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| Accelerator Advisory Committee (AAC) Recommendations Report | May 5  2015 | |
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Accelerator Advisory Committee Charge

The Accelerator Advisory Committee (AAC) for the SNS met March 24-26, 2015. This was the sixth meeting of the SNS ACC; the previous meeting was May 7-9, 2013. Committee membership is shown in Appendix A. Several new members have been added: John Thomason, Kazuo Hasegawa, and Walter Hartung. Not present were Masatoshi Futakawa, Stephen Holmes and Robert Macek.

Prior to this meeting, the SNS had just conducted a DOE review of the target systems. For this reason, there were no target experts present at the AAC, and our charge contained no questions related to the target. We did receive a briefing on this target review, but our report makes no explicit comments or recommendations to target systems, as those are covered in that report. Our charge was:

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

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.

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.

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

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

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.

We have differentiated charge question #2 from #3 by focusing on management responses and plans in the answer to #2, and technical issues of the systems in question #3. The answer to charge question #4 is used to address the technical issues with the RFQ.

Executive Summary

The SNS team is to be congratulated on the achievement of 1.4MW 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 several major downtimes, beam availability was easily in excess of 90%. It is anticipated that this level can be maintained at 1.4MW operation with appropriate investments in maintaining and upgrading accelerator systems. This conclusion is supported by the fact that availability did not degrade as the beam power was ramped up over several months when the 1.4MW 30-hour-demonstration was achieved.

The major downtimes since the last meeting were: two target failures, MEBT flooding and the PPS grounding fault. At the time of this meeting, the SNS was operating at about 850kW in what is known as target conservation mode. This is a management decision to operate at reduced power levels when less that two spare targets are on site. The second spare target is expected shortly, at which time ramp up to 1.4MW will commence. The body of this report addresses the challenges in achieving and sustaining this power level; indeed most of the charge questions relate directly to achieving sustainable, high availability at 1.4MW.

Through the presentations, we were presented with system-by-system plans to deal with this objective. We report on these in the first sections (I-V) of our report. What struck the committee is that while these system-by-system plans look very promising for addressing the outstanding issues and meeting the 1.4MW objectives, there are insufficient resources (both labor and funding) to address them all. Additionally, resolution of the problems related to the downtimes, have consumed a large amount of effort in a reactive way. The committee wrestled with 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:

## Recommendation

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.

# I. Ion Source and Integrated Test Stand Facility

## Observations and Comments

As was true at the last review, the ion source reliability continues to be very good. Antenna failure rates are much reduced from in the past due to improved quality control; there has been only one antenna failure since the last review.  There is an ongoing optimization of source parameters due to the influence of hydrogen gas coming from the ion source on RFQ performance, especially considering the close coupling between the source and RFQ. One tries to maintain low source gas flow for the RFQ, but if it is made too low, one has source plasma outages.  Part of this optimization involves trying to better understand the rf ignition process of the source plasma.

The ion source test stand is operational again.  (This was a recommendation in the 2013 review.) It was also very nice to see that external antenna development has resumed on the test stand, since ultimately this will most likely be the preferred configuration, compared to the internal antenna.

It was stated at the review that production sources 2 and 4 are preferred over source 3. The inferiority of source 3 is noticed in performance through the injector chain. The assumption is that the emittance is larger in source 3, but this would be good to verify with new measurements on the test stand. In addition, while one tries to make the sources nearly identical, it would be good to inspect the three sources carefully for mechanical differences, to see if any differences in emittance can be understood.

The short electrostatic LEBT has been operating reliably. A routine change-out of LEBT is now done twice a year (insulator coating), which seems to be a good practice to facilitate this reliability.  The LEBT gate valve, separating source vacuum and RFQ vacuum, had been removed in the past due to reliability issues. The need for the reinstallation of a valve in this location has been realized, partly due to recent accidental ventings of the RFQ. Improvements to the valve operation have been made, and it now seems reliable where it is being used 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. Ultimately, one hopes that there will be little need to ever vent the RFQ vacuum, which is a good thing for the RFQ.

