SNS Accelerator Advisory Committee Report

March 8-10

2017

Contents

Introduction

The Accelerator Advisory Committee (AAC) for the SNS met March 8-10, 2017. This was the eighth meeting of the SNS ACC; the previous meeting was February 2016. Committee members are shown in Appendix A. Absent from this meeting were Craig Burkhart and Kazuo Hasegawa.

Accelerator Advisory Committee Charge

In this meeting, we were given a total of eleven charge questions in the context of two high-level objectives for the next two years. The objectives are:

A. By the end of FY 2018 achieve sustainable and predictable routine operation at or near 1.4 MW to the First Target Station (FTS) with availability against published schedule of ≥ 90% while using 3 target vessels per year.

B. Enable success of the Proton Power Upgrade project by providing key technical and management resources as required to meet project objectives.

Charge Questions

1. Do the capability and performance of the accelerator complex and neutron source support achieving Objective A?
2. Is the Prioritization process and Project Planning strategy that has been developed and is in use for outage planning reasonable?
3. Is the operating strategy with three outages per year reasonable?
4. Is the scope of work and prioritization process for ongoing and future Accelerator Improvement Projects (AIP) appropriate and balanced between the competing interests building necessary margin for routine operation at 1.4 MW while addressing system obsolescence?
5. Are non-AIP accelerator and beam delivery initiatives addressing issues of importance to present and future SNS operation?
6. Is the Beam Test Facility being utilized effectively to address items of importance to present and future SNS operation?
7. Are other test facilities (Ion Source Test Stand [ISTS], Cryogenic Test Facility [CTF], Radio Frequency Test Facility [RFTF], Modulators, etc.) being utilized effectively to address items of importance to present and future SNS operation?
8. Is the SNS response to issues with the existing Inner Reflector Plug (IRP-01) and the IRP under construction (IRP-02) reasonable and adequate? Are there key lessons learned from the IRP-01 and IRP-02 experiences that should be considered in the design and fabrication of the next-generation IRP (IRP-03)?
9. Is the SNS Target Management Plan a reasonable approach to improving both performance and understanding of SNS mercury targets?
10. Is the strategy and schedule for deployment of gas injection in mercury targets reasonable?
11. Are the SNS responses and ongoing actions to recommendations from the 2016 AAC meeting satisfactory?

Executive Summary

The committee is pleased to see that, since the last AAC meeting, sustained operations with beam powers between 1.0 and 1.2 MW have been achieved. The performance for FY16 and Q1 of FY17 has been impressive with 5,832 operating hours achieved in FY16 (with 4,230 hours delivered to the user community). Availability was 92.9% not including target failures. Target failures accounted for 47% of downtime in FY16. Excluding target failures, ≥90% availability is now regarded as routine.

Concern has grown over replacement of the Inner Reflector Plug (IRP). At the last meeting, we were told to expect replacement of this device during a shutdown occurring at the beginning of 2017. The installation is now delayed until the beginning of 2018 due to manufacturing problems. Any further slippage becomes problematic in that the IRP has a lifetime for useful neutron production, and degraded performance is already being seen.

The replacement RFQ has been successfully tested. Its performance meets the requirements for both present operation, and higher current operation needed for the Proton Power Upgrade (PPU). Unfortunately its replacement is scheduled to be coincident with the IRP installation (to avoid two long shutdowns), so it will not be installed until early 2018. However this is allowing further testing and beam characterization which is beneficial.

The SNS team has made great strides in adopting procedures to prioritize smaller projects and operational tasks. Included in this is transparency which allows one to see how decisions have been made. Along with this approach to work prioritization, SNS is moving toward a project-like approach to planning the work, namely a resource loaded schedule. While not fully there yet, the committee is pleased to see this and encourages SNS to continue to develop and use these tools. We believe they will be necessary during execution of the PPU Project. Regarding the PPU, we are pleased to see the progress that SNS has made in clarifying the technical challenges (we continue to believe they are under control), and identifying the challenges of executing the project work interleaved with operating the accelerator. However, upgrading an operating facility has been done at a number of laboratories recently, and in the experience of the committee, SNS is taking the appropriate steps to be successful.

I. Operations

Observations and Comments

The SNS team should be congratulated that since the last AAC meeting, sustained operations with beam powers between 1.0 and 1.2 MW have been achieved. The performance for FY16 and Q1 of FY17 has been impressive:

- In FY16 5,832 operating hours were achieved (exceeding the neutron production target of 5,000 hours), with 4,230 hours delivered to the user community. Availability was 92.9% (but this decreases to 86.4% if target failures of T12 in October 2015 and T13 in March 2016 are included in the statistics). Target failures accounted for 47% of downtime in FY16.
- FY17 started with excellent machine performance, but mitigating the recent Inner Reflector Plug leak has now resulted in some unplanned downtime.

Excluding target failures, ≥90% availability is now regarded as routine to the extent that the DOE is becoming less interested in this as a key performance indicator (being more concerned about hours delivered and beam power achieved). However, there is evidence from other neutron sources that availability is actually one of the most important factors in the user experience at such a facility, and hence should remain at the forefront of thinking on beam power levels and scheduling.

Performance metrics and downtime analysis at SNS are particularly strong and clearly show that the operations team has achieved year-on-year reductions in <1 minute downtimes, but that long downtime events continue to have significant impact on scheduling, performance, and beam power levels.

Recommendations

See Charge Question 1 for recommendations for Operations.

II. Shutdown Planning

Observations and Comments

Since last year, SNS has developed and implemented a new prioritization and outage planning process which is more quantitative and integrates overall facility activities.

All projects are put into the new tool to be categorized and scored under a number of criteria. The projects are categorized, based on funding stream, into one of five categories. The categories may be either an Accelerator Improvement Project (AIP), General Plant Project (GPP), Institutional General Plant Project (IGPP), Line Item Construction (LI/MIE), or Operational Improvement Project (OIP). The relative importance of projects is also considered within the context of mission imperatives. The criteria of delivering predictable and reliable operation, maximizing operating power, improving facility capability, responding to external drivers, and supporting externally funded projects are considered. SNS has developed a scoring methodology which includes relative weighting of the different criteria. The projects are also assessed by risk management, with discrete scores for probability and consequence being factored in. This process has undergone several iterations and now appears to be providing consistent, reasonable priority lists. The spreadsheet-based results of this process were on display and the committee felt it was significant progress over what had been in use last year.

Another significant tool that SNS is developing is a high-level block schedule for each outage. In this facility-wide schedule, activities that may impact the work of individual teams are listed, with examples being power outages, major projects, tunnel access restrictions for testing, etc. This effectively provides all potentially impacted organizations with a framework of scheduling constraints around which to detail their team level activities. It appears to be a good common baseline for coordination issues and constraints during an outage.

The project prioritization process provides a framework within which the highest-priority projects are selected for the next outage. There is extensive discussion of which projects should be included in an outage and the chosen projects are documented via memo by the RAD Director. A detailed outage schedule is then developed based on the project prioritization and constraints documented on the block schedule. This schedule has logical ties and is resource-loaded. The Accelerator Operations Group Leader now wears a double hat as the SNS Outage Manager and significantly, a professional project controls support person has been engaged to further enable this process. More recently, the schedule has been expanded to include standard maintenance activities. Refinements will continue. SNS is not yet making significant use of the resource-loading information and this is an obvious next step as they continue to improve and refine this process.

Recommendations

Recommendations for this topic are found in the answer to Charge Question 2.

