

Office of Project Assessment

CD-2/3 Review Report on the

**Proton Power Upgrade (PPU) Project**

**at Oak Ridge National Laboratory**

# July 2020

# EXECUTIVE SUMMARY

A Department of Energy/Office of Science (DOE/SC) review of the Proton Power Upgrade (PPU) project, located at Oak Ridge National Laboratory (ORNL), was conducted remotely due to the global COVID-19 pandemic on July 14-17, 2020. The review was conducted by the Office of Project Assessment (OPA) at the request of Linda Horton, Associate Director of the Office of Science for Basic Energy Sciences (BES). Kin Chao, OPA chaired the review.

The purpose of this review was to assess the project’s readiness to request approval of Critical Decision (CD) 2/3, Approve the Performance Baseline and Approve Start of Construction. The CD-2/3 Total Project Cost is $271.6M with a CD-4 date of fourth quarter FY 2028. Overall, the Committee found a strong basis for moving forward with approval of the project baseline and judged that the project is properly positioned to execute the balance of construction.

***Superconducting RF***

PPU managers have experience from the original Spallation Neutron Source (SNS) installation. This reduces the likelihood of loss of institutional knowledge and is important for complex cavity and cryomodule systems.

The SNS vacuum, cryogenics, and controls groups, and the superconducting linac (SCL) team generally appear to have sufficient workforce and expertise to perform the work plan. As with any lean group, the loss of key managers or technical staff could have a significant impact.

New technical staff recently hired at Thomas Jefferson National Accelerator Facility (TJNAF) will require time on site to ramp-up to full productivity. The issue could be compounded by COVID-19 restrictions. So far, the TJNAF team has not been limited by such restrictions.

The SCL cost and schedule are not yet impacted significantly due to COVID-19. This appears to be because both the SNS and PPU vendors have continued hands-on work these past months. Required hands-on work at TJNAF during the shutdown was limited.

Overall, the SCL systems are progressing well with respect to the Primavera (P6) project plan. SCL controls work appears to be progressing well. The approach is to replicate existing cryomodule controls and adjust, where necessary, for obsolescence. Cryogenics work is a moderately sized effort (cost ~$1M) and appears to be progressing well. Technical review of the system has been performed as part of major DOE reviews. Utilities work includes vacuum and water systems. This work is largely a replication of existing systems and progress to date is good.

The TJNAF/SNS/PPU team have robust tools in place for tracking vendor hardware. Much of the hardware needed to perform work is in hand, but key pieces are still with industrial partners. Therefore, the project team should be willing to change or supplement vendors if necessary. This does not likely apply for cavities, vacuum vessels, or other major components, but could be a wise course for smaller components.

Small changes to the cavities and couplers are well thought out. Overall, the SCL system is technically conservative. This adds confidence that systems will perform as planned.

There are planned repairs to three existing SNS cryomodules. These may be time consuming for technical staff but would not appear to have major impact for installation or performance.

The technical choice not to perform cavity chemistry after jacketing is not the normal practice for SRF cavities. The ongoing work at TJNAF to test, jacket, and re-test three existing cavities from the original SNS is needed to vet the plan for chemistry. If it is found that chemistry is desired after jacketing, this would impact cost and schedule. Even though the team has four spare cavities planned, it would be prudent to consider a course of action in case chemistry after jacketing is needed.

Much information was shared about the status of cavities, helium vessels, and couplers, but other major components are also critical to cryomodule fabrication. These include vacuum vessels, thermal shields, space frames, and tuners. Some of these require close interaction with their respective vendors, particularly if vendors are new. Oversight is more difficult with restricted travel and the project needs to continue with diligence to ensure the status of procured items is understood and that these remain on schedule to the extent possible.

***Target***

The Committee was impressed with the amount of progress and number of tasks performed since the CD-3b review in the various technical subprojects of the First Target Station (FTS). The design for each subsystem of the FTS is matured at the appropriate level: 2MW target and the delay beds, shielding and crane of the Mercury Off-gas Treatment System (MOTS) are ready to proceed to CD-3. The Mercury Process Systems, Moderator Cryogenic Systems, Target Utility Systems, remaining parts of the MOTS, and the safety-control systems are ready to proceed to CD-2 and are well advanced at that stage.

Work is supported by a strong, well-balanced team including experienced personal and young staff. New hiring in the Target Utility Systems from industry is beneficial for the project.

Recent results with operation target on strain measurement with gas injection increase the confidence in the ability of the project to operate PPU target at 2 MW for at least 1,250 hours.

Having routine strain measurements on the operating target vs. the gas flow and the beam power (equivalent beam power) confirmed the efficiency of gas injection for fatigue stress mitigation. The Committee encouraged continuation of this good practice when higher gas rate and higher beam power are available.

The team continues systematic Post Irradiation Examination (PIE) on spent targets to characterize damage and determine leak causes. Again, the Committee encouraged continuing this good practice to evaluate the effect of gas injection or design modification on fatigue and cavitation mitigation.

The target implementation strategy includes two “test” targets that will be placed into operation, demonstrating target features and potentially higher beam power. The fabrication of test target 2 will have the same design as the production targets. It will be a good preparation for the fabrication of the production target, and it will increase the likelihood of project success.

Numerous design reviews have been completed and resulted in significant feedback, advancing the designs. This practice should be continued through construction readiness and operations.

Target welding quality assurance/quality control (QA/QC) is a critical aspect of the 2 MW operation in view of maximizing reliability. Design reviews and discussions with vendors should be continued with the aim of maximizing the QA in their production. Multiple sourcing of targets should be sought to avoid relying on single source expertise. An analysis on whether in-sourcing of some of the components may be cost, as well as schedule, effective is encouraged.

R&D efforts within (and outside) the PPU project have made substantial contributions to support design and operation improvement. The remaining project R&D tasks should be completed in the next four months. Continuing R&D beyond CD-3 and scheduled project development is strongly encouraged as it will be beneficial for target operation lifetime.

Most of the upgrade and installation will be performed remotely. The Committee supported the new activity to build a mock-up of the Hg Pump Overflow Tank (OFT), and of the Gas Liquid Separator (GLS) for remote installation test. The Committee encouraged the team to complete the final design and procure the mock-up as soon as possible to implement any changes if needed in the final design of the OFT and the GLS.

Extensive R&D led to a GLS that is well developed and mature. Experimental results show a separation ratio close to 90%, which is already above PPU requirements.

In-situ diagnostics, with Raman spectroscopy for confirmation of H2, state that by using direct laser viewing through dual sapphire windows will provide higher sensitivity than current diagnostics. The integrity test was delayed and started in June. This test needs to be complete as soon as possible (before end of July 2020) to validate the final design (the Final Design Review (FDR) scheduled in August 2020).

The Committee endorsed the addition of two trains of two beds to increase reliability and to provide capability to regenerate while MOTS is in operation.

The thermomechanical evaluation of the working conditions of permanent components (vessel, shielding, inner reflector etc.) shows an acceptable level of temperatures and stresses. The components have been validated according to American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Certification (BPVC) criteria, and areas with high radiation level are limited in volume. Based on that, the safety margins are acceptable for reliable operation of the components for PPU conditions. The Committee supported the lifetime extension of the facility to 60 years and endorsed the increase of the administrative dose limit to 20 DPA (displacements per atom) for the Outer Reflector Plug (ORP) shell structure.

It is assumed that the Aluminum Proton Beam Window (PBW) will be maintained. Contingency plans should be envisaged in case finally a decision (by operations) is taken to use an Inconel PBW.

Involvement of safety experts and controls experts in each design review is a good practice and should continue during procurement, installation, and test/commissioning of the upgraded systems.

The Committee commended the analysis done on the target safety systems and encourages the implementation of the evolutionary upgrades foreseen to mitigate the mercury spill events.

The Off-Normal Analysis review for Target Utility System is delayed due to COVID-19 and may impact the FDR and procurement. If the in-person meeting could not take place by autumn, it was suggested to conduct it remotely to avoid potential delays in the target procurement.

The COVID-19 impact has been limited on the FTS. Nevertheless, the 2 MW target is on the critical path and careful follow-up is needed to investigate potential delays with vendors, due to backlog or procurement challenges.

***Radio Frequency (RF)***

The RF systems team is experienced, skilled, and qualified with many years of design and operation experience. The project team made great strides since CD-3a and CD-3b. The technical presentations were detailed and highly informative. The RF systems technical design is mature and likely to meet the project baseline performance. Overall, the level of RF systems documentation is sufficient to support the baseline design.

RF systems design is about 90% complete. FDRs of RF quadrupole (RFQ)-DTL High Voltage Converter Modulators (HVCM) and low-level RF (LLRF) are planned for Summer/Fall 2020.

The project team was encouraged to perform timely on-site acceptance tests of the RF components as they arrive from vendors. Procurement of new 3 MW klystrons needs continuing vendor follow-up to prevent further delivery delays.

The project team successfully tested the new LLRF system on SCL cavity 23D. A full control test of LLRF system on SCL-23D is planned for summer 2020. The Committee supported completing the LLRF system “full control” test (field control) on SCL cavity 23D before holding the FDR of the LLRF.

Managing LLRF collaboration with LBNL and the vendor could be particularly challenging. The project team needs to exercise due diligence to stay the course.

The Committee supported the project team’s choice of a µTCA.4 platform for the LLRF system; leveraging μTCA commercial hardware is sound.

Controls are based on existing designs that have been demonstrated and present minimal risks.

Based on the simulated operation of the normal conducting linac circulator and load at normal and off-normal reflected power conditions, there is no need to upgrade circulator or load for PPU—the Committee concurred with this conclusion.

The RF team should complete the final design reviews of the LLRF, high-power RF (HPRF) transmitter (with the vendor) and RFQ/DTL HVCM by end of first quarter FY 2021.

The RF team should continue to stay vigilant and proactive on QA of RF components delivered by the vendors to identify noncompliance issues early on for timely corrective actions.

The project team should continue to review documentations as the project progresses and update as needed specially the integrated control documents (ICDs), installation, test, and commissioning plans.

All recommendations from past reviews have been addressed and closed.

COVID-19 has not yet had a significant impact on RF systems that would require changes to the project milestones. The project team is doing regular follow-ups with the vendors to measure the impact on hardware delivery schedule. However, a notable impact is the delay in 3MW klystron delivery, which moves it to “near” critical path. RF systems has some schedule float available if needed.

The procurements of all RF components should be closely monitored with regular follow-up and communication with vendors, particularly given the COVID-19 pandemic uncertainty.

RF systems staffing has not changed since the June 2019 DOE/SC review. The project believes that it has the required engineering and technician staff to adequately support PPU. COVID-19 mitigation plans for on-site work will impose new restrictions that may require staffing adjustment. The project team should reevaluate RF systems staffing level as the situation evolves.

***Ring-Accelerator***

The final design is well-defined and technically sound (CD-2/3 ready); some outstanding scope will have its final design review (FDR) in September 2020. One outstanding system, the Beam Power Limiting System (BPLS) will have its Preliminary Design Review (PD) in February 2021 and its FDR in August 2021. The BPLS system is on a near-critical path but it is well-defined in scope and there are mitigation plans in place in case there is a schedule delay.

The Committee noticed big improvements in defining the performance specifications for several systems (e.g., BPLS and the beam dump). Also noted is the successful 1.7 MW equivalent demonstration of beam, stored in the ring (1.83e14 protons at extraction, higher than the threshold Key Performance Parameters (KPP)).

The project team has made excellent progress since the June 2019 review. The project team considered the comments from the June 2019 review and changed some technical specifications and designs.

The successful 1.7 MW equivalent beam power test is a significant step towards the PPU performance goal.