A major MEBT vacuum water leak occurred in September, 2014, during a machine downtime period. The leak was such that the MEBT was filled with water, and had to be disassembled and cleaned. It took 6 weeks to clean and then re-establish beam. The leak occurred in the MEBT chopper dump. This dump has now been removed, since the MEBT chopper use had not been essential, and any benefit with respect to reduction in losses was found to be minimal.

An ion source, LEBT, the second RFQ, and MEBT are now in place, comprising the Integrated Test Stand Facility (ITSF). This gives SNS a very important capability to, first, verify performance of the second RFQ, but then more generally perform studies of the LEBT, RFQ, and MEBT, all of which facilitate improvements to the front end. Although significantly behind the schedule presented at the last review, almost all equipment is now in place for RFQ testing with beam. Remaining items are the beam stop shielding, and the Personnel Protection System (PPS).

It was noted that there is no LEBT valve installed on the ITSF. A valve should be made similar to the one to be put back on the operating beamline, and installed here. The ITSF RFQ should be kept under vacuum as much as possible, and one should expect frequent source changes as the ITSF can be used to test source improvements, along with its other uses.

## 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. Put priority on installation of PPS, but if that is not possible, early operation at low rep rate prior to installation of the PPS would allow timely measurements of transmission, energy and emittance.

# II. Superconducting Linac and Superconducting RF

## Observations and Comments

The SNS team described results on the spare high-beta cryomodule, which was fabricated in-house. This cryomodule was demonstrated to have good performance and hence is a valuable asset for the SNS linac. This is a significant and impressive achievement. The committee commends the SNS team on their work and their results.

The SNS team described their progress on in-house infrastructure for superconducting cavities and cryomodules. A substantial investment has been made by SNS, including a clean room, a heat treatment facility, a cavity test facility, and a cryomodule test facility. The committee views this as a good investment in sustainability, considering that the SRF linac is critical to operation of SNS as a user facility.

A plan was presented by the SNS team for an on-site small-scale electropolishing facility for SRF cavities. The plan includes an investigation into the possibility of using alternative surface preparation methods in order to avoid the need for hydrofluoric acid. The committees sees alternative methods as having the potential to reduce substantial safety hazards associated with cavity preparation; we think that, if successful, such methods could provide significant benefits for the entire SRF community. Plans for a larger production-oriented facility were described as a follow-on step after completion of the small-scale electropolishing facility.

Results were presented by the SNS team on plasma processing of multi-cell cavities, both in a laboratory environment and on a cavity in a cryomodule. The plasma processing technique developed by SNS 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 cryomodules in the SNS linac. The committee views the plasma processing work at SNS to be relevant to the greater SRF community. Hence, we feel that plasma processing tests in a configuration which allows RF measurement of the quality factor (e.g. in the vertical test area) would be useful to more completely quantify the effect of plasma processing on cavity performance.

## 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 the plan presented by SNS for the spare medium-beta cryomodule. However, we encourage the inclusion of the procurement of this spare cryomodule 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.

# III. High Power RF

## Observations and Comments

The Committee recognizes the accomplishments of the HVCM system in improved availability. With the installation of the improved IGBT gate drive circuit with fault detection, controlling the pulse termination, and the addition of the IGBT snubber to eliminate overvoltage on the IGBTs, as well as the preventive maintenance replacement of the high voltage resonance capacitors, the down time events have been reduced and the availability increased. The previously known IGBT failure problem remains a potential significant risk. A new pulse controller has been implemented on a test stand and lifetime testing is in process. The new controller will allow for pulse voltage droop control and reduce the failure risks significantly. Previous attempts to reduce the modulator pulse voltage droop had produced catastrophic failures in the modulator. The new controller has remote monitoring capability during operation of HVCM supply with the potential to predict or prevent serious failures.

The Committee recognizes that the alternant topology, with the strip line buss connection, is the most likely approach to solve the ongoing high voltage equipment corona failure problems in the modulator and increase availability by reducing failure rates. The alternant topology is under evaluation at low voltage.

