive implementation of Human Performance Improvement (HPI), rigor in WPC, and continuous improvement.

SC-10: ES&H/QA

- **Response to Charge Questions (ES&H/QA)**

-- Are ES&H aspects properly addressed and are future plans sufficient given the project's current stage of development? **Conditional yes; the QAP has not been fully implemented and tested.** Has the project considered COVID-19 related safety protocols in their plans? **Yes**

Subcommittee 11: Cost & Schedule

- **Subcommittee Chair –** M. Vivian (LLNL)

- **Subcommittee Member --** C. Brackett (SLAC)

SC-11: Cost & Schedule

- **Observations/concerns**
  - CD-3A TPC is $98M with a BAC of $80.3M
  - Project CD-3A baseline was set in June 2020. The project was able to provide 2 months of performance (July & August).
  - Project has developed a detailed LLP baseline with clear critical path. Integration/communication with partner labs seems to be organized and working well.
  - Contingency % is 24% on work remaining for CD-3A ($72,536K, EAC-ACWP).
  - BABO chart based on CD-3A point estimate of 428M. It will be crucial to update this chart to include the new scope so that current funding request and project schedule can be analyzed.

SC-11: Cost & Schedule

- **Observations/concerns (Cont)**
  - Baselined CD-3A critical path runs through JLAB Cryomodule Assy. Some activities overlap and have high concentrations of tech support. Additional staffing analysis might be beneficial as project schedule continues to develop.
  - Some known CV-19 impacts have already been included in project CD-3A baseline. However, it will be important for the project to continue to assess both cost and schedule future impacts.
  - Project's previous plan for CD-2/CD-3 is 2Q22. Proposed plan is projecting a new CD-2/CD-3 of 4Q22.
  - Project presented a 5 month slip due to LCLS-II, due to CV-19 impacts.
  - CD-3A point estimate is $428M and upcoming pending BCR changes are $58M. The contingency remaining of 15% appears to be inadequate to cover potential future risk on the project at this stage.

SC-11: Cost & Schedule

- **Recommendations**
  - Prior to upcoming DOE review, project should develop a detailed roadmap to CD-2/CD-3

SC-11: Cost & Schedule

- **Response to Charge Questions (Cost & Schedule)**

  - Is the LLP cost and schedule performance, including contingency utilization, reasonable and properly managed based upon project performance to date? Yes

    LLP is progressing well, with many of the major procurements already awarded (~80%).

SC-11: Cost & Schedule

- **Response to Charge Questions (Cost & Schedule)**

  - Are cost and schedule estimates progressing adequately to support proposed CD-2 and CD-3 decisions as early as 2QFY2022? Yes, Conditional

    Project is working hard towards prepping for CD-2/CD-3 with the original scope. However, with shared resources with LCLS-II (System Engineers, CAM's, PMCS and other areas) and the likely addition of new scope, project is already projecting an additional 6 months delay of CD-2/CD-3.

SC-11: Cost & Schedule

- **Response to Charge Questions (Cost & Schedule)**

  - Is the TPC preliminary point estimate adequately justified and credible for this stage in the project? No

    With the original CD-3A point estimate ($428M) and the pending BCR list of upcoming changes ($58M), the contingency remaining (15%) appears to be inadequate to cover potential future risk on the project at this stage.

Subcommittee 12: Management

- **Subcommittee Chair –** D. Stout (MSU)

- **Subcommittee Member --** J. Hoy, Lydia Young (SLAC)

SC-12: Project Management

- **Observations/concerns**
  - A capable LCLS II HE management team is in place that has made commendable progress since the last Director's Review (October 2019). The two partner laboratories (FNAL and JLab) have indicated their commitment to the project's success. LBNL is in the process of joining the collaboration in conjunction with a proposed scope addition to upgrade the SXU.
  - In general, due attention is being focused on satisfying the prerequisites for achieving CD-2 (Approve Performance Baseline).
  - The baselined CD-3a (Long Lead Procurement) scope has been progressing, including procurement awards, according to the planned schedule. The CPI and SPI are satisfactory. There is 24% of contingency remaining on work-to-go.