The beam dump has a power limit 150 kW and has been established conservatively with the help of models and the experimentally verified temperature evolution of the concrete under load. It appears that the thermal time constant of the beam dump concrete is hundreds of days, which should allow for some operational flexibility to exceed the rated power for short periods of time. The project team should evaluate and document such a relaxed flexibility.

The BPLS, while well-defined in its requirements, will be challenging to implement in the time scale foreseen. Issues that may take additional effort are noise on the Fast Current Transformer (FCT) data, difficulty in maintaining calibration of the FCT under changing beam properties, programming effort for the field programmable gate arrays (FPGAs), and the general overhead incurred when building credited safety systems. Presently the BPLS is not rated as high risk despite being near the critical path. The Committee supported an early installation (now) of a test FCT to start recording and processing signals.

The upgrade of the kicker pulsers is an efficient scheme and avoids reconfiguration in the extraction area. The added stress on the kickers is quite marginal and should pose no issues for reliability.

An impressive amount of high-quality data for the Ring Injection Dump power-handling capability was shown, and the imaging system to be installed appears well thought out and analyzed, and it will be a valuable diagnostic.

The upgraded deionized water system that lower the temperatures in the ring systems should not change the temperature of the RF cavities in the ring.

It may be prudent to anticipate sporadic leaks when the water temperature is lowered (because of different thermal expansions).

***Conventional Facilities (CF)***

The CF team is well established and fully functional and project scope as outlined in the final design report will meet the approved Mission Need.

The utilization of Building Information Modeling (BIM) for the klystron gallery buildout is a best practice and the project has already experienced added value from BIM. Although the CF team did not have much BIM experience and has realized challenges implementing BIM practices, the project team recently added a BIM coordinator, which has helped to finalize the BIM model. The project team is also actively tracking BIM lessons learned that will benefit the Second Target Station (STS) project and other projects at ORNL that will utilize BIM.

The CD-3b scope for the klystron gallery building modification is currently behind schedule with a Schedule Performance Index (SPI) of 0.75. This schedule delay is due to inclement weather, but also contractor performance. The CF team is working with laboratory procurement to obtain a corrective action plan from the contractor to get back on schedule. If the klystron gallery building modifications scope is further delayed, then this may cause construction to coincide with the technical installation in the same area. This will make the technical installation more challenging but still achievable with minimal schedule risk

The CF team updated the Ring to Target Beam Transport (RTBT) stub cost estimate to reflect the realization of high bids on the CD-3b procurement. While a great step to mitigate the risk of high bids, there is opportunity to improve the confidence level of the CF budget with an independent cost estimate. To mitigate the schedule risk of the RTBT stub construction, the CF team should work with the contractor prior to award to ensure a credible working schedule.

Since the outage construction of the RTBT stub scope is near critical path, the project team is working to maximize the amount of work that can be completed before the outage.

The STS project may seek CD-3a approval for site work that could coincide with the RTBT stub construction and would create logistical challenges.

The RTBT stub procurement approach includes utilizing the STS construction manager with a fallback option to competitively bid the scope. The plan is sound but there is still significant risk due to the unknowns surrounding the STS construction manager, as well as the volatility of the contractor market.

The CF team is actively managing the schedule risk for the RTBT stub outage construction; however, no such risk exists in the project risk register.

Past review recommendations have been appropriately addressed.

***Environment, Safety, and Health***

Integrated Safety Management is well established in the project and is being flowed down to lower, tiered subcontractors through the ORNL Chestnut Ridge Project Safety and Health Plan.

ESH&Q personnel are well integrated into the project and providing support for project document reviews and field inspections.

Construction oversight and safety is well-managed, and a safety services representative provides 40% time for construction oversight and safety review.

ORNL has implemented robust, COVID-19 precautions and safety measures through response plans, density monitoring, training, and testing which have been flowed-down to lower, tiered subcontractors and is commendable.

A COVID-19 Subcontractor Hazard Analysis is required to address precautions and safety measures for onsite construction work, which is a best practice.

A Hazard Analysis Report or an unreviewed safety issue (USI) should incorporate and address hazards associated with the connection of the RTBT to the main SNS.

The Committee suggested re-evaluating the Oxygen Deficiency Hazard calculations with the increased helium usage.

The QA program has improved and is in place. QA coordination with partner laboratories is very well structured.

The project team should ensure that the statement of work review includes completion of the Quality Assurance Grading checklist and development of acceptance criteria.

The RTBT design review should include project QA and ESH organization to review the CF construction for the RTBT stub to be sure requirements are incorporated.

Procedures and an engineered containment have been incorporated into the design to mitigate the sources of the March 2020 Occurrence Reporting and Processing System (ORPS) mercury release.

Project plans include revisions of the Facility Safety Document (FSAD-PF) and Accelerator Safety Envelope (ASE) to support crediting the BPLS after the first cryomodule outage and Radiation Safety can implement a hold process till the BPLS is ready.

Increased proton energy and intensity for the project will potentially increase residual radiation levels in the ring injection area, which would require additional evaluations and mitigations of radiation hazards.

***Cost and Schedule***

The project team has demonstrated good project cost and schedule performance in executing CD-3a/CD-3b scope.

Final design is estimated at 92% complete. Remaining design effort is rated as low risk. A total of 81% of the fabrication/procurement estimates are based on vendor input creating a strong basis of estimate.

Risks appear to be understood and the project team is using best practices and utilizing industry leading outside expertise to help advance risk management planning. Another best practice would be to have risks independently reviewed.

Possible impacts of COVID-19 should continue to be analyzed. Despite this being an evolving issue, mitigations need to be developed for the various scenarios at various vendors and institutions and near-term risks (6-9 months) added to the register.

Continued attention to the potential impacts the project could have on related projects, especially around the RTBT stub, will be required as the project moves along. It is not anticipated that the RTBT stub work schedule would impact other projects at this time.

***Project Management***

The Project Management team is functioning well and was well prepared for this review.

The new Director of Projects, reporting to the Laboratory Director, should serve the PPU project well in addressing resource needs and sharing lessons learned from other laboratory projects.

The partner laboratory, TJNAF, has benefitted from lessons learned in CM production for other projects. Overall, PPU would also benefit from increased communication between project managers of other large DOE/SC accelerator projects.

Matrixing seems to be working well, especially since SNS operations has recently shown high reliability. It is understood that user operation has priority, and the project needs to be well positioned to argue for appropriate resources to meet the cost and schedule.

The project team should ensure effective communications with other activities, both large and small, throughout the SNS.

The cost and schedule contingency is appropriate.

The project responded well to previous recommendation to better develop the risk-based contingency.

The project has a top-down assessment of COVID-19 impacts, and should start a bottom-up assessment of impacts to cost and forecast schedules.

The project is encouraged to continue flushing out scope contingency, both removal and buy-back. Scope buy-back discussions with STS could be pursued.

The change management process seems sound—the project should continue to communicate technical changes to all stakeholders.

The project needs to consider the need for and risk to the duration associated with safety system certification and/or revalidation at the end of each of the planned outages and plan accordingly.

Key stakeholders need to be aware of the need to communicate emergent issues with meeting outage schedules at least six months in advance. Valuable lessons learned were made available from the recent LCLS-II long down time.

The three-phased approach to commissioning and operations is reasonable, and makes appropriate use of external reviews.

The remaining designs are low risk.

Management of vendors should be tightened across the project, since visits to remote sites, both domestic and international, are restricted due to the COVID-19.

***Key Recommendations***

* Tabulate PPU SCL RF power requirements by the next DOE/SC review. The table should include the following operating parameters supporting 1.3 GeV beam energy and 38 mA macro-pulse average beam current: 1) klystrons operating voltage and beam current;

2) nominal and maximum klystron output power; 3) RF power transmission losses;

4) accelerating gradient; 5) cavities loaded-Q; 6) Lorentz detuning; 7) microphonics detuning; 8) RF source power overhead; and 9) cavities control power margin.

* By the next DOE/SC review, evaluate adding a risk registry entry for the BPLS.
* Prior to CD-2/3, complete a thorough risk analysis of the RTBT stub procurement, construction logistics, cost, and schedule to identify risks not currently in the project risk register, and update the risk register accordingly
* Present evaluations and mitigations of radiation hazards from the increase in proton energy and intensity at the next DOE/SC review.
* Change wording in RTBT design review from “Project QA and ESH organization should to shall review the Conventional Facilities construction documents for RTBT stub” to ensure requirements are followed.
* Supplement the PPU COVID-19 vendor impacts list with the following information: PPU point-of-contact (both procurement and technical); planned frequency of vendor contact; date of last vendor contact; and method of last vendor contact. This revised PPU COVID-19 vendor impacts list shall be appropriately communicated to DOE starting next month and continue monthly.
* Proceed to CD-2/3.

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**1. INTRODUCTION**

The Proton Power Upgrade (PPU) is a U.S. Department of Energy (DOE) project at Oak Ridge National Laboratory (ORNL) to upgrade the Spallation Neutron Source (SNS) to maintain leadership among domestic and international neutron scattering facilities. SNS currently serves over 850 unique users annually from national laboratories, domestic and international universities, and industry. SNS provides the most intense pulsed neutron beams in the world for scientific and industrial research and development.

Neutrons for materials research can be generated by two different types of facilities. One utilizes a fission research reactor such as the High Flux Isotope Reactor (HFIR), and the other (SNS) utilizes an accelerator to produce high energy protons that in turn strike a heavy metal (liquid mercury) target producing neutrons by a spallation process. Both neutron scattering facilities in the Office of Basic Energy Sciences (BES) portfolio, HFIR and SNS, are sited at ORNL and address one of the DOE’s key research areas—the use of neutrons and sophisticated instrumentation to probe materials.

The SNS was completed and approved for operations on June 5, 2006. It was designed and constructed to accommodate future upgrades. The SNS Second Target Station (STS) Mission Need Statement (MNS), approved in October 2008, described the “need to upgrade the SNS to provide higher beam power and a second target station.” The PPU project will double the proton accelerator power from 1.4 MW to 2.8 MW, providing an increase in proton power to 2 MW at the existing First Target Station (FTS), as well as providing sufficient proton power for the future STS.

PPU project will design, build, install, and test the equipment necessary to double the accelerator power from 1.4 MW to 2.8 MW, upgrade the existing SNS target system to accommodate beam power up to 2 MW, and deliver a 2 MW qualified target. PPU also includes the provision for a stub-out in the SNS transport line to the FTS to facilitate rapid connection to a new proton beamline for STS. The project also includes modifications to some buildings and services.

PPU will accomplish the energy upgrade by fabricating and installing seven new superconducting radio frequency (RF) cryomodules with supporting RF equipment in the existing linac tunnel and klystron gallery. The high-voltage convertor modulators and klystrons for some of the existing RF equipment will be upgraded to handle the higher beam current. The pulse accumulator ring will be upgraded with minor modifications to the injection and extraction areas. The FTS mercury target has been upgraded with a new high volume helium gas injection system for pressure pulse mitigation in the mercury target. A redesigned mercury target vessel and other design and operational improvements will enable robust operation of the FTS at the threshold power of 1.7 MW and the eventual objective power of 2 MW. The FTS operating at 2.0 MW and 60 Hz will receive 33 kJ of energy per pulse. Additional upgrades will be needed for the future STS project to operate the FTS reliably at 2 MW and 45 Hz, when it receives 44 kJ per pulse, which is an increase of 33 percent.

On April 5, 2017, Dr. J. Stephen Binkley, Acting Director, Office of Science and the Project Management Executive, approved the path to Critical Decision-1 (CD-1), *Approve Alternative Selection and Cost Range*, for PPU, which is based on the 2008 STS MNS and CD-0, *Approve Mission Need*, determining that a separate CD-0 for PPU was not necessary. CD-1 was approved on April 4, 2018 by Dr. J. Stephen Binkley. CD-3a, *Approve Long Lead Procurements (LLPs)*, for $10.505M of procurements was also approved by Dr. Binkley on October 5, 2018. CD-3b for an additional $53.43M of LLPs was approved by Dr. Chris Fall on September 3, 2019. The preliminary Total Project Cost (TPC) established for CD-2/3 is $271,567,178 which includes 40% contingency on work to go. The proposed CD-4, Approve Project Completion, date is July 2028, which includes 42 months of schedule contingency.

