U.S. DEPARTMENT OF ENERGY

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Closeout Report on the DOE/SC Review of the

Linac Coherent Light Source II (LCLS-II) Project

SLAC National Accelerator Laboratory

March 19-21, 2019

Ronald J. Lutha

Committee Chair

Office of Science, U.S. Department of Energy

http://www.science.doe.gov/opa/

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Injector/Linac
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RF Power Systems
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Count: 34 (excluding observers)

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Charge Questions

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1. Project Scope: Is the project prepared to deliver sufficient scope to meet the KPPs? Will the scope of work as baselined at CD-2, be delivered? Are there any proposed scope reductions that put any of the objective KPPs in jeopardy? If yes, which ones?

2. Technical: Does the project have the technical knowledge, skills and staff to successfully fabricate, assemble, install, test, and commission all of the major technical subsystems on time and on budget? Is the project team performing the proper oversight of the partner labs for the work scope they are undertaking? Has the project planned appropriate roles for the partner labs in the installation and commissioning phases? Will the necessary procedures exist to successfully operate the new facility after project completion? Does the project have a thorough list of the technical risks and mitigation strategies to complete the project?

3. Cost and Schedule: Does the project have adequate cost and schedule contingency to successfully complete the project? If not, how much additional cost and schedule contingency is the project likely to need? Will the scope contingency list and action dates developed by the project provide adequate cost and schedule contingency?

4. Management: Does the current management team possess the necessary experience and personnel to successfully complete and deliver the project? Are the remaining risks well understood and is there adequate contingency (cost and schedule) to mitigate them should they occur? Are there significant risks the project team has not considered?

5. Environment, Safety & Health: Is the management of the ES&H program for the entire LCLS-II project including partner labs being properly executed? Is the project adequately prepared to safely receive, install and commission all the hardware at SLAC? Has the project adequately planned the phased Accelerator Readiness Reviews to commission the new facility? Is the proper work planning and control in place for completing the remaining work and to safely operate the new facility?

6. Recommendations: Has the project responded appropriately to all recommendations from prior DOE/SC reviews?

2.1 Accelerator Physics

C. Schroeder, LBNL / W. Decking, DESY

1. Project Scope: Is the project prepared to deliver sufficient scope to meet the KPPs? Will the scope of work as baselined at CD-2, be delivered?

Yes. The project is prepared to deliver threshold KPPs at CD-4, and objective KPPs during operation.

Are there any proposed scope reductions that put any of the objective KPPs in jeopardy? If yes, which ones?

Qualified No. Reduction of cryomodule spares should not impact achieving acceleration to 4 GeV in terms of available gradient; however, cryomodule spares should be retained as risk mitigation during cryomodule installation and commissioning.

2. Technical: Does the project have the technical knowledge, skills and staff to successfully fabricate, assemble, install, test, and commission all of the major technical subsystems on time and on budget?

Yes. Staffing and skills available for accelerator systems and gun/injector installation and commissioning. Staff available and qualified for cryomodule installation (welding and BLA), but welding and beamline assembly procedures still under development and project is leveraging knowledge from DESY.

2.1 Accelerator Physics

C. Schroeder, LBNL / W. Decking, DESY

2. Technical:

Is the project team performing the proper oversight of the partner labs for the work scope they are undertaking? Yes.

Has the project planned appropriate roles for the partner labs in the installation and commissioning phases? Yes, but recommend continued engagement with LBNL during injector commissioning.

Will the necessary procedures exist to successfully operate the new facility after project completion? Yes.

Does the project have a thorough list of the technical risks and mitigation strategies to complete the project? Yes.

6. Recommendations: Has the project responded appropriately to all recommendations from prior DOE/SC reviews?

Yes. (recommendations for Accelerator Physics 2.1)

Findings:

- Project scope delivers threshold and objective KPPs. Proposed de-scope (reduction of spare cryomodules) does not threaten threshold and objective KPPs.
- Sufficient staff for accelerator systems installation (e.g., magnets, BCs, bypass, BSY, LTU, EBD), including QA and verification. Staff resources can be increased if necessary.
- Magnet measurements (tolerances) nearly complete and loaded into databases (MAD).
- All warm beamline components (> Sector 10 to EBD) to be completed during LDT.
- Injector commissioning delayed due to contaminants, prevented pump down and RF conditioning. Thermal baking process developed; baking completed and has achieved ~1E-10 Torr (~1E-9 Torr with RF). EIC installation complete and commissioning ongoing; 85 kW peak power at 99.95% duty cycle delivered to gun.

2.1 Accelerator Physics

C. Schroeder, LBNL / W. Decking, DESY

Findings:

- Photocathode laser performing and met TTO specs (93 kHz with > 3uJ); however at 929 kHz thermal effects in frequency conversion crystals (IR to UV) influencing mode quality and stability. Temporal profile shaping to be done during commissioning.
- TTO plan is advanced and we anticipate that the necessary procedures and staff will be in place for operations.
- A Cu linac to soft x-ray line (CLTS) will be installed in the LDT, to provide high fluence x-ray pulses with Cu-linac. CLTS enables early commissioning of SXU.

2.1 Accelerator Physics

C. Schroeder, LBNL / W. Decking, DESY

Comments:

- Accelerator systems (e.g., magnets, BCs, bypass, BSY, LTU, EBD) installation is well planned and fully integrated into a lab-wide resource loaded schedule. Team is well prepared to meet project goals in given time frame.

- Catastrophic linac venting accident is a risk during installation/interconnection and commissioning of cryomodules. WPC procedures prepared or in preparation (BLA installation); extensive training (mock-up practice) being executed. Review of cryomodule welding procedures is scheduled. Project should continue to prepare and plan for cryomodule interconnection with vigor.

- Cable installation was delayed. Project should monitor progress closely and resources added where necessary.

2.1 Accelerator Physics

C. Schroeder, LBNL / W. Decking, DESY

Comments:

- Sufficient diagnostics available for commissioning (306 BPMs installed; 168 BPM electronics available from Project; 79 additional BPM electronics will be provided through operations for added efficiency). Several phase-space diagnostics (TCAV, XTCAV, OTR) provided by operations (e.g., XTCAV available late 2020). These phase-space diagnostics valuable to meet objective KPPs.

- Commissioning schedule is laid out and continues to be refined. Schedule benefits from EIC and early SXU commissioning with Cu linac. About 8 month of commissioning time from start of cooldown to first light with SC linac seems reasonable (compared with DESY experience), providing that the cryoplant performs to specifications.

Recommendations:

- Perform thermal emittance measurements on electron beam from gun during early injector commissioning (TTO). Complete by October 2019.

2.2 Injector/Linac

D. Nguyen, LANL & P. Piot, NIU / Subcommittee 2

1. Project Scope: Is the project prepared to deliver sufficient scope to meet the KPPs? **Yes** Will the scope of work as baselined at CD-2, be delivered? **Yes.** Are there any proposed scope reductions that put any of the objective KPPs in jeopardy? **No.** If yes, which ones?

2. Technical: Does the project have the technical knowledge, skills and staff to successfully fabricate, assemble, install, test, and commission all of the major technical subsystems on time and on budget? **Yes, but personnel with experience in CW injector are needed in the next phase of injector commissioning.** Is the project team performing the proper oversight of the partner labs for the work scope they are undertaking ? **Yes.** Has the project planned appropriate roles for the partner labs in the installation and commissioning phases? **Yes.** Will the necessary procedures exist to successfully operate the new facility after project completion? **Yes** the project have a thorough list of the technical risks and mitigation strategies to complete the project? **No, past experience has shown it is impossible to predict all technical risks especially with the injector commissioning.**

6. Recommendations: Has the project responded appropriately to all recommendations from prior DOE/SC reviews? **Yes**

2.2 Injector/Linac

D. Nguyen, LANL & P. Piot, NIU
Subcommittee 2

Findings:

- The current gun commissioning will focus in demonstrating operating parameter consistent with attaining the threshold KPPs.
- The early-injector commissioning (EIC) activities have been going on since September 2018.
- RF bake-out was not successful due to hydrocarbon contamination which came from the NEG pumps that had been improperly cleaned at LBNL.
- The hydrocarbon contamination delayed the commissioning schedule by 4 months.
- The VHF gun has been baked three times to remove hydrocarbon contamination. The gun vacuum level has improved and so has the multipacting.
- The hydrocarbon contamination has led to outgassing when the gun is powered with RF and the pressure is higher than normal for Cs_2Te cathodes. However the measured O_2 and H_2O vapor pressures are sufficiently low and should not affect Cs_2Te lifetime in the gun.
- The thermal bake of the gun is successful and has achieved vacuum level less than 1E-10 torr without RF.
- The gun has been powered up to 85 kW at 99.95% duty factor.
- The gun vacuum is 1E-9 torr with RF on; the measured dark current is 10 nA.

2.2 Injector/Linac

D. Nguyen, LANL & P. Piot, NIU
Subcommittee 2

Findings (continued):

- The VHF gun has another unexplained multipacting behavior that may be caused by the LLRF trying to maintain resonance by measuring the decay of the RF transients.
- A major risk associated with the injector is possible venting of CM10 (Injector CM) in case of accidental venting of the gun.
- An FDR for the 3.9-GHz linearizer module was conducted in January and is one of the critical-path items. The 3.9-GHz cryomodule will be among the last CMs to be delivered.
- The project delivers all 306 BPMs in the linac and undulators but only 168 BPM electronics are delivered.
- Of these, 59 BPMs are deemed low priority based on accelerator physics considerations
- There will be 79 BPM without electronics and the team plan to move the electronics around during the commissioning (and if needed).

Findings (continued):

- SLAC has 4 Cs_2Te cathodes with 7% Q.E. in the cathode cassette.
- The drive laser has delivered 3 mJ at 92.9 kHz which is sufficient to generate 3 nC with 0.5% Q.E.
- The drive laser can operate up to 93 kHz reliably.
- Operating the laser at 1 MHz is prone to instability due to thermal issues in the HG crystals (conversion from IR to UV). Cooling of the HG is being planned.
- The laser has a Gaussian temporal shape with FWHM of 22 ps obtained using a UV stretcher.
- The required flat-top pulse shape needed to produce the low-transverse-emittance beam will be developed during the operation phase.
- Operation has decided to fund items (e.g., BPM electronics, deflecting cavity for the injector,…) for added efficiency.
- CM cryo pipes are misaligned and require adding “spiders” to bring them back.
- Welding the CM interconnections with “spiders” is being planned
- The beam-rastering system needed to send 240kW-beam in the dump has been descoped. The BSY dump has been descoped to 120 kW.

2.2 Injector/Linac

D. Nguyen, LANL & P. Piot, NIU
Subcommittee 2

Comments

- The team is commended for discovering and mitigating the hydrocarbon contamination problem during the EIC. This contamination problem is unexpected.
- There is a transient temperature rise before the gun reaches resonance during turn-on; however, thermal management is challenging when the gun goes off resonance.
- The resonance control software is a possible source of problem that prevents attaining continuous-wave (CW) operation of the gun.
- Additional personnel with experience in CW gun design and operation may be needed in the next few months.
- It is very important that the VHF gun, after the EIC period, is to be operated for an extended period of time to explore the thermal transient behaviors, photocathode lifetime and possible operation-related failure.
- An independent method, other than RF, is needed to measure the beam energy.
- It is generally not a good idea to run high-current beam through the undulator unless there is a user's need for such operation.
- Efforts should be made to instrument the gun to monitor arcs and pressure and interlock the downstream slow-valve as there is not enough drift space to all for a fast gave valve. In addition the process for swapping cathode should include a hardware interlock that closes the gate-valve upstream of CM01.

2.2 Injector/Linac

D. Nguyen, LANL & P. Piot, NIU
Subcommittee 2

Recommendations

- Consider adding more personnel or seek additional help to support the Injector Commissioning as soon as possible.
- Reevaluate the hydrocarbon contamination issue and consider a more complete thermal bake of the gun to attain better vacuum level by October 2019.

