Report of the Laboratory Director's Review

of the

Proton Power Upgrade Project

Status Review

Conducted Remotely for the

Oak Ridge National Laboratory

Oak Ridge, TN

August 3-5, 2021

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1 Executive Summary

At the request of the ORNL Laboratory Director, a readiness review of the Proton Power Upgrade (PPU) project was held from August 3-5, 2021, to assess the project's status and progress since the CD-2/3 Independent Project Review in July 2020. Due to the COVID-19 pandemic, this review was conducted remotely.

The Director's Review Committee was comprised of 17 independent technical and management experts with extensive experience from similar projects and the technical systems associated with PPU. The review assessed all aspects of the project with specific emphasis on the Charge Questions (see Appendix for the Director's Review Committee and Committee's Charge Questions). In addition, the committee provided several recommendations as a result of this review, some of which should be addressed prior to the upcoming DOE Office of Science Independent Project Review (IPR).

As a summary, the Committee found that:

- The PPU project is being effectively led and managed by an experienced technical and management team which has implemented a robust set of project management systems. ORNL and NSCD management are providing strong support to the PPU Project. Strong support from DOE BES is evident and the Integrated Project Team (IPT) appears to be working well.
- Coordination with JLab as a significant partner for cryomodules is going well; this is a well-developed relationship with excellent communications and a pro-active mindset to stay ahead of potential problems.
- PPU project performance since setting the baseline at CD-2/3 has been good and the project is currently on track to achieve its Key Performance Parameters (KPPs) within the project baseline.
    - PPU is currently about 53% complete as per the May 2021 cost and schedule report (was 25% complete at CD-2/3). SPI and CPI are at 0.96 and 1.00, respectively.
    - CD-3A and CD-3B procurements are proceeding as per the baseline. Some delays have occurred, but to date estimated deliveries support the project early finish date.
    - Cost contingency + management reserve for remaining work (per the EAC) is currently at 52%. Schedule contingency (float) from project early finish to CD-4 (Q4FY28) is currently at 42 months.
- While the Committee found the project proceeding well, PPU management should remain attentive to areas of concern, some of which are:
    - PPU management is starting to see vendor delays and cost increases associated with COVID control measures. The extent of the COVID impact, or when it may end, is not yet fully known, and as further supply chain or critical staffing shortages could occur, PPU should remain vigilant.

- The drafting of a PPU Contingency Management Plan to establish a process to allocate potentially available budget to facility enhancements is commendable. However, PPU management is advised to clearly lay out the priorities for the use of contingency, and to ensure that the process for making decisions on contingency and baseline change management is consistent with the PPU PEP. Fortunately, with ~42 months of schedule float to CD-4, the project is favorably setup to address risks to the PPU baseline first, and still have adequate schedule to include facility enhancement afterwards.
- The PPU scope to fabricate magnets at FNAL for the SNS Ring, while of limited dollar value, could have a serious negative impact on the success of the PPU project due to readiness for the long shutdown. The Committee encourages the PPU team to be proactive on this issue, and consider multiple strategies to ensure this key deliverable stays on track (see Management Comments and Recommendations for more detail).
- The Klystron modification construction package received only two bids and the winning contractor was not experienced at being a general contractor. The Ring-Tunnel-Beam-Tunnel (RTBT) stub procurement needs to be developed, with lessons learned from the Klystron modification procurement, to ensure an adequate number of qualified bids are received.
- The organizational responsibility for QA oversight of PPU construction did not appear to be clearly defined. PPU management should address this as soon as possible (see ESH&Q and Management Comments and Recommendations for more detail).

The committee commends the PPU team on excellent presentations and candid discussions with the Committee. We also thank PPU for the logistics support to the committee which made this remote review proceed smoothly.

2 Project History and Background

The SNS PPU project will design, build, install and test the equipment necessary to double the accelerator power from 1.4 MW to 2.8 MW and to deliver a 2.0 MW qualified target. PPU also includes the provision for a stub-out in the SNS accumulator RTBT to facilitate a rapid connection to a new proton beamline for the Second Target Station (STS). Doubling of the power will be achieved by increasing the proton beam energy by 30% and peak beam current by 50%, relative to the current accelerator performance. The project also includes modifications to some buildings and services. Costs for acceptance testing, integrated testing, and commissioning through the demonstration of the KPPs are included in the PPU scope.

PPU will accomplish the energy upgrade by fabricating and installing new superconducting RF cryomodules, with supporting RF equipment, in the existing linac tunnel and klystron gallery, respectively. The High Voltage Converter Modulators (HVCM) and klystrons for some of the existing installed RF equipment will be upgraded to handle the higher beam current. The target's ability to handle the increased beam power of 2 MW will be enabled by the addition of a new high-volume gas injection system for pressure pulse mitigation in the mercury target and a redesigned mercury target vessel.

The STS Mission Need statement that was approved in October 2008, and the subsequent Critical Decision-0 (CD-0) approved in January 2009, included both the STS facilities as well as the PPU. The approved mission need of the STS and CD-0 has not changed and remains valid including its reliance on a power upgrade. Hence, an independent CD-0 approval for PPU is not required. This decision was approved by the Project Management Executive in an Action Memo signed on April 5, 2017.

The PPU Project received approval of CD-2 and CD-3 in October 2020. The klystron gallery construction is nearly complete, most of the technical components are under fabrication or received, and the project is >50% complete by cost.

The threshold KPPs are the minimum parameters against which the project's performance is measured at completion. The objective KPPs describe the technical goals of the project. The threshold and objective KPPs are presented in Table 1.

