Report of the Fourth Spallation Neutron Source Accelerator Advisory Committee Meeting

SNS Accelerator Advisory Committee

February 12, 2012

Contents

1 Executive Summary

This was the fourth meeting of the SNS Accelerator Advisory Committee. The Committee members absent were Alexander Chao, Masatoshi Futakawa, Roland Garoby, Steve Holmes, and Rod Keller.

During the two day meeting, the Committee heard reports on the progress made since the 2010 meeting and the plan to ramp-up the beam power to the design level. This executive summary provides a brief overview of the report.

We understand the constraints which recent funding limitations have imposed on plans for future upgrades. Our comments and recommendations in this report are given in the context of a tightly constrained budget. Any recommendations noted in the executive summary are also repeated in the body of the report.

1.1 General remarks, RAD re-organization, current operations and ramp-up plans.

The committee congratulates the staff on the progress it has made since the last review. The beam availability has increased from ∼82% in FY10 to ∼94% in the first quarter of FY12. This availability increase has been made at the same time that the facility has been providing useful neutron beams at the ∼1 MW level to SNS users.

Since the last committee meeting, there has been a major reorganization of the Neutron Sciences Directorate, designed to focus attention on Neutron Science. This reorganization almost doubled the size of the Research Accelerator Division from 200 to 400, due to the addition of facility management and instrument operation, data acquisition and slow controls responsibilities, along with the staff that carried out these functions. In the judgement of the committee, the organization is rational, putting like skills together, and the managers (at least all that we were introduced to) are both competent and experienced.

The Power Upgrade Project was indefinitely suspended in 2011. At an indefinite point in the future, a linac energy increase to 1.3 GeV and power increase to 3 MW may be supported as part of a Second Target Station upgrade.

In the near-term future, the Division's goal is to ramp up the machine's power to 1.4 MW over the next five years, primarily using operations and AIP funds. A straw man cost and schedule for this upgrade was made available to the Committee in a very preliminary form, but was not ready for wide distribution.

It will be important to prioritize the R&D directions rather soon. It is when funding is tight that a clear strategic vision is really valuable. The RAD management team should finalize the strategic plan for the power ramp-up to 1.4 MW, defining which areas should be accelerated, which should be delayed, etc. The prioritization should also consider how the short-term improvements prepare the way for the long-term improvement to 3 MW, but this should not be the only criterion.

The committee feels strongly that, despite SNS funding limitations, resources should be made available which will at least allow a start on the 5 year power ramp-up plan in FY12.

1.2 Ion source and LEBT

The Ion Source group has made good progress over the past two years. Although the downtime from source failures is now the highest among accelerator systems, good progress with the source and LEBT has been made, improving source reliability over the years. Additionally, progress is being made in understanding the performance of the source, which indicates a path toward achieving the needed performance.

Of the three factors which must be addressed to accomplish the power ramp up to 1.4 MW, one is the stable and predictable operation of the source, at current levels already achieved, but not demonstrated by any of the sources over a period of time. Thus fundamental improvements must be made to the sources.

We note that there are a number of well thought out, important R&D items for the source that are being considered. In the short term we recommend focusing on the more limited program of thoroughly understanding the issues with the present sources, as this will address issues related to present operation and lay the foundation for proposed future developments.

1.3 Front End and Normal-Conducting Linac

The performance of the front end and the warm linac has been significantly improved since the last AAC (2010).

Problems with the chopper and the MEBT have been resolved. DTL availability improvements have reduced downtime, although issues remain with the windows. There are plans to replace all of these windows with locally made replacements.

The front end seems to be performing well and is not a cause for concern.

1.4 Superconducting Linac Performance

Ever since first operation of the SNS, beam loss in the SC linacs has been considerably greater than foreseen. Valeri Lebedev (FNAL) proposed a new mechanism for beam loss in the superconducting linac: intrabeam stripping of the H^- ions. A nice experiment was carried out at SNS to use a foil to strip the H^- ions and create protons, which showed significantly lower losses under identical focusing conditions. This result convincingly confirms the mechanism.