2.3 RF Power Systems

A. Fabris, Elettra and A. Nassiri, ANL

Subcommittee 3

1. **<u>Project Scope</u>: Is the project prepared to deliver sufficient scope to meet the KPPs?**

   YES. The installed SSPAs are sufficient to meet the threshold KPP. Upon procuring the remaining RF components followed by installation, the RF power systems will meet the objective KKP. The construction of the LLRF systems is progressing well and the installation activities are well underway.

   Will the scope of work as baselined at CD-2, be delivered?

   YES. HPRF Resources are sufficient to meet Objective KPP by CD4

   Are there any proposed scope reductions that put any of the objective KPPs in jeopardy? If yes, which ones?

   The RF Power Systems WBS does not currently have any proposed scope reduction.

2.3 RF Power Systems

A. Fabris, Elettra and A. Nassiri, ANL

Subcommittee 3

1. **Project Scope: Is the project prepared to deliver sufficient scope to meet the KPPs?**

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   Are there any proposed scope reductions that put any of the objective KPPs in jeopardy? If yes, which ones?

   The RF Power Systems WBS does not currently have any proposed scope reduction.

2. **<u>Technical</u>: Does the project have the technical knowledge, skills and staff to successfully fabricate, assemble, install, test, and commission all of the major technical subsystems on time and on budget?**

   Yes, HPRF team is experienced and capable of meeting the major technical requirements. The LLRF team is expanding, bringing onboard several additional staff for the completion of the work-to-go.

   Is the project team performing the proper oversight of the partner labs for the work scope they are undertaking?

   Yes.

   Has the project planned appropriate roles for the partner labs in the installation and commissioning phases?

   Yes.

   Will the necessary procedures exist to successfully operate the new facility after project completion?

   Yes.

   Does the project have a thorough list of the technical risks and mitigation strategies to complete the project?

   The project does not have any RF Power Systems technical risks identified in the Risk Registry.

6. <u>Recommendations</u>: Has the project responded appropriately to all recommendations from prior DOE/SC reviews? YES

2.3.1 Findings - General

- Project reports that Threshold KPP will be met at or before CD-4
- Projects thinks that Baseline Scope will enable achievement of objective KPPs
- Project thinks that scope transfers to Ops and LCLS-II HE do not put KPPs at risk
- CD-4 milestone is schedule for June 30, 2022. With Early finish to Ready to CD-4 foreseen on May 21, this means 13 months float.
- Risk based Schedule Contingency Analysis (Monte Carlo at 80% confidence level) suggests achieving Threshold KPPs with as much as a 6 month delay to early finish. Leaves 7 months of float (95% conf. is ~8 month delay, leaving 5 months of float)
- Remaining scope includes cryomodule installation (1.3GHz and 3. 9 GHz)
- Procedure to attach WG to CM and final checkout written and successfully implemented on 3 CM to check the procedure.

2.3.1 Findings - HPRF

- HPRF will Deliver Threshold and Objective KPP by CD4
- HPRF Resources Sufficient to Meet Objective KPP by CD4
- So far, 277 L-band SSPAs have been delivered to the project, 236 installed, 25 units at JLab, 11 at FNAL, 7 on addback list and 5 in test stand/ storage.
- The project has received 266 (out of 284) high power isolators and expect the delivery of 18 units in April 2019. As of now, 220 units have been installed in LCLS-II and 16 units at JLab.

2.3.1 Findings - HPRF

- All the waveguide components are received, 92 of the vertical waveguide runs from the source to inside tunnel are complete and checked and ready for CM installation.
- Twenty-four directional couplers installed on final CM connections.
- All 284 WG penetration bundles and 160 (out of 280) housing installed.
- All 285 NIRP panels installed, 94 NIRP Systems checked out (including EIC)

2.3.1 Findings – Remaining L-band work

- Receive the last 18 isolators and install 64 isolators.
- Install remaining WG runs
- Install 48 more L-band SSPAs
- Checkout 188 more WG runs from source to end of housing ceiling
- HPRF team conducts careful QC of all HPRF components through visual inspections, 25% tests (no issues), 100% final installation pressure and NIRP checks .

2.3.1 Findings – 3.9 GHz and S-band

- Sixteen 3.9 GHz SSPAs are needed and 16 have been received.
- All the S-band WG components are received and 16 waveguide penetration bundles installed.
- The remaining S-band activities include the installing of 16 more sources (8 racks), 16 isolators and the completion of waveguide installation.

2.3.1 Findings - LLRF

- LLRF system includes Precision Receiver Chassis (PRC), RF Station (RFS), and Resonance Control.
- The Gun LLRF controls system was demonstrated during Gun RF bake-out
- The remaining work includes LLRF and Cryogenic software to be demonstrated at LERF (JLab), software development, Beam Containment System (BCS), cable verification, termination and full checkout.
- The LERF has provided opportunity to troubleshoot hardware commissioning and firmware/software tools.
- SLAC is testing LLRF system hardware and rack integration with a full set of hardware installed in production test rack, cavity emulator for system testing and EPICS interfaces and control, waveform readouts.
- Prototype 3.9 GHz LLRF chassis have been built and tested

2.3.1 Findings – LLRF Status

- Hardware Production
  - Boards/component procurement:
    - 95% of PCBs have been ordered in full production quantities
    - In house testing performed on sensitive RF boards
  - Chassis assembly
    - Outside assembly houses used to assemble:
    - Power Supply – 100% complete
    - Optical Patch Panel – recent problem discovered by LERF, fixed by vendor
  - In-house production of
    - Resonance Control – 100% complete, bulk testing starting now
    - LO distribution – 100% complete
    - RFS and PRC – 40% complete

2.3.1 Findings - Linac Commissioning

- Commissioning sequence include RF setup, then beam based hardware and software checkout
- Project Commissioning will be directed at attaining the threshold KPPs (or better)
- As Transition to Operations (TTO) goals are surpassed, systems transfer to operations as defined in Acceptance Criteria and Transfer of Systems (LCLSII-1.1-PM-0269)
- Operations Commissioning continues after TTO
- Objective KPP goals will be met or to exceed
- 5 year plan developed to improve performance while delivering beam to users
- Power ramps slowly from 10 kW up to 120 kW

2.3.2 Comments

- The team continues to do a great job. This is evident from their steady progress and many achievements since the last Independent Review. They are to be commended.
- We believe the current (~FTEs) for HPRF (including technical lead, engineers, technicians) is adequate for the completion of the reaming tasks.
- The RF team has produced extensive level of documentation in all areas of RF systems including fabrication, installation, test, and checkout.
- We encourage the team to continue improving processes for the rest of the project based on experiences and lessons learned from the RF systems performance on EIC.
- The project is encouraged to evaluate potential schedule and technical risks impacts of the 3.9 GHz cryomodules and the associated systems including HPRF and LLRF.
- The project should consider plans for HPRF and LLRF longer term contingency recovery (if needed).

2.3.2 Comments

- The project will meet the threshold KPP (3.5 GeV) with 235 cavities. This assumes an average accelerating gradient of 15.5 MV/m. The Objective KPP can be achieved with 264 SSPAs. The project has 277 SSPAs in hand.
- The current Linac plan allows only 3 months for the SRF commissioning. Consider if additional commissioning time could help the commission efforts.
- In coordination with the partner labs, develop a plan for the return of all or partial set of SSPAs to SLAC. The project should ensure that an adequate units are on hand at SLAC if needed for the LCLS-II injector/linac beam commissioning, TTO and delivering objective KPP.
- LERF has provided opportunity for LLRF team to troubleshoot hardware commissioning and firmware/software tools. We believe is very valuable and we support this effort.
- We encourage the team to work closely with the partner labs on transfer of knowledge and ownership of firmware to LCLS-II.

2.3.2 Comments - LLRF

- As the chassis production progresses, continue to pay close attention schedule and QA.
- Continue implementing partner labs' experience and other lesson learned in EIC and LERF.
- Up to now software has the ability to control individual SRF cavities but not an entire CM. The development is on course and tests are foreseen to be done at LERF. The team is encouraged to continue to take full advantage of LERF facility.

2.3.2 Comments

- Pay close attention to cable termination, installation and checkout. Careful planning supported by procedures and checklists is essential to avoid after-installation problems.
- Continue tracking RF systems resources needed for installation and checkout to ensure timely completion.

2.3.3 Recommendations

1. Reevaluate the Risk Registry entries for HPRF and LLRF systems. Make a determination whether any of the identified issues/concerns should be captured as risks into RR. Complete by July 2019.

2.4 Undulator

T. Tanabe, BNL / Subcommittee 4

Team members: Toshi Tanabe (BNL) , Joachim Pflueger & Suren Karabekyan (XFEL.EU)

1. Project Scope:
- Is the project prepared to deliver sufficient scope to meet the KPPs? **YES**
- Will the scope of work as baselined at CD-2, be delivered? **YES**
- Are there any proposed scope reductions that put any of the objective KPPs in jeopardy? **No** If yes, which ones?

1. Technical:
- Does the project have the technical knowledge, skills and staff to successfully fabricate, assemble, install, test, and commission all of the major technical subsystems on time and on budget? **YES**
- Is the project team performing the proper oversight of the partner labs for the work scope they are undertaking? **YES**
- Has the project planned appropriate roles for the partner labs in the installation and commissioning phases? **YES**
- Will the necessary procedures exist to successfully operate the new facility after project completion? **YES** (Details on HXR undulator systems are still under testing)
- Does the project have a thorough list of the technical risks and mitigation strategies to complete the project? **YES**

6. Recommendations: Has the project responded appropriately to all recommendations from prior DOE/SC reviews? **YES**

2.4 Undulator

T. Tanabe, BNL / Subcommittee 4

- **Findings**

- All SXR undulators delivered & 18/21 are RFI
- All 33 new Quad magnets have been fiducialized and they are RFI
- All 65 RFPBMs + 3 Proto-types delivered, 55/68 RFI and 5 more spares ordered
- All undulator vacuum chambers delivered
- 18/21 of SXR undulators are RFI and by April all will be RFI.
- 7 HXR undulators have been tuned but only one has been calibrated.
- Since the last review, additional flexures have been implemented to motor connection in HXR undulators to reduce the thermal instability.
- Plungers in HXR devices also have been replaced from steel to aluminum.
- Original full gap encoders in HXR device did not meet the spec.
- With new Ranishaw encoders +/- 0.5 micron repeatability has been obtained (+/- 4 microns before modifications) but only mechanically . Magnetic field repeatability with new Ranishaw encoders has not been confirmed yet.
- Phase shifters is planned to be ready by May 2019 (after encoder scale modification by the vendor)

2.4 Undulator

T. Tanabe, BNL / Subcommittee 4

- **Findings**

- o 14/65 RF-BPMs experienced vacuum leak. 5 more has been ordered for spare. Assembly procedures have been reviewed but the cause is still unknown. However, only a few hours may be needed to replace it in case one of them fails.
- o RFBPM electronics have not been tested.
- o For SHR 22 vacuum chambers and 4 for spare have been fabricated.
- o For HXR 33 chambers and 6 spares have been fabricated.
- o Hard X-ray self seeding system uses new monochromator rotated by 90 degree.
- o LBNL has one bench dedicated to tune half the HXR undulators
- o ANL has one bench dedicated to tune the other half of HXR undulators
- o Calibration of all HXR undulators at SLAC is a bottleneck. To meet installation schedule only ~14 HXR undulators will be calibrated and installed within the downtime – and 32 need to be Installed for SC operation. For the warm Linac operation 20 units are sufficient.
- o Conversion of the SXR undulator measurement bench to calibrate HXR undulators will allow 20 HXR undulators RFI by the end of the shutdown (BCR in progress)
- o SXR undulator transportation / installation procedures have been tested and confirmed no impact on the undulator performance.
- o HXR undulators transportation / installation procedures have not been tested yet.