III. Beam Test Facility (BTF), Ion Source, and RFQ

Observations and Comments

BTF: The buildup of the BTF has progressed greatly and is a significant improvement to operations and beam physics. Previous AAC meetings had noted that SNS should move forward with the BTF work and would benefit from testing of the new RFQ and other beam line elements. This has been accomplished and testing of the new RFQ was successfully completed. As expected, having the BTF allows for testing of beam line elements, diagnostics, and beam physics concepts. An important aspect of BTF is to mitigate risks as demonstrated with the new RFQ.

A first pass at possible subjects was displayed. It should be managed so that these planned and future experiments do not interfere with the laboratory's primary mission. Source development, LEBT-RFQ gate valve, chopper target, an upgraded emittance scanner and associated hardware should continue and be prioritized by supporting it with both labor and funds.

ION SOURCE: This past year (FY16) has been very productive for both ion source development and operations. Previous work on electron beam catcher and insulator thickness seems to have been resolved with little downtime associated with either issue. Additional improvements to cooling lines and their breakdown were identified and corrected largely by extending the length and the use of clear tubing to allow visual inspections. Source output has also improved and is at a level suitable for 1.4 MW operations with adequate margin. (As noted in previous AAC meetings: The limitations of the present RFQ do not provide adequate operating margin.) The present RF internal antenna design has made progress in understanding lifetime issues and with present antenna coating thickness should continue to fit into planned target changes. The results of these and more improvements resulted in ion source operations registering about 32 hours of downtime out of the approximately 5500 hours of operations. Contributing to the high up-time is the source group taking advantage of target and other outages to replace sources and perform repairs as not to incur downtime.

External antenna studies were continued first on the Ion Source Test Stand (ISTS) and then moved to the new BTF. However, the ISTS remains a critical part of operational reliability and should not be forgotten with the buildup of another test facility, the BTF. External antenna emittances as well as the beam current measurements from both of the test stands look very good. This is very good news and certainly shows the external antenna design could be a path forward to either a longer lifetime source or reliable alternative to the internal antenna design.

The SNS team has and will continue to play an active role in the source community. Collaborations with SNS expertise certainly help the source development field and should continue.

A LEBT vacuum valve looks to have passed the design stage and is being prepared for installation along with the new RFQ. Design improvements such as to cantilever it off the face of the surface will make the valve more operationally reliable. As noted in previous AAC meetings it is believed that the valve installation will improve operational reliability and up-time.

RFQ: The committee congratulates SNS for the successful testing of the new RFQ! The BTF has allowed the testing of the new RFQ at desired power and has verified its capability to deliver the desired beam parameters. The success of this work can't be emphasized enough and should allow SNS to move forward with the eventual swap of RFQs. The AAC heard details regarding the commissioning and conditioning of the new RFQ that were very encouraging. Good vacuum pressures, stable resonance and low reflective power certainly mean the SNS team should be confident in the mechanical operations of the new RFQ.

In addition, as configured in the BTF, the new RFQ has demonstrated the beam physics requirements needed for the PPU. The RFQ efficiency at the required beam current of 38 mA was measured to be about 88%. Higher beam currents were also demonstrated and show that the system has plenty of margin.

The old RFQ presently is planned to be moved to the BTF after the shutdown swap. Although it may be acceptable for BTF studies, it will not be good to re-install if the new RFQ fails since it will continue to have less than adequate performance for operational SNS needs. The AAC believes that the SNS should consider ordering an RFQ spare that would meet facility requirements.

Recommendations

None

IV. Superconducting Linac and SRF

Observations and Comments

The SNS team reported that the reliability and availability of the superconducting linac were generally good for the past 6 years, which is very encouraging. Some degradation of cavity performance is observed over time, but it can be recovered during outage periods. The committee commends the SNS team on the success of their "Superconducting Linac Stewardship Program."

The committee was happy to hear about significant progress on the preparation of a spare medium-β cryomodule, following a methodology similar to that used for the successful fabrication of the spare high-β cryomodule. Design improvements are being implemented, as was done for the spare high-β cryomodule. We view these efforts as being important to the SNS mission. The committee believes that the completion of the spare medium-β cryomodule before the ramp-up of PPU activities would be beneficial for both the SNS mission and PPU.

The SNS team reported that the cryogenic plant has generally been operating reliably, which is very encouraging. The plan to add a spare carbon bed for purification of helium gas returned to the CHL is viewed by the committee as being a good investment in sustainability.

The SNS team has made a significant investment in SRF infrastructure over the past several years. Recent R & D activities have been oriented toward better-quantifying preparation steps and cleanliness. The committee views this R & D work as being worthwhile for the existing SNS scope as well as future upgrades.

So far no funding has been made available for in-house etching or electropolishing. This necessitates outside partners for cavity R & D and cryomodule development. The SNS team might consider allocating some funding to (i) developing some minimal capabilities for chemical etching and (ii) planning for a future larger-scale facility.

Seven additional high-β cryomodules are needed for PPU. The plan is to out-source the fabrication of these cryomodules to a partner lab. This plan is similar to the approach that was used to build the existing linac.

Three high-β cryomodules have been plasma-processed, two of which are operating in the linac. All of the plasma-processed cavities showed improved performance; reductions in X-ray production are also observed after plasma processing. The increased gradients have helped increase the linac energy from 939 MeV to 972 MeV. The committee congratulates the SNS team on these excellent results.

Additional plasma processing in the SNS tunnel is planned for future outages, and the target cryomodules have been selected. A second plasma processing station will be used to allow for processing of two cavities in parallel; additional people have been trained in plasma-processing techniques. The committee views the expansion in capability as a good investment.

It is encouraging that no degradation in cavity performance due to particulate contamination has been observed in connection with plasma processing. However, the committee feels that the lack of contamination does not mean that it is time for a relaxation in vigilance—we hope that the SNS team will continue to be proactive in minimizing the risk of contamination in the superconducting linac.

A variable coupler has been developed for use in Dewar tests. It is anticipated that this will allow for measurements of the intrinsic quality factor after plasma processing. The committee sees this as being a worthwhile endeavor which will be of interest to the SRF community.

A partnership has been initiated with 2 other labs to study plasma processing of cavities of a different design and with different surface preparation. The committee sees this as a positive development which may ultimately benefit the accelerator community.

Recommendations

1. Proceed with the fabrication of the spare medium-β cryomodule; if possible, make sure the funding profile is adequate to complete this task in a timely manner.
2. Continue to emphasize the SRF R&D program at SNS, particularly to support PPU.

V. Ring and Accelerator Physics

Observations and Comments

The present Electron catcher for convoy electrons from the ring injection stripper is not properly aligned and does not absorb all convoy electrons, thus many are accelerated back to the foil holder and have caused thermal damage to the foil holder. A new removable catcher is being designed and is a priority for 1.4 MW operations. This has been included in the prioritization process and addresses a recommendation from the last meeting.

Stripper foil development is a significantly enhanced, ongoing development effort formally transferred (9/29/2016) to the Center for Nanophase Material Sciences (CNMS), co-located with SNS. The enhanced R&D effort should provide sustainable R&D progress on stripper foils able to withstand higher beam power and is especially important for the PPU and STS projects. At 1.3 GeV the stripper foil thickness needs to increase 8% and the energy deposited in the foil will be ~50% higher than at 1.0 GeV, thus significantly raising the foil temperature and reducing foil lifetime by an unknown factor. This is a critical area that requires productive and ongoing modeling and experimental efforts.

Laser stripping is a promising long-range, basic research effort that is being carried out by post docs and graduate students. It is a very commendable program that is making significant progress of great value to the larger Accelerator community and should continue to be supported.

The committee heard very promising progress on the renewed computational efforts on the development of "Self-Consistent Beam Distributions" along with possible hardware modifications to the SNS ring to create a self-consistent beam distribution. The next steps would be valuable checks on the feasibility of these changes and more study of the modeling, especially of fringe field effects.