Table 1 – Key Performance Parameters

Key Performance Parameter	Thresholds (Performance Deliverable)	Objectives
Beam power on target[1]	1.7 MW at 1.25 GeV	2.0 MW at 1.3 GeV
Beam energy[2]	1.25 GeV	1.3 GeV
Target operational time without failure	1,250 hours at 1.7 MW	1,250 hours at 2.0 MW
Stored beam intensity in ring[3]	$\geq 1.6 \times 10^{14}$ protons at 1.25 GeV	$\geq 2.24 \times 10^{14}$ protons at 1.3 GeV

[1] The single target lifetime threshold requirement will be operation at 1.7 MW at 1.25 GeV and 60 Hz for 1,250

[2] Beam energy will be measured with time-of-flight instrumentation at the end of the linac.

[3] Stored beam intensity will be measured by a current monitor in the ring.

The Total Project Cost (TPC) range was estimated to be $184M – $320M at CD-1. At CD-2, the Total Project Cost (TPC) was set at $271.6M with 40% contingency (plus management reserve) on remaining work.

Early finish of the project is currently forecast at February 2025. There are 42 months of schedule contingency to CD-4 (July 2028). The May 2021 Cost and Schedule Status Report (CSSR) indicates the project is 53% complete (on BAC) and contingency (plus management reserve) is now at 53% on remaining work. See Table 2 for more details

Table 2 – PPU May 2021 Cost and Schedule Status Report ($k)

May 2021 ($k) ITEM	Cumulative to Date						
	BCWS	BCWP	ACWP	BAC	EAC	ETC (BAC)	% Complete (BAC)
P.01 - PPU Project Management	8,832	8,816	8,437	22,169	21,791	13,354	40%
P.02 - SCL Systems	9,241	8,875	8,444	24,082	23,652	15,207	37%
P.03 - RF Systems	19,180	19,596	19,532	43,696	44,098	24,100	45%
P.04 - Ring Systems	9,959	9,206	9,693	20,662	22,382	11,455	45%
P.05 - First Target Station Systems	17,584	16,463	17,031	34,544	35,119	18,081	48%
P.06 - Conventional Facilities	2,758	2,772	2,846	10,900	10,974	8,128	25%
P.07 - R&D	2,267	2,315	2,328	2,476	2,488	161	94%
P.08 - Pre-Ops	87	87	76	1,137	1,127	1,050	8%
P.09 - Pre-CD-1 Activities	7,250	7,250	7,250	7,250	7,250	0	100%
P.10 - Long Lead Procurements	43,007	40,108	39,554	49,785	49,346	9,677	81%
TOTAL	120,165	115,488	115,190	216,701	218,229	101,213	53%
		Mgmt Reserve		5,105	5,105		
		Contingency		49,762	48,233		
		TPC		271,567	271,567		

The DOE Level 1 project milestones are shown in Table 3.

Table 3 - Level 1 DOE Milestones

Level 1 Milestone	Schedule
CD-0, Approve Mission Need	Jan 2009 (A)
CD-1, Approve Alternative Selection and Cost Range	Apr 2018 (A)
CD-3A, Approve Long Lead Procurement	Oct 2018 (A)
CD-3B, Approve Long Lead Procurement	Sep 2019 (A)
CD-2, Approve Performance Baseline	Oct 2020 (A)
CD-3, Approve Start of Construction	Oct 2020 (A)
CD-4, Approve Project Completion (Level 0 Milestone)	Q4 FY2028

The PPU project is being performed by UT-B which manages and operates ORNL for the DOE under the terms and conditions of Contract No. DE-AC05-00OR22725.

3 Subcommittee Reports

3.1 Superconducting Linac

Findings

- As of the May 2021, PPU SCL long lead procurement and construction scope is at 92% and 37% complete, respectively.
- All 30+2 cavities have been delivered to JLab. 18 have been certified for jacketing. 14 have been jacked with helium vessel. CM1 string is assembled.
- All 32 fundamental couplers have been delivered to SNS. 20 have been high power conditioned and 18 have been delivered to JLAB. The remaining will be processed and shipped to JLab by the end of CY2021.
- An 8th cryomodule was added to the scope using contingency in the category of spares for operational improvement as defined in the project execution plan. CM8 has an estimated cost impact of $2.95M + $97K CM test and extension of JLab schedule of 30 days.
- First cryomodule assembly is around 60% complete and is on track to be delivered by February 2022.
- A shipping test was conducted using a dummy cryomodule between Newport News and Richmond. The data collected on inner and outer frames validated the design and analysis. The transverse load is close to the design allowable. A dedicated shipping test was done on the FPC with acceptable results.
- All cryomodule stands were received and installed in tunnel.
- JLab ramped up staff since last review (59 to 72) and 10 additional positions open to support PPU, LCLS-II HE and in-house cryomodule repair and maintenance. Available resources at JLab is not a concern for PPU scope or schedule.
- Cavity test results showed that Q_0 and maximum gradient have comfortable margin against PPU specifications.
- 50% of cavities received from the vendor required reprocessing (HPR) and retesting to be certified for jacketing.
- Early field emission onset of jacked cavities was reported. Process improvements were recently implemented and results will be available in the coming month. A dedicated workshop with JLab and SNS staff has been conducted on this topic.
- Recently, two medium beta cryomodules had to be removed from the tunnel simultaneously. Helium leaks are increasing in frequency due to age of the equipment. This activity reflects potential ongoing risk due to current machine operation.