SC-12: Project Management

- **Observations/concerns**
  - With the encouragement of BES, the project is preparing to incorporate a set of proposed major scope enhancements (new Injector with one new CM, upgraded SXU, two additional Endstations, and three additional CMs) that will substantially improve its scientific value to the XFEL user community. This review and the upcoming IPR can only view and assess snapshots of project status during this rapidly evolving stage of development on the way to CD-2/3 (now forecast for August 2022 if proposed scope is approved).
  - It will be quite challenging to clearly explain this rather complicated situation to the IPR committee.
  - If these scope enhancements are implemented, the present strategy to combine CD-2 and CD-3 may need to be re-considered. The previous CD-2/3 was predicated on a simpler project.

SC-12: Management

Observations/Concerns

- Project staff resources are currently inadequate to achieve the December IPR and CD-2/3 on the current schedule (forecast for August 2022), especially in project controls which is crucial for developing proposed project-wide baseline cost and schedule estimates (with adequate contingency) and a supporting annual funding profile. More full-time, dedicated staff will be required across the project WBS. This will be a challenge considering the competing resource demands for timely completion of LCLS II.
- The proposed additional Injector (with a SCRF Gun and need for tunneling) brings with it considerable cost/schedule risk, far beyond that for the original project scope. The ~3 year long Gun R&D program and tunneling effort are expected to be project schedule drivers, and so a phased CD-4 is a reasonable idea. They will also require more cost and schedule contingency than most other project WBS elements.

SC-12: Management

Observations/Concerns

- Current project plans and status (e.g., scope, CD strategy, cost, and preliminary annual funding profile) have evolved well beyond that described in the FY 2021 Construction Project Data Sheet. The same can be said of the Preliminary Project Execution Plan (PPEP).

- The project's FY 2021 funding level is still uncertain and it may fall short of that needed to achieve CD-2 as planned in August 2022.

- Assuming that all of the proposed project scope enhancements are incorporated, the Total Project Cost will increase to about $640M. This is almost 50% above the high end of the CD-1 approved TPC Range. SLAC will need to support DOE/SC in ensuring that the scope enhancement cost is appropriately socialized up the funding approval chain. This will require more frequent IPT communication.

SC-12: Management

Observations/Concerns

- The Project is commended for developing and adopting best practices including use of Smartsheet for tracking changes and risks, use of requirements tracking system, config management, assessing staff skills for match to needs.
- The Project is commended for recognizing the need and proactively working to build a community not only within its immediate realm but also in partnership with Lab directorates who provide resources and who are end users of the Project deliverables.
- The Project is commended for its focused attention to development of an approach of integrated QA, systems, and procurement processes. These are driven by Lessons Learned and appear to be a good framework to guide HE staff. The challenge will be whether the current team leads will have bandwidth and patience to apply the necessary diligence required for the cultural change.

SC-12: Management

Observations/Concerns

- The Project stated that only the plans presented for CD-3A are baselined. Further, the proposal for replacing the LEX by undulators has only just recently been processed. Finally, the proposal for an additional 3 CMs, expanded experimental stations and injector is no more than a proposal. It is unclear which of these 3 scopes is being evaluated for CD-2 (PDR) readiness.
- Design maturity as presented in the Technical Plenary does address CD-2 (PDR) readiness for the current scope, but will need to be revisited for the proposed new scope and for a combined CD2-CD3.
- The proposed 1 year down in place of two 6 months down will reduce technical risk and can enable continuing copper linac operation.
- The proposed 3 additional CMs, injector, and additional experimental stations are a good idea and will reduce technical risk and achieve science goals.