Recommendations

None

VI. Target Systems (including IRP)

Topic: Target Operations & Summary

SNS operations have continued in the previous year with high up-time by limiting the beam power on target, proactively replacing a target, and reactively replacing a failed target.

Target 13 ran to 2600 MW-hr at which point it developed a leak. It was the second target to run for an extended time near 1.4 MW. Target 13 suffered cavitation damage similar to the Target 12 leak. Target 14 completed its run at 1.0 MW for 2700 MW-hr. Target 15 completed its run, but was preemptively removed for concern about potential damage based on T14 postirradiation examination (PIE). Target 16 operation has just begun -1.2 MW for 1700 MW-hr. Availability goals (90%) seem to drive operations, appropriately for a mature user facility. Target outages accounted for 47% of downtime.

Sixteen targets have been operated: 7 have leaked mercury. Current operational target is of the jet-flow design which is to reduce cavitation damage on the entry window. Improvements to the design are expected to be continuous, given time to incorporate solutions via the Target Management Plan. Changes in mercury flow path to reduce cavitation damage will continue to be implemented; for example, on the "corners" in addition to the window center. The structure has been optimized to resist cyclic loads. Inert gas will be mixed into the flowing mercury to reduce structural loading and cavitation damage. Only two spares are ready – both are not optimal designs (one original, one jet-flow). Four targets are in fabrication, all reinforced structurally, but two are still the original style of flow. Final design is finishing on the "blue" design; will start fabrication of two in the near future. Blue design was produced with a faster design iteration process. FEA has been improved with tetrahedral meshing – modelling is an extremely important component of the process.

Jet flow is a promising method to reduce cavitation damage. It has been successful on the proton entry window; it will soon be implemented on the "corners" with the blue target, and the result will be impactful for future operations and designs. Numerical simulation continues to be needed to understand and improve the design. Engineering judgement is extensively used in concert with simulations. Furthermore, the erosion model is known to be incomplete and requires further development and input from PIE.

Fatigue and cavitation damage can combine such that development of mitigation techniques on pressure waves and thermal stress is essential.

The target carriage has started to suffer several major issues: frozen rollers, vibration-loosened set screws, iron seal leaks, carriage drive has been stuck. These issues are not likely fatal, but are starting to complicate operations, add delay, and suggest increased risk. Repair or replacement should be seriously considered. A yearly plan should be made to address issues with the carriage.

The mercury processing system has several issues that have been identified, which may be exacerbated by gas injection. Flowmeters have failed; alternate/spare supply has been found. Replacement or repair should be considered, and needs to be coordinated with the schedule of major outages.

Recommendations

None

Topic: Target Management Plan

The Target Management Plan is the interface of engineering with operations. Ultimate goal is 1.4 MW, two target changes per year, no unplanned target exchanges. The goal of two changes per year is relaxed to three per year in the near future, however it increases the target production tempo.

In the Target Management Plan the PIE supplies the key information to allow the progression to higher power. Timing should be added to the schedule to make decisions for each of the next steps. The Target Management Plan, as described, is the only way to obtain realistic damage information and offers the greatest promise for future design improvements.

The eventual goals of 1.4 MW, two target changes per year, and no unplanned target changes are appropriate. In the short term, building to 1.4 MW with three target changes per year will be the approach to build confidence and gain operational data. This approach allows implementation of improved target features and collection of PIE results, while supporting a vital user program

The balance between operations and development conditions is considered in the Target Management Plan. The ongoing and planned activities which SNS is pursuing can still be expected to provide data to the team on future development needs in preparation for higher power (1.4 MW and above) on a useful time scale.

However, some uncertainty in the plan's execution does remain. The mechanism of mitigation by jet flow is understood only at a phenomenological level. The erosion on the corners may not be sufficiently mitigated by only the jet flow. In parallel, the numerical simulations should continue. Margin must be preserved for unmodeled effects such as radiation degradation and Liquid Metal Embrittlement (LME). Continue to reconsider the structural design of vessel, especially as it changes with other enhancements. PIE is important throughout this process.

The Target Management Plan is a living document, signed-off by division heads. Division heads are aware that additional resources are needed to achieve the plan and have therefore committed to increasing budgets to be consistent with the plan.

Recommendations

3. Management must be vigilant to support the budget needs of the target management plan as it evolves, particularly the support of ancillary activities such as PIE.

Topic: Hot-Cell Servomanipulators

SNS has two servomanipulator devices, absolutely critical for operations and PIE (the overhead devices in the service bay and the high bay). The vendor is out of business. Many parts are of high concern, particularly software which is a black box and cannot be re-engineered. Use of devices has already been limited to extend lifetime.

Potential outage during replacement is 3-6 months, therefore planning and coordination is required. These devices are used on a regular basis for PIE and target operations; they are used both during outages and between outages. Phasing the work will not be trivial, and performing work on proper conjunction with long outages will be critical.

Options were identified, and complete replacement chosen as the preferred approach (with using the high-bay device as contingency). A phased plan has been explored, but there are many inputs which may affect the schedule or technical requirements. Starting "Phase I – Project Planning" immediately would be efficient and prudent as risk mitigation. The phased replacement of the two devices is also prudent.

Two vendors were extensively investigated, both appeared to be adequate, and one preferred. Quantitative scoring of technical capability was used, but may be overly prescriptive and did not include issues of cost, risk, support, etc. Vendors were open to placing software into an "escrow" such that it would become available if the company failed or discontinued its product line; this is an attractive feature of the arrangement that should be pursued. Vendors are also willing to provide electronic board layouts and mechanical drawings.

Cabling is a particular issue that may require a different approach, and may not be supported by vendors. Some recabling could also be performed preemptively, though with significant risk and schedule impact.

Haptic feedback was identified as a strict requirement. This feature is not ubiquitous to remote handling machines and may only be customary to the SNS team. Its necessity and alternatives should be explored.

Customized machines are an optional alternative to a very general-purpose servomanipulator, but carry risks and costs related to storage and handling. While perhaps not so attractive, this option should not be ignored.

Recommendations

4. Produce a management plan or roadmap for replacement of the servomanipulators. This plan should include decision points and incorporate continuing input from operations and projects. Start proceeding with "Phase I" of project planning as soon as possible.

Topic: Source Development and Engineering

"Source Development and Engineering" is a group in the Instrument and Source Division. They are responsible for development, target systems, mercury target engineering, and manufacturing. This includes test stand, experimental devices, design analysis. Manufacturing management is a big deal – many complicated items have been coming in late.

This department implements many of its own processes for engineering data management. They seem to have systematic workflow methodologies and are intent on developing these approaches further. Integration of their management systems with the rest of the division / directorate / laboratory was less clear.

Recommendations

None

Topic: IRP Operation, Fabrication, and Development

The currently-installed IRP is approaching end-of-life and has developed a water leak. An initial replacement of the primary proton beam window temporarily stopped the leak (suggestive of two separate leaks: on PBW cooling and on concentric fluid lines). The second water leak required rerouting back into the closed loop. The exact location of the leak is not known. More investigations, particularly PIE may be necessary to identify the root cause of the leak in the IRP-01. The repair was clever and involved no operational compromises. It was executed safely and expeditiously.

SNS should be concerned about moisture within the core vessel and IRP. Corrosion can easily result from water and radiation products (ozone, nitric acid, etc.); this can strongly affect carbon steel, but also stainless steel and aluminum (windows). Circulation and treatment of the helium gas can proactively remove moisture from the vessel, in addition to standpipe draining (J-PARC has implemented such a recirculation system).