- There are total 11 risks in SCL systems scope: pre-mitigated ranking: 6 low, 5 medium; post-mitigated ranking:10 low and 1 medium. No high risk items. Two risks have been realized since last review (cavity delivery delay and vacuum vessel and end cap delivery delay) and one risk has been retired.
- JLab PPU team returned to the lab since mid-June 2020 (MEDCON5) to work on cavity test and CM assembly.
- SNS hired a local consultant in Germany to monitor the cavity vendor and to support QA which helped minimize COVID impacts.
- No COVID impacts on final cryomodule delivery schedule reported.
- No safety incidents reported in SCL scope at JLab or at SNS.
- U-tube procurement has not started but is on schedule.
- Cryogenic system parameters and pumping sequence may require optimization for 2K operation. The budget and schedule allow this optimization to occur in 2022 and 2023.
- Plasma processing scope for CMs in tunnel completed.
- Division of responsibilities between JLab and SNS for CM non-conformance resolution is determined on an issue-by-issue basis. However, if a cavity string needs to be removed from a cryomodule, the teams agreed that the CM should be shipped back to JLab for repair.
- CM02 and CM03 string assembly is delayed. CM deliveries are still on track.
- Upgraded beamline vacuum components, including cold-cathode gauges are included between the PPU modules.
- All mechanical interfaces between PPU modules and the up and down stream connections remain the same as other linac CMs.
- New insulating vacuum systems incorporated for PPU modules with high gas handling capacity. The design adopts the strategy used for new systems supporting the DTL and CCL.
- Procurement of vacuum components is advanced by several months due to likely supply chain problems.
- Controls scope consists primarily of sub-system replication of existing operating systems. However, obsolete components like VME crates will be replaced.
- Most controls functions will be validated during CM testing. However, final Cryogenic system controls testing and validation will occur during the CM integration, cooldown, and operation.
- New instrumentation (cernox sensors, etc.) require new controls programming and architecture to be developed.

- Minor schedule impact due to COVID-19 at controls cabinet fabricator occurred. Downstream impacts are minimal.

Comments

- Partnership with JLab on cryomodule production is critical for the success of SCL system and has been smooth. The communication between two teams is effective and helped to resolve the technical issues in a timely fashion as presented.
- There are small modifications to the original shipping fixture used for current SNS modules to accommodate the redesigned end can. Cryomodule shipping test validated the design and reduced risk associated with shipping. Committee commends the effort. The risk will not be retired until the first successful cryomodule shipment.
- No spare cavities are available to support 8 strings in the event one or more cavities fail or are unrepairable.
- Three cavity-coupler integrated RF tests in HTA have been planned. One cavity is ready for HTA test. Test before cryomodule integration helps fully validate cavity performance in as-installed tunnel configuration.
- Overall production process flow is well defined from vendor to JLab to SNS. Cryomodule integrity thermal cycle and check out at 2K in test cave as final qualification of cryomodule at JLab before shipment is a practical and reasonable approach that helps mitigate potential QC issues before the CMs arrive at SNS.
- Supplemental Quality Assurance Plan serves as a bridge between PPU QA program and JLab QA. This created a good understanding of expectation and delivery between partners.
- First cryomodule production is on track. Committee reiterates the importance of testing this module as soon as possible.
- Second cryomodule has 45 days float after bunker test at SNS before installation in the tunnel. Due to the uncertainty of COVID impact, alterative installation scheme such as 1-4-2 shall be carefully evaluated with other stakeholders to fully understand the impact. If schedule allows, CM3 may be used in slot #2 if issues arise with CM1 or CM2. However, schedule delays in CM2 or 3 may eliminate this option.
- Current inventory of return end cans can only support first module production. Incentive programs have been utilized to expedite vendor delivery. Project team shall monitor the progress closely and develop backup plan to mitigate possible impact to production.
- CM8 actual costs may be higher than estimated when vendor quotes are finalized.

- Consider adding SPI and CPI curves to L2M summary slides for upcoming OPA review.
- Advancing procurements where possible is a commendable strategy due to potential and ongoing supply chain problems. Vacuum systems have advanced their procurement starts by several months. Remaining procurements in the SCL system should also consider this strategy.
- Committee commends the active removal of obsolete or soon to be obsolete components from the SCL scope. This strategy was demonstrated for the ion pump controllers and several components within the SCL Controls scope.
- Controls effort may be slowed by lack of drafting support for red line changes as field and fabrication work started. Consider alternative support options if new hires are not available.

Recommendations

- Develop a strategy to have spare cavities available to support the 8th cryomodule integration before next OPA review.

Responses to Assigned Charge Questions

1) Technical: Are the accomplishments to date and planned future activities consistent with the approved baseline plan? ***Yes.*** Are the technical challenges, including the target performance issues, being properly addressed, and is the remaining design progressing per the baseline plan? ***Yes, last design review was completed Jun 2019.*** Are major technical risks and interfaces well understood and being managed to mitigate related impacts? ***Yes.***

2) Procurement: Are the phased procurement plans and associated contracts progressing satisfactorily to support the activities per the approved baseline? ***Yes.*** Subcomponent inventory received supports cryomodule production for the near term. Are the procurements being effectively monitored to ascertain and react to supply chain issues and delays caused by material and labor shortages and the COVID-19 pandemic? ***Yes. However, two major procurements are delayed due to technical issues. Team should manage the vendors closely to mitigate the risk of further delay to impact cryomodule production schedule.***

6) Recommendations: Have the CD-2/3 review and corresponding Director's review recommendations been appropriately addressed, or on schedule for completion? ***Yes.*** Are there any outstanding recommendations from the prior DOE SC reviews and Director's reviews? ***No.***

3.2 First Target Station and R&D

Findings

- Four of the eleven elements within the First Target Systems (FTS) WBS have been completed prior to this review.
- The PPU targets are all in fabrication. Scheduled delivery for Test Target #1 is September 2021 for January 2022 operations.
- A decision was made to eliminate the mercury return line gas-liquid separator.
- Attrition of some key staff, including the Cryogenic Moderator System (CMS) lead engineer, has impacted the design progress of a limited amount of FTS scope.
- One half of the remaining risks for FTS with a rating greater than 1 belong to NScD operations, including the highest post-mitigation risk (2 MW operation of the CMS).