## Comments

* The new improved IGBT gate driver circuit addresses a significant number of limitations of the original gate driver. The new trigger driver corrects timing variations, fault currents magnitude, detection, and protection against excessive currents. It does not address the problems of over temperature due to excessive switching losses from improper timing from the controller. The new controller, which utilizes the advanced features of the gate driver, is capable to address these switching loss issues and allows for more reliable, longer pulse operation by reducing the IGBT switching losses.
* The installation of the snubber network on the IGBTs, with the help of the new controller can eliminate the IGBT overvoltage problem during inadvertent pulse termination. The new controller has demonstrated the capability to reduce the voltage droop during the pulse and has the potential of limiting the excessive switching losses by improving the switching control and detuning of the modulator resonance.
* The coronal failures of the capacitors and pulse transformer are best addressed by reducing the fast voltage change (dv/dt) on the high voltage resonant capacitor and transformer windings. With the present transformer configuration, it is impossible to reduce the fast rate of change of voltage. The best engineering practice in a direct current high voltage supply is to series stack supplies to reduce the dv/dt voltage on each supply. The innovative alternate topology being evaluated at the present time stacks power supplies without increasing the number of transformer cores reducing the dv/dt on the transformers and resonance capacitors. The secondary winding could further be divided and series stacked with diodes to reduce the dv/dt on the transformer windings and resonant capacitor.
* Another issue, which has been apparent for a long time, does not easily attribute to modulator failure but it has caused poor performance of the modulator, is the electrical connection between the energy storage capacitors and the switching modules. Although the multiple coaxial cables between the energy storage capacitor and the switching modules appears to have very low inductance, they in fact cause voltage ringing between the energy storage capacitor and switching plates. The result is voltage fluctuations on the nominal grounds and ripple voltages on the total output. It has been demonstrated by replacement of these cables with a strip line bus configuration that voltage fluctuations on the grounds and output can be eliminated.
* There appears to be an abnormal number of premature klystron heater failures. This could be caused by excessive heater temperature. Periodic monitoring of the klystron saturation current versus heater power and reductions in the heater to the minimum power could prolong the klystron lifetime. There appears to be sufficient spare klystrons to allow for evaluation of the klystron failures.

## Recommendations

1. Complete replacement of 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. When available, 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.
5. Monitor all klystron saturation characteristics and adjust heaters for minimum operating temperature and track heater adjustment trends to assist in indication of end of life.

# IV. Controls

## Observations and Comments

The Controls teams appear to have more demands made upon their resources than they can deliver with the available effort. These teams include: protection systems, process controls and vacuum controls.

In particular, the protection system (PS) group seems to be on the critical path for RFQ testing in the IFTS. PS resources are needed to move the RFQ project forward in time to meet the 2016 installation window.

Installed equipment approaching or reaching obsolescence is a situation confronting a number of groups, including Controls. The Controls group is taking a logical approach to managing the situation by examining the “burn rate” of spares to forecast when systems will become unsupportable.

Following the “PPS incident” that was caused by a misconfigured ground connection, the Protection System team has taken a thorough and deliberate approach to ensuring the future performance of the system will be robust. This has included bringing in numerous external SMEs and not shirking from making improvements where necessary. For example they appear to be taking a thorough and deliberate approach to documenting and re-engineering their systems. Another aspect the PPS team is addressing is to consolidate the number of architectures in the facility. This is the correct approach.

The Instrument Data Acquisition and Controls team appears to have done a very good job of bringing standardization to instrument controls, with 5 instruments converted so far. We heard that instrument scientists are asking to be next on the conversion list, so the team must be doing an excellent job. There will be a challenge in the future as already converted instruments start to need maintenance or new capabilities. This will act as a drag on the team’s ability to take on new instruments. Management can help by understanding this situation and being clear in setting expectations for instrument scientists.

## Recommendations

1. We recommend examining the benefits of augmenting Protection Systems and Process Controls teams with contractors. If the need is to get over a limited period of high demand this may be sufficient.
2. In a budget constrained environment it may be necessary to rebalance resources across the division if it is thought that the higher demands on Controls will be sustained. If budgets are very constrained, a rebalancing of resources may be beneficial even to get through a short-term period of high demand.
3. Standardization of Protection Systems is essential to realize future efficiencies, reliability and safety. Continue this activity.
4. In a budget constrained environment, the approaching obsolescence of systems presents the organization with a dilemma; do we redevelop an old system or do we invest those resources in developing the facilities capabilities? This is a prioritization decision that is best made by the SNS management team. It may be that individual system managers have to cope with a lower level of spares than they are comfortable with. It may also be that the facility decides that it can take the risk of living with system obsolescence if it believes the system is stable, performing adequately and the functional requirements of the system are unlikely to change for the foreseeable future.