The original IRP-01 should be replaced as soon as IRP-02 becomes available. The production schedule for the IRP-02 has been longer than 8 years. During the final stages of fabrication, the IRP-02 developed a leak. The root cause of the leak was identified as the welding shrinkage of concentric piping, overconstraints, and interferences from other parts. The IRP-02 will be delivered in August 2017 if no additional issues emerge. Substantial effort from the SNS target team is required to maintain this schedule, particularly by working directly with the vendor on fabrication issues. The IRP-02 is scheduled for delivery in August 2017, and could arrive as late as October 2017 without affecting the outage schedule. However, planning for users is optimally set at least four months out so SNS management should anticipate any delays so as to provide enough warning to users.

IRP lifetime could be extended by proton power reduction, allowing greater up-time with optimal neutron characteristics, but lower intensity. Communication should be continued with instrument scientists on optimizing this approach, especially if further delay becomes likely.

The SNS team is pursuing design of the next generation IRP-03. Lessons learned from the operational experience with IRP-01 and issues with the manufacturing of IRP-02 are being incorporated into the design of IRP-03 – changes appear well conceived (laser welding and additive manufacturing could be further options). The robustness and lifetime of the IRP should be reconsidered for both IRP-03 and future devices, including issues of fabrication complexity and disposal. Future IRP construction plans have not been developed. The question of strategy with these devices was open (as well as many other single-points-of-failure within the complex): should a ready spare be on-hand? Increased beam power will shorten the lifetime of the IRP to as little as 6 years; an 8-year procurement cycle is not sustainable, particularly if an inventory is desirable. Plans for IRP-04 need to be initiated.

The effort to re-design the inner reflector plug with the goal of simplifying its exchange, increasing its service life, reducing the waste stream and at the same time improving moderator performance is clearly a step in the right direction. Given the difficulties in manufacturing the highly complex structure of the present design, any simplification that can help to avoid such difficulties is highly desirable. Conduct a detailed review of the inner plug design at the earliest possible point in time.

IRP form factor could be improved for disposal, by increasing its modularity. Different parts of the device will have quite different activations. Since its lifetime is limited by burn-up of the poison in the poisoned moderator, regular exchange of the whole plug is unnecessarily expensive for the facility; perhaps only the innermost section needs regular replacement. Lifetime extension of future IRPs could be pursued through improved moderators (replaceable, additional) and improved structural materials (better understanding of radiation damage limits of aluminum or alternate materials). Serpentine cooling channels in aluminum plate requiring many bolts and welds are to be replaced by a simpler channel system. This could further be improved by "conformal cooling": 3-D manufacturing of aluminum plates with integrated cooling channels.

A manufacturing group was created within the Instrument and Source Division (ISD) to overlay the design-and-build process. The intent is to reduce delays and flaws and improve documentation. Having a healthy procurement strategy makes the lab stronger in relationships with vendors, sponsors, users. Procurement model is now to have manufacturing engineers and a technical project officer between design engineers and manufacturers. This strategy can work if the properly motivated people are in the correct positions. This approach risks overly diffusing responsibility and adding communication complexity.

Recommendations

5. Consider PIE of IRP-01 to clarify the root cause of the water leak to inform the IRP-03 design.
6. Work with the vendor to deliver the IRP-02 per current schedule (August 2017) by providing support in engineering, welding, inspection, and leak testing. Actively anticipate any production delays in order to inform scheduling, in case a delay of the installation outage is required.
7. Consider off-line cryogenic testing of the IRP-02 prior the installation in December 2017.
8. Consider measures to increase the lifetime of future IRPs.
9. If possible, perform PIE on the removed proton beam window to find the water leak location on the core vessel side.

Topic: Mercury Target Engineering

The target is designed for 1.2B beam pulses, 10k thermal cycles (trip induced). The target is known to suffer from cavitation (asymmetric collapse of voids creating jets). Radiation damage of stainless is under control from studies; SNS has recently increased the limit on the shroud structure.

SNS has an erosion rate model by cavitation with fourth-power scaling – but it not consistent with T13 failure. The model is known to be incomplete, particularly as new operating conditions are encountered. Research should continue into these models both experimentally and computationally. Flow will be introduced at the corners of that target in hope of reducing cavitation erosion. The results of this experiment will be vital for defining the future path of SNS target design and construction, as part of the Target Management Plan. Further concepts should be developed to reduce the corner erosion.

Strain gauges have been introduced to the target and survive for an unexpectedly long time. Initial measurements have had inconsistent correspondence to simulation. At this point, it is unclear whether it is a sensor or target fabrication issue. Dynamic response measurements with fiber strain gauge are important to know in detail the effect of gas injection on pressure wave mitigation. The difference of measured strain time-responses between T13 and T15 needs to be better understood to allow quantitative use of this data. This is a promising tool that should be implemented on further targets to gain a consistent data history.

Stress fatigue on the body is now believed to be under control. However, it is well known that introduction of new design features has the potential to also introduce vulnerabilities. Vigilance must be maintained in the design sequence.

Targets are now capable of gas injection – awaiting the gas / mercury pump design (see "Topic: Target Gas Injection").

The FESAFE tool (sophisticated treatment of stress history) is used to evaluate fatigue. Engineering judgement is still used extensively. The design process includes structural design, FEA, and then fatigue analysis. Output of fatigue analysis is number of cycles at which fatigue damage starts (a conservative criterion). Inverting the question is not generally possible (e.g., allowable stress), and is too simplistic.

Contingent target swap is 8 days (declared time adds two days additional for float). This is admirably swift for such a complicated operation and allows user operations to continue with only nominal delay.

Recommendations

None

Topic: Post-Irradiation Examination (PIE)

An 8-step post-irradiation examination procedure has been developed for each target with mandatory and optional sections. This procedure is performed on all expended targets whether they completed their runs or developed issues.

Pressure decay test is performed first as a verification of leaks (or non-leaks) and verification of the operation burst disks. The videoprobe inspections on failed targets are vital to maintaining a history, and should be maintained. The videoprobes are expensive and are destroyed in the inspection process; the procedure is vital and needs to be continued, but less expensive alternatives could be explored.

Consistent damage and cracking of central baffle has been observed, not leading to failure, but putting the target into an unmodeled condition, potentially with parts colliding into each other. The feature is a liability as the target power is increased, and should be redesigned or removed.

Target sectioning has also become quite systematic for quantitative measurement of erosion and investigation of weld failures. Tensile tests are valuable for radiation-damaged properties of materials. Tensile testing of high-dose target material showed appreciable ductility remained in targets that operated to ~4200 MW-hr. Digital image correlation allows additional observations and data to be collected beyond the standard tensile test (for example, non-uniform flow of material was observed). Total elongations measured are 17-25% for irradiated steel, which when beyond 10% is considered adequately ductile. However, the measurements of total elongation performed at this facility tend to be systematically higher than at other facilities – a difference which should not exist and must be attributable to some issue such as sample preparation or surface finish. This anomaly should be understood in order to have confidence in measurements.

The T10 leak location was coincident with welding overpasses which could have increased the residual stress due to the repeated welding. The crack at the leak location extended via fatigue crack growth – fractography observations suggest low-cycle fatigue (a very reasonable conclusion). Even before exposure to operation, cracks were already created due to the welding process. Partial penetration welds are a problem for fatigue, and must be avoided through quality assurance practices during fabrication.