Approval of the PPU does not obligate DOE to complete the SNS STS project, and progress toward CD-1 for the STS will depend on the amount and timing of additional funding. The existing SNS FTS will realize the benefits of increased power and improved operational flexibility and reliability achieved through the PPU. The PPU also takes advantage of ongoing work to improve the operational reliability of current targets that are funded through the SNS operations budget.

***Charge to the DOE Review Committee***

In a June 2, 2020 memorandum (see Appendix A), Dr. Linda Horton, Associate Director of Science for BES, requested that Kurt Fisher, Acting Director, Office of Project Assessment (OPA), organize and conduct an independent project review (IPR) on July 14-17, 2020 by videoconference. The purposes of the review are to assess the project’s readiness to request approval of Critical Decision-2 (CD-2), “*Approve Performance Baseline”*, and CD-3, “*Approve Start of Construction*” and to assess the project’s status and progress. The Office of Project Management (PM) will conduct an independent cost review in conjunction with the IPR.

***Membership of the Committee***

OPA assembled a Review Committee composed of members (see Appendix B) selected based on their independence from the project, as well as for their technical and management expertise, and experience with building large and complex scientific research facilities. The Committee was organized into eight subcommittees, each assigned to evaluate a particular aspect of the project corresponding to the subcommittee members’ areas of expertise. The eight subcommittees are superconducting RF cryomodules, target systems, RF power systems, ring-accelerator systems, conventional facilities, environment, safety and health, cost and schedule, and project management. Observers from the Office of Science (SC) and the Oak Ridge Site Office (OSO) also attended.

***The Review Process***

The review was conducted over 3 ½ days using Microsoft TEAMS videoconferencing software on July 14-17, 2020. Representatives from the PPU Project Team, OSO, and OPA jointly developed the meeting agenda (see Appendix C) with BES concurrence. The PPU project personnel provided information to the Committee in advance of the review and committee members submitted questions and received responses prior to the review.

The first day of the review began with an executive session in which Ethan Merrill, the OPA Chair running the review, covered the logistics and schedule for the review. Then Ed Stevens, the BES Scientific User Facilities Division (SUFD) PPU Program Manager read the charge letter, and James Barnard, the Federal Project Director discussed the project’s progress in preparing for the combined CD-2/3. The review on the first day started at 9:00 am Eastern Time (6:00 am Pacific Time and 3:00 pm Central European Time) and ended approximately at 3:00 pm Eastern Time. The open sessions of the review began with a welcome by Dr. Thomas Zacharia, ORNL Laboratory Director; the Jefferson Lab perspective by Stuart Henderson, the TJNAF Director, and Dr. Paul Langan, ORNL Associate Laboratory Director for Neutron Sciences. The plenary session of the review included presentations by Dr. John Galambos, PPU Project Director; Mr. Mark Champion, PPU Project Manager; Mr. Wayne Steffey, PPU Project Controls Lead and key scientific, engineering, and technical members of the project team to cover all aspects of the project (see Appendix C). Due to COVID-19 pandemic safety protocols and the fact that the review was conducted by videoconference, there were no tours of the SNS accelerator, target, or conventional facilities, as was done in the past, but the project posted video tours on the TEAMS web site of the “Klystron Gallery Construction”, “Target Test Facility”, and the “Thermal Hydraulics Lab.” The first day ended with an executive session to review progress made throughout the day.

The second day continued with plenary sessions for the Ring Systems, Conventional Facilities, First Target Station, and ESH&Q before breaking to the subcommittee parallel breakout sessions, which included further presentations and discussions with project representatives in order to gain additional information, and follow-up on remaining questions and issues of interest. The full committee reconvened in an executive session to discuss specific questions and concerns and discuss initial findings, comments and recommendations.

The third day continued with additional breakout sessions to receive additional presentations, conduct drill-downs, and follow-up on remaining questions and issues of interest before the full committee reconvened in an executive session to discuss specific questions and concerns and discuss preliminary findings, comments and recommendations.

The morning of the fourth day was used to do a factual accuracy check of the draft closeout presentation, finalize the closeout materials based on inputs from the project and flip through the presentation to ensure the latest edits were incorporated prior to delivering the closeout presentation to ORNL, SNS and PPU management, the PPU team and the OSO and BES observers. Closing remarks and thanks for the time and effort from all the participants were given by Mr. Ethan Merrill, Chair (OPA); Dr. Linda Horton, AD of Science for BES, Mr. Ed Stevens, SUFD PM PPU; Mr. James Barnard, OSO FPD PPU; and Dr. John Galambos, PPU Project Director. Final results are contained in this report, which the Committee members have individually authored and collectively reviewed.

**2. TECHNICAL SYSTEMS EVALUATIONS**

**2.1 Superconducting RF**

**2.1.1 Findings**

The review committee was briefed on the status of the project in plenary talks and then presented with the details of PPU superconducting linac systems in breakout sessions. The PPU will double the present SNS beam power capability from 1.4 MW to 2.8 MW. Thirty percent of the beam power increase will come from an increase in beam energy. Fifty percent will come from an increase in beam current.

The present field performance of the existing SNS superconducting linac (SCL), when combined with the PPU, would be sufficient to provide the total desired beam energy of 1.3 GeV. No upgrades of the existing SCL are needed. The existing SCL beam energy and power capability were demonstrated in a 1.7 MW beam power test.

Long lead procurements have been previously approved and initiated. The CD-3a approval provided $10.5M for cavities and couplers. The CD-3b approval provided $53.4M for cryomodules and the klystron gallery buildout. CD-3a contracts for cavities and couplers were placed on schedule and work is approximately 75% complete. Contracts associated with CD-3b have begun and are on schedule. The latter activities are 19% complete. The receipt and installation activities for seven new cryomodules are on or near the project critical path. New cryomodule installation at the SNS is required to coincide with three planned maintenance outages from FY2022 to FY2024. Jefferson Laboratory (TJNAF) remains the PPU partner for cryomodules. TJNAF does have other significant and overlapping commitments including work on their CEBAF cryomodules. The reviewers note that the LCLS-II project work is wrapping up, at the same time LCLS-II-HE and PPU activities are ramping up.

PPU work at the SNS has been ongoing throughout the first several months of the COVID pandemic. TJNAF was largely shut down for the early period of the pandemic but restarted PPU activities in June 2020. PPU is indicated to be one of the priority activities at TJNAF and was among the initial restart activities.

The majority of the PPU managers at the SNS were present at the original SNS installation. However, TJNAF is in the process of hiring thirteen new technical staff to meet its cryomodule assembly needs, both for PPU and other projects. Eleven of the planned thirteen staff have been hired to date.

All 30 fundamental power couplers have been received at the SNS. Six have been delivered to TJNAF. Processing is ongoing for the remaining couplers. As discussed in previous reviews, new PPU cavities are using high-purity niobium end groups and have a coupler probe that is slightly thicker and shorter than for the existing SNS couplers. The cryomodule will include a re-design of the warm-to-cold transition. This re-design is led by TJNAF. The warm-to-cold transition on the beamline is now assembled in the cleanroom rather than outside. Sixteen of thirty couplers received have been tested and conditioned to specifications. RF couplers are currently being conditioned at 700 kW in traveling wave and 600 kW in standing wave. More bridge waveguides have been ordered, but the SNS has used nearly all existing devices. This could potentially lead to a gap in coupler testing.

Cavities are in production at Research Instruments (RI). An experienced local accelerator scientist has been hired to perform vendor visits on behalf of the SNS. Two additional cavities are being ordered from RI, bringing the total to 32, of which 28 are needed to go into the PPU cryomodules. The new cavities from RI will be chemically processed at the vendor. Helium jacketing will be performed at TJNAF. We note specifically that no subsequent chemistry is planned. The first four RI cavities will be tested at TJNAF both before and after helium jacketing. In addition, three original SNS spare cavities have already been sent to TJNAF for jacketing and testing. These cavities will be tested, jacketed, and re-tested by the end of summer 2020 in order to demonstrate the processes. SCL activities have approved high-level Interface Control Documents (ICDs). One is for the cryomodule assembly at TJNAF and the other for the cryomodule installation in the SNS tunnel.

Costs for SCL systems are about 50% long-lead procurements (CD 3a/3b). The remaining 50% will be based on CD-2/3 approval. The cryomodule delivery dates are sufficiently advanced to allow strategic cryomodule placement into the SNS tunnel. The project is attempting to have more than the required number of cryomodules on hand for each of the three planned outages. Delivery for the first five cryomodules arein Nov. 2021, Feb. 2022, March 2022, May 2022, and July 2022.

Sixteen low and medium risks, and no high-level risks have been identified for SCL systems. In the context of relatively recent cryomodule shipping issues for other DOE projects, a cryomodule shipping test has been added to the PPU work scope. A slow tuner test has also been added. In total, one complete cryomodule worth of spare cavities and couplers is included in the project plan. PPU cryomodules delivered to the SNS from TJNAF will undergo extensive cold testing up to the operating gradients at the SNS both before and after installation into the tunnel. The new plan for plasma processing is to only perform this on medium beta cryomodules outside of the tunnel.

The cryomodule support saddles are one part of the SNS team scope for the SCL. These are under fabrication in US industry and are behind schedule due to a problem with a subcontracted US vendor. There is presently sufficient float with respect to the project schedule that no impact is expected. We note also that two medium beta cryomodules (CM1 and CM11) are planned for repair at the SNS ahead of PPU cryomodule arrivals.

There is some risk of delay in delivery of inter-cavity bellows due to a vendor being redirected for other work.

On the issue of crymodule cool down rate, there do not appear to be practical limits on either the primary or thermal shield circuits. The primary circuit is cooled at a rate of about 100 K/hr. with a similar rate on the thermal shield. On the PPU helium refrigeration system, a new nozzle is available for one of the turbines. This is designed for 20% increased flow and a corresponding increase in shield refrigeration capacity from 8.3 kW to 10 kW. The new nozzle will only be installed at the SNS if it is found to be needed later.

**2.1.2 Comments**

PPU managers have experience from the original SNS installation. The committee feels this reduces the likelihood of loss of institutional knowledge and is important for complex cavity and cryomodule systems. The SNS vacuum, cryogenics, and controls groups, and the SCL team generally, appear to have sufficient workforce and expertise to carry out the work plan. As with any lean group, the loss of key managers or technical staff could have a significant impact. New technical staff recently hired at TJNAF will require time on site to ramp up to full productivity. The issue could be compounded by COVID restrictions.

The SCL cost and schedule are not yet impacted significantly due to COVID. This appears to be because both the SNS and PPU vendors have continued hands-on work these past months. Required hands-on work at TJNAF during the recent shutdown was limited.

Overall, the SCL systems are progressing well with respect to the P6 project plan. SCL controls work for PPU appears to be progressing well. The approach is to replicate existing cryomodule controls and adjust, where necessary, for obsolescence. SCL cryogenics work for PPU is a moderately sized effort (cost ~$1M), and also appears to be progressing well. Technical review of the system has been performed as part of major DOE reviews, but we note that it is difficult for committees in these reviews to delve into much of the technical detail. SCL utilities work includes vacuum and water systems. This work is also mostly a replication of existing systems and progress to date is good.

The TJNAF/SNS/PPU team have robust tools in place for tracking vendor hardware. Much of the hardware needed to perform work is in hand, but key pieces are still with industrial partners. Therefore, the team should be willing to change or supplement vendors if necessary. This does not likely apply for cavities, vacuum vessels or other major components, but could be a wise course for smaller components.