2.4 Undulator

T. Tanabe, BNL / Subcommittee 4

- **Findings**

- For XHR, Production EPICS IOC and Extensible Display Manager (EDM) screens are 90% complete.
- 2-3 weeks are needed to integrate BiSS-C interface in HXR undulator controls.
- For SHR, production EPICS IOC and EDM screens are 70% complete.
- HXR LCLS-I rack modifications will be complete on all 32 racks (March-Mid April 2019)
- There are nine spare LCLS-I racks but only two have been converted as spares for HXR undulators.
- SXR Beckhoff temperature IOC and EDM screens to completed Mid-April 2019 and LCLS-II production IOC's will be configured (April 2019)
- Operation check-out of systems follows the equipment check-out by different teams.
- HXR beamline commissioning has higher priority due to planned user experiment.
- The plan is to exchange selected undulator segments every 3 months to test for damage after achieving 1kW of beam power.
- There is no plans for a refurbishing strategy for radiation damaged undulators.
- Recent HXR undulators were delivered with full documentation packages. Early units which were reconfigured during prototyping phase need additional work to complete. All documents are standardized for all providers.

2.4 Undulator

T. Tanabe, BNL / Subcommittee 4

- **Findings**
  - SXR phase shifters calibration must be re-checked after replacement of the encoder scale.
  - The positions of all HXR undulators are planned to be equidistance despite the original LCLS support systems which are not.
  - The team owns K-monochromator for single photon energy only.

2.4 Undulator

T. Tanabe, BNL / Subcommittee 4

- **Comments**

- LBNL group has shown commendable effort to identify and correct many issues of the original HXR undulator design.
- Not all the issues on HXR undulator have been confirmed to be “solved” yet. For example, repeatability check of magnetic field with newly installed encoder has not been completed.
- The present installation schedule for the HXR undulator is insufficient due to limited calibration capacities. For mitigation the SXR undulator bench could be upgraded for HPVPU calibration.
- The impact of transport of HXR undulators has to be carefully checked with field measurements.
- There is a plan for frequent re-measurement of undulators, but no plan for refurbishing when radiation damage is observed.
- Local control system must be completed as soon as possible and testing integration to the global controls should start.
- A few SXR undulators show increased hysteresis for $\Delta K/K$ value. The reason could be figured out before installation in the tunnel.

2.4 Undulator

T. Tanabe, BNL / Subcommittee 4

- **Comments**
  - Magnetic middle plane of SXR undulators appear to change depending on the gap.
  - The tempering of vacuum chamber cooling water has not been designed yet.
  - There are concerns about the manpower for HXR undulator calibration, installation related activities and commissioning. Two people are leaving the group soon.
  - In case not all the HXR undulators cannot be calibrated in time, it is suggested to install all the tuned devices.
  - It is prudent that necessary documents for the ARR should be examined in advance so that they are ready by the ARR date.

- **Recommendations**

  - Execute the BCR to convert the 2nd magnetic measurement bench to allow the calibration of HXR undulators so that 20 devices will be ready when the operation starts in spring 2020. (As soon as possible)

  - Allocate more resources to ensure smooth work flow from magnet calibration through fiducialization, installation and testing for HXR undulator.
    (By the end of Q3 FY2019)

2.5 XTES

Z. Hussain, LBNL(retired) ; J. Wang, ANL/ Subcommittee 5

1. Project Scope: Is the project prepared to deliver sufficient scope to meet the KPPs?

   Yes, XTES will meet KPP that require delivering beam to one or more high rep rate capable end stations and delivering beam to =>2 endstation at upto 15 keV.

   Will the scope of work as baselined at CD-2, be delivered?

   Yes, XTES progress on the technical scope is consistent with the baseline at CD-2

   Are there any proposed scope reductions that put any of the objective KPPs in jeopardy?

   No

2.5 XTES

Z. Hussain, LBNL(retired) ; J. Wang, ANL/ Subcommittee 5

2. Technical: Does the project have the technical knowledge, skills and staff to successfully fabricate, assemble, install, test, and commission all of the major technical subsystems on time and on budget? **Yes**

   Is the project team performing the proper oversight of the partner labs for the work scope they are undertaking? **N/A**

   Has the project planned appropriate roles for the partner labs in the installation and commissioning phases? **N/A**

   Will the necessary procedures exist to successfully operate the new facility after project completion? **Yes, commissioning and operation procedures are under development. Experimental instrumentation and research program is ramping up.**

   …….. Continue

2.5 XTES

Z. Hussain, LBNL(retired) ; J. Wang, ANL/ /
Subcommittee 5

<u>Technical: ….</u>

Does the project have a thorough list of the technical risks and mitigation strategies to complete the project? **Yes, but the fabrication of XTES components through the SLAC shops are cutting very close without much of time contingency.**

6. <u>Recommendations</u>: Has the project responded appropriately to all recommendations from prior DOE/SC reviews?

Yes. Although design continued to be tweaked to accommodate further optimization of components required by L2SI for benefiting the LCLS-II user experiments. These tweaks were implemented through the LCLS-II Design Change Process and the layout design is now considered as final.

2.5 XTES

Z. Hussain, LBNL; J. Wang, ANL/
Subcommittee 5

2.5.1 Findings

- **The LCLS-II X-ray Transfer Experimental System (XTES) system characterizes, conditions, and delivers the X-ray FEL beams produced by the SXR and HXR undulators to the experimental halls.**
- **As a current baseline and KKP's, the project will provide:**
  1. **Photon beam to one or more experimental instruments capable of using high rep rate x-ray beam of energies 250 eV – 3,800 eV, and**
  2. **Photon beam to two or more experimental stations from normal conducting LINAC (1 keV – 15 keV).**
- **Users science needs have been translated into experimental tools by LCLS/L2SI team and the experimental program is ramping up.**
- **LCLS detector group has a plan to deliver detectors for L2SI instrumentation which is also planned in phases.**
- **Because of maintaining soft x-ray user science program, L2SI team now plan to deliver soft x-rays from Cu warm LINAC by installing a cross over line. As a result this will help starting the commissioning of XTES around April 2020.**…..

....continued

2.5 XTES

Z. Hussain, LBNL; J. Wang, ANL/
Subcommittee 5

2.5.1 Findings

- **Dismantling of the FEE and experimental hall for construction/modification of conventional facility went ahead of schedule by couple of weeks.**
- **Installation plan includes a single schedule (3D model) for both XTES and L2SI components.**
- **LCLS is providing technicians for installation of both XTES and L2SI components.**
- **Fabrication of the remaining XTES components and its assembly is carried out in SLAC shops. There is a high level of coordination and priority meetings to set the shop priority.**
- **There is about 4 weeks of time float at the end of 2019 for installation of XTES.**
- **The XTES mission is to perform commissioning by demonstrating performance level needed to realize science.**
- **The plan is to develop instruction manuals at the end of commissioning before handing over to operation.**

2.5.2 Comments

- **There are still a large number of XTES components being fabricated by the SLAC shop and there is a risk if the shop does not give the required priority to the XTES, the delivery of the photon beam may be delayed. There is very little time float left in the schedule.**
- **XTES and L2SI teams are coordinating their effort and has developed an integrated installation plan.**
- **LCLS is proving the technical staff for installation of both XTES and L2SI components. As the XTES transition to commissioning and operation, this technical staff will continue this effort and take over the ownership.**
- **Installation of cross-over line by LCLS team to deliver soft x-rays from Cu warm LINAC will help ramping up commissioning of XTES before it is ready for accepting higher power superconducting LINAC beam.**
- **The detector group is making progress in delivering suitable detectors capable of operating upto 1MHz by working closely with other national laboratories.**
- **L2SI team has a staged plan to deliver instrumentation that is in line with the experimental needs of scientific user community.**

2.5.2 Comments (cont'd)

- **Progress is being made to provide seeded SXR beam as R&D project by LCLS. Currently, LCLS plans to utilize additional cooling of the grating to deliver soft x-ray self seeded beam at LCLS-II near similar performance as they have achieved at LCLS. However, we encourage the LCLS team to continue their R&D effort and find optimal solution for seeded x-ray beam.**
- **The availability of seeded FEL, near transform limited performance, will allow LCLS-II users to carry out some of the most innovative experiments using multidimensional spectroscopy.**
- **XTES team has kept good oversight of the expenditure and plans to complete the project on budget.**
- **There is no major risk identified in achieving the KPP.**

2.5.3 Recommendations:

- **SLAC/LCLS-II project management needs to provide appropriate priority for fabrication and delivery of the remaining XTES components from SLAC shops to avoid any further delays.**

2.6 Cryo System

M. Howell, ORNL / Subcommittee 6

Team Members: Philipp Arnold, Fabio Casagrande, & Arkadiy Klebaner

1. Project Scope: Is the project prepared to deliver sufficient scope to meet the KPPs? **YES** Will the scope of work as baselined at CD-2, be delivered? **YES** Are there any proposed scope reductions that put any of the objective KPPs in jeopardy? **NO** If yes, which ones?
2. Technical: Does the project have the technical knowledge, skills and staff to successfully fabricate, assemble, install, test, and commission all of the major technical subsystems on time and on budget? **Yes, but there is more work to do to ensure success on time and on budget.** Is the project team performing the proper oversight of the partner labs for the work scope they are undertaking? **Yes, but there are challenges.** Has the project planned appropriate roles for the partner labs in the installation and commissioning phases? **Detailed commissioning plan is being developed. Recently, the commissioning responsibility has been transferred from Jlab to SLAC.** Will the necessary procedures exist to successfully operate the new facility after project completion? **Yes, but significant majority of procedures are yet to be developed.** Does the project have a thorough list of the technical risks and mitigation strategies to complete the project? **Yes, but risks need to be more detailed at this point in the project.**

6. Recommendations: Has the project responded appropriately to all recommendations from prior DOE/SC reviews? **Yes**

Findings

Much progress has been made in building and filling out the cryogenic team. Seventeen FTEs are working in the cryogenic plant team and five more will be hired. Cryoplant group has 3 Engs, 5 SMEs, 6 in operations, and 3 in controls.

General contractor for cryoplant installation is on site now.

Kinetics Systems, Inc., is the GC for LCLS-II cryoplant equipment installation.

Kinetics Systems, Inc., did CDS transfer line installation very successfully.

There are 15 change orders with the GC for installation.

Chosen as the site contractor for ALATUS.

Cryoplant 1 (CP1) and Cryoplant 2 (CP2) commissioning are now planned in series. CP1&2 installation completion dates are February 2020 and October 2020.

Findings Cont'd

CP1 commissioning completion date is May 2020. CP1 is 6 days off the critical path

JLab is working closely with the SLAC team to identify roles & responsibilities for commissioning.

Jefferson Lab does not plan to have fulltime presence at SLAC during the commissioning period. They will provide site support (3 FTEs) for critical activities including first turn on of rotating equipment for the commissioning of CP1. It is not in the project scope for Jefferson Lab to provide commissioning support for CP2.

The project is working to maximize the work done by the SLAC staff. Commissioning will be led by SLAC with support from Jlab. This is a change since the project baselined.

The Cryoplant commissioning team will be the same core team currently involved in it's installation.

Findings Cont'd

87 of 94 major components delivered. The balance is in fabrication.

Key Deliveries:

- 2K Cold Boxes – April and May
- 4.5K Lower cold box for CP2 – June
- Interface box and Multi-transfer line – September and June

The interface box is not required for commissioning but it does affect the installation of the piping platform.

The installation schedule is monitored weekly.

The controls staff has 2 FTEs to work on the cryoplant and cryomodules. An additional software engineer has been hired.

The final leak checking of the 2K cold box has not been completed.

Findings Cont'd

A scope gap was presented concerning Control and Instrument Air (IA) Tubing

- Estimate is in EAC. ROM: $200-500k
- Scope finalized with GC and currently cost and schedule being estimated. Expect to issue Proposed Change Order (PCO) by April 1, and will impact performance period A completion

Comments

The LCLS-II project is making the transition from design and procurement to installation and commissioning. The project team has done an incredible amount of work to get to this point. There are new challenges ahead that require a diligent focused approach.