Comments

- The design and planning work done on the 2 MW Target Module is excellent. The design work collected inputs from prior operations, prior design work, and manufacturability experience. As a result, targets are coming in under budget and ahead of schedule. PPU test target #1 has only a few months of float, but it is nearing completion. Other targets currently have more float. Going forward, this direct focus and planning on target manufacturing should continue.
- The target R&D work completed is impressive and has provided an excellent basis for the design and implementation of the target systems modifications.
- Coordination with SNS engineering and operations is excellent. The PPU FTS team is actively incorporating operational challenges and successes into its plans. Nonetheless, a significant portion of project risks are associated with SNS operations performance. Examples are the Cryogenic Moderator Systems (CMS) 2 MW operation & exchange of the target carriage vent line shield block.
- The decision to descope the gas-liquid separator has been carefully considered. It has been reviewed, documented, and appears to be the correct decision for the project and future operations.
- Operation of the PPU test targets will require an Unreviewed Safety Issue Determination (USID). This should be addressed as soon as possible so that any unforeseen mitigating actions can be taken in time to limit delays.
- The required redesign of the molecular sieve beds and the loss of key CMS personnel have eliminated float relative to the installation schedule. These designs should receive full attention. In addition, the installation timelines should be evaluated for alternative options and impacts.

- Consideration should be given to a fallback plan if planned approaches to achieving 2 MW operation of the CMS are not successful. What is the preferred option to achieving 2 MW operation and when does that plan need to be implemented? This is operations scope but should include PPU staff in the planning.
- Consider updating risk T-P.5-024 (additional controls and/or protection system requirements for 2 MW target). The current mitigations listed were planned prior to CD-2. There may be ongoing possible mitigation.

Recommendations

- Complete the swirl bubbler USID for Test Target #1 prior to the FY22A outage to support January 2022 operations

Responses to Assigned Charge Questions

1) Technical: Are the accomplishments to date and planned future activities consistent with the approved baseline plan? ***Yes, current plans support the earlier finish schedule.*** Are the technical challenges, including the target performance issues, being properly addressed, and is the remaining design progressing per the baseline plan? ***Yes, items in MOTS, Utilities and Controls have lost float, but are being addressed by incorporating all available R&D, operational and manufacturing experience.*** Are major technical risks and interfaces well understood and being managed to mitigate related impacts? ***Yes. Remaining target performance risk is simply inherent to new frontiers of high-power target operations. The most significant risk to 1.7/2MW target station operation is CMS performance, which is outside the scope of the project.***
2) Procurement: Are the phased procurement plans and associated contracts progressing satisfactorily to support the activities per the approved baseline? ***Yes.*** Are the procurements being effectively monitored to ascertain and react to supply chain issues and delays caused by material and labor shortages and the COVID-19 pandemic? ***Yes, target module manufacturing is going well and has been under budget. Upcoming procurements are relatively small, and could be impacted by shortages, but adequate float remains at this time.***

6) Recommendations: Have the CD-2/3 review and corresponding Director's review recommendations been appropriately addressed, or on schedule for completion? ***Yes.*** Are there any outstanding recommendations from the prior DOE SC reviews and Director's reviews? ***There are no open recommendations from earlier DOE or Director's reviews.***

3.3 Radio-Frequency Systems

Findings

- On-going COVID-related delays to procurements have moved RF Systems (and many sub-systems) to near critical path.
    - RF transmitter: sub-supplier delays
    - SCL klystrons: only 4 of 12 received, three have failed
    - 3MW DTL klystron: prototype not complete (factory acceptance testing expected this month)
    - LLRF: key vendor delayed due to unavailability of ICs
    - AT-HVCM: component supplier delays
- 40 spare SCL klystrons can be used by the PPU project to meet schedule
- 2.5 MW Klystrons can be used by the PPU project with an impact on current capability.
- Multiple issues have been encountered with the circulators. The vendor has not yet delivered a functional device.
    - An order for 8 (of 28 total) has been placed with an alternative vendor
    - It may be necessary to cancel original order and purchase all 28 from the alternative vendor
- Delay in prototype 3 MW DTL klystron will limit the time to manufacture the 3 production units to 2 years.
- Extensive testing of the new LLRF control unit on SCL23D (with beam) has matured the technology
- LBNL contract for LLRF support has been extended because of Covid travel delays
- Adaptive beam control has not been tested…waiting on the timing system.
- Existing LLRF system can be used for initial Phase 1 testing
- 3 AT-HVCMs are being purchased to power the RF sources for the new cryomodules. Delays in production of SCL-Mod30 put it near critical path for Phase 1 installation
- A retired LANL engineer has been hired as a consultant to assist in the modulator vendor site testing and project oversite.
- Prototype of the upgraded HVCM did not meet requirements, the addition of a series inductor or modification of the transformer will correct this, and both will be investigated.

- Utilities upgrade scope includes new cooling water and electrical distribution for the new RF sources and cooling water system upgrades to the existing NC linac system.
- Installation of the upgraded DTL cooling water system is estimated to require 37 working days of a 41-day downtime.
- Specialized cables are scheduled for delivery in October 2021. They are not needed until March 2022 for installation.
- Supply-chain delays of controls components may impact system availability for Phase 1 installation. This can be mitigated by using units that are currently at SNS for the initial Phase 1 testing.
- Controls has enough uTCA crate processors to cover the first two cryomodule zones for LLRF.

Comments

- PPU presentations were informative and consistent. The PPU RF team works well together.
- Excellent progress has been achieved against the Radio-Frequency Systems since CD-2/3, the fraction of completed scope increased from 21% to 45% with excellent cost and schedule compliance (SPI = 1.02, CPI = 1.00).
- The technical maturity of the RF system is at a high level. Most sub-systems have been prototyped and tested.
- RF/LLRF controls/software going forward needs to have a high priority and access to controls resources.
- Unavailability of "craft labor" has been attributed to schedule delays and is a point of concern for future schedule delays.
- RF system utility installation needs to coordinate with SNS operations if the October installation pushes into run the schedule.
- uTCA timing receivers are critical for successful LLRF operation with beam.
- As the team is doing now, continue to closely monitor vendor performance. Consider regular monthly/bi-monthly visits if the delivery delays continue for the following components; Circulator, Klystrons, LLRF PC boards, Modulators, RF Transmitter (should consider a mitigation if the transmitter misses schedule).