Small PPU changes to the original SNS cavities and couplers are well thought out. Overall, the SCL system is technically conservative. This adds confidence that systems will perform as planned. There are planned repairs to three existing SNS cryomodules. These may be time consuming for technical staff but would not appear to have major impact for PPU installation or performance.

The technical choice not to perform cavity chemistry after jacketing is not the normal practice for SRF cavities. Therefore, the ongoing work at TJNAF to test, jacket and re-test three existing cavities from the original SNS is needed to vet the present plan for chemistry. If it is found that chemistry is desired after jacketing at TJNAF, this would have a negative impact on cost and schedule. Even though the team has four spare cavities planned and believes that additional chemistry is probably not needed, it would be prudent to consider a course of action in case chemistry after jacketing is needed.

Much information was shared about the status of cavities, helium vessels, and couplers, but other major components no presented in great detail are also critical to cryomodule fabrication. These include vacuum vessels, thermal shields, space frames, and tuners, just to name a few. Some of these require close interaction with their respective vendors, particularly if vendors are new. Oversight is more difficult with restricted travel and the project needs to continue with diligence to ensure the status of procured items is understood and that these remain on schedule to the extent possible.

**2.1.3 Recommendation**

1. Proceed to CD-2/3.

**2.2 Target**

**2.2.1 Findings**

The Proton Power Upgrade Project at Oak Ridge National Laboratory will increase the beam power on target from 1.4 to 2 MW, and the beam energy from 1 GeV to 1.3 GeV, involving evaluation and modification on the target and the target station. PPU will deliver 33kJ per pulse at 60 Hz to the FTS and it will extend the FTS facility lifetime from 40 to 60 years.

The scope of the target systems is to provide a First Target Station (FTS) that sustain high beam power and higher beam energy. The FTS includes the 2MW target (P.5.9), the Mercury Process Systems (P.5.3), the Moderator Cryogenic Systems (P.5.4) the Vessel and Shielding System (P.5.5), the Target Utility Systems (P.5.6), the Instrument System (P.5.7), the Mercury Off-gas Treatment Systems (MOTS, P.5.8), the Safety, Controls and Operations (P.5.10); as well as the Neutronics (P.5.2) and the Gas Injection Developments (P.5.11) to support the evaluations and the development of the above systems.

Most of FTS (except the target module) were initially designed for 2.0 MW with 1.0 GeV protons. Only the target module needs new design inside the Monolith, and it is a replaceable system. All the other hardware inside the Monolith (replaceable or permanent ones) are ready for PPU operation and extended lifetime of 60 years. Gas injection increase and beam energy increase imply some work on other subsystem outside of the Monolith. They were evaluated and addressed in the PPU FTS system.

Contemporary computing power, modeling & simulation techniques have provided more robust and resolved evaluations compared to original SNS efforts.

Collaboration with JPARC was effective on gas injection development (design of bubbler, simulations), the Moderator Cryogenic Systems, and the Molecular Sieve Beds (tritium retention).

***P.5.9 – 2 MW target and P.5.11 – Gas Injection Development***

The design of the target module is based on 10+ operational experience and an extensive R&D program.

High flow gas injection in the target to mitigate the target vessel fatigue and the cavitation damage is essential. Measurements during operation show gas injection reduces strain on target structure by significant amount. Last target (T24) operated at ~1.4 MW up to 2967 MW-hr with a minimum gas flow (0.71 SLPM) with much less cavitation damage and no failure.

The target implementation strategy within PPU includes two “test” targets that will be placed into operation, demonstrating target features and potentially higher beam power. The test target 2 will have the same design as of the PPU production targets. There is a strong and well-developed collaboration with target manufacturing companies. This manufacturing experience has been integrated in the PPU target.

To streamline the approval process, one purchase requisition will be placed with two-line items: one for one (1) PPU Test Target 2 and one for the three (3) production targets and will not be exercised until CD-3 and ESAAB approval is received.

***P.5.2 – Neutronics***

Neutronics provide the bases for evaluations, design upgrades, n-performance, facility safety support. There is no design or hardware upgrade scope within neutronics. Confidence builds up on several years of experience and simulation benchmarking.

***P.5.3 – Mercury Process Systems***

The Mercury Process System needs 3 new hardware to support higher flow gas injection (up to 20 SLPM): Mercury Pump Overflow Tank (OFT), Return Line Gas Liquid Separator (GLS), In-cell target gas supply hardware. All of them are well developed for preliminary design status. The final design reviews should be completed by November 2020 and fabrication expect to start early 2021.

Gas Liquid Separator (GLS) is well developed and mature. Experimental results show a separation ratio close to 90% which is already above PPU requirements.

***P.5.4 – Moderator Cryogenic Systems***

The addition of the catalyst beds to each of the three LH2 loops will ensure consistent neutronic performance by maintaining >99% parahydrogen to guarantee stable operations and to meet the required stability in minutes compare to hours or days.

***P.5.5 – Vessel and Shielding System and P.5.7 – Instrument System***

The vessel, shielding, and instrument systems evaluations confirm that all temperatures and stresses under PPU operation are acceptable.

***P.5.6 – Target Utility Systems***

After evaluation of the Target Utility Systems, FTS cooling systems has the capacity for PPU operation. Scope were updated to supply target gas with two different ways: primarily via recirculation and via once-through gas injection as backup to recirculating system.

***P.5.8 – Mercury Off-Gas Systems (MOTS)***

The Mercury Off-Gas Treatment System (MOTS) needs upgrades to support higher flow gas injection (up to 20 SLPM): a second delay bed (final design complete), additional cryogenic carbon adsorber (preliminary design), and larger molecular sieve beds for the 20 SLPM gas injection flow.

***P.5.10 – Safety, Controls and Operations***

5 unreviewed safety issues (USIs) identified in the Hazard Analysis Report (HAR) are related to the FTS : “beam energy increase” doesn’t require further action, “Target gas injection rate increase” requires a credit Rad Protection Program to control entry to the Gold amalgamation room (GAR), “introduction of new Ortho-Para Catalytic Converter” requires credited catalyst module retention elements, “Excessive Power (> 2 MW) Directed to Target” requires credited Beam Power Limiting System (under P.4 WBS).

**2.2.2 Comments**

The design for each sub systems of the FTS is clearly defined and technically sound to achieve the specified technical performance requirements and to establish a performance baseline and start construction. It is matured at the appropriate level: the 2 MW target and the delay beds, shielding and crane of the MOTS are ready to proceed to CD-3. The Mercury Process Systems, Moderator Cryogenic Systems, Target Utility Systems, remaining parts of the MOTS, and the safety-control Systems are ready to proceed to CD-2 and are well advanced at that stage.

The project scope, as currently defined, will achieve the objectives in the Mission Need Statement. The Work Breakdown Structure dictionary and the key performance parameters are appropriately defined to establish a credible performance baseline and start construction.

The technical progress to date is sufficient to meet the performance specifications and support the procurements and installation as planned. The trajectory is appropriate for meeting the threshold KPPs by CD-4.

All the recommendations have been appropriately addressed.

The Committee was impressed with the amount of progress and number of tasks performed since the CD-3b review in the various technical subprojects of FTS.

P.5 is supported by a very strong and well-balanced team between experienced personal and young staff. New hiring in the Target Utility Systems from industry is beneficial for the project.

***P.5.9 – 2 MW target and P.5.11 – Gas Injection Development***

Numerous design reviews have been completed and resulted in significant feedback, advancing the designs. This practice should be continued through construction readiness and operations.

The target implementation strategy includes two “test” targets that will be placed into operation, demonstrating target features and potentially higher beam power. The fabrication of test target 2 will have the same design than the production targets. It will be a good preparation for the fabrication of the production target, and it will increase the likelihood of project success.

Target welding QA/QC is a critical aspect of the 2 MW operation in view of maximizing reliability. Design reviews and discussions with vendors should be continued with the aim of maximizing the QA in their production. Multiple sourcing of targets should be sought in order to avoid relying on single source expertise. An analysis on whether in-sourcing of some of the components may be cost as well as schedule effective is encouraged.

Recent results with operation target on strain measurement with gas injection increase the confidence in the ability of the project to operate PPU target at 2 MW for at least 1,250 hours.

Having routinely measurements on operation target of the strain vs. the gas flow and the beam power (equivalent beam power) confirmed the efficiency of gas injection for fatigue stress mitigation and the committee encourages to continue this good practice when higher gas rate and higher beam power are available.

The team continues systematic PIE (Post Irradiation Examination) on spent targets to characterize damage and determine leak causes. Again, the committee encourages to continue this good practice to evaluate the effect of gas injection or design modification on fatigue and cavitation mitigation.

R&D efforts within (and outside) the PPU project have made substantial contributions to support design and operation improvement. The remaining project R&D tasks should be completed in the next four months. Continuing R&D beyond CD-3 and the scheduled project development is strongly encouraged as it will be beneficial for target operation lifetime.

COVID-19 impact has been limited on the FTS. Nevertheless, 2 MW target is on critical path and careful follow-up is needed to investigate potential delays with vendors, due to backlog or procurement challenges.

***P.5.3 – Mercury Process Systems***

Most of the upgrade and installation will be performed remotely. The committee supports the new activity to build a mock-up of the Hg Pump Overflow Tank (OFT), and of the Gas Liquid Separator (GLS) for remote installation test. We encourage the team to complete the final design and procure the mock-up as soon as possible to implement any changes if needed in the final design of the OFT and the GLS.

Extensive R&D led to a Gas Liquid Separator (GLS) that is well developed and mature. Experimental results show a separation ratio close to 90% which is already above PPU requirements.

***P.5.4 – Moderator Cryogenic Systems***

In-situ diagnostics with Raman spectroscopy for confirmation of H2 state by using direct laser viewing through dual sapphire windows will provide higher sensitivity than current diagnostics. Integrity test was delayed and started in June. This test needs to be complete ASAP and before end of July to validate the final design (FDR scheduled in August 2020).

***P.5.5 – Vessel and Shielding System and P.5.7 – Instrument System***

The thermomechanical evaluation of the working conditions of permanent components (vessel, shielding, inner reflector etc.) shows acceptable level of temperatures and stresses. The components have been validated according to ASME BPVC criteria, and areas with high radiation level are limited in volume. Based on that, the committee considers that safety margins are acceptable for reliable operation of the components for PPU conditions. The review panel supports the lifetime extension of the facility to 60 years and endorses the increase of the administrative dose limit to 20 DPA for the Outer Reflector Plug (ORP) shell structure.

It is assumed that the Aluminum Proton Beam Window (PBW) will be maintained. Contingency plans should be envisaged in case finally a decision (by Operation) is taken to use an Inconel PBW.

***P.5.6 – Target Utility Systems***

Off-Normal Analysis review for Target Utility System is delayed due to COVID-19 and may impact the final design review and procurement. If the in-person meeting could not take place by autumn, it is suggested to carry out remotely in any case to avoid potential delays in the target procurement.

***P.5.8 – Mercury Off-Gas Systems (MOTS)***

The committee endorses the addition of two trains of two beds to increase reliability and to provide capability to regenerate while MOTS is in operation.

***P.5.10 – Safety, Controls and Operations***

Involvement of safety experts and controls experts in each design review is a good practice and should continue during procurement, installation and test / commissioning of the upgraded systems.

The committee commends the analysis done on the target safety systems and encourages the implementation of the evolutionary upgrades foresee to mitigate the mercury spill events.

**2.2.3** **Recommendation**

1. Proceed to CD-2/3.

**2.3 RF**

**2.3.1 Findings**

The primary requirements for PPU RF systems are to support the increased beam current of 38mA and the increased beam energy to 1.3 GeV. The PPU will double the SNS beam power capability from 1.4 MW to 2.8 MW. This goal will be achieved by 30% of the beam power in increased in beam energy and 50% from an increased in beam current.