Equipment turn on and the necessary documentation to get through safety reviews is coming together, but has a long way to go.

Proceeding to commissioning with only one nitrogen Dewar may provide favorable schedule benefits.

The conditioning of the helium gas tanks and carbon beds can take a long time to complete. The cleaning and drying of the piping system will significantly reduce risk of contamination. Expediting this activity is likely to benefit the project.

GC performance is very good. Delays in GFE has been the main concern in installation schedule.

Comments

The controls staff seems light for the work load ahead. Additional resources will be required (~2.5 FTEs).

It is unclear who will provide process control functions that coordinate and integrate the cryo plant, cryomodules and CDS. Adding this scope to project will clarify the roles and responsibilities.

Procuring hardware at SLAC for controls to do integrated testing of epics to PLC to equipment will increase efficiency and speed up deployment of the code.

The PLC and software plan for installation and commissioning should ensure effects on operations will be minimized.

For equipment shipped from overseas (for example: MTL), conducting site acceptance test that includes helium leak checking prior to installation will reduce potential delays in commissioning.

Comments

Clarity in understanding documentation requirements, roles and responsibilities, and durations for review and approval, would minimize delays in getting approval to proceed with equipment testing and commissioning.

Detailed understanding of requirements for tools and consumables to conduct commissioning activities will help minimize potential delays in start up. Once the details are understood, appropriate budget should be allocated.

Without having previous experience with the GC cable installation, quality control of the GC instrument cable installation and termination is essential to the success of the enterprise.

Cable installation is scheduled to begin soon. Any slip in the cable installation could adversely effect the installation and commissioning schedule of the cryo plant.

Installation and validation of the ODH system is a prerequisite for commissioning.

Comments

Delay in the delivery of the 2K cold box will cause subsequent delays in the platform installation, installation completion, and potentially start of commissioning with additional cost to the project.

The LCLS2 Cryoplant C1 and C2 Commissioning Scope Sharing (LCLSII-1.1-PM-1432-R0) document was released on March 19, 2019. This document defined roles and responsibilities for SLAC and Jefferson Lab in the pre-commissioning and commissioning activities. With this agreement in place, the detailed commissioning plan can be formulated and the schedule can be finalized.

Recommendations

1. By the end of April 2019, revise the existing list of documentation required to support the commissioning schedule development to include missing documents and expected delivery dates from Jefferson Lab.

2. By the end of May 2019, complete development of the commissioning plan and determine the best resources to execute the tasks within the plan. Ensure that best resources from Partner lab's are available to support commissioning and that safety and quality are not compromised in the execution of the commissioning tasks.

2.7 Cryomodules

S. Kim & M. Doleans, ORNL / Subcommittee 7

1. Project Scope: Is the project prepared to deliver sufficient scope to meet the KPPs? YES. Will the scope of work as baselined at CD-2, be delivered? YES. Are there any proposed scope reductions that put any of the objective KPPs in jeopardy? YES at this stage of the project. If yes, which ones? See comments

2. Technical: Does the project have the technical knowledge, skills and staff to successfully fabricate, assemble, install, test, and commission all of the major technical subsystems on time and on budget? Conditionally YES (see comments) Is the project team performing the proper oversight of the partner labs for the work scope they are undertaking? YES. Has the project planned appropriate roles for the partner labs in the installation and commissioning phases? Partially. (see comments) Will the necessary procedures exist to successfully operate the new facility after project completion? Under development. Does the project have a thorough list of the technical risks and mitigation strategies to complete the project? YES

6. Recommendations: Has the project responded appropriately to all recommendations from prior DOE/SC reviews? YES

2.7 Cryomodules

S. Kim & M Doleans, ORNL / Subcommittee 7

- Findings
  - The Cryomodule scope has not changed since last review. The scope of work mainly consists of the design, fabrication and testing of forty 1.3-GHz cryomodules, and installation/commissioning of thirty-five 1.3-GHz cryomodules. Each 1.3-GHz cryomodule has eight nine-cell cavities, a single superconducting quadrupole magnet package, and a BPM for an overall cryomodule length of about 13 m. The scope of work also consists of the design, fabrication and testing of three 3.9-GHz cryomodules, and installation/commissioning of two 3.9-GHz cryomodules. Each 3.9-GHz cryomodule has eight nine-cell cavities and a BPM. Operating temperature of all cryomodules is 2 K. The design of the cavities is closely based on TESLA/EU-XFEL/ILC superconducting RF technology. All 1.3-GHz cavities are nitrogen doped to increase Q0. The design Q0 at operating gradient (16 MV/m) is 2.7e10.

2.7 Cryomodules

S. Kim & M Doleans, ORNL / Subcommittee 7

- Findings (cont.)
  - 1.3-GHz cavities, cryomodule production, installation and commissioning is on the critical path.

  - Cryomodule assembly, test and shipping are in progress.

    Number of useable cryomodules delivered: total 7 (4 from FNAL and 3 from JLAB)
    Number of cryomodules in preparation for shipping: total 6 (6 at FNAL and 0 at JLAB)
    Number of cryomodules in cold test: total 4 (1 at FNAL and 3 at JLAB)

    Number of cryomodules in assembly stations: total 9 (5 at FNAL and 4 at JLAB)
    Number of cryomodules requires partial rework: total 3 (0 at FNAL and 3 at JLAB)
    Number of cryomodules requires total rework: total 6 (3* at FNAL and 3 at JLAB)
    *F-05 will be used as a test cryomodule at SLAC for installation exercise.
    Number of cryomodules no started: total 5 (0 at FNAL and 5 at JLAB)

2.7 Cryomodules

S. Kim & M Doleans, ORNL / Subcommittee 7

- Findings (cont.)
  - Cost Variance (CV) of WBS 1.04 (Cryogenic Systems) is -$5.7M (-$5.3M from Cryomodule) related to 1.3-GHz cryomodule production and delivery challenges, requiring repair of damage to three cryomodules at FNAL and three cryomodules at JLAB.
  - Schedule Variance (SV) of WBS 1.04 (Cryogenic Systems) is -$26.2M (-$14.8M from Cryomodule) that has been driven by various project challenges (delays in cavity preparation/test, delays in cryomodule assembly, delays in delivery and inspection of cryomodule components such as vacuum vessel, interconnects, magnetic shielding, late procurement of 3.9-GHz cryomodule components procurements and subsequent fabrication, and stand-down during investigation of problems with cryomodule shipping). The schedule float decreased by 5 months mainly due to rework required to address the 1.3-GHz cryomodule assembly and transportation challenges.

- Findings (cont.)
  - Remaining contingency is very tight and the project has proposed a de-scope list
    - First round descope (August 2018): $11.6M (e.g. niobium to HE, spare cryo-plant to operation)
    - Proposed second round descope: $18.2M including selling 16 unjacketed spare cavities to LCLS-II HE $1.7M, those not needed to build 40 CM; selling two spare CM to LCLS-II HE $3.9M; selling two additional cryomodules to LCLS-II HE $3.9M; selling 1 spare functioning CM to LCLS-II Ops $3M
  - “Delta” Final design review for 3.9-GHz cryomodule was completed in January 2019. 3.9-GHz cryomodules will be fabricated at FNAL after completion of 1.3 GHz module production; this may place the 3.9-GHz CMs on critical path depending on actual 1.3-GHz CM production.

§ Findings (cont.)

- The cryomodule production plan is to have all cryomodules at SLAC by the end of Q2 FY20. All cryomodule installation is scheduled to be completed by July 2020 followed by Linac cool-down in September 2020.

- Five moderate risks on cryomodule production and eight moderate risks that impact SRF commissioning are identified.
    - CM damages
    - CM installation and particle-free assembly in the SLAC tunnel
    - 3.9-GHz CM production and testing
    - Commissioning of SC Linac

- Research Instrument has completed delivery of all cavities in their contract and Ettore Zanon has four cavities remaining to deliver. In total 355 cavities have been received from the two vendors. 272 cavities were qualified out of 335 cavities tested. Efforts for cavity rework has been stopped due to anticipated yield rates exceeding LCLS-II needs. Cavity testing for 1.3-GHz cavities is scheduled to be completed in May 2019.

- Findings (cont.)
  - Major NCRs to the cryomodule acceptance test at SLAC due to cryo-pipes and gate valve alignment issues. Investigations are underway.
  - The first four cryomodules were installed in the SLAC tunnel into their slots and F05 cryomodule was also installed for the installation test/practice purpose. Preparation for the critical integration activities (installation of BLA and welding of the cryo-piping) is progressing.
  - Basic plans for cryomodule installation and SRF commissioning were drafted. Commissioning will begin in October 2020 for 6 weeks.

2.7 Cryomodules

S. Kim & M Doleans, ORNL / Subcommittee 7

§ Comments

- Significant progress on 1.3 GHz cryomodule production and shipping from both partner labs. Improvement of the shipping technique using M-mounts has been successfully implemented and seven cryomodules are presently at SLAC. The systems in place for tracking of components availability, and for the assembly, test and shipment of cryomodules at both partner Labs are mature at this stage of the project.

- Very nice achievement at JLab bringing the LERF cryomodule testing facility into operation. Very positive leveraging of this new testing facility not only for testing cryomodules but also for developing LLRF control tools for LCLS-II commissioning. Involvement of SLAC personnel at LERF has started and plans to be expanded. The committee strongly supports this plan as it will strengthen the readiness of the LCLS-II team for future commissioning activities at SLAC.
  - Currently J-5 and J-12 are installed and at cold in LERF. J12 testing is on-going and progressing well. The committee believes testing J-5 and J-12 simultaneously would also provide a very valuable learning experience.
  - Continue using LERF if cryomodule delivery schedule allows

- Comments (cont.)
  - The 1.3 GHz cryomodule production plan is to have all cryomodules at SLAC by the end of Q2 FY20. This schedule can be achieved assuming no further delays in production, rework or shipping activities.
  - Nice progress on the fabrication and testing of 3.9 GHz cavities. Continued work with cavity vendor is critical to guarantee cavity delivery schedule and cavity performance. Delta design review for the 3.9 GHz cryomodule is complete and the committee was pleased to see that lessons learned from the 1.3 GHz cryomodule effort were incorporated. Because the production of the 3.9 GHz cryomodules is close to the critical path, planning and execution for all activities related to the 3.9 GHz cryomodule production and testing should be closely managed and coordinated adequately with the 1.3 GHz cryomodule production effort.
  - The Project presented descoping options related to cryomodule production. The committee strongly encourages the project to complete the fabrication of all 40 1.3-GHz cryomodules. The committee believes that descoping more than 2 cryomodules at this stage of the project would be premature.

§ Comments (cont.)

- A significant milestone has been achieved with the installation of the first four cryomodules in the SLAC tunnel into their slots. Preparation for the critical integration activities (beamline vacuum connections and welding of the cryo-piping) is progressing well. Nonetheless recent discovery of cryo piping alignment issues should be carefully analyzed. Also, the sequence for the beamline vacuum connections of all cryomodules should be planned in more details. The committee believes that a comprehensive review of the procedures, QA and detailed sequence for the installation of all the cryomodule interconnects is highly desirable.

- A plan was presented regarding gradient optimization to achieve beam energy KPP while minimizing cryogenic load based on the available data from the testing of cryomodules. The committee feels that this plan is reasonable and should be finalized once all the cryomodules have been tested.

- Comments (cont.)
  - Basic plans for cryomodule installation and SRF commissioning were presented to the committee. The overall scope is captured but the committee feels that the interface, roles, responsibilities and authorities need to be clearly defined.
    - Then, the team for the SRF commissioning with all the required personnel (including ES&H and partner Labs personnel) should develop a comprehensive commissioning plan with adequate documentation (equipment checklists, turn on procedures, etc.) for all technical and safety related aspects. Once the SRF commissioning plan is approved, the team lead should have the authority to execute the plan.