Recommendations

- To perform a near critical path analysis for RF system to identify subsystem components that could put project critical path at risk. Subsystem L3s should track delivery of those critical path components, and identify mitigations for project schedule delays.

Responses to Assigned Charge Questions

1) Technical: Are the accomplishments to date and planned future activities consistent with the approved baseline plan? ***Yes.*** Are the technical challenges, including the target performance issues, being properly addressed, and is the remaining design progressing per the baseline plan? ***Yes.*** Are major technical risks and interfaces well understood and being managed to mitigate related impacts? ***Yes.***

2) Procurement: Are the phased procurement plans and associated contracts progressing satisfactorily to support the activities per the approved baseline? Are the procurements being effectively monitored to ascertain and react to supply chain issues and delays caused by material and labor shortages and the COVID-19 pandemic? ***Conditional Yes. See recommendation.***

6) Recommendations: Have the CD-2/3 review and corresponding Director's review recommendations been appropriately addressed, or on schedule for completion? ***Yes.*** Are there any outstanding recommendations from the prior DOE SC reviews and Director's reviews? ***No.***

3.4 Ring Systems

Findings

- Final designs of ring systems are complete except injection region vacuum chamber and stripper foil changer and beam power limiting system.
- One high risk (injection magnet, schedule), one medium risk (beam power limiting system, schedule) and two low risks (ring vacuum, schedule; removal/installation, schedule) have been identified in the ring systems.
- Injection region magnets contract has been placed with FNAL.
- Injection region vacuum design was delayed; and foil changer scope was reduced (COVID impact).
- FCT for the Beam Power Limiting System was installed and calibration is in progress.
- A Beam Power Limiting System Preliminary Design Review (PDR) was held in Feb 2021.
- The Injection magnet power supply has been upgraded and tested.
- Extraction septum analysis is complete and ready for detail drawing of shims.
- Completed extraction Power supply 30-day test successfully.
- Completed final hardware design of injection dump quadrupole and place contract for fabrication.
- Injection dump window installation delayed to September 22 by operations.

- The Final technical design and implementation for extraction controls (software) is schedule for FY23 Q2.
- Contracts are in place for ring injection dump window, custom telescope and mirrors to be installed in Spring 22.

Comments

- The Committee congratulates all contributors for the very visible progress since the CD-2/3 review in 2020.
- The Committee commends exploring option for administrative control of beam power as a mitigation for a risk in beam power limiting system and encourages to finalize plan (device) to control the beam power.
- The reviewers did not find any technical risks with the design and implementation of any components of the Ring System. A reminder; There are sextupoles for chromaticity adjustment if needed when the beam intensity increases. No issues with the stripping foil due to the increase of the beam intensity.
- No technical issues with the replacement of the injection chicane magnets. The extraction kickers can easily provide the field required for beam extraction at 1.3 GeV . Field maps of the modified Lambertson magnet and the injection chicane magnets have been used to validate the beam optics at extraction, and injection region.
- The magnet design of the Rings System uses a state-of-the-art method for the validation of the required magnetic fields.
- No issues were found with the upgrade of utilities, control system and injection dump imaging system.
- The Injection region magnet delivery schedule has no float, should be monitored very closely (biweekly).
- Finalize injection magnet measurement plan to gain some float in the schedule.
- Most of the cost next year in procurement. Due to COVID, delays are possible in delivery. The committee encourages to monitor delivery schedule closely.
- World-wide computer chip shortage may cause delays in schedule for control and beam power limiting system. The committee encourages to monitor closely.
- Schedule for beam power limiting system is very tight with uncertainty of post FDR activity is a concern.
- Monitor both, current and voltage of the critical-devices(magnets) of the Beam Power Limiting System to avoid "setting-errors" from any electrical shortage of the coil-conductors.

Recommendations

- To closely manage the high risk associated with the delivery of injection region magnets from FNAL, establish communication at the Laboratory level as soon as possible.
- Finalize plans for measurements of injection region magnets and monitoring the progress bi-weekly by OPA review.
- Finalize plan for administrative control of beam power as a mitigation in beam power limiting system by OPA review.

Response to Assigned Charge Questions

1) Technical: Are the accomplishments to date and planned future activities consistent with the approved baseline plan? ***Yes, this does not include any nonpredictable events like COVID.*** Are the technical challenges, including the target performance issues, being properly addressed, and is the remaining design progressing per the baseline plan? ***Yes.*** Are major technical risks and interfaces well understood and being managed to mitigate related impacts? ***Yes.***
2) Procurement: Are the phased procurement plans and associated contracts progressing satisfactorily to support the activities per the approved baseline? ***Yes.*** Are the procurements being effectively monitored to ascertain and react to supply chain issues and delays caused by material and labor shortages and the COVID-19 pandemic? ***Yes, at project level for COVID-19.***
6) Recommendations: Have the CD-2/3 review and corresponding Director's review recommendations been appropriately addressed, or on schedule for completion? ***Yes.*** Are there any outstanding recommendations from the prior DOE SC reviews and Director's reviews? ***No.***

3.5 Conventional Facilities

Findings

- The scope of the conventional facilities included design and construction of the RTBT Stub and modifications at the Klystron Gallery. This scope includes HVAC and DI water controls.
- The design of the RTBT Stub is complete and the construction at the Klystron Gallery is complete.
- RTBT Stub construction is scheduled for the SNS FY 23A outage beginning February 2023.
- Klystron Gallery included complicated overhead piping and a hanger grid system. Building Information Modeling (BIM) was used during design and

construction which resulted in advantages but caused some issues. The AE did not scan the existing site conditions prior to starting the BIM model.