The RF systems technical scope includes: (1) addition of 28 new SCL HPRF stations rated at 700kW peak, (2) upgrade of 3 DTL HPRF stations to 3 MW peak, (3) development of 28 new LLRF systems, (4) upgrade of existing RFQ and DTL modulators to support 3MW operation, (5) addition of 3 new modulators (AT-HVCM) in the SCL, (6) addition of mechanical and electrical utilities in the SCL, (7) upgrade of mechanical systems in the DTL, and (8) EPICS programming and extension of the network, timing, machine, and personnel protection systems.

New RF stations to support the new SCL cavities are basically duplicates of the existing RF systems with some improvements.

To support the proton beam current increase to 38 mA, DTL3-DTL5 of the NCL will be upgraded to 3 MW klystrons as well upgrading to HVCMs. There is no need to change the circulator or load.

The LLRF will provide control and protection for the 28 new SCL cavities.

LLRF will regulate the amplitude (±1%) and phase (±1°) of the cavity field. LLRF Final Design Review (FDR) is planned for summer 2020.

The existing linac modulators will support the use of both 2.5 and 3 MW klystrons by updating the modulator topology.

Three new linac modulators (AT-HVCMs) will power groups of 9, 9, and 10 klystrons.

Utilities will provide electrical and mechanical support to all PPU technical equipment including new SCL and DTL upgrades.

Controls will integrate new technical equipment into the site wide controls infrastructure.

The RF systems team issued a number of purchase orders since the CD-3b including AT-HVCM transformer, SCR and built-to-print tanks, cable and tray for the first two transmitters, SCL DI water pumps and heat exchanger and controls hardware and HPRF transmitters and SCL klystrons.

The RF systems team completed NCL circulator and load review and continued the design of 3W klystron with vendor.

For the RF systems, currently COVID-19 has no impact to the project milestones. The team review vendor updates regularly to assess potential future schedule impact.

The RF systems do not have any high risk items in the Risk Register. Risks are all medium or low.

Final design reviews of HPRF transmitter (with the vendor), RFQ/DTL HVCM, and LLRF are planned for Summer/Fall 2020.

Receipt of major RF components (transmitters 30 and 31, 1st 12 SCL klystrons, and SCL-MOD-30) are expected in summer 2021.

Installation of transmitters 30 and 31 equipment will start in summer 2021.

The circuit topology of the RFQ HVCM mimics the Alternate Topology HVCM (AT-HVCM) used in for the new SCL RF stations.

The exiting linac modulators have updated design to support 3MW klystron operation. It provides a common design for both RFQ and DTLs.

New LLRF system successfully “witnessed” 23D operation – cavity control test is scheduled for this summer. RF systems awarded CD-3b procurements totaling ~$23M.

The entire RF systems will be at final design after the completion of HVCM and LLRF FDRS. Installation of equipment starts in summer 2021.

The existing LLRF systems for the linac have components that are obsolete.

The existing system is PPU capable but cannot meet Second Target Station (STS) requirements (cannot support more than one beam flavor and cannot do pulse-to-pulse AFF correction).

The LLRF system is responsible for high-power protection of cavities by providing fast shutdown of the RF drive signal as part of the High-power protection and interlocks.

Cavity field control module-II hardware development. The team has partnered with a company on board fabrication.

The team has partnered with LBNL for firmware collaboration. LBNL team is assisting with upgrading system model and providing DSP firmware and knowledge transfer.

The klystron gallery bldg. modifications were part of the project CD-3b approval and the construction portion of this scope was moved to WBS P.10 Long Lead Procurements.

COVID-19 risk is held as a management assessment outside of the risk register.

There are no high risks associated with the RF systems.

**2.3.2 Comments**

The RF systems team is experienced, skilled, and qualified with many years of design and operation experience. The team has made great strides since CD-3a/CD-3b.

The technical presentations were detailed and very informative. We appreciate the team’s availability to answer our questions and provide us with additional information before and during this review.

RF systems technical design is mature and likely to meet the project baseline performance.

RF systems design is about 90% complete. Final design reviews of RFQ-DTL HVCM and LLRF are planned for summer/fall 2020.

Overall, the level of RF systems documentation is sufficient to support baseline design.

The team is encouraged to do timely onsite acceptance tests of the RF components as they arrive from vendors.

Procurement of new 3 MW klystrons needs continuing vendor follow-up to prevent further delivery delays.

The team successfully tested the new LLRF system on SCL cavity 23D. Full control test of LLRF system on SCL-23D is planned for summer 2020.

We support completing the LLRF system “full control” test (field control) on SCL cavity 23D before holding the Final Design Review of the LLRF.

Managing LLRF collaboration with LBNL and vendor could be very challenging. The team needs to do their due diligence to stay the course.

The Committee supported the project team’s choice of a µTCA.4 platform for the LLRF system; leveraging μTCA commercial hardware is sound.

Controls are based on existing designs that have been demonstrated and present minimal risks.

Based on the simulated operation of NCL circulator and load at normal and off-normal reflected power conditions, there is no need to upgrade circulator or load for PPU. We concur with this conclusion.

The RF systems team should complete the final design reviews of LLRF, HPRF transmitter (with the vendor) and RFQ/DTL HVCM by end of Q1 FY21.

The RF team should continue to stay vigilant and proactive on QA of RF components delivered by the vendors to identify noncompliance issues early on for timely corrective actions.

Continue to review documentations as the project progresses and update as needed specially the ICDs, installation, test and commissioning plans.

All recommendations from past reviews have been addressed and closed.

L2 and L3 managers have a general understanding of the impacts of COVID-19 on RF systems. COVID-19 mitigations are addressed at the Project-level. COVID-19 has not yet had a significant impact on RF systems that would require changes to the project milestones. The team is doing regular follow-ups with the vendors to measure the impact on hardware delivery schedule. A notable impact from COVID-19 on RF systems is the delay in 3MW klystron delivery which moves it to “near” critical path. RF systems has some schedule float available if needed.

The procurements of all RF components should be closely monitored with regular follow-up and communication with vendors, particularly given the COVID-19 pandemic uncertainty.

RF systems staffing has not changed since the last review. The Project believes that it has the required engineering and technician staff to adequately support PPU. COVID-19 mitigation plans for onsite work will impose new restrictions that may require staffing adjustment. The team should reevaluate RF systems staffing level as the situation evolves.

* + 1. **Recommendations**

1. Tabulate PPU SCL RF power requirements by the next DOE IPR. The table should include the following operating parameters supporting 1.3 GeV beam energy and 38 mA macro-pulse average beam current:
   * Klystrons operating voltage and beam current
   * Nominal and maximum klystron output power
   * RF power transmission losses
   * accelerating gradient
   * Cavities loaded-Q
   * Lorentz detuning
   * Microphonics detuning
   * RF source power overhead
   * Cavities control power margin
2. Proceed to CD-2/3.

**2.4 Ring-Accelerator Systems**

**2.4.1 Findings**

To achieve the goal of 2.8 MW beam power, the beam energy is to be increased by 30% and the beam intensity by 50%, while the beam pulse rep rate stays the same, 60 Hz.

One of the project threshold KPPs, “Stored beam intensity in ring 1.6e14 protons per pulse at 1.25 GeV”, has been partially demonstrated in advance, 1.83e14 protons in the accumulator ring at extraction at 1.0 GeV beam energy. Purpose of this demonstration was to test if there are any beam instabilities in the ring at 1.7-MW beam power operation. No instabilities were observed.

All existing ring magnets can accommodate the higher beam energy, except for the magnets in the injection and extraction sections. In these sections, the drawings for the new chicane and dump septum magnets are being finalized.

The injection kicker power supply is upgraded. The required performance has been demonstrated, and the power supply is now undergoing a 30-day test to verify reliability. The handling of the increased particle-throughput by the stripping foil was reported to result in increased temperature but within acceptable limits. With a nominal beam size on the stripping foil, it is estimated that the foil can handle up to 5 MW of beam power.

The Ring Injection Dump (RID) imaging system design and engineering reviews are nearing completion and a new injection dump line quadrupole adds additional control of beam spot size. The main concern for the injection beam dump is overheating of the concrete by exceeding the acceptable power over longer time scales (months). Work is underway to appropriately document use of the code-allowable higher temperature bound. The RID is capable of handling up to 150 kW beam power with the limit established by calibrated temperature modelling. The current beam power to the RID in normal operation is 60 kW.

The extraction septum shims analysis is in progress with initial data showing distortion roughly halfway between original design and current operation at 1.0 GeV.

In the utilities WBS the transformer fan upgrade kits have been selected. The water cooling design is mature, and system design emulates standard, proven SNS best practice. For the PFN air conditioning upgrade two unresolved issues were found while preparing for the vendor FDR, and a design recovery plan was put in place.

The Beam Power Limiting System (BPLS) was added to the scope after CD-1. The BPLS cost has increased substantially since last review (June 2019) because of a better scope and schedule definition. Some technical requirements were relaxed since the previous review (beam shut-off after 60 seconds instead of two 60-Hz pulses). The BPLS is based on COTS/MOTS hardware where possible. Custom designs are based on industry standards for high reliability signal processing.

**2.4.2 Comments**

The Committee congratulated the team on excellent progress since the previous review.

The successful 1.7 MW equivalent beam power test is a significant step towards the PPU performance goals. The upgrade of the kicker pulsers is simple and low risk. It is an efficient scheme and avoids reconfiguration in the extraction area. The added stress on the kickers is quite marginal and should pose no issues for reliability.

The imaging system to be installed appears well thought out and analyzed, and it will be a valuable diagnostic. Bench testing for the RID imaging system provides confidence in the design.

The injection dump power rating of 150 kW has been established conservatively with the help of models with the experimentally verified temperature evolution of the concrete under load. An impressive amount of high-quality data for the Ring Injection Dump power-handling capability was shown, It appears that the thermal time constant of the beam dump concrete is 100-s of days, which should allow for some operational flexibility to exceed the rated power for short periods of time. We suggest the project team evaluate and document the temperature model and the impact on the concrete to allow for increased operational flexibility.

There is no technical risk in the cooling water upgrade. The upgraded DI water system that lowers the temperatures in the ring systems should not change the temperature of the RF cavities in the ring. It may be prudent to anticipate sporadic leaks when the water temperature is lowered (because of differential thermal expansions).

The ring controls scope is well understood and supports the PPU KPPs. With exception of BPLS, the ring controls are based on mature, proven designs. The BPLS, while well defined in its requirements, will be challenging to implement in the time scale foreseen. Issues that may take additional effort are noise on the FCT data, difficulty in maintaining calibration of the FCT under changing beam properties, programming effort for the FPGAs and the general overhead incurred when building credited safety systems. Presently the BPLS is not rated as high risk despite being near the critical path. The committee supports an early installation (now) of a test FCT to start recording and processing signals.

**2.4.3 Recommendations**

1. By the next DOE/SC review, consider adding a Risk Registry entry for the Beam-Power Limiting System.
2. Proceed to CD 2/3.

**3. CONVENTIONAL FACILITIES**

**3.1 Findings**

WBS P.6 Conventional Facilities (CF) includes the design, procurement and construction of:

* Klystron gallery bldg. modifications to support the installation, assembly and operation of the technical components.
* A new Ring to Target Beam Transport (RTBT) stub to facilitate the beam tie-in for the Second Target Station Project without a major shutdown
* Water & HVAC controls for the klystron gallery buildout

CF technical requirements are listed in the Final Design Report.

CF scope contains several interfaces with other parts of PPU that are recorded in Interface Control Documents.