# V. H- Stripping

## Observations and comments

Although H- stripping is a concern in any high power H- injection scheme, SNS has had good operational experience, up to and including injection at 1.4MW power levels. This experience does lead to expectations that the foil scheme will work for the near term operation at 1.4MW, and with the ongoing foil development, to the expected power level of 2.5MW when the second target station (STS) power upgrade is done.

However, there are consistent issues related to damage to the foil brackets at power levels greater than 1.2MW. Evidence points to the electron catcher not functioning properly. The short term solutions include better foil / catcher alignment, implementation of a longer bracket leg and different bracket material. There is evidence that this will mitigate the damage. A longer term solution depends on developing a new injection vacuum chamber with these components reengineered. This is an outstanding AIP.

A new foil test lab is being setup, and the foil fabrication facility is being moved to the Center for Nanophase Material Science on SNS site in 2015.

If one wishes to go beyond foil stripping, the primary R&D approach has been laser stripping. The SNS, along with the University of Tennessee and Fermilab has an HEP funded grant entitled, “H- laser-assisted stripping with 90% efficiency for a ~μs long 1 GeV H- beam.” The project is in its third year of funding. This grant has a strong educational component supporting undergraduates, graduate students, and a post doc. Some of the study topics include simulation work of the laser stripping process, laser development, and requirements for beam optics.

The project is leading up to the installation of an experimental station in the High Energy Beam Transfer line. 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. This leads to our recommendation.

## 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.

# VI. Accelerator Physics

## Observations and Comments

The committee commends the AP group for its work in educational activities, and use of students in addressing relevant SNS challenges. An example is the “Study of Coupling Resonance in the Ring” which is a thesis topic.

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, and indicates an innovative response to our previous recommendation, “Retain flexibility to respond to development outcomes by adjusting to new points in (E, I, L) space if the primary plan does not pan out.”

Open XAL work has been a good step, benefitting both SNS as well as the entire community.

The AP group has done conceptual design work for the STS.

## Recommendations

None.

# VII. Charge Question 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 1.4MW 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 was easily in excess of 90%. It is anticipated that this level can be maintained at 1.4MW operation with appropriate investments in maintaining and upgrading accelerator systems. This conclusion is supported by the fact that availability did not degrade as the beam power was ramped up over several months when the 1.4MW 30-hour-demonstration was achieved.

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 (developed from root cause analysis of downtimes) need to be carefully developed and tested along with identification of other vulnerable areas. Shorter downtimes continue to need regular attention to ensure that the overall goal of 90% availability can be attained in spite of longer downtime impacts. Extensive performance metrics have been developed and are used in weekly meetings to analyse down times and review the health of the accelerator. Future problem areas are examined through a review of auto-correcting faults, a good example of reviewing precursors before significant failure events.

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. It appears that the tune space for the accelerator is quite large. Further analysis of results with the new tool may provide additional operational insights.

Although in general the performance of the accelerator since the last meeting has been outstanding (barring the major downtimes), there are a couple of areas of concern that lead to recommendations.

* Some reliability mitigation efforts are highly labor intensive (e.g., HVCM capacitor replacements). This observation leads one to a concern about the distribution of labor resources. Are resources aligned carefully to mitigate problems and make progress on other projects? Is there progress in reducing the labor requirements needed to mitigate reliability efforts?
* Mitigation efforts of problems have delayed the development of new systems due to insufficient effort resources. An example is the delay in design and installation of a PPS system for the injector test facility. Tests of the new RFQ with beam have been delayed due to lack of resources for development and installation of a new PPS on the test stand.

## 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 an examination of the distribution of resources as part of the project prioritization process.

# VIII. Charge Question 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 1.4MW 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. 1.4MW was achieved primarily because of improvements in chopping factor: other variables such as beam energy, beam current and macro-pulse length were below design specification. SNS will need to provide greater margin in all these parameters to permit reliable, steady 1.4MW 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 (AIP). Almost 30 hours of operation at 1.4MW has demonstrated that the stripping foil, beam stability, RF loading and beam loss in the linac and ring (all of which were potential causes for concern) behaved well and should not be a problem for sustainable operation at 1.4MW. Unfortunately 1.4MW has not been repeated since June 2014 and this is attributed to degradation in RFQ performance. A new RFQ is now regarded as key to achieving sustainable operation at 1.4MW (see charge 4).