Now that the dominant mechanism for beam loss in the SC linacs has been confirmed, efforts should turn to mitigation strategies such as controlled emittance enlargement.

Beam loss events associated with errant beams are damaging SC cavities. The committee recommends the development and implementation of mitigation strategies for particle loss and errant beams.

Halo studies continue and show that some improvement of halos in the SC linac can be obtained by collimating in the MEBT. The present collimation suite in the MEBT does not allow for full collimation of the beam. A full collimation scheme in the MEBT that eliminates halo produced in the injector should be implemented.

1.5 High Voltage Converter Modulators

The committee recognizes the accomplishments of the HVCM system in reliability. Improvement in the HVCM down time was the major contributor to meeting the SNS availability goal. The down time of the HVCM system in 2009 was 338 hours. It was reduced to 72 hours in 2011.

A substantial reduction in IGBT failures has come from correcting the IGBT overvoltage resulting from the normal pulse turn off procedure. Fires have been eliminated by replacing the oil filled capacitors on the switch plate with dry type capacitors. Upgrades to components and correction of fabrication problems have substantially improved the availability and reduced the modulator trips.

The committee recommends installing new IGBT driver cards and the IGBT snubbers as soon as possible. The final design of a new controller to insure proper IGBT commutation and shut down should be completed, and the alternate modulator topology should be developed and implemented. This last step will be required to make the power ramp-up to 1.4 MW possible.

1.6 RF and electrical systems

The RF systems have made significant improvements in availability. Implementation of a solid state amplifier for the MEBT was a major availability improvement. The availability of the AC power systems has also been improving.

RF trips generated by "errant beam" events on the SCL limits the RF availability. The number of spare klystrons is adequate for the near future.

1.7 Superconducting linac cryomodules and cryogenics

The management has formed a new SRF team which consists of the personnel of the former cryogenic and SRF groups. Since it is highly advisable to establish an experienced and permanent team knowledgeable in cryogenics and SC technology for a proton SC linac, the committee is pleased to see that such team is now organized at SNS.

The SCL operated at high reliability: the total downtime of the linac from SRF trips in FY11 was 90 hours (98% availability). 70% of the 90 hours were due to errant beam conditions. In addition, several cavities lost performance (due to errant beam loss, bad vacuum, 2K CB trip, irregular vibrations, and other causes) but could partially be recovered (by RF conditioning, warm up, etc.). In general two spare modules (high and medium beta) are foreseen for ready replacement of a failed module. One high beta module is nearly finished; a medium beta module is in planning.

The SCL supports neutron production at 925 MeV, up to 1 MW. But 80 MeV is missing to run at 1000 MeV in the future. The gradient setting is limited by collective (field emission) effects.

There has been considerable progress in operation and development of the SRF Test Facility. The design and assembly of cavity and module have been improved. There are plans for module rework, electropolishing, plasma cleaning and horizontal cavity testing.

Short term funding has been provided for assembly of a HB spare module, test cavity development, installation of VTA, RF, HPR and CTF. No funding has been allocated for assembly of a spare MB module, R&D for plasma processing, HTA and Chemistry. The committee recommends that additional funding should be applied with first priority to assembly of a spare MB module. SNS should work with a partner laboratory (e.g., JLab) to develop plasma cleaning R&D.

1.8 HEBT/Ring/RTBT, foil development, laser wires and laser stripping

The ring is operating very well at ∼1 MW with high availability, thanks to several improvements in the last 2 years.

Very commendable progress to date has been made with laser based diagnostics, including an SCL laser wire profile, a laser emittance scanner (HEBT), and a laser bunch shape monitor (MEBT).

Foil flutter and shaking is an intermittent issue which is not well understood. An electron beam test stand for stripper foils has been built and is ready for use. This will be a valuable tool for the stripper foil development effort. Foil development is a high priority for 1.4 MW and needs to continue at a pace that is sufficient to keep ahead of the needs of power ramp up.