Technical requirement specifications/final designs for CF scope are complete, though the BIM model for the klystron gallery buildout is not finished.

High Performance Sustainable Building guidelines are not applicable for this project since the building does not exceed 5,000 gsf.

The klystron gallery bldg. modifications were part of the project CD-3b approval and the construction portion of this scope was moved to WBS P.10 Long Lead Procurements.

Construction of the klystron gallery bldg. modifications is in progress.

* CPI = 1.00
* SPI = 0.75

The klystron gallery bldg. modification scope experienced challenges during procurement due to lack of contractor interest and high bids.

CF scope is not currently listed on the PPU critical path schedule.

The planned construction period for the RTBT stub is during the extended SNS outage in FY23.

Outage construction of the RTBT stub is near critical path with 37 days of float

Bids are not in hand for the RTBT stub and will not be until closer to the anticipated start of construction in FY22.

The RTBT stub cost estimate and schedule were developed by the A/E design firm with input from an outside CM contractor.

The COVID-19 pandemic has had little/no impact on CF scope to date.

The CF team received three prior review recommendations. All three recommendations are closed.

**3.2 Comments**

The CF team is well established and fully functional.

The CF scope as outlined in the final design report will meet the approved Mission Need.

The utilization of BIM for the klystron gallery buildout is a best practice and the project has already experienced added value from BIM.

The CF team did not have much BIM experience and has realized challenges implementing BIM practices. However, the team has recently added a BIM coordinator which has helped to finalize the BIM model. The team is also actively tracking BIM lessons learned which will benefit the Second Target Station Project and other projects at ORNL that will utilize BIM.

The CD-3b scope for the klystron gallery bldg. modification is currently behind schedule with an SPI of 0.75. This schedule delay is due to inclement weather but also contractor performance.

The CF team is working with lab procurement to obtain a corrective action plan from the contractor to get back on schedule.

If the klystron gallery building modifications scope is further delayed, then this may cause construction to coincide with the technical installation in the same area. This will make the technical installation more challenging but still achievable with minimal schedule risk.

The CF team updated the RTBT stub cost estimate to reflect the realization of high bids on the CD-3b procurement. While a great step to mitigate the risk of high bids, there is opportunity to improve the confidence level of the CF budget with an independent cost estimate.

Since the outage construction of the RTBT stub scope is near critical path, the project team is working to maximize the amount of work that can be completed before the outage.

To mitigate the schedule risk of the RTBT stub construction, the CF team should work with the contractor prior to award to ensure a credible working schedule.

The STS Project is seeking CD-3a approval for site work that could coincide with the RTBT stub construction and would create logistical challenges.

The RTBT stub procurement approach includes utilizing the STS construction manager with a fallback option to competitively bid the scope. The plan is sound but there is still significant risk due to the unknowns surrounding the STS CM as well as the volatility of the contractor market.

The CF team is actively managing the schedule risk for the RTBT stub outage construction, however no such risk exists in the project risk register.

Past review recommendations have been appropriately addressed.

* 1. **Recommendations**

1. Prior to CD-2/3 ESAAB, complete a thorough risk analysis of the RTBT stub procurement, construction logistics, cost, and schedule to identify risks not currently in the project risk register, and update the risk register accordingly.
2. Proceed to CD-2/3.

**4. ENVIRONMENT, SAFETY and HEALTH**

**4.1 Findings**

DOE O 413.3B requires the preparation, updating and completion of several Environment, Safety and Health (ES&H) documentation for approvals at the Critical Decision (CD) 2 and 3 levels.  The National Environmental Policy Act (NEPA) Strategy for a Categorical Exclusion Determination has been approved.  The Hazard Analysis Report (HAR) has been prepared and updated. The Construction Project Health and Safety Plan, which is a DOE O 413.3B CD-3 requirement was completed in September 2019 and is currently being utilized for early construction activities associated with the Power Proton Upgrade (PPU) project.

The Quality Assurance (QA) Plan has been completed and was prepared specifically for this project.  In addition to the QA plan, the transition to operations plan has a milestone for the performance and approval of an External Readiness Review (ERR) or Accelerator Readiness Review (ARR) prior to operation of the new beam line.

In addition to the ES&H DOE O 413.3B requirements for CD-2 and CD-3, the emergence of the COVID-19 pandemic has created additional health and safety challenges.  Implementation of COVID-19 protections and safety measures was added to one of the ES&H charge questions for the CD-2/3 Independent Project Review for the PPU project.  The project presented their COVID-19 protection and safety measures and these elements are being flowed-down to lower-tiered subcontractors working on the project.

**4.2 Comments**

Integrated Safety Management is well established and is being flowed-down to subcontractors through the Oak Ridge National Laboratory (ORNL) Chestnut Ridge Project Safety and Health Plan.  ESH&Q personnel are well integrated into the project and provide support for project document reviews and field inspections.  Construction oversight and safety is well managed and the project has a Safety Services Representative that is able to provide 40% time for construction oversight and safety reviews, which appears to be an adequate level of effort for the construction activities on this project.

Currently, the COVID-19 pandemic has created a new hazard that affects the safety and health of project personnel and construction subcontractors.  In response, ORNL has implemented robust, COVID-19 precautions and safety measures with response plans, density monitoring, training and testing.  These precautions and safety measures have been flow-down to lower-tiered subcontractors and are commendable.  Construction subcontractors are required to address onsite precautions and safety measures for COVID-19 through specific Hazard Analysis documentation.

The Hazard Analysis Report (HAR) provides information about hazards associated with the construction project, and future building and research operations.  For CD-2/3 requirements, the HAR is developed by updating the Preliminary Hazards Analysis Report from CD-1, which identified and evaluated all potential hazards and established a preliminary set of safety controls for the project’s operations.  The hazards associated with construction and installation activities were being addressed by ORNL’s Standards Based Management System (SBMS) since the Spallation Neutron Source (SNS) is a mature operating facility and covered by ORNL’s programmatic requirements and procedures.  The PPU HAR focused on the operational risks resulting from installation of the proposed upgrades.  It was noted during the review that the construction and connection of the Ring to Target Beam Transfer (RTBT) system to the main SNS was not covered in the HAR.  The HAR would benefit from the identification and control of hazards associated with the connection of the RTBT.  An Unreviewed Safety Issue (USI) could also be developed to address this element of the project that is evaluating against the SAD/ASE for the operating facility where this structure ties into SNS and the potential impacts to the facility during the opening of the wall and construction activities.

The HAR and USIs identified an increased use of helium during operations.  The ESH&Q review subcommittee noted that the Oxygen Deficiency Hazard (ODH) calculations should be re-evaluated prior to operations.  The review also identified that the increased proton energy and intensity for the project will potentially increase residual radiation levels in the ring injection area.  This situation would require additional evaluations and mitigations of radiation hazards.

Quality assurance (QA) is an important element for project success and safe operations.  The QA program has improved since prior reviews and is implemented with functional requirements to support elements needed for a successful QA program.  QA coordination with partner Laboratories is well structured.  The ESH&Q subcommittee noted that the project needs to ensure the statements of work for procurements and construction to come after CD-2/3 should include a process for completion of the Quality Assurance Grading checklist and development of acceptance criteria consistent with the well-developed QA plan.

Prevention through Design principles should continue as a form of hazard control during design review.  The implementation of these principles with ES&H participating in design reviews can mitigate potential hazards for research, building operations, and construction.  Procedures and an engineered containment system have been incorporated into the design to mitigate the sources of the March 2020 mercury release.

Project plans include revisions of the Facility Safety Document for the Proton Facility (FSAD-PR) and Accelerator Safety Envelope (ASE) to support crediting the Beam Power Limiting System (BLPS) after the first cryomodule outage.  If the BPLS is late, radiation safety can implement a hold process till the BPLS is ready.  Both of these processes are important operational safety controls.

**4.3 Recommendations**

1. Prepare prior to, and present evaluations and mitigations of radiation hazards from increase in proton energy and intensity at the next project review.
2. Change wording in RTBT design review from “Project QA and ESH organization

should to shall review the Conventional Facilities construction documents for RTBT stub” to ensure ESH&Q requirements are followed.

1. Proceed to CD-2/3.

**5. COST and SCHEDULE**

**5.1 Findings**

|  |  |  |
| --- | --- | --- |
| **PROJECT STATUS as of March 2020** | | |
| **Project Type** | **Line Item** | |
| CD-1 | Planned: 3QFY17 | Actual: 04/04/2018 |
| CD-3A | Planned: 2QFY19 | Actual: 10/05/2018 |
| CD-3B | Planned: 4QFY19 | Actual: 09/05/2019 |
| CD-2/3 | Planned: 2QFY21 | Actual: |
| CD-4 | Planned: 4QFY28 | Actual: |
| TPC Percent Complete | Planned: 33%\* | Actual: 32%\* |
| TPC Cost to Date | $51.8M |  |
| TPC Committed to Date | $33.1 M |
| TPC | $271.6M |
| TEC | $197.8M |
| Contingency Cost (w/Mgmt Reserve) | $63.0M | 40% to go |
| Contingency Schedule on CD-4b | 42 months | 72% to go |
| CPI Cumulative | 1.0\* |  |
| SPI Cumulative | .96\* |

The eproject status table (shown above) provides relevant cost and schedule statistics for the project as of March 2020. The Committee reviewed the project as a whole to determine readiness for a combined CD-2/3.

***Cost***

The project is requesting baselining a TPC of $272M. This TPC represents an overall increase of $42M since CD-1 and reflects both concerns for COVID impacts and the maturation of the project scope. The increase is within the percentage allowed for increase and has been in communication with the program office regarding the changes over time.

The project added $16M to contingency (included in the TPC) to address possible COVID impacts. The contingency amount was developed in a top-down method.

The overall project design is estimated to be 92% complete. The estimate has matured and now includes 81% vendor input – which was derived from 33% Vendor Estimates, 41% Place Contracts and 7% Vendor Quotes. Remaining design efforts are small and low risk.

**Table 5-1. Design Percent Complete by WBS Element**

The cost estimates are documented in the cost estimating database and values are loaded and reflected in the P6 Schedule at the activity level and is generally supported at WBS Level 4.

A bottom up ETC for the proposed baseline was completed in April 2020.

Two CAM interviews were performed; the RF systems ($65M) and the SCL Systems ($39M). The CAMS were well prepared.

The current project contingency is $63M and is 40% of the work to go. This is an increase from CD-3b.

**Table 5-2. Cost Estimate History**

****

***Schedule***

The PPU total project schedule has 6,096 activities and 841 milestones, is resource loaded and logically tied. The schedule shows maturation appropriate to this phase of the work.

The standard quality analysis were run on the schedule and resulted in a health score/metric of 88. Drivers for the score were discussed and the score is consistent with prior reviews.

The critical path runs through the fabrication of the target and includes scheduled outages. The schedule assumes a 8.5 month shutdown in 2023.

The project schedule with float has minimal external constraints due to other downstream or parallel efforts. The Secondary Target System will need a hand-off from the PPU project currently well after the current scheduled hand-off.

Schedule contingency is currently 42 months which is comprised of the following; 8 months from the risk register, 22 months due to the 1,250 KPP and 12 months for COVID risks.

***TPC Point Estimate***

The Total Project Cost (TPC) point estimate has grown from ($216.3 million, $55.9 million contingency) since the CD-1 review to ($230.2 million, $57.1 million contingency) at CD-1, to ($238.8 million, $65.4 million contingency) at CD-3a, to ($244.9 million, $57.5 million Contingency) at CD-3b,. to ($271.6 million, $63.0 million Contingency) for the current CD 2/3 review.

Contingency is calculated by project controls using Acumen Risk Monte Carlo output and has had a top down estimate for COVID Risks added.

Of the $156.5 million of Estimate to Complete (ETC), $81 million is for procurement and fabrication.

