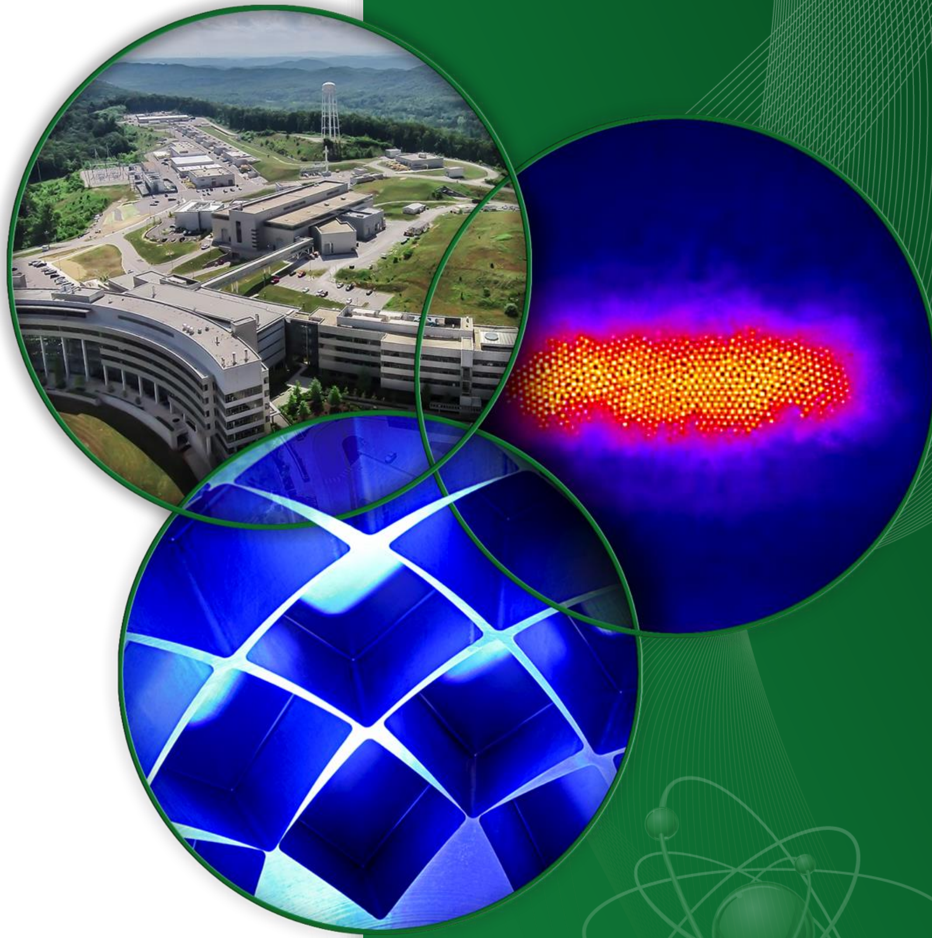
2015 SNS AAC Close-out

March 24-26, 2015



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Ion Source & Integrated test stand facility

Observations and Comments

- Ion source reliability has been very good. Antenna failure rates are much reduced (1 failure since the last review). Plasma outages/gas flow tradeoffs are part of an ongoing optimization process.
- The ion source test stand is operational again. It is nice to see that external antenna development has resumed.
- Production sources 2 and 4 are preferred over source 3. The assumption is that the emittance is larger in 3, but would be good to verify with new measurements on the test stand, and inspect carefully mechanical differences to see if it can be understood.
- LEBT has been reliable. A routine change-out is now done twice a year (insulator coating).
- LEBT gate valve had been removed due to reliability issues, but now the need for it to be reinstalled has been realized (recent accidental ventings of the RFQ). Improvements have been made, and it now seems reliable on the ion source test stand. It should be reinstalled in LEBT so that in the future, one will be able to keep the RFQ under vacuum during source and LEBT maintenance, which should lead to better overall RFQ performance.

Ion Source & ITSF (cont)

- A major MEBT vacuum water leak occurred in September, 2014, during a machine downtime period. (6 weeks to disassemble, clean, and re-establish to beam). The leak occurred in the chopper dump, which has been removed since the MEBT chopper use has not been essential, and any benefit with respect to reduction in losses was limited.
- ITSF gives SNS a very important capability to perform studies of the LEBT, RFQ, and MEBT, all of which facilitate improvements to the front end.
- Almost all equipment is in place for RFQ testing with beam. Remaining items are the beam stop shielding, and the PPS.