- Recommendations
  - Conduct a review of the procedures, QA and detailed sequence for the installation of all the cryomodule interconnects by the end of April 2019.
  - Develop a comprehensive SRF commissioning plan by the end of December 2019.

Control Systems Subcommittee Members:
Steven Hartman (ORNL), Aaron Coleman (ORNL), Greg Portman (LBNL)

1. Project Scope: Is the project prepared to deliver sufficient scope to meet the KPPs?

Yes

Will the scope of work as baselined at CD-2, be delivered?
Yes. There is much work remaining but controls related work is expected to be delivered.

Are there any proposed scope reductions that put any of the objective KPPs in jeopardy? If yes, which ones?
No. The identified cost-savings reduction options for controls scope are limited and will not impact the ability to achieve the KPPs.

2. Technical: Does the project have the technical knowledge, skills and staff to successfully fabricate, assemble, install, test, and commission all of the major technical subsystems on time and on budget?

Yes. There are many control systems staff from across SLAC who are contributing to the project. Ongoing diligence will be required to maintain prioritization of these resources for project needs.

Is the project team performing the proper oversight of the partner labs for the work scope they are undertaking? Has the project planned appropriate roles for the partner labs in the installation and commissioning phases?

Yes. The relationship with the partner labs is mature.

Will the necessary procedures exist to successfully operate the new facility after project completion?

Yes. Good progress is being made in working towards turn over to operations.

Does the project have a thorough list of the technical risks and mitigation strategies to complete the project?

Not to the level needed for this stage of the project. Further refinement of the risks, taking into account recent progress and remaining challenges, is still to be made. (See Recomm.)

6. Recommendations: Has the project responded appropriately to all recommendations from prior DOE/SC reviews?

Yes. The updates to the BCS design reduced the number of sensors required, simplifying this credited system.

2.8 Control Systems

S. Hartman, ORNL / Subcommittee 8

- **Findings**

Overall System

- Controls System's CPI is 0.88 and SPI is 0.93. Estimate at completion is $82M with an expected variance at completion of -$9.7M.

- Accelerator systems schedule variances are mostly due to BCS design, controls hardware procurement and installation.

- Accelerator systems cost variances include: controls systems - engineering design ($3.99M), Injector Controls ($354k), Linac controls ($1.04M), cryomodule controls ($2.09M) and undulator controls ($97k).

- Top Risks include: cable plant installation (LCLS-Cable-001 and LCLS-Cable-002) with a 80% likelihood, and interlock software readiness (LCLS-CryoPlant-021B) with 50% likelihood.

- **Findings**

Overall System (cont.)

- Twenty-two controls sub-system designs are complete. All systems have completed Final Design Review, with the BCS FDR completed in February 2019.

- A number of systems were considered nearing completion and were not presented including BPMs, timing system, MPS, LLRF.

- 13 FTEs are planned for controls support for accelerator commissioning.

- Gun LLRF controls have been demonstrated during Gun RF bake.

- Rack installation is 87% compete in Sectors 0 to 10.

- EPICS software systems will be using EDM, ALH, and EPICS 3.15.

- **Findings**

Cable Plant

- Project technical challenges have included the cable plant. The project has added additional staff to increase attention on this area.

- Portions of Cable Plant installation must be completed on schedule during Long Down Time.

- Cable verification, termination and checkout is still to be done.

- Responsibility for cable installation is managed through two subcontracts, with the design responsibility managed through the CAMs from the appropriate technical systems. Terminations are the responsibility of controls.

- SLAC scope of work for the cable plant includes design, final dressing of cables to technical equipment, providing equipment to installation contractor, and cable terminations to technical equipment.

- 150 out of 155 cryo racks were completed by vendor. Five remaining racks (end-caps, cryo distribution) are to be built by SLAC. Overall rack production is nearing completion.

2.8 Control Systems

S. Hartman, ORNL / Subcommittee 8

- **Findings**

Undulators

- Undulator controls checkout is planned to take 5 days for a group of 5 undulators, i.e. 1 day per undulator. This will be verified in October.

- HGVPU full gap encoders were not performing to specification and will be replaced.

- **Findings**

BCS and Safety Systems

- Remaining challenges for the project in the Long Down Time include Beam Containment System procurement and installation.

- Long lead procurements for BCS have begun.

- Any bypassing of the PPS needed for test/commissioning of other equipment will use SLAC existing procedures for radiation safety.

- ODH systems are installed in the cryo-plant and the Linac. However, they are not fully yet functional, and need power to the rack to operate.

- **Findings**

Cryoplant and Cryo Systems

- Cryoplant commissioning is near the critical path. Commissioning will be started this spring.

- LLRF and cryo software will be demonstrated at JLab's LERF. LERF will be used for testing only six cryomodules prior to shipping to SLAC and installation. SLAC is relying on this pretesting to assume a reduction in commission time for controls cryomodule checkout.

- PLC programming is complete for cryo-plant's utilities, all compressors, and gas management system.

- A change request was approved to understand the process control functions that must be implemented to coordinate Cryoplant, CDS, and Cryomodules controls and decide what functions must be automated to meet KPPs

- SLAC controls leads are responsible for acceptance testing of subcontractor electrical installation and termination for the cryo-plant

- Cryo-plant ODH needs to be fully operational prior to helium or nitrogen being introduced into the building.

- Scope for "integrated" controls (between PLCs, or PLCs to other systems) and local cryo IT room was not initially included in scope. A BCR will be required to add this scope.

2.8 Control Systems

S. Hartman, ORNL / Subcommittee 8

- **Comments**

Overall System

- Control System's CPI dropped during the second half of CY2018 but has since leveled off over the time period presented to the committee. SPI continues to show a downward trend which is concerning.

- Good progress is being made with procurements, software and PLC-based controls across a large number of subsystems.

- Available staff and staff technical expertise appear to be sufficient for control systems. However, the complex matrixed organizational structure makes it difficult to assess during a review if the staffing levels and staffing profiles are appropriate for this stage of the project.

- **Comments**

Overall System (cont.)

- Many controls subsystems have been tested as part of injector commissioning. Many additional systems are using controls based on existing LCLS system. This experience will be beneficial for upcoming commissioning activities.

- Good checkout processes and procedures are being developed.

- The new device checkout tool from JLab should improve ability to gather checkout information for readiness reviews.

- User interfaces and the alarm handler being used for the project rely on legacy software tools (EDM, ALH). It is unfortunate that the project wasn't able to migrate to up-to-date software tools with a longer support lifetime. This will become an operations issue.

- A paper-based Traveler system is in place for tracking installation and checkout. This seems to be meeting basic needs, however there is no central system (e.g. a relational database) to provide system-wide reports. This will require care to ensure there are no gaps or omissions in traveler sign-off through installation, checkout, readiness reviews, and initial commissioning**.**

- **Comments**

Cable Plant

- Changes in the team responsible for cable plant design, production and installation have been made. These changes appear to be a positive improvement towards addressing prior issues.

- Impressive progress has been made in installation of cables, cable trays and control rack installation in sectors 0 to 10.

- Improvements have been made in tracking cable consumption rates by the contractor. This should reduce the risks of delays from availability of government furnished equipment.

- The work to update the drawings and the cable database for sectors 11 to EBD is critical for meeting schedule for the long down time. This will require focused attention during the LDT.

- Lessons learned regarding QA for errors in cable definitions and routing issues are being applied. Maintaining sufficient resources for assuring design quality can help mitigate risks in this area going forward.

- **Comments**

Undulator

- Undulator controls for the SXR appears to be in very good shape. Most of the SXR undulators have already been fully tested. Since the control chassis is part of the device, only power and an Ethernet cable is required at installation. Post installation checks and EPICS support should go smoothly.

- Undulator controls for the HXR are progressing fine but they are not in as good a position as the SXR. They have a fully tested design (also used in LCLS) and the hardware is on hand. Integrated testing with the insertion devices will occur over the next few months. Some delays were caused by a need for better resolution of the vertical gap. A new Renshaw encoder (50nm resolution) has been retrofitted to the devices, however, it doesn’t integrate into the existing VME based motion control system very well. The data is only available in EPICS via Delta Tau power-PMAC board. The power-PMAC is a very capable motion control system, hopefully, this provides an upgrade path to move past the old VME system.

- **Comments**

Cryoplant and Cryo Systems

- SLAC personnel will provide oversight of CP1 and CP2 cable pulls and terminations by the subcontractor. SLAC controls lead have communicated previous termination errors to the subcontractor and they don't believe this will be an issue. Closer oversight of the subcontractor while they are performing this work is strongly encouraged.

- The relationships with the partner laboratories appear to be mature and working well. The experience gained from the LERF collaboration is very beneficial. They did find missing scope with JLab in what is need for full control of the cryo plant.

- SLAC controls have bench tested ODH monitors prior to installing the units in the field. This should help save time when the units are commissioned in the field.

- Several test boxes for testing cryomodule instrumentation have been constructed and are now being used to verify this instrumentation. This has made check out the cryomodule instruments quicker.

- **Comments**

Cryoplant and Cryo Systems (cont.)

- Delay to the IT Room for Cryo systems and development effort for controls software may delay CP1 commissioning. Since CP1 commissioning is on the project critical path, effort should be made to minimize any delay. (See Recommendations.)

- SLAC control leads for the cryo-plant need to complete their change request evaluation so they can determine how the additional scope of work for “integrated” controls will impact cost and schedule.

- SLAC controls leads are still waiting on requirements for operational sequences needed for PLC programming.

- More explicit control systems scheduling links for cryoplant commissioning would be beneficial for upcoming commissioning activities.

- **Comments**

BCS

- The committee is very please to see the progress on the BCS and the successful Final Design Review. The BCS team is to be commended for improvements to simplify the design and reduce the required sensors. Ongoing attention will be required to complete this effort as much work remains. This is a complicated system for a credited control. A number of devices in this system are new to SLAC.

- There are still concerns with meeting spec for the average current monitor sensor for the BCS. Work with the partner labs will be beneficial.

- A number of recommendations came out of BCS FDR. Most can be addressed, however calibration of the sensitivity of the system will be a challenge since there are large uncertainties.

- A supplemental BCR is needed for production and implementation of BCS. It is planned that this will be submitted this month. We encourage this to move forward as soon as possible.

- Currently, the BCS is expected to be partially operational at the end of the LDT to support copper linac operations. However, this is an extremely aggressive time line given that the final design was only recently completed and procurements are still underway. However, this risk can be mitigated (“Plan B”) by reimplementing a modified version of the prior protection system to support initial operations. (See Recommendations.)

- **Recommendations**

1. For scope where changes to future work is needed, prepare BCRs as required and execute BCRs in a timely way, including those already submitted. This includes known increased costs for the cables and racks, scope for “integrated” cryo process controls and cryo IT room, and an updated cost and schedule for the BCS. Update or retire relevant risks for cable plant after applying lessons learned to improve QA processes. Complete by the end of June.

2. Define, by end of June, control system resources needed for successful commissioning of the cryoplant and ensure sufficient resources are available to avoid negative impact to overall project schedule.

3. In parallel with continuing effort for BCS implementation, immediately begin work to also implement “plan B” to resume operations of the copper linac using the prior protection system. Ensure that this parallel effort does not impede progress with the BCS.