***Earned Value Reporting***

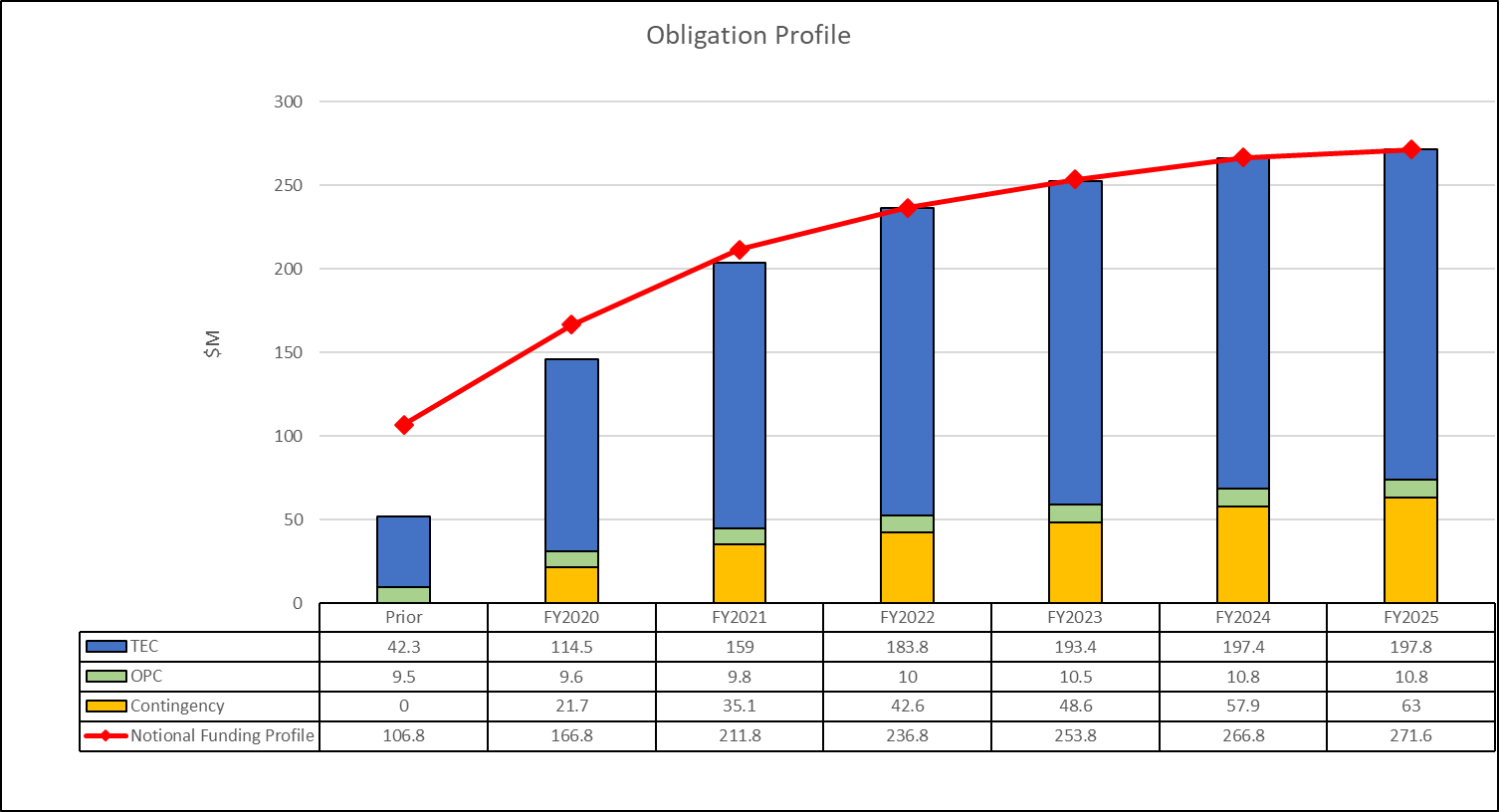
The project has continued to be supported by an experienced project controls staff who have put systems in place for successful implementation of the lab’s EVMS. The project has been reporting EV on the CD 3a/3b items. The system for the lab was surveilled in December 2019.

***Funding***

The project has benefited from strong funding support to-date. As of this DOE/SC review the project has received a total of $166.8 million in funding.

**Table 5-3. Funding Profile**

**Table 5-4. Obligation Profile**



***Risk and Contingency***

Project risks are captured in a risk register. The risk register currently identifies 2 high risks, 32 medium risks 41 low risks after mitigation.

The project held a risk workshop conducted by Keith Molenar in January of 2019.

A buydown list exists for the use of contingency totaling $23.5 million. The buydown list is comprised of critical, operational and economical spares.

**Table 5-5. Buydown**



The project is carrying $63 million (40% to go) of cost contingency. Cost contingency continues to be mostly derived from a Monte Carlo simulation. The contingency is comprised of $45.2M Risk Based, $1.7M management assessment and $16M for COVID identified concerns.

The project’s CD-4 date is now planned for July 2028 with early completion in January 2025. The project currently has 42 months of schedule contingency (comprised of 8 mo risk based, 22 mo 1,250 KPP based and 12 mo COVID). The project anticipates that the additional time outside is well covered by the contingency at this time.

***Other***

Two Cost and Schedule related recommendations from CD-3b have been addressed.

**5.2 Comments**

The project team demonstrated good project cost and schedule performance in executing CD-3a/ CD-3b scope. The estimated TPC for the project seems appropriate and the CD 2/3 seems credible. The team was well organized and demonstrated competency with both their estimates and schedules.

Final design is estimated at 92% complete. The remaining design effort is rated as low risk. 81% of estimates for fabrication and procurements are based on vendor input created a strong basis of estimates.

Risks appear to be understood and project team is using best practices and utilizing industry leading outside expertise to help advance risk management planning. Another best practice would be to have risks independently reviewed.

**Table 5-6. Cost Contingency**



Possible impacts of COVID should continue to be analyzed. Despite this being an evolving issue, mitigations need to be developed for the various scenarios at various vendors and institutions and near term risks (6-9 months) added to the register.

Continued attention to the potential impacts the project could have on related projects, especially around the RTBT stub, will be required as the project moves along. It is not anticipated that the RTBT stub work schedule would impact other projects at this time.

**5.3 Recommendation**

1. Proceed to CD-2/3a.

**6. PROJECT MANAGEMENT**

**6.1 Findings**

The point cost estimate for the performance measurement baseline (PMB) is $271.6M. This represents an increase of $26M from the point cost estimate at CD-3b, but is within the $184M - $320M CD-1 cost range. PPU uses a Cost Estimate Data Base tool to aid in the development of the point cost estimate. To date, 61% of point cost estimate has been appropriated. Potential delay due to lack of future funding is considered in the risk register.

A bottom up estimate-to-complete (ETC) exercise was completed in April 2020, with an estimate-at-complete (EAC) determined from actual costs plus the ETC. The EAC was used in determining the point cost estimate.

The point cost estimate includes 40% cost contingency on the remaining work and 42 months of schedule contingency. The cost contingency includes $16M to cover potential COVID-19 impact. The potential cost impact attributed to COVID-19 is approximately 10% on remaining work. The schedule contingency has three contributions: 8 months due to uncertainties determined from a three-point Monte Carlo analysis; 12 months attributed to possible COVID-19 impacts; and 22 months assigned for meeting the target lifetime Key Performance Parameter.

The PPU critical path runs first through the civil construction for klystron gallery, then transitions to the design and procurement of target modules, the installation of cryomodules, and ends with the final readiness review and commissioning. There are many tasks are have been identified by the project as being near the critical path. The geographical extensiveness of PPU means that work scope encompasses many locations across the SNS.

PPU is utilizing an Earned Value Management System (EVMS) that went through a surveillance review in December 2019. The review resulted in no Corrective Action Requests (CARs) and two (2) Continuous Improvement Opportunities (CIO\*). The two CIO\* were addressed and closed.

The project is reporting on Earned Value for long-lead procurement (LLP). The Schedule Performance Index (SPI) is 0.98 and the Cost Performance Index (CPI) is 1.03. To date, 26% of the work has been performed. For the LLP within the scope of CD-3a (which includes superconducting cavity fabrication) the work is 75% complete and on schedule for March 2021 completion. The scope for CD-3b includes cryomodule procurement and assembly, RF system procurements, and klystron gallery construction. The work is 19% complete, with a forecast finish in the second quarter of FY2022.

A project assumptions document has been prepared. PPU assumes that the project is not funding limited. It also assumes that there will be three planned SNS outages to allow for installation of technical equipment. These SNS outages serve as schedule constraints for the project. Each quarter of the published operations schedule, which includes maintenance outages, is made official one month prior to the start of that quarter.

Risks are continually evaluated and monitored by the project. The risk register currently has 72 active threats and 3 active opportunities. A total of 49 threats and 13 opportunities have been retired from the register to date. Since CD-3b, 10 new risks have been added.

The project conducted a risk workshop in January 2019 that was led by K. Molenaar to train CAMS in the identification and mitigation of risks. Recently, management assessed the risk associated with the COVID-19 situation, and presently this risk is held outside of the risk register. The project is also actively assessing and analyzing the impact of COVID-19 on high value (>$150k) procurements. With restrictions on travel due to COVID-19, visits to vendor sites is not possible. PPU has hired a consultant to represent ORNL interests for the delivery of the superconducting cavities from the international vendor.

A project management plan is in place that provides a comprehensive description of the processes and guidance for cost, schedule, and technical scope management. There is an experienced leadership team in place. Since CD-3b, there have been three changes in senior project management. A new position for Environment, Safety, Health, and Quality (ESHQ) Lead reporting to the Project Director was created and filled. New Work Breakdown Structure (WBS) Level 2 Leads were also named for Ring Systems and Pre-operations. A new Deputy Director for Projects has been appointed by ORNL to ensure that current and planned major scientific projects, including PPU, move forward to support DOE’s national missions as strongly as possible.

There are three (3) partner National Laboratories delivering scope for PPU: Thomas Jefferson National Accelerator Laboratory (TJNAF) is providing cryomodules; Fermi National Accelerator Laboratory (Fermilab) is providing new chicane magnets and the injection dump septum magnet; and Lawrence Berkeley National Laboratory (LBNL) is collaborating on low-level radiofrequency (LLRF) development. TJNAF actively participated in the CD-2/3 review. There is a Memorandum of Understanding (MOU) between ORNL and TJNAF for PPU. A standardized set of tools for project management are being used by the labs.

A three-phased approach to commissioning and operations is planned. The approval process steps are defined and includes externals reviews, including an Accelerator Readiness Review (ARR) at the end of the second phase.

Some project spares are included in the PMB. A list of critical, operational, and economical spares ($23M) has been prepared and published by the team. PPU has also had internal discussions regarding scope contingency, both scope removal and scope buy-back.

PPU has a change management board that consist of technical system owners who review proposed technical changes to assess and mitigate impacts.

Project staffing is currently near peak. The PPU head count between April and June 2020 ranged from 168 to 196 persons. The number of persons supporting PPU at >50% level of effort in this time period is between 51 to 54 persons. The full-time equivalents (FTEs) charging effort to the project in this time period ranged from 62.1 to 66.9 FTEs. A majority of PPU staff is matrixed from the ORNL Neutron Sciences Division (NScD). Staffing needs are being met due to improved operations management and higher SNS reliability. The PPU team noted that a major laboratory staff structure reorganization effort has just initiated.

ORNL is providing the project with reduced overhead rates and conditioned storage facilities.

Requirements for CD-2 are mostly in place, with exception for the Project Execution Plan (PEP) finalization and two subsystems that are still in preliminary design. The CD-3 requirements are also mostly in place, outside of PEP, the final design status, and the final design review. The Key Performance Parameters are defined in the PEP, the technical parameter list, final design report, and interface control documents (ICDs) are published.