Recommendations:

1. After further testing continue plans to reinstall the LEBT valve to better protect the RFQ vacuum.
2. Beam tests at the ITSF should be done ASAP. While seemingly not an option, early operation at low rep rate prior to installation of the PPS would allow timely measurements of transmission, energy and emittance.

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SCL and SRF

Observations and Comments:

- The **spare high-beta cryomodule** fabricated in-house by SNS was demonstrated to have good performance and was shown to be an asset to the SNS linac. This is **a significant and impressive achievement**. The committee commends the SNS team on their work and their results.
- A **substantial investment has been made by SNS in infrastructure** for superconducting cavities and cryomodules, including a clean room, a heat treatment facility, a cavity test facility, and a cryomodule test facility. **This is a good substainability investment**, considering the importance of SRF cavities for SNS.
- A plan was presented for an on-site small-scale **electropolishing facility** for SRF cavities. The goal of using alternative methods in order to avoid the need for hydrofluoric acic was articulated. Alternative methods may have the potential to reduce substantial safety hazards associated with cavity surface preparation; if successful, such methods could provide significant benefits for the entire SRF community. The possibility of a larger production-oriented facility was mentioned.

SCL and SRF (cont)

- Results from **plasma processing** were presented. This technique appears **very promising**. The committee commends the SNS team on their work and results. The committee feels that plasma processing has **good potential** to remedy problems with the linac cryomodules. Plasma processing tests in a configuration which allows RF measurement of the quality factor (e.g. in the vertical test area) would be useful and of interest to the SRF community.

Recommendations:

1. Proceed with plans for on-site electropolishing. The committee agrees with the plan to develop a small-scale facility as a first step. The committee supports the goal of exploring alternative methods with reduced safety hazards.

2. The committee accepts plans for spare medium-beta cryomodule. However we encourage the inclusion of the procurement of the spare into the project prioritization process.

3. Proceed with plans for plasma processing. Consider additional plasma processing tests in a configuration where the *Q* can be measured. Plan the in-situ plasma processing carefully to minimize the risk of particulate contamination in the linac.

High Power rf

Observations and Comments

- With the installation of the improved IGBT gate drive circuit with fault detection, the addition of the IGBT snubber to eliminate overvoltage on the IGBTs, as will as the preventive maintainance replacement of the high voltage resonance capacitors has improved the availability of the HVCM.
- Intensive maintenance is required during downtimes to maintain the availability of the HVCM during operation.
- The new controller has been designed and lifetime tested in a test stand that will allow for pulse voltage droop control and remote monitoring of the operating HVCM supply.
- The alternant topology, with the strip line buss connection, now under evaluation is the upgrade to the HVCM that is the most likely approach to solve the on going high voltage corona and IGBT failure problems in the modulator
- There have been several premature klystron heater failures with unknown causes, resulting in significant operation down time. Concerns remain for klystron lifetime and spare availability.

High Power rf (continued)

Recommendations:

1. Complete replacement the improved IGBT gate drives and snubber networks.
2. Implement the new controllers on a HVCM in the linac to verify operation into beam loading cryogenic module.
3. Replace all HVCM with new controller as soon as practical.
4. Complete evaluation of the alternant topology in the test stand at full power levels. The alternative topology could have a significant impact on the ongoing maintenance of the HVCM.
5. Monitor all klystron saturation characteristics and adjust heaters for minimum operating temperature and track heater adjustment trends to assist in indicate end of life.

Controls

Observations and Comments:

- The Protection Safety team and the Process Controls team appear to be on the critical path and are their capacity appears to be a limiting factor on progress for a number of projects, e.g. ITFS, RFQ
- Installed equipment approaching or reaching obsolescence is a situation confronting a number of groups, including Controls. The Controls group are taking a good approach to managing the situation by examining the “burn rate” of spares to forecast when systems will become unsupportable.
- The Protection Safety team appear to be taking a thorough and deliberate approach to documenting and re-engineering their systems. This is the correct approach
- The Instrument Data Acquisition and Controls team have done a very good job of bringing standardization to instrument controls, with 5 instruments converted so far. If other instrument scientists are asking to be next on the conversion list the group must be doing an excellent job.