The most prominent feature determining cavitation damage on the target shell is the pressure wave interference pattern resulting from the thermal expansion of the mercury due to the energy deposited by the protons in the volume. The compression and rarefaction interference pattern is largely dominated by the structure mechanics of the target shell. Once erosion damage has occurred in the regions of long saturation time (in particular, in the center of the target window) other effects may come into play and determine damage propagation (for example, stress concentrations around erosion pits and pitting). One would expect that this leads to increased tensile stress in the center line of the target window and the center baffle and hence to crack propagation along these directions, as observed.

T12 and T13 experienced cavitation-induced erosion. A previous AAC recommended developing a technique to measure and characterize erosion. The hand-held laser-scanning technique takes 1 minute to scan a disc, producing a rough 3-D model with ~ 25 um resolution. Three discs were hand-scanned in the work cell. 0.7 mSv dose was accumulated for the full job. Dose may be acceptable. "Material removed" is the metric used – it is calculated from a nominal model of the coupon. Deformation could produce artifacts, but they would appear different than the erosion marks.

Quantitative, systematic data have been quite a step forward. PIE will continue to be responsive to conditions, but consistency is also quite valuable in making use of the quantitative data.

The proton beam window was removed with a water leak in the core vessel, but PIE was inadequate to find leak location. A vulnerability potentially remains. The Inconel window has been sectioned and sent to BWXT for tensile testing.

Recommendations

10. Support for PIE has been adequate, and must remain strong. PIE activities should be considered a mandatory component of the target lifecycle, and cannot be avoided or delayed indefinitely.

Topic: Target Gas Injection

He micro-bubble injection clearly has the effect to reduce the cyclic pressure pulse induced by proton beam bombardment, thereby reducing fatigue and cavitation-reduced erosion. It is essential, however, to consider the effective bubble condition; bubble size, population, and distribution throughout the target. One also must consider opposing effects, e.g., bubble coalescence. Furthermore, heat transfer capability will degrade due to the bubbles coalescing and creating an insulating gas layer. Flow resistance could also be increased. Finally flow-induced vibration of the gas line and other mercury lines may be an issue.

Gas injection is contingent on an extensive installation in summer. Expect that an accelerator-readiness review is required because of an unreviewed safety issue determination. October startup goal requires installation in summer to allow review. Good cooperation is required with the DOE site office. DOE needs to be delivered a plan (and buy in to it) on how SNS will stage, install, review, and address all safety issues. Several uncertainties remain in the process, and demonstration remains a priority for the ultimate success of the Target Management Plan.

Gas injection tubing has a spiral spring structure to rest within the inlet structure of the mercury target. It is a retrofit design, which admirably fits within the existing envelope, but is not necessarily optimal for the future. More integrated design will eventually be implemented (Blue). It is a once-through helium injection system. Flow of the initial system is low to avoid overflowing of mercury into the gas treatment system. Eventually an overflow will be added to the pump and gas-liquid separator (will occur significantly later – perhaps not until PPU). Gas could accumulate on heat exchanger or other locations to increase the mercury height. Initial installation is only a low-flow system, but is integral to achieving 1.4 MW. Eventual high-flow implementation is conceived, but has rightly been a lower priority.

Potential improvements with gas flow are a substantial reduction in the stress (leading to fatigue) and void formation (leading to erosion). These have been validated at various experiments, but the correspondence is not precise. Efforts should be made to reduce the pressure wave and imposed stresses as low as possible because of the uncertainty in the unique environment presented by mercury targets. It is difficult to quantitatively evaluate the effects in the design due to lack of data in the literature.

Experiments were performed at LANSCE-WNR with a mercury loop in a focused proton beam. Gas injection bubblers were chosen from about twelve options (two swirl, and one orifice). Reduced measured strain from 70 u to 20-40 u at a distance from beam spot – within the beam spot the data was not as clear. Initial cavitation reduced by ~ ½.

Pressure wave mitigation requires gas bubbles in the range of 50 μm radius and void fraction of at least 10^{-4}. The swirl bubbler successfully implemented in the JSNS target can deliver the proper bubble conditions, and should be evaluated by SNS to see if it can be retrofitted into the targets currently being fabricated, as an alternative to the SNS-designed bubblers. Consider cooperation with the J-PARC team.

To reduce the pressure-induced stress to a greater extent, gas curtain + bubbling are proposed. In this case, the gas flow rate will increase dramatically. Evaluate experimentally the gas flow rate under the condition with gas curtain + bubbling through the cold test, i.e., TTF loop, to decide the capacity of gas-supply-pump. Cooling to portions of the stainless steel body could be severely degraded with a gas curtain and must be critically evaluated. Thermal cycles of the target body may be more numerous with the intermittent coolant contact.

The gas bubble injection system has and will need significant effort – focus must be maintained. Improvement of analytical models to simulating mercury with bubbles is essential. Continued research on several avenues is required and the people required may not be available.

Recommendations

11. Maintain momentum towards deployment of the gas injection system as an integral part of the Target Management Plan.

Topic: Target Development Plan for 2.0 MW PPU

2 MW target design plans are at a very preliminary model. Intent is a workable 2 MW design without gas injection, and then take gas injection for additional reliability and longevity margin. Automated optimization tools were offered as a path, but they include great risk and cost as no initial estimate of performance improvement can be made and convergence can be elusive. PPU will need to develop a plan for a 2 MW target.

It is estimated from the design curve on fatigue, that the fatigue damage maybe more serious when considering other uncertainties related to the effects of radiation, LME, inclusion in Giga-cycle fatigue, and from the pitting damage.

Gas injection is expected to reduce the pressure load by some factor. However, the effect is not constant, but rather fluctuates with time. If the fatigue becomes critical in the new design, also maybe consider fatigue-life calculation by rainflow counting method because of the fluctuated loading. The gains from gas injection must be rejustified with every power regime. Margin must be maintained to account for the further uncertainties due to unique environment based on mercury and irradiation.

Part of the approach is to balance the unquantified benefit of gas bubble injection against the unquantified detriment of unmodeled effects. While these effects certainly cancel to some extent, they cannot be relied upon to cancel completely.

TOSCA simulation is planned to optimize various features. It is an iterative approach to reducing stress risers. There are numerous unmodeled effects. The approach is termed "Interactive Design

Space Exploration" and can result in arbitrary shapes. Issues of manufacturability must be handled manually as constraints to the model. Quantitative estimates of potential gain are elusive. Other experience with automated design process show that convergence sometimes fails, finds local optima, or finds unsatisfactory extrema that must be manually restrained (leading, again, to a lengthy, iterative design process). These tools must be used judiciously.

Recommendations

12. Start developing concepts for specific target features to allow 2 MW operation for PPU. The presented approach of "Interactive Design Space Exploration" may be valuable, but presents no specific concepts for marginal performance improvements. The gas injection data cannot (yet) be robustly extrapolated to those powers, and cannot be relied on as a design feature without additional research.

VII. Pulsed Power and Electrical Systems

Observations and Comments

The committee is pleased to see that most of the proposed improvements recommended for the HVCM have been implemented. This includes IGBT snubbers, an improved trigger control resulting in correction of the output voltage droop, and operation at full pulse width. These have resulted in the elimination of the catastrophic IGBT failures.

The alternative topology modulator has been implemented. Under testing, it demonstrates improvement in operation at higher power levels. A decision on the conversion of HVCM to the new topology should be made.

Preventive maintenance replacement of high failure rate capacitors will keep the modulator reliability high until a confirmed replacement can be installed.

The use of an oil gas analyzer could detect incipient failures inside the tank before they become a serious problem requiring a long down time.

At present, SNS does not have enough klystron spares to cover all sockets. As all klystrons could reach end of life in a rather short window of time, SNS should consider ordering more spares before this happens.