The PPU final design is at 92%, with remaining subsystem/component designs to be completed, reviewed and recommendations resolved prior to fabrication or procurement of these items. The remaining design accounts for $7M of $83M total cost for the design elements.

All recommendations from prior DOE/SC reviews (26) are closed. The recent Director’s Review held in June 2020 in advance of the CD-2/3 review had 8 recommendations, of which 7 have been closed and one is in progress.

**6.2 Comments**

The Project Management team is functioning well and was well prepared for the CD-2/3 review.

The new Director of Projects, reporting to the Laboratory Director, should serve PPU project well in addressing resource needs and sharing lessons learned from other laboratory projects.

TJNAF, as a partner laboratory in PPU, has benefitted from lessons learned in cryomodule production for other projects. PPU overall would also benefit from increased communication between project managers of other large DOE-SC accelerator projects.

The matrixing of ORNL and SNS staff to PPU seems to be working well, especially since SNS operations has recently shown high reliability. It is understood that user operation has priority, and the project needs to be well positioned to argue for appropriate resources to meet cost and schedule when demands from operations increases.

Project needs to ensure effective communications with other activities, both large and small, throughout the SNS. This is especially true for routine maintenance activities associated with accelerator operations that are executed in spaces where PPU construction and installation activities are planned.

The subcommittee feels the cost and schedule contingency is appropriate. The project responded well to a previous recommendation from the CD-3b review to better develop the risk-based contingency. The project is also encouraged to continue flushing out scope contingency, both removal and buy-back. Scope buy-back discussions with STS could be pursued.

The project has a top down assessment of COVID-19 impact, and should start a bottom up assessment of impacts to cost and forecast schedules. This assessment provides a means to expose and address issues that CAMs identify and provide (where possible) mitigations.

The subcommittee feels that the remaining designs are low risk. The change management process seems sound, and the project should continue to communicate technical changes to all stakeholders.

The planned outages are a critical constraint to project schedule. The project needs to consider the need for and risk to duration associated with safety system certification and/or revalidation at the end of each of the planned outages and plan accordingly. Also, key stakeholders should be informed of the need to communicate, at least 6 months in advance, emergent issues that may impact meeting outage schedules. Valuable lessons learned are available from the recent LCLS-II long down time.

The three-phased approach to commissioning and operations is reasonable, and makes appropriate use of external reviews.

Management of vendors should be tightened across the project, since visits to remote sites, both domestic and international, are restricted due to the COVID-19 situation.

**6.3 Recommendations**

1. Supplement the PPU COVID-19 vendor impacts list with the following information: PPU point-of-contact (both procurement and technical); planned frequency of vendor contact; date of last vendor contact; method of last vendor contact. This revised PPU COVID-19 vendor impacts list shall be appropriately communicated to DOE starting next month and continue monthly.
2. The project is ready to proceed to CD-2/3.

Appendix A Charge Memo



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Appendix B Review Committee



Appendix C Review Agenda

**OPA Review of the**

**Proton Power Upgrade (PPU) Project at ORNL**

**July 14-17, 2020**

**Tuesday, July 14, 2020 – via Teams (All times listed are in PDT, EDT, and CEST (EU))**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| PDT | EDT | CEST | Topic | Presenter |
| 6:00 AM | 9:00 AM | 3:00 PM | Full Committee Executive Session | Ethan Merrill |
| 6:40 AM | 9:40 AM | 3:40 PM | ORNL Welcome | Thomas Zacharia |
| 6:50 AM | 9:50 AM | 3:50 PM | Jefferson Lab Perspective | Stuart Henderson |
| 7:00 AM | 10:00 AM | 4:00 PM | NScD Welcome | Paul Langan |
| 7:00 AM | 10:10 AM | 4:10 PM | Overview, Issues, Assessment (A1) | John Galambos |
| 7:40 AM | 10:40 AM | 4:40 PM | Project Management (A2) | Mark Champion |
| 8:05 AM | 11:05 AM | 5:05 PM | Break |  |
| 8:20 AM | 11:20 AM | 5:20 PM | Cost and Schedule (A3) | Wayne Steffey |
| 8:45 AM | 11:45 AM | 5:45 PM | Technical Highlights (A4) | Sang-Ho Kim |
| 9:10 AM | 12:10 PM | 6:10 PM | Superconducting linac (A5) | Matt Howell |
| 9:35 AM | 12:35 PM | 6:35 PM | Radio-Frequency Systems (A6) | John Moss |
| 10:00 AM | 1:00 PM | 7:00 PM | Lunch/Meal Break | All |
| 11:00 AM | 2:00 PM | 8:00 PM | Full Committee Executive Session | All |
| 12:00 PM | 3:00 PM | 9:00 PM | Adjourn | All |

**Wednesday, July 15, 2020 – via Teams (All times listed are in PDT, EDT, and CEST (EU)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| PDT | EDT | CEST | Topic | Presenter |
| 6:00 AM | 9:00 AM | 3:00 PM | Ring Systems (A7) | Nick Evans |
| 6:25 AM | 9:25 AM | 3:25 PM | Conventional Facilities (A8) | Mark Connell |
| 6:50 AM | 9:50 AM | 3:50 PM | First Target Station (A9) | Bernie Riemer |
| 7:15 AM | 10:15 AM | 4:15 PM | ESH&Q (A10) | Sam McKenzie |
| 7:40 AM | 10:40 AM | 4:40 PM | Break |  |
| 7:55 AM | 10:55 AM | 4:55 PM | Subcommittee Breakout Sessions |  |
| 7:55 AM | 10:55 AM | 4:55 PM | Session B1—Superconducting linac | SC1 |
| 7:55 AM | 10:55 AM | 4:55 PM | Session B2—Target Systems | SC2 |
| 7:55 AM | 10:55 AM | 4:55 PM | Session B3— Radio-Frequency Systems | SC3 |
| 7:55 AM | 10:55 AM | 4:55 PM | Session B4—Ring-Accelerator Systems | SC4 |
| 7:55 AM | 10:55 AM | 4:55 PM | Session B5—Conventional Facilities | SC5 |
| 7:55 AM | 10:55 AM | 4:55 PM | Session B6— ESH&Q (Joint with B8) | SC6 |
| 7:55 AM | 10:55 AM | 4:55 PM | Session B7— Cost & Schedule (with B8) | SC7 |
| 7:55 AM | 10:55 AM | 4:55 PM | Session B8— Project Management | SC8 |
| 10:00 AM | 1:00 PM | 7:00 PM | Lunch/Meal | All |
| 11:00 AM | 2:00 PM | 8:00 PM | Full Committee Executive Session | All |
| 12:00 PM | 3:00 PM | 9:00 PM | Adjourn | All |

**Thursday, July 16, 2020 – via Teams (All times listed are in PDT, EDT, and CEST)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| PDT | EDT | CEST | Topic |  |
| 6:00 AM | 9:00 AM | 3:00 PM | Subcommittee Breakout Sessions / Working Session | All |
| 9:00 AM | 12:00 PM | 6:00 PM | Lunch/Meal | All |
| 10:00 AM | 1:00 PM | 7:00 PM | Full Committee Executive Session / Dry Run | All |
| 12:00 PM | 3:00 PM | 9:00 PM | Adjourn | All |

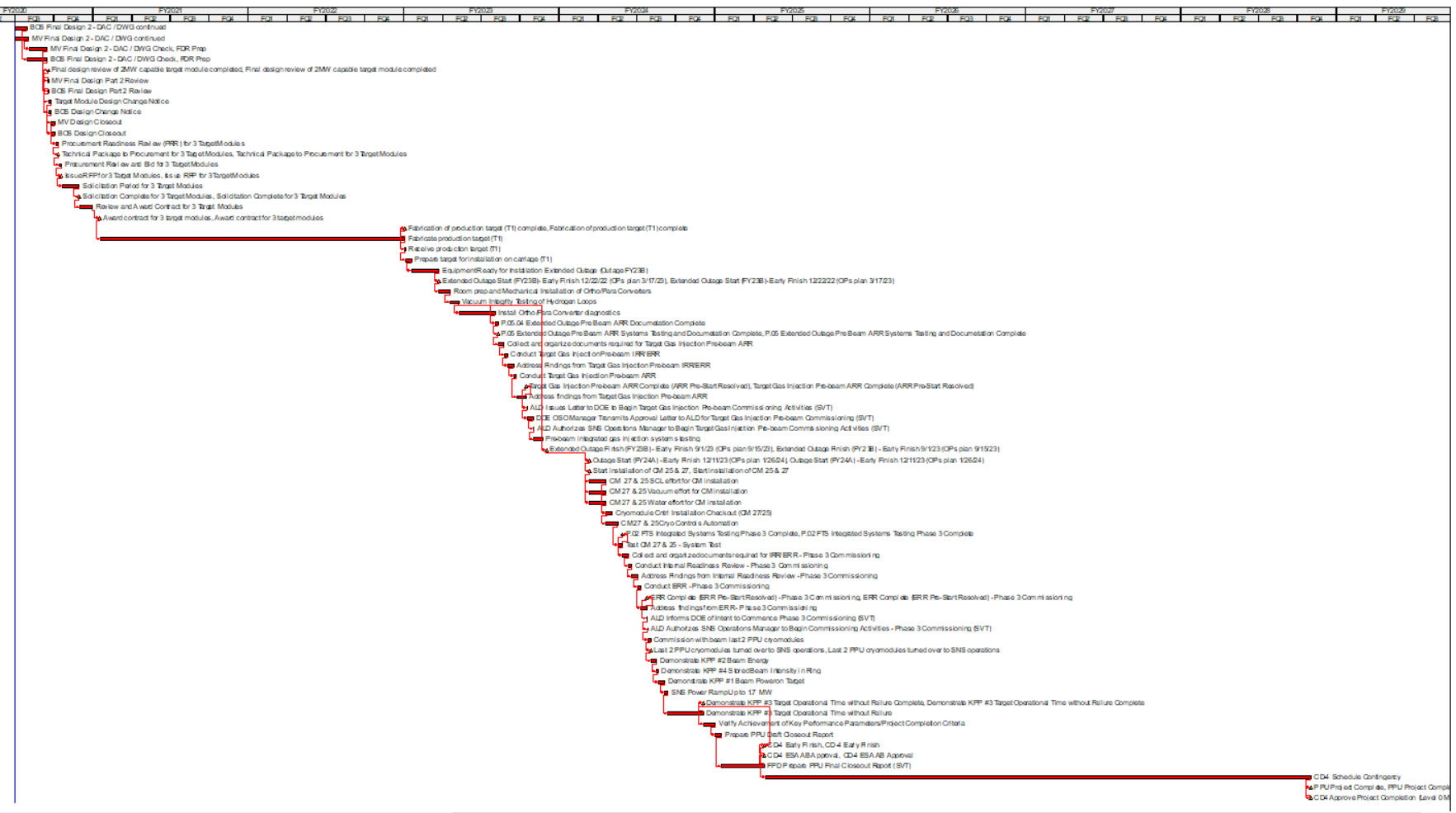
**Friday July 17, 2020 – via Teams (All times listed are in PDT, EDT, and CEST)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| PDT | EDT | CEST | Topic |  |
| 6:00 AM | 9:00 AM | 3:00 PM | Subcommittee Working Session | All |
| 7:00 AM | 10:00 AM | 4:00 PM | Full Committee Executive Session / Dry Run | All |
| 9:00 AM | 12:00 PM | 6:00 PM | Closeout Presentation | All |
| 10:00 PM | 1:00 PM | 7:00 PM | Adjourn | All |

Appendix D PPU Cost Table



Appendix E PPU Schedule Chart

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Appendix F PPU Management Chart