Controls (cont)

Recommendations:

1. Consider augmenting Protection Systems and Process Controls teams with contractors. Restructure resources if necessary.
2. Standardization of Protection Systems is essential to realize future efficiencies, reliability and safety. Continue this activity.
3. In the prioritization process of resources across the facility, consider the use of some obsolete systems as something that facilities can live with.

H^- Stripping

- H^- Stripping has been effective in operations, up to and including 1.4MW power level.
- There are consistent issues related to damage to the foil brackets at power levels greater than 1.2 MW. Evidence points to the electron catcher not functioning properly.
- Short term solutions include better foil / catcher alignment, implementation of a longer bracket leg and different bracket material.
- Longer term solution depends on a developing a new injection vacuum chamber (AIP)
- "H^- laser-assisted stripping with 90% efficiency for a ~μs long 1 GeV H^- beam" is the focus of a HEP funded grant, involving three institutions, UT, SNS, and Fermilab. The project is in its third year of funding.
- Installation of the experimental station in the tunnel is scheduled for the summer of 2015. This will compete with other projects for resources, particularly controls.
- The committee believes this is a very important project, from the perspective of the benefit to H^- accelerators, accelerator S&T, and the demonstration of SNS delivering on its grant.

H^- Stripping

Recommendation

1. The committee supports the installation of the laser stripping experimental station in FY2015 as an important activity, and encourages its inclusion in the project prioritization process.

Accelerator Physics

Comments and Observations:

- The committee commends the AP group for its work in educational activities, and use of students in addressing SNS challenges
- We appreciate the response to our previous recommendation regarding the development of a transverse damper, capable of dealing with potential e-p instabilities, and the indication that this effort will be ongoing.
- The work on decreasing the duration of the extraction kicker gap has been a good cost effective step-up in power.
- Open XAL work has been a good step, benefitting both SNS as well as the entire community.
- AP group has done conceptual design work for STS

1. Assess the performance of the accelerator complex and neutron source since the last meeting.

Observations and Comments

- The SNS team is to be congratulated on the achievement of 1.4 MW beam power demonstration for almost 30 hours! This is a significant and challenging milestone for the accelerator and represents a new record for short pulse spallation sources.
- Excluding major catastrophes, beam availability easily excess 90%. It is anticipated that this level can be maintained at 1.4 MW operation with appropriate investments in maintaining and upgrading accelerator systems. This conclusion is supported by the fact that availability did not degrade as higher power operations were ramped up over several months.
- Some significant down times resulted from target problems and other issues (e.g., MEBT flooding and PPS grounding fault). Longer downtimes typically have a greater impact on the user program and long-term solutions need to be carefully developed and tested along with identification of other vulnerable areas.
- A new algorithm for beam turn-on has provided impressive results with times measured in minutes rather than hours. New information on tune stability has been enabled through this new capability.

Charge Point #1 (cont)

- Extensive performance metrics have been developed and are used in weekly meetings to analyze down times and review the health of the accelerator. Future problem areas are examined even through a review of auto-correcting faults, a good example of reviewing precursors before significant failure events.

- Some reliability mitigation efforts are highly labor intensive (e.g., HVCM capacitor replacements).

- Mitigation efforts of problems have delayed development of new systems due to insufficient effort resources. Example is the PPS problem which has delayed the development of the PPS system for the ITSF.

Recommendations:

1. Challenges exist in setting priorities for resources, including those between instruments and accelerator functions. The committee recommends development and use of a defensible project priority evaluation method, perhaps based on risks.
2. The committee encourages inclusion of a examination of the distribution of resources as part of the project prioritization process.

2. Assess and provide advice on the plans for sustainable beam operation with availability at the ≥90% level at ~1.4MW beam power for 5000 operating hours per year in a constrained funding environment. Consider the lessons learned from the high power run in the first half of 2014 and current maintenance strategy.