3. Infrastructure/Installation

J. Eng, DOE/BHSO, J. Haslam LLNL, D. Leitner LBNL / Subcommittee 9

1. **Project Scope: Is the project prepared to deliver sufficient scope to meet the KPP? (Yes) Will the scope of work as baselined at CD-2, be delivered? (Yes) Are there any proposed scope reductions that put any of the objective KPPs in jeopardy? (No) If yes, which ones?**

2. **Does the project have the technical knowledge, skills and staff to successfully fabricate, assemble, install, test, and commission all of the major technical subsystems on time and on budget? (Qualified Yes, see comments and recommendations) Is the project team performing the proper oversight of the partner labs for the work scope they are undertaking? (N/A) Has the project planned appropriate roles for the partner labs in the installation and commissioning phases? (N/A) Will the necessary procedures exist to successfully operate the new facility after project completion? (N/A) Does the project have a thorough list of the technical risks and mitigation strategies to complete the project? (Yes, see comments)**

3. **Has the project responded appropriately to all recommendations from prior DOE/SC reviews? Yes**

Findings (Conventional Facilities)

The infrastructure scope (WBS 1.05) is divided into seven Level 3 WBS elements.

Within these WBSs, there are six major field work Construction Packages (CP).

Of the six CPs, four have been completed as of to date.

The outstanding construction packages yet to be completed are CP-3B (Photon Infrastructure) and the Near Experimental Hall (NEH).

CP-3B work consist of utilities for the photon system. The NEH is to reconfigure an existing experimental facility. Both of these construction contracts were awarded to the same construction contractor (Gilbane) and Notice to Proceed was issued January 29, 2019.

Comments (Conventional Facilities)

The project team made a good decision not to self-perform and hire a general contractor for CP-3B. This relieves the team from managing detail activities with limited resources.

A good decision was also made to combine the two CP-3B and NEH construction packages for efficiency. However, construction started about a month later than anticipated. NTP issued Jan 29, 2019 and LDT started Dec 20, 2018.

The contractor, Gilbane, and the project team have good relationship from past experience. This give some level of confidence that the work can be completed successfully.

CP-3B, Photon Infrastructure

This package was awarded at $2.12M above the budget of $6.5M. This was a draw-down from the overall project contingency. Current contractor indicated that this work can be completed by end of Aug 2019 with co-occupancy available sooner. However, there is no schedule contingency. The project team recognizes that they need to evaluate opportunities to regain schedule and cost contingency where possible. The Review Committee supports this approach.

The project team needs to control field changes to a minimum.

3. Infrastructure/Installation

J. Eng, DOE/BHSO, J. Haslam LLNL,
D. Leitner LBNL / Subcommittee 9

The Near Experimental Hall (NEH) construction package

Construction started in late January 2019 and scheduled to be complete January 2020. This schedule does not have any schedule contingencies, however it is not the project critical path. The work in the six month look ahead schedule needs to be monitored, progress evaluated timely and corrective actions taken swiftly as needed.

The project may consider additional working hours early in the project as safety and demolition allows to create schedule float that currently does not exits.

Co-occupancy starting Aug 2019 needs to be managed closely. The condition and assumptions of co-occupancy should be communicated and documented to technical teams to avoid surprises and conflict in space claims.

Commissioning agent to support the review of submittals and assist in the transition will be very helpful.

The review committee commends the project team in their effort to enhance communication through their daily tail gate meetings, electronic white board, afternoon wrap-up meetings, weekly progress and coordination meetings. The LCLS-II management team also has good communication with the LCLS team as a result of past lessons learned.

Recommendations (Conventional Facilities)

None

Comments (Global Installation)

We commend the project for recognizing the need for an Installation Coordination Manager. An experienced coordination team is in place and is benefiting the project. The review committee agrees that centralizing this effort is essential.

Substantial change orders have been issued for the first two task orders to the installation contractor of Cables. The base contract was awarded at $7.7M, however there were $2.4M of changes. This was mainly due to delays in providing Government Furnished Equipment (GFE) and poor design documents.

To avoid this in task orders 3 & 4, an experienced project manager has been added to the cable plant effort and the issues are now better understood.

Additional manpower is needed to remain on schedule with the cable installation moving forward. This includes QA/SME and engineering manpower to improve installation readiness and installation drawings. Senior management attention is needed.(see recommendation)

GFE readiness is a common thread and is an installation challenge. Additional attention to the inventory management is needed to reduce this thread moving forward. (see recommendation)

Comments (Global Installation)

The number of Field Construction Managers (FCM) available is limited and may prohibit construction contractor from working OT or weekends. Consider adding FCM to enable flexibility and as backup.

There is 0 days of float in the current LDT schedule. The project is trying to generate 30 calendar days. The committee endorses this goal and encourages the project in this effort with additional resources and/or length of shift where possible and safe.

Strengthen tie-in and add performance milestones for control software in the P6-schedule to ensure readiness of this work package for check-out and commissioning.

A very well thought out cable installation issues log has been developed and is maintained together with the cable pulling contractor. The log is reviewed daily. The review committee is commending this effort.

Access to qualified matrixed staff to complete cable termination on time is critical and needs to be closely monitored by the installation coordination team and advertised at lab wide coordination meetings.

Recommendations (Global Installation)

Assign additional QA/SME resources immediately to field verify the cable plant installation, and reconcile with CAPTAR and cable tray design drawings by mid April, 2019.

Develop a prioritized cable and hardware acquisition list based on lead time to address GFE shortages for the cable installation by Mid-April, 2019.

5. Environment, Safety & Health: Is the management of the ES&H program for the entire LCLS-II project including partner labs being properly executed? **Yes** Is the project adequately prepared to safely receive, install and commission all the hardware at SLAC? **Yes** Has the project adequately planned the phased Accelerator Readiness Reviews to commission the new facility? **Yes** Is the proper work planning and control in place for completing the remaining work and to safely operate the new facility? **Yes**

6. Recommendations: Has the project responded appropriately to all recommendations from prior DOE/SC reviews? **Yes**

Findings

- Project director has identified a, “safe working environment” and, “managing the readiness process” as remaining priorities and notes that, “Safety is a Top Concern”.
- The project has developed all required ESH documentation for this phase in the project. The SAD & ASE will be updated based on upcoming Accelerator Readiness Reviews
- The LCLS-II Project has generated 3.2 million manhours with a DART rate of 0.12; TRC rate of 0.12 (SLAC: DART 0.83; TRC 1.15)
- The Project continues to communicate lessons learned through daily, weekly, and monthly coordination meeting at all levels.
- The project has developed an enhanced technical work planning and control procedure to augment the existing SLAC work planning and control (WPC) process. Tasks are evaluated for inclusion into two categories based on technical risk. Presently the project has identified two Category 1 and nine Category 2 tasks

Findings

- The LCLS-II project has a defined ESH support team including both construction and cryogenic SME support
- Partner lab ESH support organizations are actively engaged with the project through implementation of their own ESH program and QA plans
- Partners labs are completing weekly field observation visits, routine walkthroughs/field observations of production and assembly areas.
- The project has participated in commissioning workshops with partner labs
- The project has developed an Equipment, Instrument, and Accelerator Readiness review process (LCLSII-1.1 PM-0520-R1). Several levels of review are established to provide a graded approach
- The LCLS-II readiness review process incorporates a list of major LCLS-II hardware and systems for review. Major elements of accelerator readiness for commissioning and operations are to be reviewed
- The ODH safety system has been designed and is the responsibility of the SLAC controls group, while the ESH group along with AD are developing the personnel ODH requirements

Comments

- The roles and responsibilities identified within the SLAC work planning and control procedure are well defined within the project
- The Project and their subcontractors are successfully implementing the SLAC work planning and controls procedure including the development of job hazard analysis documentation and daily work planning meetings
- The LCLS-II technical WPC program is being implemented and accepted. Use of the new quality categories addresses past difficulties with installation. The SLAC site would also benefit from this process
- The inclusion of technical risks into WPC helps integrate quality and provides a commendable approach to preventing equipment damage or installation error.
- The project adoption of the three pillars of readiness is a comprehensive approach in the development and implementation of the LCLS-II readiness review process.
- The use of the ARR process in commissioning the LCLS-II injector provided the LCLS-II ARR committee an introduction to the review process and the process was endorsed by the committee

Comments

- SLAC and the Project should be commended for implementation of Human Performance Improvement training for LCLS-II personnel
- The LCLS-II Readiness Review Coordinator is not identified on any project management organizational chart.
- The LCLS-II ESH support organization does not identify matrixed ESH support or SME's within their organizational structure
- The LCLS-II ESH support is integrated into the work planning process and provides assurance that WPC requirements are being implemented in the field
- The enhanced technical work planning and control methods contributes to the success of the integrated safety management process

Comments

- Readiness Review processes are not well socialized with all levels of LCLS-II project management.
- The accelerator readiness review team could be strengthened with the inclusion of an accelerator physicist.
- The readiness review process does not clearly define which review type will be applied to each system or component. There needs to be some definition as to when the ERR, SRR, IRR or ARR review types will apply.

Recommendations

- The LCLS-II Readiness Review Coordinator should be identified within the LCLS-II organizational structure (by May2019)
- The LCLS-II project management team should be educated on the requirements within the Equipment, Instrument, and Accelerator Readiness review process (LCLSII-1.1 PM-0520-R1). (by July 2019)
- The project should clarify how the graded approach to readiness reviews will be applied to individual systems including defining when the ERR, SRR, IRR or ARR will be used. (by July 2019)
- The Project ESH Manager should complete assurance visits to partner labs to validate ESH program compliance (by May 2019)

5. Cost and Schedule

E. McCluskey, FNAL / Subcommittee 11

SC 11 includes Elmie Peoples-Evans (ANL) and Joel Sefcovic (ANL)

2. Technical: Does the project have the technical knowledge, skills and staff to successfully fabricate, assemble, install, test, and commission all of the major technical subsystems on time and on budget? Is the project team performing the proper oversight of the partner labs for the work scope they are undertaking? Has the project planned appropriate roles for the partner labs in the installation and commissioning phases? Will the necessary procedures exist to successfully operate the new facility after project completion? Does the project have a thorough list of the technical risks and mitigation strategies to complete the project? Close, but no. Technical risks are fairly complete with mitigations planned into the project, but several technical areas identified additional risk assessment to assure successful completion.

3. Cost and Schedule: Does the project have adequate cost and schedule contingency to successfully complete the project? Yes, with low probability, see comments. If not, how much additional cost and schedule contingency is the project likely to need? The ETC may be low by roughly $10M over current EAC, cost contingency low by roughly $9M over current cost contingency and 4 months of additional schedule contingency in addition to current 6 months of schedule contingency. Will the scope contingency list and action dates developed by the project provide adequate cost and schedule contingency? The list could be sufficient, but action dates are not specific enough.