Recommendations

None

VIII. Controls

Observations and Comments

The team's responses to 2016 recommendations were good. In particular:

- Participation in DHS Industrial Control Systems Joint Working Group is very interesting.
- System validation using ICS-Cert tools and action taken as a result is to be commended.
- Disk-to-disk backup is a good enhancement.
- Testing restore from backup regularly.

- Code management for PLCs is moving forward. The commercial tool (Asset Center) being used looks powerful. The team has adopted standard processes and procedures in this area, which is essential to success. The adoption of any tool will not provide success without this discipline in place.
- The team should keep moving forward to include PPS in the code management system in FY18.
- CSS Display Builder approach looks promising.

There were an increased number of hardware failures last year (although Controls downtime was still within its downtime budget). This may be a situation the team will have to live with for a while, as other facility obsolescence issues take priority.

The steps made to address obsolescence from within a group's budget, for example, the rolling program of CPU replacements, are a good approach. Moving from obsolete VME OMS58 to a PLC solution shows good and appropriate use of newer technology to reduce system cost, complexity and improve supportability.

The decision to hire early career staff is good, given that a good proportion of existing staff are in their later career stages.

The group leader achieved significant diversity in hiring (60% of new hires are female or underrepresented minorities) which is highly commended.

The new hires in the process control section seem to be a direct result of a bottleneck in this work, revealed by the much-improved project prioritization process. This speaks to the importance of the prioritization process and management willingness to act on the information revealed by it.

The team continues to provide effective support and integration for other technical systems, allowing improvements to accelerator performance. An example of this is seen in the work to improve chopper control and to provide faster shutdown response to part of the PPS.

Recommendations

13. The evaluation of the SLAC archiver was a good exercise and revealed some shortcomings when applying the tool to SNS use. The team should look for collaboration opportunities in archiving before going it alone. SNS requirements are unlikely to be unique in the community.
14. The choice of platform for high performance elements of the control system are perhaps “religious” issues, with no one solution gaining universal acceptance, in the way VME had at the time of the original SNS construction. Consider holding a design review for the high-performance system (currently uTCA) solution to ensure it meets current requirements, has room for future growth and is cost effective.

IX. Diagnostics

Observations and Comments

The committee was pleased to hear the report on the progress and plans for very ambitious and innovative 6D phase space measurements at the Beam Test Facility. The measurement data will provide new capabilities for experimental validation of beam physics simulations and numerical models.

It is very important to measure the ring injection stripper foil temperature at present operating currents. Measurements using thermal imaging are promising and are strongly encouraged. With this data as a baseline, the temperature increases for PPU and STS power levels can be more reliably calculated from good models.

Hardware and software obsolescence is a recurring theme for diagnostics as well as other systems. Obsolescence is a growing concern and is being continually addressed in a systematic facility-wide approach. Additional funding is needed to address the problem and the committee was gratified to learn that the diagnostics AIP-37 (Beam Instrumentation Infrastructure Upgrade) is scheduled to begin in FY17. However, we note that a substantial portion of diagnostics obsolescence mitigation will be done with operational funding.

Recommendations

None

X. Proton Power Upgrade and Second Target Station

Observations and Comments

As was the case at last year's meeting, the Proton Power Upgrade (PPU) project and the Second Target Station (STS) project remain separated. A pre CD-1 Director's review of the PPU Project was recently held that determined that technically the PPU is ready to proceed. That committee's reviewers, as well as this committee, believe that there are no significant technical challenges with accelerator systems in achieving PPU goals. Some challenges exist in the target systems and are addressed in that section.

Regarding the execution of project related work, a draft Project Assumptions Document has been written which defines the work scope that will be done by the NScD operations budget. These are items that ensure the SNS is capable of delivering beam at 2.0 MW and 1.0 GeV, the design deliverables of the SNS project. Therefore this work is planned and ongoing.

A concern of the SNS staff, and of reviewers (i.e., pre CD-1 review), is the effective matrixing of the SNS staff such that both operations and the project can effectively be done. At the last AAC meeting, this committee noted that…

> "It is therefore essential that SNS develop the outage planning tools (e.g., using resource loaded scheduling during outages, and well developed prioritization) to be ready for PPU installation work."

We feel that SNS has made significant progress over the past year in addressing this approach. The organization has embraced this mindset. For the present work, this is moving in the right direction and the push needs to continue. Until there is actual PPU work, a final assessment cannot be made but the committee feels that application of these tools prior to the PPU is essential.

Recommendations

15. Continue to develop and use the Project Prioritization System for all ongoing SNS work, keeping in mind the factors that the PPU project will bring to this challenge. More on this is in charge question 5.

XI. Charge Question 1: Do the capability and performance of the accelerator complex and neutron source support achieving Objective A?

Observations and Comments

The SNS accelerator complex as it stands today is capable of meeting Objective A, but with very little operational margin. Considerable progress has been made since the last meeting on the key accelerator performance improvements required to achieve a suitable beam power margin and to mitigate known vulnerabilities for high power operation. The trajectory of this work appears to be correct and well aligned with the required timescale of the end of FY18.

Efforts to increase the beam power margin have concentrated on the ion source performance (increased current and extended source lifetime have both been demonstrated), the spare RFQ (which has been fully tested on the BTF and is now ready for installation on SNS), *in situ* plasma processing (on track for 1 GeV operations in 2018) and smart chopping (new infrastructure installed and waiting for test). Most of these developments have been commented on extensively and positively elsewhere in this report.

Vulnerabilities for operating at high power are being addressed with new in-house foil production capabilities and an electron catcher redesign, but further R&D will be required to be confident of meeting the high power specification.

Since the last meeting, significant progress in target technology has been made for target design and development, including a better understanding of current cavitation damage erosion limits, improved post-irradiation examination, and initial implementation of gas injection. The Target Management Plan has been assembled to manage the risk of user program interruption while successfully handling increasing beam powers and advancing jet-flow target operation with incremental design improvements.

Recommendations

16. Keep doing what you are doing on gathering performance metrics, analyzing data and underpinning operations by tackling shorter downtimes.
17. Keep doing everything possible to tackle long downtime events, primarily focusing on understanding and alleviating target failures (see Charge Questions 8 – 10).

XII. Charge Question 2: Is the Prioritization process and Project Planning strategy that has been developed and is in use for outage planning reasonable?

Observations and Comments

Yes, a new process is in place which is more quantitative and integrates overall facility activities. This strategy of quantifying the project prioritization process, selecting the highest priorities for the next outage, documenting this set of priorities via memo, documenting the facility-wide schedule/constraints, and implementing and updating a detailed outage schedule with logical ties and resource loading is now in place and being refined. This appears to be a reasonable process/strategy and refinements of it continue.

Recommendations

18. As SNS continues to use and refine this process, start quantitatively analyzing the available resource loading information.

XIII. Charge Question 3: Is the operating strategy with three outages per year reasonable?

Observations and Comments:

The committee is satisfied that the three outages per year operating strategy is appropriate for managing predicted target lifetimes and avoiding unplanned outages.

A "typical" three outage year is expected to have two outages of about six weeks each and one outage of about two weeks. These outages must facilitate target changes and also provide for accelerator and source maintenance and development. This new regimen will provide roughly the same number of operating hours as the current two outage year but limits the maximum duration of maintenance periods. Therefore there will be some reduction in flexibility for doing accelerator work, but this is considered to be something which can be managed.

The RAD Division Director has produced a convincing long range facility schedule to 2025 based on three outages per year which takes account of requirements for 1.4 MW operation by the end of FY 2018 and the Proton Power Upgrade.

Recommendations

19. The team should review the effectiveness of the three outages per year operating strategy at regular intervals to ensure it remains optimal.