SC-12: Management

Observations/Concerns

- The Project is commended for setting up the risk management dashboard in Smartsheet to track and communicate status. It is an advancement over what many other projects use. However, true value will come if it helps the entire project team (not just leads) embrace management of risks as a necessary part of the project management mindset - this would be a cultural change.
- Planned labor vs actuals indicate that there are insufficient resources. The Project Director indicated that the biggest shortcomings are dedicated project controls experts and dedicated Controls System Manager, both of whom are critical for detailed CD-2/3 planning.
- The Project does not seem to have considered the advantages that SLAC's PLM system (Teamcenter) can bring to supporting QA/Systems processes.

SC-12: Project Management

- **Observations/concerns**
  - The Project Design and Milestone Review document is very thorough. It includes a graded approach for quality level to set guidelines for application of the many added reviews. In practice, execution may be more complicated and demanding on resources than the authors are anticipating.
  - Systems Engineering Management appears to offer the start of a solid framework for managing requirements. The Project team should consider steering toward Teamcenter PLM as the long term repository for controlled technical documents (design and text) and records.

SC-12: Project Management

Observations/concerns

- The ties between Project initiated process developments/improvements and recent incident driven Lessons Learned is well explained. Whereas errors are always more visible than when things go well, the team might want to fold into their explanations one or two lesson examples that indicate progress in adapting improvements.
- There are inconsistencies throughout presentations in CD-2/3 targets dates: CD-2/3 formal request vs CD-2/3 formal response.
- The project's MOU with SLAC is important for defining LCLS II HE interfaces with and dependencies on various Lab infrastructural preparations/improvements. Unfortunately, it is at present only a work-in-progress draft. The MOU should be in place prior to the upcoming IPR.

SC-12: Management

Recommendations

1. For the IPR, develop credible plans in the areas of baseline development, final design maturity, and management/staffing to achieve CD-2/3 for the "current project scope"; separately develop a plan that shows how the "proposed new scope" will be integrated into it.
2. SLAC management must allocate resources necessary for the Project to prepare for the IPR and ultimately achieve CD-2.
3. Work with BES/OPA to re-evaluate the CD strategy going forward considering the forthcoming scope additions.
4. Strengthen communication within the IPT to include more frequent discussions with BES and OPA.
5. For the IPR, finalize the SLAC-HE MOU and update the PPEP.

SC-12: Management

Response to Charge Questions

3. Management: Is the project being appropriately managed to advance the design effort and deliver the long lead procurements? **Yes** Does the project have the necessary resources to succeed? **No, not for achieving CD-2/3 in August 2022 (including additional scope)** Does the project team have sufficient expertise and experience to successfully execute the project? **Conditional Yes, there are expert and experienced personnel but not enough of them (full-time)** Are the multi-laboratory partnerships functioning effectively? **Yes**

5. Risk Management: Are risks being properly managed? **Yes, for this stage of the project** Are the risks associated with the long lead procurement scope being properly managed? **Yes** Have the COVID-19 risk been appropriately identified and managed? **Yes** Is the overall risk registry sufficiently developed for this phase of the project? **Yes, the recent risk workshop appeared very productive**

SC-12: Project Management

Response to Charge Questions (Project Management)

7. Lessons Learned: Has the project adequately addressed LCLS-II lessons learned? **Yes**

8. Recommendations: Has the project responded appropriately to recommendations from the last DOE review? **Yes**

Status Review Take-aways

- For the IPR:
  - Work with BES/OPA to clarify/understand their expectations related to the charge (e.g., exactly which scope is to be reviewed) and receive guidance on how to present scope enhancements (simply proposed vs supported by DOE, timing for integrating each one into the project)
  - Develop/clarify the project's messages and plans based on the above guidance to: (1) mature the design; (2) develop the estimates/schedule; and (3) establish staffing commitments
- There is valuable and extensive experience to be applied from LCLS-II, albeit that performance in several areas is yet to be demonstrated and care must be taken to avoid blanket assumptions (risks)

Close out Complete

Thanks to the Committee and the Project Team for a smooth review.

Thanks to Charlene,Laura, Jacki and Mayu for their excellent support!

Best wishes to the LCLS-II HE team for continued success!