6. Recommendations: Has the project responded appropriately to all recommendations from prior DOE/SC reviews? Yes

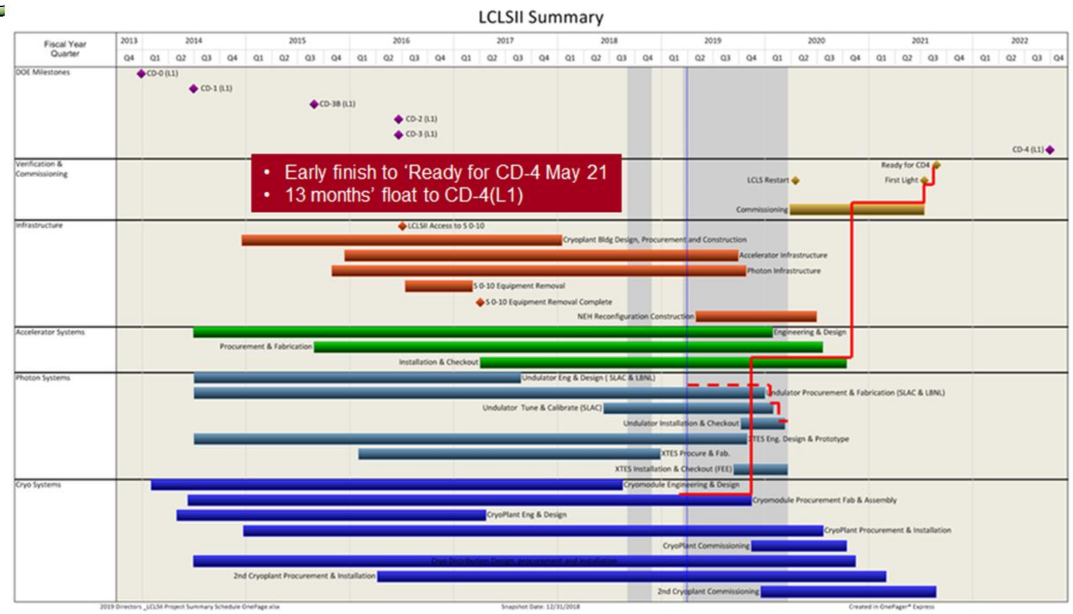
SCHEDULE

Findings

- The project maintains Primavera P6 baseline and forecast schedules, that include activities from all partner labs. The forecast schedule has 38,295 (vs 36,620 at 5/18) activities, with 31,817 (vs. 26,462 at 5/18) activities complete, 940 (vs. 1,299 at 5/18) in progress and 5,538 (vs. 8,859 at 5/18) yet to start as of January 2019 status update.
- The LCLS-II Project received CD-2/3 approval on 3/21/2016, and has been reporting earned-value since that time. The CD-4 milestone early completion baseline date is December 2020, and forecast date is May 2021, providing approximately 13 months of float to the DOE CD-4 milestone date of 6/30/2022.
- Since the May 2018 DOE IPR, the project extended its baseline schedule by approximately two months. The forecast schedule shows completion in May 2021, 5 months beyond the baseline completion of December 2020.
- The critical path to CD-4 is through CM shipping => CM receipt at SLAC => Installation => V&C (this is ‘First Light’) =>Tie-In #2 Cryo plant to Distribution => Cryo plant 2 Operations. Off the critical path only by a few days is a parallel critical path for Cryo plant Installation => Cryo plant commissioning => V&C. This produces a May 2021 Early Finish – including CM rework and shipping solution.

SCHEDULE

Findings



- As of the January 2019 status update, the project is 80.8% complete based on earned value (per EAC) and is reporting an SPI of 0.94, with a schedule variance of -$49.4M. The drivers of the schedule variance include delays to late engineering for beam control systems and XTES development, late procurement of cables and photon systems equipment, and delays in delivery of HXR and SXR hardware. Additional delays in cryo systems were due to late cavity preparation/test and subsequent cryomodule assembly, late procurement of 3.9 GHz components and fabrication as well as shipping issues. Delays to start of cryoplant installation have been due to late delivery of lower 4.5K coldbox.

SCHEDULE

Findings

- The Short Downtime (SDT) occurred in 2018 and completed the planned scope. The FY19 Long Downtime (LDT) started in December 2018 and is planned to be completed in December 2019. The LCLS-II LDT day-to-day schedule is managed in MS Project, and is integrated and statused with the project's P6 schedule monthly and coordinated with the SLAC-managed overall LDT schedule being managed under the SLAC Deputy Director. There is no float on the LCLS-II LDT schedule.

SCHEDULE

Comments

- The project recognizes that schedule contingency at 6.1 months is tight at this stage of the project based on a Monte Carlo analysis on the identified schedule risks. Further assessment of schedule contingency need by the cost/schedule subcommittee showed current estimates & 4 additional months may be needed:
  - Current assessment does not account for any unknown unknowns or uncertainties in schedule durations outside the identified risks. Other means of evaluating sufficiency of schedule contingency and completing the project within the 13 months available schedule float should be considered in order to have more confidence in the contingency need analysis. For example, contingency is assessed at 80% CL, but at this late stage higher CL may be more appropriate. 99% CL for schedule = 9.7 months vs. 6.1 months at 80% CL.
  - Per the January forecast schedule, the project has about 27 months (February 2019 - May 2021) of remaining work to the Level 4 Ready for CD-4 milestone (L4_V&C_M0126). The baseline schedule has this same milestone at December 2020, which indicates a 5 month delay. Using a quick “schedule EAC” calculation of the 27 months of work divided by the SPI (at 0.94) to date reveals the project will likely be delayed 7 months from the baseline and finish in July 2021.

SCHEDULE

Comments

SUGGESTIONS FOR BETTER ASSESSMENT

- The use of progress override versus retained logic makes it difficult to use as a management tool and the ability of outside reviewers to assess feasibility to achieve the schedule presented. The project should consider the following:
  - Checking both options (progress override and retained logic) going forward to see if you've missed something by continuing the progress override method. Tight timeline, ability to check things is important, even if it means adding another resource to get this done.
  - A review of the schedule for the remaining work may be required when the project can provide a forecast that uses the logic links.

SCHEDULE

Comments

SUGGESTIONS FOR BETTER ASSESSMENT

- It might be useful for the project to find a way to simplify the forecast schedule in way that allows it to manage only in-progress and future work as of March 2019 going forward. There are many activities and significant history that makes it challenging to do proper analysis, and it's also easy to miss something because the schedule is overwhelming. Consider finding a way to separate past, present, and future activities in a manner that doesn't violate EVM but focuses on what's remaining, to better utilize the schedule as an informative tool for the project.
- Quick analysis such as the schedule EAC can be very useful and may be required for this project to have a better grasp on when the project is likely to be completed. A more interesting calculation that can be used in the future is to just use the SPI of the CAs that are in progress.

SCHEDULE

Comments

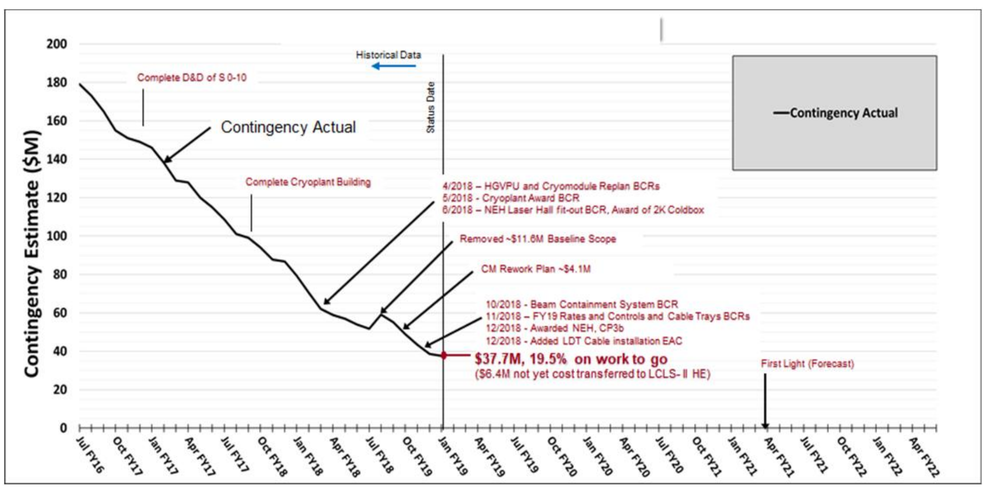
SUGGESTIONS FOR BETTER ASSESSMENT

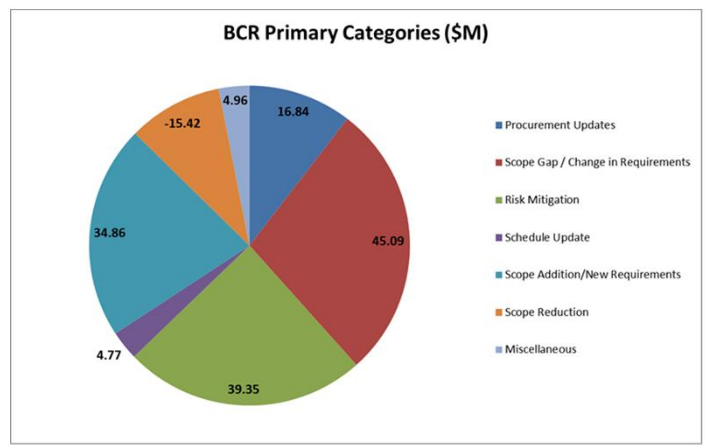
- The project has been using optimistic, aggressive schedules for several years, and projecting the resulting performance on work-to-go is a concern. At the risk of a short delay, it may be worthwhile to review the remaining plan to be sure it's solid before proceeding further. Because of the pace of the work, the project is in a reactive mode which can cause even bigger delays.
- The project is commended for actively maintaining a pending change list that includes projections for completing work within the forecast schedule date. At this review, the ETC spreadsheet showed several control accounts with uncertainty regarding the forecast dates. As each ETC evaluation is done, a schedule duration ETC should also be performed to most accurately project not only the ability to complete within the time remaining, but also the need for additional standing army support.
- Out of sequence activities can mask potential schedule issues. Verify that logic links forward are correct for the out of sequence items.

COST

Findings

- The project TPC is $1,045M and the CPI is 0.98.
- The CV is -$18.1M driven by PM ($4.4M), Accelerator Systems ($3.2M), Cryo Systems ($5.7M) and Infrastructure Systems ($4.1M).
- The project is 83.3% complete based on BAC and 80.8% complete based on EAC.
- January 2019 status EAC is ~$1007M. The $37M of available contingency is 19.5% of EAC work to go and 41.6% BAC work to go.
- The monthly EAC includes pending BCRs and accepted CV only and processed EACs.
- The project used $22.7M of cost contingency since the May 2018 DOE IPR and $129.5M of the $191.1M available contingency at CD-2 in March 2016.





COST

Findings

- The project last did an EAC in June 2018 and said they will continue the annual EAC process through the end of the project as well as complete a monthly EAC assessment. The project showed $11.4M pending changes that they expect to implement into the project RLS. No timeframe for inclusion was presented.
- The project executed $11.6M descopes in late 2018 based on an August 2018 assessment. They are planning $5.6M additional descopes in FY19. There is a future potential descope list of $12.7M that could be implemented if necessary in FY20. None of this descoping threatens the objective KPPs.

COST

Findings

- Executed descoping in late 2018 totaled $11.6M and was for the items shown below. The first item has not yet been transferred to LCLS-II-HE and won't be until it receives CD-3a approval.
  - Excess Niobium Purchased by LCLS-II-HE $5.9M
  - Partner Laboratory Reductions $1.8M
  - Spare Warm Compressors Purchased by Operations $2.5M
  - Spare Parts for Cryoplant purchased by Operations $0.36M
  - Single Cavities Purchased by LCLS-II-HE $0.25M
  - Electrical Power for Cryoplant Commissioning $0.8M
- The remaining BAC based on performance is about $163M, the project is showing an ETC of $175M. The $12M delta includes $11.4M of pending BCRs and $.6M in escalation for work beyond the baseline date.
- The project has areas in the schedule where management LOE is not planned to the end date of the corresponding technical scope in the forecast schedule. Key personnel such as QA and ESH roll off the project at the end of FY20 and early FY21, and the project is forecast to finish in May 2021.

COST

Comments

- The project recognizes that cost contingency is insufficient at this stage of the project based on bottoms up estimate uncertainty a Monte Carlo analysis on the identified risks. It is the cost/schedule subcommittee's estimate that the present ETC is low by possibly as much as $10M due to the following:
  - The review committee collectively assessed that additional labor resources are likely to be required to complete the project, including ~ 8 FTEs for undulator design, injector commissioning, cryoplant controls, and cable QA and design engineering. If estimated at $250k/yr for 2 yrs, this would require up to additional $4M.
  - Accounting for 5 additional months of missing LOE for project management in the forecast plan at $1.2M/month would require additional $6M.

COST

Comments

- In addition to underestimation of budget to go, there is possible underestimation of contingency need of roughly $9M.
  - $11.2M of work to go has no estimate uncertainty contingency assigned. This is out of compliance with SLAC Cost Estimating Procedure. $60.7M of work to go only includes a judgement factor (and not design maturity) to calculate the estimating uncertainty contingency. This results is a possible underestimating of required estimate uncertainty contingency on work to go at roughly $3.6M.
  - As noted in the schedule comments, a higher CL on the schedule contingency would require 4 more months of standing army cost at up to $1.2M/month, for additional $5M.