XIV. Charge Question 4: Is the scope of work and prioritization process for ongoing and future Accelerator Improvement Projects (AIP) appropriate and balanced between the competing interests building necessary margin for routine operation at 1.4 MW while addressing system obsolescence?

Observations and Comments

The scope of work being considered seems appropriate with both building operating margin and addressing obsolescence projects being submitted. The number of projects that can be funded causes the committee some concern.

Going forward, with the need to address operating margins, obsolescence, and preparing the accelerator for the PPU, the current funding level seems unsustainable. A level of funding of between $5-7M seems reasonable from the evidence presented to the committee.

The prioritization process used appears similar to the broader process presented for project prioritization. There could be much merit in making these processes as similar as possible if not the same. The process appears to be fit for purpose and should continue to be improved as experience is gained.

Recommendations

None

XV. Charge Question 5: Are non-AIP accelerator and beam delivery initiatives addressing issues of importance to present and future SNS operation?

Observations and Comments

This question overlaps with both Charge Questions 2 and 4. The project prioritization and outage planning processes are significant improvements to consolidating activities into a single, coordinated story of what SNS needs to plan to in the coming years. This integrated, documented prioritization and planning process has the potential to improve communications and efficiency.

While the Prioritization Plan does not answer Objective B in its entirety (i.e., it does not describe how effort resources are provided), the Prioritization Plan is necessary to establish a culture where Objective B can be met, and additionally to understand how to make decisions to meet the objective.

XVI. Charge Question 6: Is the Beam Test Facility being utilized effectively to address items of importance to present and future SNS operation?

Observations and Comments

Yes, the Beam Test Facility (BTF) has successfully moved from concept to operation over the last year. The BTF has proven its worth with the qualification testing of the new RFQ.

Emittance, energy and transmission measurements of the new RFQ have been completed reducing the risk associated with the upcoming RFQ swap.

Developments of new ion sources, LEBT hardware, and operational components have already started. Additional plans are being developed that will extend the use of the BTF proving itself a critical asset for SNS.

Recommendations

None

XVII. Charge Question 7: Are other test facilities (Ion Source Test Stand [ISTS], Cryogenic Test Facility [CTF], Radio Frequency Test Facility [RFTF], Modulators, etc.) being utilized effectively to address items of importance to present and future SNS operation?

Observations and Comments

Yes, we saw evidence of this and encourage the on-going use of these important facilities. Test stands are notoriously difficult to construct from a funding point of view, but they are invaluable for maintaining operational viability and developing new capabilities. As these facilities at SNS presently exist, they should be treated as a required operational resource.

XVIII.Charge Question 8: Is the SNS response to issues with the existing Inner Reflector Plug (IRP-01) and the IRP under construction (IRP-02) reasonable and adequate? Are there key lessons learned from the IRP-01 and IRP-02 experiences that should be considered in the design and fabrication of the next-generation IRP (IRP-03)?

Observations and Comments

The SNS response to the issues with the IRP-01 and IRP-02 is quite reasonable and adequate. Thorough investigation of the water leak in IRP-01 enabled development and implementation of a repair plan. The leaking water was rerouted back into the closed loop to avoid accumulation of liquid waste. SNS was able to restart delivery of proton beam with nominal parameters to the target.

A leak was detected in the IRP-02 at the last stage of fabrication. The root cause of the leak has been identified and reassembly of the IRP-02 is in progress with prudent design modifications.

The SNS target team is designing IRP-03 to incorporate several new features to address lessons learned from operation of IRP-01 and fabrication of IRP-02. They have simplified manufacturing and increased lifetime up to 50 GWh while maintaining the current physics design. Particularly, more robust joints of helium lids were introduced to avoid possible leaks which appeared in both IRP-01 and IRP-02. Split aluminum plates were removed. The complicated and hard-to-fabricate water cooling channels were replaced with deep hole drilling. Transfer lines will be modified for easier manufacturing. Water and helium layers will be branched off from concentric lines just above intermediate IRP instead of at top of IRP. Cadmium coating will be applied to different surfaces to simplify fabrication process. Further enhancements appear possible, but must be approached within the limits of the schedule.

Management of the construction of the IRP has been identified as an issue as its construction timeline has stretched to eight years, which is not sustainable in the future (when the lifetime will be shorter as measured in years). A manufacturing group has been assembled within ISD with the goal of accelerating and improving management of large procurements for technical items such as the IRP as well as targets, beam windows, and other components.

Recommendations: (repeated from report text)

20. Consider PIE of IRP-01 to clarify the root cause of the water leak to inform the design.
21. Work with the vendor to deliver the IRP-02 per current schedule (August 2017) by providing support in engineering, welding, inspection, and leak testing. Actively anticipate any production delays in order to inform scheduling, in case a delay of the installation outage is required.
22. Consider off-line cryogenic testing of the IRP-02 prior the installation in December 2017.
23. Consider measures to increase the lifetime of future IRPs.

XIX. Charge Question 9: Is the SNS Target Management Plan a reasonable approach to improving both performance and understanding of SNS mercury targets?

Observations and Comments

The Target Management Plan is a detailed plan to obtain realistic damage information and offers the greatest promise for future design improvements. It must be pursued aggressively.

The eventual goals of 1.4 MW, two target changes per year, and no unplanned target changes are appropriate. In the short term, building to 1.4 MW with three target changes per year will be the approach to build confidence. This plan allows implementation of improved target features and collection of PIE data, while supporting a vital user program.

However, some uncertainty in the plan's execution does remain. Jet flow has successfully mitigated erosion at the inner beam window, but will only later be implemented in the corner regions. Mitigation of erosion in the corners is reasonably expected, but not yet proven; results from implementation as part of the Target Management Plan will be invaluable to future development. In parallel, the numerical simulations of void cavitation should continue. Margin must be preserved for unmodeled effects such as irradiation degradation and Liquid Metal Embrittlement (LME). Continue to reconsider the structural design of vessel. PIE is important throughout this process.

The plan is a living document, signed-off by division heads. Division heads are aware that additional resources are needed to achieve the plan and have therefore committed to increasing budgets to be consistent with the plan.

Recommendations (repeated from report text)

24. Management must be vigilant to support the budget needs of the target management plan as it evolves, particularly the support of ancillary activities such as PIE.
25. Support for PIE has been adequate, and must remain strong. PIE activities should be considered a mandatory component of the target lifecycle, and cannot be avoided or delayed indefinitely.

XX. Charge Question 10: Is the strategy and schedule for deployment of gas injection in mercury targets reasonable?

Observations and Comments

The He micro-bubble injection has the effect to reduce the cyclic pressure pulse induced by proton beam bombardment. Reducing the pressure pulse mitigates both erosion and stresses in the target body – both prominent failure modes of previous targets.

Initial gas injection will be implemented this year with low flow rate, with an upgraded system to come later, perhaps with PPU. Safety assessment is still required for the initial implementation this year with an aggressive schedule. The external data on mitigation effect with this low flow rate are in tension; therefore the results will be of experimental interest and inform later efforts. Consequently, timely implementation of this system is important both for short-term gain and for long-term benefit with the ultimate gas injection system.

The R&D activities have been extensive, but there is still much work to do, even for the initial system. An aggressive approach must be maintained to validate this potentially powerful mitigation. Focus on the near-term system should not be deterred by the need of a higher flow system.

Recommendations: (repeated from report text)

26. Maintain momentum towards deployment of the gas injection system as an integral part of the Target Management Plan.

XXI. Charge Question 11: Are the SNS responses and ongoing actions to recommendations from the 2016 AAC meeting satisfactory?