- Only two bids were received on the Klystron Gallery construction package. The awarded Fixed Price Subcontractor (FPSC) did not have experience as a general contractor.
- Klystron Gallery construction achieved zero recordable incidents in 58,300 hours worked.
- Construction during COVID 19 resulted in numerous challenges and some delays due to quarantined workers, remote management and material delivery delays.
- RTBT Stub scope included minimum tunnel length with earth cover and stacked shielding configuration to ensure adequate Proton Beam Shielding during beam operations which allows Second Target Station construction to tie-in with minimal outages.
- Geotechnical and structural analysis show acceptable levels of differential settlement along RTBT Stub.
- RTBT Stub must complete construction and restore shielding to allow beam operations within the 6-month outage schedule.
- Procurement options for RTBT Stub include awarding a stand-alone FPSC contract or using the STS Construction Manager (CM), if available. Award of contract is scheduled for August 2022.

Comments

- The CF team is qualified and experienced and has successfully completed the construction modification of the Klystron Building.
- The effective Klystron modification construction during COVID was commendable. They were able to overcome worker quarantines, remote management and material delays. During construction there were zero recordables over the 58,300 work hours.
- The use of BIM during Klystron modification design and construction had numerous advantages, which should be highlighted in the presentation. Advantages include technical equipment integration, allowing offsite piping spool fabrication, using clash detection for installation planning, etc. The lack of a scan of the existing facility prior to start of the BIM model resulted in field delays as the model was revised. Expectations and alignment of the purpose and scope of using the BIM tool between parties was not adequately established during contract formation. These lessons learned will be used to improve future BIM designs.
- The Klystron modification construction package received only two bids and the winning contractor was not experienced at being a general contractor. A

lesson learned and procurement plan for the RTBT Stub needs to be developed to ensure an adequate number of qualified bids are received.

- Red lines were done but the as built drawings need to be completed.
- Klystron modification HVAC and CF controls had a pervasive issue with non-compliant equipment and components. These non-compliances were not discovered until after installation or during testing. This resulted in rework which required additional project oversight and caused schedule delays. A lesson learned should address this issue so it will not reoccur on the next construction package. Project oversight of contractor quality control process is needed so these issues are found early and corrected.
- Barton Mallow performed a constructability review of the design and developed a construction schedule for the RTBT Stub. This should be included in the presentation. The detailed schedule slides should be moved from the back up to the main presentation.
- When discussing the different approaches to procurement, the presentation should make clear that the PPU FPSC award is the approach included in the baseline.
- A risk should be added to the CF risk register for using the STS CM to manage the RTBT Stub construction. This risk will address the increased costs above the baseline for this alternate approach.
- It is critical for the RTBT Stub construction package to receive an adequate number of qualified bids. The experience from the Klystron Modification contract leads us to believe that this is not likely, if the same procurement process is used. The two proposed RTBT Stub construction procurement approaches are to award a FPSC using a similar process to the Klystron Modification procurement or to use the STS CM to award and manage the contract. The STS CM path appears less likely due to a recent delay in the schedule for the STS CM award. The project should work with procurement and PPU management to develop a plan to ensure award to a qualified contractor that will meet the 6 month outage schedule.

Recommendations

- Develop a plan with procurement and PPU management to ensure the award of the RTBT Stub contract to a qualified contractor that can meet the 6 month outage schedule. The procurement plan needs to be developed as soon as possible after the DOE IPR; the solicitation is scheduled to be issued by May 1, 2022 with award in August 2022.

Responses to Assigned Charge Questions

1) Technical: Are the accomplishments to date and planned future activities consistent with the approved baseline plan? ***Yes.*** Are the technical challenges,

including the target performance issues, being properly addressed, and is the remaining design progressing per the baseline plan? ***Yes.*** Are major technical risks and interfaces well understood and being managed to mitigate related impacts? ***Yes.***

2) Procurement: Are the phased procurement plans and associated contracts progressing satisfactorily to support the activities per the approved baseline? ***Yes.*** Are the procurements being effectively monitored to ascertain and react to supply chain issues and delays caused by material and labor shortages and the COVID-19 pandemic? ***Yes.***

6) Recommendations: Have the CD-2/3 review and corresponding Director's review recommendations been appropriately addressed, or on schedule for completion? ***Yes.*** Are there any outstanding recommendations from the prior DOE SC reviews and Director's reviews? ***No.***

3.6 ESH&Q

Findings

- The ESH&Q function is sufficiently staffed with experienced and motivated people and is well supported by project management.
- The PPU quality program is supported by the JLAB quality program – a crucial supplier of the 8 cryomodules.
- The quality assurance approach focus is on the front end – to identify and reduce risks before they become issues.
    - Design review participation, procurement contractor selection, fabrication oversight.
- The PPU design has been subjected to the rigors of a hazard analysis process where impacts of all changes have been evaluated, analyzed where necessary, and credited controls identified and implemented.
- An unreviewed safety issue evaluation process (USIE) is in use.

Comments

- The PPU project is seamlessly linked in with SNS accelerator processes, and the safety staff is familiar with the facility and hazards for PPU.
- A previously recognized good practice continues – production and use of the Acceptance Criteria List.
- Oversight of subcontractor safe performance has been clearly demonstrated during the recent klystron gallery buildout.

- Oversight of subcontractor quality performance during the klystron gallery construction proved less than fully adequate in assuring good contractor performance.

Recommendations

- SNS PPU QA should maintain closer oversight of construction support of PPU project.