The AIP plan is well aligned with ambitions for sustainable 1.4MW running, and is already taking into account aspects of obsolescence mitigation and sustainability issues which will be vital to addressing long-term, reliable running at the ≥90% level. However, at present the AIP budget trend is downward, and therefore it is expected that prioritisation will need to take place: to this end the SNS accelerator team has begun to produce a formal risk matrix in order to prioritize projects in a quantitative and defensible manner. It should, however, be noted that the expected AIP budget of ~$1.5M/year compares very poorly with other facilities; for instance the ISIS accelerator sustainability budget is ~$8M/year (for a much smaller, although admittedly older facility).

Accelerator spares provision is well understood and prioritized, although some examples of large value spares items which could not be funded at the moment were given (most notably the spare medium-beta cavity). The SNS accelerator performance metrics are extensive, and weekly meetings to analyse these metrics and production of a “Weekly Machine Health Report” are excellent examples of good practice to minimise downtime. Excluding major catastrophes such as target failures, availability easily exceeds the ≥90% level and there seems no reason that this will not continue to be the case at 1.4MW if appropriate investment is made in maintaining and upgrading the accelerator systems.

5,000 operating hours per year is probably close to the limit that can be expected as compatible with keeping up 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 replacements (approximately every 5 years) is good practice. The SNS accelerator test facilities are very impressive and are being wisely used to minimize 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 “1.4MW” (rather than 1.35MW 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!

# IX. Charge Question 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 1.4MW 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 this report.

## 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 within the division and across the facility to align resource allocation with goals. We encourage adopting a system that incorporates the following aspects:
   * Risk analysis, using a common risk assessment methodology.
   * Accounts for the Opportunity Cost of a decision (i.e., the opportunity forgone by not following a particular course of action).
   * A transparent process, so that all stakeholders understand how and why decisions are determined.

# X. Charge Question 4: Is the SNS response to the observed RFQ issues adequate?

## Observations and Comments

There have been a series of problems with the SNS RFQ, starting more than 10 years ago:

* Unexplained shifts in the resonant frequency of the structure occurred in 2003 and again in 2009, requiring retuning of the cavity in both cases.
* In 2011, there appears to have been a degradation in beam transmission through the structure, although there was no frequency shift in that instance. In spite of opening and checking the field flatness as much as they are able, it seems that the RFQ transmission has never really recovered to what was achieved in the past. Therefore, while at least 80% transmission is expected, the present beam transmission through the RFQ is only 65-70%.
* Two accidental ventings in 2014 resulted in getting water vapor into the RFQ.
* There is a degradation of RFQ performance as the source hydrogen gas flow is increased, resulting in trade-offs between parameters optimized for the source and for RFQ performance.
* 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.
* Coupler problems appear periodically (overheating). Spare couplers have been procured from both US and Japanese manufacturers, with no changes to the design. One coupler which is presently overheating will be replaced in April 2015.

It was mentioned in several presentations that the poor operation of the present RFQ is considered to be the primary obstacle to running at 1.4MW, after the spare target is on site and the administrative limit is removed. There is an effort to improve the performance of this RFQ as much as possible until the spare RFQ is tested and ready for installation. 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. The installation of the LEBT valve will allow the RFQ to remain under vacuum during routine source and LEBT maintenances. In the future an improved coupler could be investigated via simulations, to try and make it more robust.

Following the occurrences of RFQ detuning, it was decided that a spare RFQ with an improved design (particularly improved cooling) was needed. The new RFQ design has better cooling and more vacuum pumping, but the beam dynamics are unchanged compared to the first RFQ.  The technique for dipole mode stabilization in the cavity is changed. (Pi mode stabilization has been changed to end wall rods.) Both methods are used in such RFQs, but the new method should allow operation at a slightly reduced cavity power.