SNS is a world leader in R&D on laser stripping for injection. Proof-of-principle has been demonstrated experimentally by the SNS team. However, many practical issues must be addressed before it can realistically replace stripper foils. Laser stripping may not be required for the 1.4 MW goal.

Significant (up to 40%) discrepancies in estimates of proton beam density on target between TIS and the RTBT Wizard are not understood and efforts to resolve them not funded.

Many worthwhile developments in this area may be impacted by the the impending budget cuts. A cost-benefit approach is recommended where risk reduction is one of the benefits considered.

1.9 Ring beam dynamics

The Ring Beam Dynamics effort is well organized, providing good insight into the performance of the ring at the present energy level.

Based on experimental work and simulations, the ring will perform well at 1.4 MW. Uncertainties exist at the projected future linac power level of 3 MW.

We encourage SNS to resume higher power beam studies in the ring. This has not been done for several years, and can be done at relatively small expense to the facility. These studies should verify the operation of the ring at 1.4 MW, experimentally evaluate the onset of instabilities, and address basic accelerator R&D issues in this unique ring.

1.10 Target systems

1.10.1 Target development

Target 3 reached end-of-life and was successful changed in ~16 days; PIE is underway.

The 4 targets used so far have all survived of the order of 3000 MW-hr. Although none of them was consistently used at 1 MW, the team counts on being able to use no more than 2 targets per year at 1 MW (2500 MW-hr per target). In this way the number of targets currently on stock or on order will take them until mid-2016.

Given the current budget limitations, priority is given to PIE on used targets, rather than pressure wave mitigation research, which has been carried out in a highly successful collaboration with J-PARC in the past. From the limited PIE undertaken so far, the results seem to support the assumption that cavitation damage reflects the pressure wave interference pattern rather than the intensity distribution in the proton beam.

Since some evidence exists that flow along the wall may reduce cavitation damage the team is now working on a target design which provides shear flow all over the target window (Jet flow target). In order to facilitate examination of used targets the team is considering new targets with a removable (bolted on) water shroud.

The committee recommends aggressive pursuit of the development and implementation of the jet flow target in combination with the removable water shroud. If the jet flow target is not a significant improvement, work on pressure wave mitigation must be resumed as quickly and as aggressively as possible. In order to be able to do this, existing equipment and know-how in the group must be preserved.

1.10.2 Moderator and reflector improvements

In order to facilitate future reflector replacements and to reduce the amount of radioactive waste the team is designing a new reflector plug with nested inner and outer reflectors.

Efforts are under way to improve the performance of the coupled hydrogen moderator by adding an ortho-para converter to the hydrogen loop to increase the fraction of p-hydrogen. This requires a larger moderator volume which cannot be accommodated under the constraints imposed by the given beam port arrangement and the complexity of the present design. With the envisaged compromise the performance of the p-hydrogen moderator will remain less than optimal.

Another thrust to improve moderator performance is the development of moderators with directionally enhanced neutron emission by "extraction channels". While this shows some promise of success with the solid moderator material used in the tests, its implementation on a liquid cryogenic moderator is unlikely to be successful.

The committee recommends proceeding with the nested reflector concept to have it ready for the upcoming reflector plug replacement (in 4 years from now, with 2.5 years lead time for procurement). Improvements to the moderator concept should not be allowed to hold up or compromise the deployment of the new plug.

1.10.3 Fusion Material Irradiation Test Station

Irradiation of fusion materials in or near spallation targets has been under discussion for all spallation sources planned or designed in the past and has been consistently dismissed because the damage created and the low damage levels achievable during the life of a spallation target are not representative of the environment of a fusion reactor. It is not obvious why this should be different for SNS. Furthermore, adding the device as studied would constitute a significant complication of the system design and handling. A fault on the irradiation rig must not be allowed to affect target operation.