Response to Assigned Charge Questions

1) Technical: Are the accomplishments to date and planned future activities consistent with the approved baseline plan? ***Yes.*** Are the technical challenges, including the target performance issues, being properly addressed, and is the remaining design progressing per the baseline plan? ***Yes.*** Are major technical risks and interfaces well understood and being managed to mitigate related impacts? ***Yes.***

3) ES&H/QA: Are Environment, Safety, and Health and Quality Assurance (ES&H/QA) requirements and plans, including COVID-19 protections and safety measures, being properly implemented? ***Yes.***

6) Recommendations: Have the CD-2/3 review and corresponding Director's review recommendations been appropriately addressed, or on schedule for completion? ***Yes.*** Are there any outstanding recommendations from the prior DOE SC reviews and Director's reviews? ***No.***

3.7 Cost and Schedule

Findings

- Funding
    - The project has received $221.8M through FY21, out of the total $272M. The funding received is greater than the project EAC of $218.2M (excluding contingency).
    - FY22 President's budget $17M, which is $8M lower than the baseline funding profile. The project team indicates that this decrease, if appropriated, should not be an issue.
    - A planned carryover (uncosted/uncommitted) of $47.8M at the end of FY21 will be available for FY22 continuing resolution needs.
- Schedule
    - Since CD-2, the project has implemented a project change to extend project ~3 weeks (from 1/24/2025 to 2/12/2025) to align with the SNS Operations schedule. The current forecast also aligns with the early finish date.

  - Schedule contingency of 41 months, 18 days remain
  - Project has completed 4 PEP L2 milestones since CD-2, each ahead of milestone dates
  - The project tracks Annual DOE milestones as part of the notable outcome performance monitoring.
  - PPU schedule is integrated with SNS operations. Increased coordination is planned with the SNS outage scheduler for the work that will be completed during the outages.
  - PPU does communicate with STS project on key dates. PPU is not impacted by STS schedule.
- Cost
  - TPC remains $271.6M. May 2021 BAC = $216.7M. May 2021 EAC = $218.2M.
  - Since CD-2, the project has implemented $8.097M in project change requests (through May 2021).
  - Contingency (plus Management Reserve) remaining = $53.3M (52% on work to go). Calculated risk exposure = $48.6M (48% on work to go).
- Risk
  - Project risk register is reviewed and updated regularly. Near term and Emerging Risks are discussed monthly in project metrics meeting.
  - Since CD-2/3, 80 threats and 16 opportunities have been retired; 6 threats and 3 opportunities have been realized. 8 new risks identified.
  - 48 active threats (3 high risks pre-mitigation, 1 high risk post-mitigation). Zero opportunities remaining.
  - COVID-19 risk has been treated as a top-down management assessment.
- Performance Reporting:
  - The project has progressed from 25% complete at CD-2/3 to 53% complete in May 2021.
  - May 2021 data shows SPI as 0.96 and CPI as 1.00.
  - Current schedule variances should not impact project early finish.
  - The project is using a certified EVMS. Project last surveyed in December 2019.
- Staffing:
  - The project controls team is fully staffed, and all members were present at CD-2.

- Project change request processed in June 2021 to react to near-term resource availability issue. FY22 is now the peak staffing year, ~7 FTEs higher than FY21, with a ramp down beginning in FY23.

Comments

- The project has a comprehensive set of reports and processes.
- Consider posting the CPR Format 1 at the control account level and VARs for the OPA review. Explore formatting possibilities to indicate closed control accounts.
- Consider adding a status report of PEP L2 milestones to the Monthly Progress Report.
- Enhance the discussion of COVID-19 related project risk for the OPA review. Possibly post the SC COVID-19 Project Impact Worksheet as evidence.
- All schedules provided represented current baseline. Be prepared to discuss forecast schedules at the OPA review.
- For items in the risk register with post-mitigation actions, consider adding these items to the contingency management plan.

Recommendations

- Prior to OPA review, add COVID-19 risk to risk register. Re-evaluate the project exposure to ensure the trending issues are addressed. There is no need to model this risk through the Monte Carlo simulation, as it is a more overarching risk.

Responses to Assigned Charge Questions

4) Cost & Schedule: Are the cost, schedule, and performance metrics being properly collected and reported? ***Yes.*** Are major cost and schedule assumptions, resource constraints, and project risks, as well as COVID-19 uncertainties being adequately addressed? ***Yes, but re-evaluation of COVID-19 exposure is needed.***

6) Recommendations: Have the CD-2/3 review and corresponding Director's review recommendations been appropriately addressed, or on schedule for completion? ***Yes.*** Are there any outstanding recommendations from the prior DOE SC reviews and Director's reviews? ***No.***

3.8 Project Management

Findings

- PPU doubles SNS power from 1.4 to 2.8 MW (30%+ beam energy, 50%+ beam current).

- PPU 53% complete through May and on track to meet early completion date of February 2025.
- 42-month schedule contingency, cost contingency >50% of ETC. CD-4 Q4 FY28.
- $221.8M of the $271.6 TPC has been funded through FY21. Funding profile through FY25.
- Power ramp up schedule in multiple phases from Q2 FY22 to Q4 FY24.
- Threshold KPP of 1250 hours continuous operation at 1.25 GeV & 1.7 MW without target failure.
- $47.8M project funding carried over into FY22 (uncosted, uncommitted) for future budget (PV).
- Key dependencies on project team members: FNAL (e.g., magnets) and JLab (e.g., Cryomodules).
- New FPD and DOE PM since last IPR.
- The project, including JLAB, is fully staffed with no shortfalls identified.
- There was some misunderstanding within the PPU team concerning the organizational responsibility for QA oversight of PPU construction. After the review, during the factual accuracy check process, it was clarified that the PPU QA has this responsibility, not ORNL Facilities and Operations (F&O).

Comments

- PPU project performance since setting the baseline has been good; the project reports that they are on-plan for the early finish (EF) date of February 2025 at 53% complete. Costs have been close to project estimates, including procurements, and Earned Value performance and indices are stable and on target. Contingency balances are healthy with 52% budget contingency remaining on the ETC of approximately $102M and 42 months of schedule float between the EF date and CD-4 in Q4FY28.
- The PPU project is effectively led and managed by an experienced technical and management team within a mature organization with robust project management systems. ORNL and NScD support to the PPU project continues to be excellent. The PPU PMCS staff are very experienced and have implemented mature, proven processes to present and review project performance that are considered best practices.
- ORNL and NSCD management are providing strong support to the PPU Project.
- Coordination with JLab as a significant partner for cryomodules is going well; this is a well-developed relationship with excellent communications and a pro-active mindset to stay ahead of potential problems.