This second RFQ was ordered in 2010. Manufacturing was started in 2011. The RFQ was delivered to SNS in November 2013. Following delivery, progress in power testing and beam testing on the Integrated Test Stand Facility (ITSF) has been quite slow for a variety of reasons, including limited resources, and the need for a personnel protection system 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.

Power conditioning of the RFQ occurred from June 2 - Aug 1, 2014.  At that point, the RFQ was able to run for 1 day at 550 kW rf power, 60 Hz repetition rate, and 925 μs pulse width. These parameters were sufficient for formal acceptance of the RFQ. The required conditioning time seems longer than one might expect, but there is some feeling that the vacuum was not ideal during the conditioning.  Also, power conditioning of the RFQ stopped once this level was reached. The final power to date is still lower than one would like to see, so it would be good to resume power testing as soon as possible.

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 system is needed before tests with beam can begin. (Operation with beam at low duty factor in the meantime could be very useful, but so far is not an option since a fail-safe way to guarantee a safe duty factor cannot be found.) Near term, until accelerated beam is allowed, one should push to increase the rf power, both peak and average, and study the effect of the ion source gas on the RFQ performance (i.e., gas flowing, but no beam from the source).

The period in the summer of 2016 when SNS will likely be shut down for Inner Reflector Plug replacement should not be missed, since the present RFQ is a bottleneck to reliable 1.4MW operation, and installation and conditioning could be a multi-month process. Even if this long shutdown is not 100% certain, it should be taken seriously at this time, since preparation for the RFQ replacement is not trivial. It is very good that a Project Manager for the front end replacement has recently been selected.

The committee feels the SNS response to the RFQ issues has been adequate, when viewed within the context of overall facility issues (particularly other demands on the limited resources).

## Recommendations

1. The committee supports the installation of the new RFQ as a very important activity for reliable operation at 1.4MW, 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 operating beamline as well as in the ITSF.

# XI. Charge Question 5: Does the AIP investment strategy align with the 1.4MW reliable, sustainable operation and STS path?

## Observations and Comments

The SNS has many 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, and further justification for doing them.

In that funding can be recolored (i.e., the SNS has some latitude in defining how much of the budget goes to AIP), 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.

## 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 is the best investment for the SNS; if that is the case, consider doing so.

# XII. Charge Question 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.

## Observations and Comments

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 at 1.3 GeV energy, and somewhat lower current levels (38 mA). These are both lower that what was anticipated at the time of the Power Upgrade Project (PUP).

The decision to utilize 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.

In that the STS has not yet achieved CD-1, it is very likely that the accelerator requirements may change based on neutron science considerations evolving. Thus it is important to keep the focus on refining the science requirements so that the accelerator system requirements are known and managed early in the process.

## Recommendations

1. 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.

Appendix A: AAC Committee Members

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| **Name** | **Affiliation** | **E-mail Address** |
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| Zumbro, Martha | Los Alamos National Lab (Retired) | [zumbromv@gmail.com](mailto:zumbromv@gmail.com) |