COST

Comments - SUGGESTIONS FOR BETTER ASSESSMENT

- Reassess the level of support for management through project completion so that it matches the forecast end date of the project, as the current staffing may underestimate the EAC.
- Current risk methodology does not account for any unknown unknowns, which may require additional contingency. Other means of evaluating sufficiency of contingency should be considered in order to have more confidence in the contingency need analysis. For example, contingency is assessed at 80% CL, but at this late stage higher CL may be more appropriate. 99% CL for cost = 27.5M for risks contingency, which would bring total cost contingency need to 27.5+ 23.7M = 50.2M, vs. 37.7M contingency available.
- Applying other EAC formulas presents a range of possible EACs that may be more beneficial to the project. Consider checking EAC using multiple formulas instead of just one, as seen in the table below.

	BCWS	BCWP	ACWP	SPI	CPI	EAC = BAC/SPI	EAC = AC + (BAC - EV)	EAC = AC + [(BAC - EV/(CPI*SPI)]
LCLS-II Performance	**863,470,203**	**814,059,847**	**832,144,928**	0.94	0.98	998,853,462	995,230,370	1,008,972,040
LCLS-II Pending List						11,413,867	11,413,867	11,413,867
Total EAC - Estimated						1,010,267,329	1,006,644,237	1,020,385,907

COST

Comments- SUGGESTIONS FOR BETTER ASSESSMENT

- The project is commended for a developing a detailed descoping list since the last review with some descopes already executed to increase cost contingency. But the strategy and timing for potential execution of future descoping was not clearly presented. Also, the cost contingency available may be overstated because the excess niobium to be purchased by LCLS-II-HE has not yet been executed and is contingent on CD-3a approval for that project.
- None of the executed or future descoping items presented would threaten the objective KPPs. No descoping list for the difference between achieving objective and threshold KPPs was presented at the review. Based on information available at the review, it seems possible that the project could be completed within the available contingency if all future descoping was executed to increase contingency and meet the additional costs listed above. However, the timing of executing descoping may be in conflict with needing the potential descoped items for project success, such as spare cryomodules. In addition, the timing of future descoping may mean that the project would have to be executed with limited contingency for a good portion its remaining two years until much of the scope has been commissioned.
- Properly apply estimate uncertainty factors to all activities to go.

RISK

Findings

- The risk register is updated monthly in a risk board meeting.
- There are 223 Risks in the Risk Registry: 69 Active Risks, 154 Retired/Resolved Risks
- Risks have been consistently retired over time
- The 69 active risks have a Likely Cost of $53.9M.
  - The Expected Value of all risks is $12.3M when Likely cost impact estimates are multiplied by the Likelihood of Impact factor by risk.
  - The Expected Value of all risks is $13.5M when Low/Likely/High cost impact estimates are averaged using the PERT model and multiplied by the Likelihood of Impact factor by risk.
  - The Expected Value of all risks is $14.8M when Low/Likely/High cost impact estimates are averaged and multiplied by the Likelihood of Impact factor by risk.
  - The Expected Value at the 80% confidence level from the Monte Carlo simulation is $18.9M.

RISK

Findings

- 54 risks have a Likelihood of Impact factor of 30% or less.
- The contingency allocation rate exceeds risk retirement.
  - Available contingency ~$37.7M (January 2019 EAC)
  - Uncertainty Contingency ($23.7) + Risk Cost from 80% Monte Carlo ($18.9M) = ~$42.6M
- For all the risks, 54% of cost risk impact is covered in top 10 risks, 70% covered by top 15 risks, and 57% of cost risk impact is from commissioning risks.
- Standing Army costs are including within the risk cost impacts.

RISK

Comments

SUGGESTIONS FOR BETTER ASSESSMENT

- Standing army costs may be modeled incorrectly in the Monte Carlo. Consider creating a more transparent approach that shows standing army costs separate from the impact of cost risks.
- The project uses several different standing army rates for schedule delay risks. It's unclear when reviewing the risk registry which standing army cost is used in each risk basis of estimate. Clarify the intent of standing army rate application for both the project team and for reviewers.
- The project may be overestimating estimate uncertainty contingency by not including this contingency in the Monte Carlo analysis. On the other hand, the duration estimate uncertainty is not included in the analysis, which may be undercounting the length of the project and associated standing army cost. For a more accurate picture of needed contingency, consider adding these elements to the analysis.

Recommendations

1. Perform an analysis using retained logic on the forecast schedule by June 2019 to better understand estimated completion date of the project and schedule contingency available.
2. Minimize out of sequence logic on a monthly basis to ensure the forecasted schedule is accurate. Demonstrate at next DOE IPR that this has been addressed.
3. Solidify dates for executing the future descoping options as well as any milestones for decision-making to be tracked in the RLS by June 2019 in a comprehensive table. Ensure this is presented in the plenary and made available to reviewers at the next DOE IPR. This should include the scope difference between objective and threshold KPPs.
4. Re-evaluate the bottom-up estimate contingency using the definitions within the SLAC Cost Estimating Procedure before the next DOE IPR.
5. Consider re-running the Monte Carlo analysis with cost estimate uncertainty, duration estimate uncertainty, but without standing army costs to provide transparency and assure that schedule and cost contingency remains available. This should be done after addressing out of sequence logic.

5. Cost and Schedule

E. McCluskey, FNAL / Subcommittee 11

PROJECT STATUS as of month end January 2019		
Project Type	MIE / Line Item / Cooperative Agreement	
CD-1 revised	Planned: Mar 2014	Actual: 8/22/14
CD-2	Planned: Mar 2016	Actual: 3/21/16
CD-3b	Planned: Apr 2012	Actual: 5/28/15
CD-3	Planned: Mar 2016	Actual: 3/21/16
CD-4	Planned: Jun 2022	Actual:
TPC Percent Complete	Planned: 88.4%	Actual: 83.3%
TPC Cost to Date	$ 832.1 M	
TPC Committed to Date	$ 66.2 M	
TPC	$ 1,045.0 M	
TEC	$ 949.5 M	
Contingency Cost (w/Mgmt Reserve)	$ 67.9M	__41.6% to go (BAC)
Contingency Schedule on CD-4	____~13_months	__46.4% to go
CPI Cumulative	0.98	
SPI Cumulative	0.94	

4. Management: Does the current management team possess the necessary experience and personnel to successfully complete and deliver the project? Yes, at the management team level. For some systems (controls, cryogenics) integrated plans to accomplish the remaining work were not presented, so it is not possible to answer this question.

   Are the remaining risks well understood and is there adequate contingency (cost and schedule) to mitigate them should they occur? A comprehensive plan for the remaining technical work was not presented in all technical areas, so the articulated risks present a lower bound. For the articulated risks, the cost and schedule contingencies are marginal at best.

   Are there significant risks the project team has not considered? None that were exposed by this review. Other projects have encountered significant, unexpected risks during commissioning.

6. Recommendations: Has the project responded appropriately to all recommendations from prior DOE/SC reviews? The project team has provided responses to previous recommendations. It is unclear if the recommendations achieved the intended benefit to the project team.

Overall Assessment

Our overall assessment is that successful baseline delivery remains possible, and if the project continues on its current path the likelihood of success is diminishing. Therefore, deliberate corrective action is required to succeed:

1. The best people must work to finish this project – this is supposedly the highest priority project for SLAC
2. Get out of reaction mode and anticipate to execute better
3. Avoid unforced, self-inflicted errors

6. Management

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Findings

- The LCLS II project is stated to be the highest priority at SLAC.
- The LCLS II collaboration with partner labs continues to be strong.
- The current early finish for CD-4 date is May, 2021, 13 months prior to the CD-4 milestone of June, 2022.
- The LCLS II Project has received 7 cryomodules that can be used. 32 were scheduled to have been received by this date. Cryomodule delivery is expected at a rate of one cryomodule every two weeks.
- The project team has made some high level staffing changes that appear to be effective.
- The Project team has introduced enhanced work process controls (WPC) to ensure high quality results for self-performed work.
- After the May 2018 review the project descoped $11M to increase cost contingency on work-to-go to 25%. This additional cost contingency generated was expended in 2018.
- Cost contingency on work-to-go is now less than 20%. The project team has generated a proposed additional descope list which identifies $18.2M of potential scope if necessary, which would bring cost contingency on work-to-go to 30%.
- The Project team has revised its approach to the cryoplant startup with SLAC assuming the lead receiving support from JLAB.

6. Management

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Findings (cont'd)

- HGVPU installation, calibration, and integration of the HGVPU must be accelerated to ensure more than 20 can be installed in the long shutdown to support user program.
- CAMs presented 6-month look-aheads
- Plans to accomplish the remaining work were not presented for all systems
- Not all presentations were prepared appropriately to address the charge questions and some presentations were too long for the scheduled time

6. Management

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Comments

- Cryomodule delivery from the partner labs has stabilized
- Remaining technical risks need to be reduced quickly: Accordingly, the construction of the first 3.9 GHz cryomodule should be accelerated.
- The current monthly EAC growth is not consistent with achieving project success.
- The rate at which the project has expended cost contingency through February 2019 exceeds the rate required for a successful delivery of the baseline.
- To successfully deliver the baseline with a reasonable likelihood of success, the project must increase its contingency and demonstrate in the next few months that the monthly growth in EAC can be reduced to a sustainable level (less than $1.5M/month)
- Towards the end of the project, Monte-Carlo contingency analysis has limited utility and managing remaining work against a list of meaningful milestones and cost affords more transparency.
- Given the constrained contingency in the cost and schedule budget, the project must be vigilant and mindful in its execution to avoid self-inflicted errors.

6. Management

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Comments (cont'd)

- The WPC team is focused and energized. The lessons learned from the cryomodule unloading event, and the mentality of moving from a reactionary mode to an anticipatory mode must now be propagated throughout the whole project.
- Assembly and acceptance of all cryoplant parts, subsystems, and ultimately the operation of the system are now a SLAC responsibility. A written plan for acceptance and testing of subsystems, completion, commissioning, and transition to operations are extremely important and will allow creation of a credible schedule.
- The project team should avail itself of every plausible opportunity to rehearse and practice new operations before they must be completed in the tunnel or in the cryoplant.
- Similarly, processes must be exercised. The employment of the full ARR team in the injector commissioning readiness assessment provided an important early opportunity to exercise the ARR process. The project should be on the lookout for similar opportunities elsewhere in the transition to operations.
- Given that the project is 80% complete, it is important to start capturing closeout documentation now. Lessons learned are still fresh enough to be vividly captured. If this work is allowed to pile up to the end, it will be a formidable obstacle to timely formal closure of the project.

Comments (cont'd)

- At the next review, all CAMs must concisely present detailed plans to complete their entire remaining scope within the allotted budget and schedule.
- The coordination between LCLS-II and LCLS-HE appears to be transactional in nature. To benefit the taxpayer and the anticipated science, the two projects must mesh and be considered and managed as elements of one portfolio of the LCLS-II science; the portfolio consisting of LCLS-II, LCLS-II HE and operations.

6. Management

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Recommendations

- Starting now, report the monthly EAC growth to the FPD, BES program, and OPA to assess continued project viability
- Starting now, report meaningful monthly progress milestones and status weekly progress for the near-critical-path items (at a minimum cryomodule delivery and cryoplant commissioning) to the FPD, BES program, and OPA
- Complete the annual EAC assessment prior to the next OPA review to assess the trajectory towards successful project completion.

Advice

- To succeed, work planning and control procedures, in the model of incorporating lessons learned from the cryomodule experience, must permeate the project, and in particular to the cryoplant assembly and acceptance asap.
- Guard schedule with your life. Even if something is not on the critical path, do not let it dally. Do not let schedule drive you to allow non-quality work. You must get to nearly flawless execution.
- *"Do your work as though you had a thousand years to live and as if you were to die tomorrow."*