1.10.4 Proton beam window

The committee noted with satisfaction that SNS has finally decided to replace the inconel window in the proton beam by one made from aluminum alloy. This bears the promise of longer life time and reduced activation and heating in the downstream components. The committee recommends simplifying the current window design, at least in the long run.

1.11 Control systems

A new group has been formed within RAD called Data Operations. This group brings together "skills": controls, IT, database; and "responsibilities": accelerator, the instruments (including data acquisition) and enterprise systems at SNS. The committee is pleased to see that this merging of groups has gone well, and is addressing appropriate challenges.

Issues discussed at the last AAC have been resolved, and control system availability is meeting expectations.

SNS has adopted Control Systems Studio (CSS) as its EPICS system toolset. Thus it benefits from and contributes to developments at many participating laboratories. These capabilities are being extended to the instruments.

The reorganization was done in part to make more resources available to support science and the instruments. Controls is the area in which these changes were most visible to the committee.

We simultaneously encourage this effort, as we know it is needed at SNS, while at the same time suggest close monitoring of the utilization of controls resources. Communication will be of utmost importance when all requests can not be granted.

1.12 Beam Instrumentation Systems

Beam instrumentation at the SNS has continued to mature and is providing the needed diagnostic tools for operation and for many of the beam studies.

Both the BLM and BPM systems are facing obsolescence issues. One of the limitations of the BPM system (the 6 Hz trigger rate) will be addressed via the BPM development project, which will provide 60 Hz capability, starting in the summer of FY12.

An out-of-tunnel camera imaging system for the stripping foil has been developed. Other diagnostics, particularly those used for beam studies, are being developed or upgraded. SNS is to be commended for this leading edge diagnostic capability.

The ring transverse feedback system is well developed, but progress has slowed with the loss of personnel, and the need to develop a low level system that can accommodate the tune splitting that is observed in the presence of the e-p instability. The committee recommends that the transverse feedback system work should be completed, or at a minimum a cost projection should be made so that it can be considered in the light of other priorities.

The committee was presented with a wish list of mostly unfunded diagnostic development projects. SNS is encouraged to indicate which accelerator performance goal is associated with each diagnostic in order to help prioritize these projects.

We encourage SNS to make a near term goal of understanding unidentified errant linac beam losses. The Beam Instrumentation Group would have the capacity to do this job.

1.13 Reliability, Availability, Vulnerability, Spares and Maintenance Management

There has been an impressive improvement in availability, number of beam hrs and MW-hr delivered since the last review, especially the 94% availability at 0.8-1 MW so far in FY12. The operational and accelerator improvement priorities established during the last two years have been have been instrumental in focusing efforts where they are most needed (for example, on the HVCM and ion source systems).

Maintenance planning and execution have been very successful to date. The maintenance period allocation is a careful balance between costs, availability goals and neutron production time. The availability during recovery from outage periods has greatly improved since the last review. The Data Stream Maintenance Management System is used extensively and effectively to plan and manage the longer maintenance periods.

A formal approach to evaluating spares needs and obsolescence has been established using industry best practices. Vulnerabilities were evaluated by seeking assets that had a high risk of bringing the accelerator down for a significant period of time. The spares policy places responsibility for ordering spares on the system owner. A Configuration Management System has been put in place to ensure that every component placed in the machine, either as a new installation or as a spares replacement, occurs in a controlled fashion.

It is tempting to believe that this methodology has, at least partially, contributed to the marked improvement in downtime The structured maintenance program has probably more to do with it. In the opinion of the Committee, this approach has great merit.

The first pass Vulnerability Analysis process was good, although the input data needs another reviewing pass. The ground rules for a major failure that shuts down the accelerator for a long period should be that there would be no financial or staffing limitations for the repair. Because of the potential that subjectivity can bias the data, it should be vetted carefully by independent experts.

The committee recommends a re-evaluation of the input data to the Vulnerabilities Matrix, with application of new ground rules for repair priority.