Observations and Comments

- The SNS team is to be congratulated on the achievement of 1.4 MW beam power in June 2014. This was a significant and challenging milestone for the accelerator and represents a new record for a short pulse spallation source
- SNS will need to provide greater margin in all parameters to permit reliable, steady 1.4 MW operation. Increased margin should be addressed by proper RFQ behavior, smart chopping, plasma processing and modulator flattop, all of which are included in the Accelerator Improvement Program.
- 1.4 MW has not been repeated since June 2014 and this is attributed to degradation in RFQ performance. A new RFQ is regarded as key to sustainable 1.4 MW operation.
- The Accelerator Improvement Program is already taking into account aspects of obsolescence mitigation and sustainability issues which will be key to addressing long-term, reliable running at the ≥90% level. However, it is noted that the accelerator improvement budget trend is downward, and therefore it is expected that prioritisation will need to take place.

Charge Question #2 continued

- The expected annual AIP budget of ~$1.5M/year compares very poorly with other facilities. The ISIS accelerator sustainability budget is ~$8M/year, for a much smaller, although somewhat older facility.
- 5,000 operating hours per year is close to the limit that can be expected with an appropriate maintenance program. This, however, presents very little room for rescheduling to make up any downtime caused by catastrophic failures.
- Scheduling long accelerator installations around Inner Reflector Plug (IRP) is good practice.
- The SNS use of test facilities is being wisely used to minimise downtime on installation of new systems.
- If a constrained funding environment or technical difficulties require a compromise in machine performance experience at other facilities (ISIS, J-PARC) would suggest that availability is the most important consideration for the user community.
- **Recommendations**

1. Consider prioritization of "availability" above the importance of "1.4 MW" (rather than 1.35 for instance).
2. We encourage a rigorous approach to project prioritization, such as the use of risk analysis, and looking into best practice elsewhere. Looking forward at least 5 – 10 years is recommended, particularly in AIP: a sustainable, predictable funding level makes this possible. Some sustainability issues can take 10 years to address – start now!

3. Assess the adequacy of our approach to sustaining and developing critical systems, including High Voltage Converter Modulators, Superconducting Cavities (plasma processing), Injection Stripping (Foils, lasers), Personnel Protection System and Controls (including high level applications) and the Integrated Front End Test Stand facility.

Observations and Comments:

- The SNS team is to be congratulated on the achievement of 1.4 MW beam power in June 2014. This was a significant and challenging milestone for the accelerator and represents a new record for a short pulse spallation source
- As noted by other reviewers, with limited resources and constrained budgets it is imperative that resources are allocated to align with the organizations goals.
- Observations and comments on the charge question are covered in topical sections of the closeout.

Question 3 continued

Recommendations:

1. Ensure that overall SNS goals are set and well communicated to stakeholders. This would help in prioritization of resources and help to manage expectations.
2. Devise a prioritization process to align resource allocation with goals.

4. Is the SNS response to the observed RFQ issues adequate?

Observations and Comments

- The poor operation of the present RFQ is considered the primary obstacle to running at 1.4MW once the second spare target is on site.
- The testing of the new RFQ is slow due to a variety of reasons including limited resources needed for a PPS for the ITSF.
- RFQ - Frequency shifts in 2003, 2009. Transmission degradation in 2011. Two accidental ventings in 2014 resulted in getting water vapor into the RFQ.
- Present transmission is 65-70% At least 80% transmission is expected.
- Coupler problems appear periodically (overheating). Doing ok on getting spares from both US and Japanese manufacturers (no changes to design). One problem coupler will be replaced in April, 2015. In the future an improved coupler could be investigated via simulations.
- Past indications were that the RFQ detunes at high duty factors, suggesting that routine operation at full duty factor could be difficult, even without the above problems.

Charge Question #4 continued

Observations and Comments

- There is a degradation of RFQ performance as the source hydrogen gas flow is increased, resulting in trade-offs between optimum source and RFQ performance.
- The committee was pleased to see planned activities such as installation of an x-ray viewport to measure vane voltage, and development of RFQ Keeper program to help keep the RFQ on resonance as the temperature changes.
- Spare RFQ was ordered in 2010. Manufacturing started in 2011. Delivery was in November, 2013.
- Following delivery, progress has been quite slow for a variety of reasons, including limited resources, and the need for a PPS for the ITSF. Power testing of the RFQ didn't begin until June, 2014, and the beam testing of the new RFQ has not yet started.