- PPU and JLab have thoroughly identified and actively managed staff resources to stay on the PPU performance plan as they approach the peak staffing year of FY22.
- The PPU scope to fabricate magnets at FNAL for the SNS Ring, while relatively low dollar value, could have a high impact on the success of the PPU project and is currently identified as the top risk rating on PPU. The risk mitigation strategy should consider all possible avenues, including alternate sources. With a number of larger projects with competing resources on-going at a lab (FNAL) that is managed by another DOE program (OHEP), PPU and ORNL should consider establishing effective communications at multiple levels (technical staff, project management, laboratory management, DOE FPD and site offices), a possible PEMP goal and when possible, a consistent on-site presence, to ensure good capability exists to monitor and deliver to the PPU baseline.
- PPU management is starting to see vendor delays and cost increases associated with COVID control measures. This risk will need to be closely managed and mitigated going forward, along with the identified risk associated with construction of the target building stub in the tight local labor market.
- The PPU project has identified available float between the project EF date and CD-4 of 42 months; care must be taken to avoid over-optimism with schedule, however, as the constraints of the outages reduce the effective float.
- PPU has initiated development of a Contingency Management Plan in order to establish a documented process to allocate potentially available budget to facility enhancements consistent with the PPU Mission Need Statement. This is a useful thing to do; however, the plan should be framed within a strategy, agreed among all stakeholders, to ensure that investment opportunities augment science output from the facility without prematurely reducing the ability of PPU management to effectively address risks to delivering the PPU baseline.
- PPU management should seek to understand how the misunderstanding around QA responsibility existed for such an extended period, and take any necessary action to ensure that PPU has a robust QA program for future PPU construction (see recommendation in the QA section of this report).

Recommendations

- In concert with the FPD and BES, PPU should develop and finalize the strategy for contingency management, by the end of the calendar year, to identify and prioritize potential scope and capability enhancements to the SNS Facility to increase the reliability and scientific productivity of both the first and second target stations, while maintaining the ability to address any remaining threats to the existing baseline commitments.

- ORNL and FNAL management should develop additional measures to track progress and maintain priority on the critical task of magnet fabrication and delivery.

Response to Assigned Charge Questions

5) Management: Is the project being properly managed and staffed to successfully deliver the scope and Key Performance Parameters within the baseline cost and schedule? **Yes**. Are the external interfaces, in particular with the SNS operation and maintenance periods, identified and managed? **Yes.** Are the major project risks, including COVID-19, captured in the risk registry and are the mitigation plans reasonable and effective? **Yes.** Is there a contingency management plan for potential scope and capability enhancements? **Yes, but see recommendation.** Is the planning for the transition to operation adequate for this stage of the project? **Yes.**

6) Recommendations: Have the CD-2/3 review and corresponding Director's review recommendations been appropriately addressed, or on schedule for completion? **Yes.** Are there any outstanding recommendations from the prior DOE SC reviews and Director's reviews? **None Outstanding.**

4 Appendix PPU Director's Review Committee

PPU Director's Review of the
Proton Power Upgrade Project at ORNL
August 3-5, 2021

Mark Reichanadter, retired SLAC, Chairperson

SC1 Superconducting Linac	SC2 First Target Station and R&D	SC3 Radio-Frequency Systems	SC4 Ring Systems
* Ting Xu, MSU	* Phil Ferguson, ORNL	* Curt Hovater, TJNAF	* Deepak Raparia, BNL
Allan Rowe, FNAL	Peter Rosenblad, ORNL	Craig Burkhart, PPPL	Nick Tsoupas, BNL

SC5 Conventional Facilities	SC6 ESH&Q	SC7 Cost and Schedule	SC8 Paroject Management
* Jack Stellern, retired ORNL	* Frank Casella, ORNL	* Janet Bivens, ORNL	* Doug Kothe, ORNL
Mark Stidham, ORNL		Tina Sowers, ORNL	Les Price, ORNL
			Carl Strawbridge, Highbridge Assoc.

Observers
Wendy Cain, PPU Federal Project Director, DOE

LEGEND
SC - Subcommittee
* Chairperson

PPU Director's Review Charge Questions

1) Technical: Are the accomplishments to date and planned future activities consistent with the approved baseline plan? Are the technical challenges, including the target performance issues, being properly addressed, and is the remaining design progressing per the baseline plan? Are major technical risks and interfaces well understood and being managed to mitigate related impacts?

2) Procurement: Are the phased procurement plans and associated contracts progressing satisfactorily to support the activities per the approved baseline? Are the procurements being effectively monitored to ascertain and react to supply chain issues and delays caused by material and labor shortages and the COVID-19 pandemic?

3) ES&H/QA: Are Environment, Safety, and Health and Quality Assurance (ES&H/QA) requirements and plans, including COVID-19 protections and safety measures, being properly implemented?

4) Cost & Schedule: Are the cost, schedule, and performance metrics being properly collected and reported? Are major cost and schedule assumptions, resource constraints, and project risks, as well as COVID-19 uncertainties being adequately addressed?

5) Management: Is the project being properly managed and staffed to successfully deliver the scope and Key Performance Parameters within the baseline cost and schedule? Are the external interfaces, in particular with the SNS operation and maintenance periods, identified and managed? Are the major project risks, including COVID-19, captured in the risk registry and are the mitigation plans reasonable and effective? Is there a contingency management plan for potential scope and capability enhancements? Is the planning for the transition to operation adequate for this stage of the project?

6) Recommendations: Have the CD-2/3 review and corresponding Director's review recommendations been appropriately addressed, or on schedule for completion? Are there any outstanding recommendations from the prior DOE SC reviews and Director's reviews?