Observations and Comments

The committee saw considerable evidence that the recommendations made in the previous year have been addressed, and followed even with enthusiasm! We are grateful to the SNS staff for responding in this way. Only one recommendation relating to gas injection in the target remains open. We note that considerable work is going into this issue.

Some of these recommendations are shown as closed but are acknowledged to be ongoing… this is particularly true in the area of project prioritization. For instance, we encourage more detailed plans involving resource loading and look forward to seeing evidence of this in coming years as noted in the recommendation associated with Charge Question 2.

Appendix A: AAC Committee Members 2017

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Appendix B: Accelerator Advisory Committee Meeting Agenda

March 8-10, 2017

Building 8600

Time	Length	ID	Event	Lead	Location
Event Contact: Lisa Eady, 865-574-0557 (office); 865-567-7202 (mobile); eadylb@ornl.gov					
Wednesday, March 8, 2017					
7:45-8:00 am	*15*		*Badging in the SNS Main Lobby (1st Floor)*	*Committee*	*8600*
8:00-8:30 am	30		Executive Session	Committee Only	C-156
8:30-8:45 am	15	P1	Welcome	Kevin Jones, Division Director, Research Accelerator Division (RAD)	C-156
8:45-9:15 am	30	P2	Management Overview and Responses to 2016 AAC Recommendations	Kevin Jones	C-156
9:15-9:45 am	30	P3	SNS Operations Report for FY16 and FY17 – Q1	Glen Johns, Group Leader, Accelerator Operations	C-156
9:45-10:00 am	15		Discussion	All	C-156
10:00-10:20 am	*20*		*Morning Refreshment Break*	*All*	
10:20-10:55 am	35	P4	Overview of PPU and STS Projects	Mike Plum, Accel. Physics Team Leader, Accelerator Physics, Beam Instrumentation and Ion Source (APBIIS)	C-156
10:55-11:30 am	35	P5	Status of Technical Initiatives to Support 1.4 MW Reliable Operations	Sarah Cousineau, Group Leader, APBIIS	C-156
11:30am-Noon	30	P6	Overview of Target Status	Mark Wendel, Group Leader, Source Development and Engineering Analysis	C-156
12:00-1:00 pm	*60*		*Working Lunch / Report on PPU Director's Review*	*Pick up lunch in C-150 and return to C-156 to eat*	*C-150*
1:00-2:30 pm	90	P7	Overview of Inner Reflector Plug (IRP) Issues	Kevin Jones and Don Abercrombie, Director, Instrument and Source Division (ISD)	C-156
2:30-2:45 pm	15		Discussion	All	C-156
2:45-3:00 pm	*15*		*Afternoon Refreshment Break*	*All*	
3:00-3:30 pm	30	P8	The SNS Accelerator Improvement Project (AIP)	George Dodson, Deputy Director, RAD	C-156
3:30-4:10 pm	40	P9	Prioritization Process and Project Planning	Kevin Jones and Glen Johns	C-156
4:10-4:30 pm	20		Discussion	All	

Wednesday, March 8, 2017 (cont.)					
Time	Length	ID	Event	Lead	Location
4:30-5:30 pm	60		Executive Session	Committee Only	C-156
6:00-8:00 pm	*120*		*Dinner and Discussion – Kevin Jones, Accelerator Science & Engineering at ORNL – at Calhoun's in Oak Ridge*	*Committee and Presenters*	*Private Room*

Thursday, March 9, 2017					
Time	Length	ID	Event	Lead	Location
8:00-9:30 am	90		Tour of SNS Accelerator/Target Facilities. Depart from Conf. Room C-156.	George Dodson / Sarah Cousineau / Mike Baumgartner, Group Leader, Mechanical Systems & Operations / Mark Champion, Group Leader, Electrical and RF Systems	C-156
9:30-9:45 am	15		Executive Session	Committee Only	C-156
Accelerator Breakout Sessions					
9:45-10:30 am	45	A1	Beam Test Facility Performance Update	Sasha Aleksandrov Team Leader, APBIIS	C-156
10:30-10:50 am	*20*		*Morning Refreshment Break*	*All*	
10:50-11:25 am	35	A2	Ion Source Performance and Progress on the External Antenna Source	Robert Welton, APBIIS	C-156
11:25 am-Noon	35	A3	Status of Linac High Voltage Converter Modulators Upgrades	David E. Anderson, HVCM Team Leader, Electrical & RF Systems	
12:00-1:00 pm	*60*		*Working Lunch / Long Range Plan for SNS to 2025*	*All*	C-156
1:00-1:30 pm	30	A4	Laser Stripping Experiment Status	Reheman Abudureyimu, APBIIS / UT	C-156
1:30-2:00 pm	30	A5	SNS Stripper Foil Production and R&D	Mike Baumgartner	C-156
2:00-2:30 pm	30	A6	Control Systems Status and Upgrades	Karen White, Group Leader, Control Systems	C-156
2:30-3:00 pm	30	A7	Self-Consistent Beams in SNS	Mike Plum, APBIIS	C-156
3:00-3:20 pm	20		Discussion	All	C-156
3:20-3:40 pm	*20*		*Afternoon Refreshment Break*	*All*	
3:40-4:10 pm	30	A8	Status of the Accelerator Radio-Frequency Systems	Mark Champion	C-156
4:10-4:40 pm	30	A9	Beam Diagnostics Systems, Status and Upgrade	Sasha Aleksandrov	C-156

Thursday, March 9, 2017, Cont.					
Time	Length	ID	Event	Lead	Location
Accelerator Breakout Sessions, Cont.					
4:40-5:10 pm	30	A10	Superconducting Linac Systems (SCLS) Status and SRF Activities	Sang-ho Kim, Group Leader, Superconducting Linac Systems (SCLS)	C-156
5:10-5:30 pm	20		Discussion	All	
5:30-6:00 pm	30		Executive Session / Questions for SNS Management	Committee Only	C-156
6:00-7:00 pm	60		Executive Session	Committee Only	
Target Breakout Sessions					
9:45-10:30 am	45	T1	Options for the Servo Manipulator Replacement	Rick DeCosta, Engineer, Control Systems Group	C-152
10:30-10:50 am	*20*		*Morning Refreshment Break*	*All*	
10:50-11:10 am	20	T2	Overview of Source Development and Engineering	Mark Wendel	C-152
11:10 am-Noon	50	T3	Mercury Target Engineering Design & Analysis	Drew Winder, Team Lead, Mercury Target Engineering	C-152
12:00-1:00 pm	*60*		*Working Lunch / Long Range Plan for SNS to 2025*	*All*	C-152
1:00-1:30 pm	30	T4	Fabrication of Major Neutron Source Components	Peter Rosenblad, Team Lead, Manufacturing	C-152
1:30-1:50 pm	20	T5	Second Generation IRP Design	Jim Janney, Target Systems Engineer	C-152
1:50-2:40 pm	50	T6	Post-irradiation Examination Activities	David McClintock, Material Scientist	C-152
2:40-3:20 pm	40		Discussion	All	C-152
3:20-3:40 pm	*20*		*Afternoon Refreshment Break*	*All*	C-152
3:40-4:20 pm	40	T7	Implementing Gas Injection at SNS: Short and Long Term	Bernie Riemer, Team Lead, Engineering Analysis	C-152
4:20-4:40 pm	20	T8	Target Design Reaching for 2 MW	Saul Kaminskas, Engineering Analyst	C-152
4:40-5:30 pm	50		Discussion	All	C-152

Friday, March 10, 2017					
Time	Length	ID	Event	Lead	Location
8:00-11:00 am	180		Executive Session / Management Response to Questions	Committee Only	C-156
11:00 am-Noon	60		Closeout	All	C-156