Charge Question #4 continued

- The new RFQ design addressed the issues seen in the first RFQ (better cooling, more vacuum pumping) but left beam dynamics unchanged. The technique for dipole mode stabilization in the cavity was changed (PISL changed to end wall rods).
- Power conditioned June 2 - Aug 1, 2014. 60 Hz, 925 us, 550 kW - ran for 1 day at full power without interruption. The conditioning time seems longer than expected. Also, the final power to date (required for acceptance), is still lower than one would like to see, so it would be good to resume power testing as soon as possible.
- Near term, until accelerated beam is allowed, one should push to increase the rf power, peak and average, and study source gas effect on the RFQ.
- Project manager for front end replacement has been selected.
- Beam tests are critical before one can be assured that this will be a reliable replacement. The Protection Systems Team Leader estimated completion of the PPS near the end of FY15. This is needed before tests with beam can begin.
- 2016 Shutdown window (for IRP replacement) should not be missed, since the present RFQ is a bottleneck to reliable 1.4 MW operation, and installation and conditioning could be a multi-month process.

Charge Point #4 (cont)

- The committee feels the SNS response to the RFQ issues has been adequate, when viewed within the context of overall facility issues

Recommendations:

1. The committee supports the installation of the new RFQ as a very important activity for reliable operation at 1.4 MW, and encourages its inclusion in the project prioritization process.
2. Immediately develop a detailed schedule for installation and commissioning. Identify and carry out ahead of time any work that can be done to prepare the location for the final installation.
3. After further testing, install the LEBT valve to better protect the RFQ vacuum on the the operating beamline as well as in the ITSF.

5. Does the AIP investment strategy align with the 1.4MW reliable, sustainable operation and STS path?

Observations and Comments:

- The SNS has a number of desirable projects addressing reliable, sustainable operation at 1.4MW; some are AIP and some are programmatic.
- Most of these projects also lie on the path to the STS, providing a strategic link
- In that funding can be recolored (i.e., is an internal choice), our following remarks and recommendations apply to the full scope of accelerator projects addressing improvements, obsolescence and spares.
- The committee feels that the scope of projects that we were shown during this meeting is well aligned with the objectives stated in this charge point. However, it is also clear to us that there is presently insufficient funding to do this work on the time scales presented. Thus we have two recommendations.

Charge Point #5

Recommendations:

1. Further articulate strategy and in concert, develop a transparent project prioritization system that can substantively inform decision making aligned with this strategy. Initially this could be limited to accelerator projects, but as we note in another recommendation, this must ultimately be done facility wide.

2. Based on the output of the above recommendation, it may be clear that increased funding for accelerator projects in the best investment for the SNS, If that is the case, consider doing so.

6. Provide advice on the accelerator systems components of the draft technical design report for the Second Target Station and provide guidance on the reasonability of the updated plan for the power upgrade in the SCL, with fewer new Cryo-modules than originally planned.

- The conceptual design to achieve the accelerator requirements for the STS is well defined. It is largely based on the original design basis of the SNS of 1.3 GeV energy, and somewhat lower current levels (38 mA) than were anticipated at the time of the Power Upgrade Project (PUP).
- The decision to utilized existing accelerator technology is to be commended.
- The committee supports the decision to reduce the number of cryomodules from 9 to 7. This decision is well supported by the success of the HB cryomodule built by SNS as well as overall progress made in the field of SRF as demonstrated by the design parameters for ESS and LCLS-II, both of which will be built before the STS.

Recommendation:

In order to continue to refine the science driven requirements for the STS accelerator design, we encourage the laboratory to provide LDRD or program development support.

Executive Summary

Aside from several long downtimes, SNS has operated well, with periods of operation at 1.4MW, and improved availability/reliability in most systems.

Several major problems, related to these downtimes, have consumed a large amount of effort in a reactive way. Aside from this the committee has had some trouble determining how effort and funding resources are allocated in proactive ways to most efficiently address the long list of very desirable projects. We have noted many of these projects which we believe are important and should be done, but do not believe it our role to set the priorities. Thus our primary recommendation is:

1. Establish a robust, useful, and uniform SNS wide prioritization process defining how both financial and effort resources are allocated in a proactive way to most efficiently address the needs of the facility. This process can be used to inform management decisions and provide documented rationale for why decisions are made.

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