Appendix B: Accelerator Advisory Committee Meeting Agenda

**March 24-26, 2015**

**Building 8600, Conf. Room C-156**

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| **Tuesday, March 24, 2015** | |  |
| **Time** | **Event** | **Lead** |
| *7:30 - 7:45 am* | *Badging at Guest House for Committee Members* |  |
| *8:00 – 8:30 am* | *Executive Session with Breakfast* | *Committee Members Kevin Jones, Director, Research Accelerator Division* |
| 8:30 – 9:00 am | Directorate Perspective – NScD Overview | Paul Langan, Associate Lab Director, Neutron Sciences Directorate |
| 9:00 – 9:30 am | Accelerator and Target Systems Management Overview | Kevin Jones, RAD Director |
| 9:30 – 10:00 am | SNS Operations Performance Metrics | Glen Johns, Group Leader, Accelerator Operations |
| 10:00 – 10:20 am | Discussion | All |
| *10:20 – 10:40 am* | *Break* |  |
| 10:40 – 11:20 am | Strategy for 1.4MW Power Ramp-Up and Reliable Operations | John Galambos, Group Leader, Accelerator Physics, Beam Instrumentation & Ion Source |
| 11:20 – 12:00 pm | Synopsis: DOE Review of SNS Response to Target Issues | John Galambos, Group Leader, Source Development and Engineering Analysis |
| *12:00 pm – 1:00 pm* | *Working Lunch / Discussion* | *Pick up lunch from Room C-150* |
| 1:00 – 1:30 pm | New Linac Tuning Algorithms and Setup Automation | Andrei Shishlo, Warm Linac Area Manager, Accelerator Physics |
| 1:30 – 2:00 pm | RFQ Performance and Status of Spare – Successes and Challenges | Mark Champion, Group Leader, Electrical & RF Systems |
| 2:00 – 2:30 pm | Integrated Test Stand and Beam Instrumentation | Sasha Aleksandrov, Lead Physicist, Accel. Physics, Beam Instr. & Ion Source |
| 2:30 – 2:50 pm | Discussion | All |
| *2:50 – 3:10 pm* | *Break* |  |
| 3:10 – 3:40 pm | RF System Performance – Normal Conducting Linac RF Performance and Challenges | Mark Crofford, Manager, RF Systems, Electrical & RF Systems Group |
| 3:40 – 4:10 pm | Ion Source Development, Plans, and Test Stand | Martin Stockli, Lead Physicist, Accel. Physics, Beam Instr. & Ion Source |
| 4:10 – 4:40 pm | Discussion | All |
| 4:40 – 6:00 pm | Executive Session | Committee Only |
| *6:30 – 8:30 pm* | *Review Dinner and Discussion* | *Riverside Grille, 100 Melton Lake Drive, Oak Ridge. Ph: (865) 862-8646.* |

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| **Wednesday, March 25, 2015** | |  |
| **Time** | **Event** | **Lead** |
| *8:00 – 9:30 am* | *Tour of SNS Facilities. Depart from Conf. Room C-156 (breakfast will be available).* | *George Dodson* |
| 9:30 – 09:45 am | Executive Session | Committee Only |
| 9:45 – 10:15 am | Linac Modulator Upgrades – HVCM development and upgrade plans and Test Stand | Dave Anderson, HVCM Development Project Manager, Electrical & RF Systems |
| *10:15 – 10:35 am* | *Break* |  |
| 10:35 – 11:15 am | Controls and Protection Systems | Karen White, Group Leader, Control Systems / Kelly Mahoney, Protection Systems Team Leader, Control Systems |
| 11:15 – 11:45 am | Accelerator Physics and Ring Injection Stripper Foil Developments | Sarah Cousineau, Physicist, Accelerator Physics |
| 11:45 am – 12:15 pm | Discussion | All |
| *12:15 – 1:00 pm* | *Working Lunch / Discussion* | *Pick-up lunch from Room C-150* |
| 1:00 – 1:30 pm | Laser Stripping Initiative (Grant) | Sarah Cousineau, Physicist, Accelerator Physics |
| 1:30 – 2:10 pm | SCLS Overview and SRF Activities | Sang-ho Kim, Group Leader, Superconducting Linac Systems / John Mammosser, Senior SRF Engineer, Superconducting Linac Systems |
| 2:10 – 2:40 pm | Plasma Processing R&D | Marc Doleans, Accelerator Physics Staff, Superconducting Linac Systems |
| 2:40 – 3:10 pm | Target Systems Operations Experience and Remote Handling | Mike Baumgartner, Group Leader, Mechanical Systems and Operations |
| 3:10 – 3:30 pm | Discussion | All |
| *3:30 – 3:50 pm* | *Break* |  |
| 3:50 – 4:10 pm | Second Target Station (STS) and Accelerator Power Upgrade | John Galambos |
| 4:10 – 4:40 pm | Superconducting RF STS Strategy - CM/Cavity Development, Facilities and Plasma Processing | Matt Howell, Lead Engineer, Superconducting Linac Systems |
| 5:10 – 5:30 pm | Discussion | All |
| 5:30 – 6:00 pm | Executive Session/Questions for SNS Management | Committee Only |
| 6:00 – 7:00 pm | Executive Session | Committee Only |

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| **Thursday, March 26, 2015** | |  |
| *8:00 – 8:30 am* | Breakfast Gathering and Greeting | All |
| 8:00 – 11:00 am | Executive Session/Management Response to Questions | Committee Only |
| 11:00 am – 12:00 pm | Closeout | All |