1.14 Power Upgrade Project

The Power Upgrade Project (PUP) goal is an energy increase to 1.3 GeV, with a consequent beam power increase to 1.8 MW. CD-1 was approved in January, 2009. The PUP had advanced almost to the CD-2 stage in 2011 but was indefinitely suspended by DOE.

In the future, a linac energy increase to 1.3 GeV and power increase to 3 MW may be supported as part of a Second Target Station upgrade.

RAD has continued to refine its concepts for the best way to implement the linac energy upgrade and the related current upgrades (e.g, the concept of constant-power operation of the SCL).

The committee recommends that the design concepts for a power upgrade to 3 MW should continue to be refined at a low level of effort, and modifications to the machine should not preclude the capability to go to 3 MW in the future.

2 Introduction

This was the fourth meeting of the SNS Accelerator Advisory Committee. The Committee membership is given in Sec. 22. The Committee members absent for this meeting were Alexander Chao, Masatoshi Futakawa, Roland Garoby, Steve Holmes, and Rod Keller.

The Charter for the Committee is presented in Sec. 21. The specific charge for this meeting was:

1. Assess the performance of the accelerator complex and neutron source to date.
2. Assess and provide advice on the plans for sustaining beam availability at the $\geqslant 90\%$ level at $\sim$1 MW beam power for 5000 operating hours per year in a constrained funding environment.
3. Assess and provide advice on the plans, risks and associated mitigating activities for continuing the ramp-up in power of the accelerator complex and neutron source to the design level of 1.4 MW absent the Power Upgrade Project. Is the approach on the most critical systems (modulators, foils, SCL, target) appropriately directed?
4. Provide advice on the conceptual path toward 3 MW operation and a Second Target Station.
5. Assess the progress and plans for neutron source development.
6. Assess and provide advice on the restructured Research Accelerator Division organization as applicable to the accelerator complex and neutron source.

Following the agenda outlined in Sec. 23, the Committee heard two days of presentations assessing the current status of the SNS accelerator systems and plans for the ramp-up to the design baseline level.

Guided by the charge, the committee has formulated findings, comments and recommendations for each of the areas covered in the presentations, which are presented in the following sections. We understand the constraints which recent funding limitations have imposed on plans for future upgrades. Our comments and recommendations in this report are given in the context of a tightly constrained budget.

3 General remarks

3.1 Findings

The committee would like to thank the SNS staff for the warm hospitality provided during the review, and the excellent presentations.

The committee congratulates the staff on the progress it has made since the last review. The beam availability has increased from ∼82% in FY10 to ∼94% in the first quarter of FY12. This availability increase has been made at the same time that the facility has been providing useful neutron beams at the ∼1 MW level to SNS users.

The availability improvements have come from a systematic approach to reducing downtime and improving reliability throughout the accelerator systems, and an improved understanding of the machine's physics.

Target 3 reached end-of-life and was successful changed in ∼16 days; PIE is underway.

The Power Upgrade Project was indefinitely suspended in 2011. At an indefinite point in the future, a linac energy increase to 1.3 GeV and power increase to 3 MW may be supported as part of a Second Target Station upgrade.

RAD has begun to develop a plan for a power ramp-up to 1.4 MW in 5 years. However, resources are severely curtailed for at least FY12.

There have been major organizational changes at SNS since the last review. To provide increased emphasis on the science, the SNS organization has become flatter, and there has been a major expansion of the scope of activities for RAD. Within RAD, there have been significant organizational changes as well.

3.2 Comments

The reorganization within RAD has resulted in the consolidation of focus and engineering manpower in several areas, which the committee feels will be beneficial to the overall mission of the division.

There has been no significant increase in the SNS power level, which remains at about 2/3 of the design level, for two years.

3.3 Recommendation

The committee feels strongly that, despite SNS funding limitations, resources should be made available which will at least allow a start on the 5 year power ramp-up plan in FY12.

4 RAD re-organization, current operations and ramp-up plans.

4.1 Findings

The RAD Director, Kevin Jones, catalogued the successes of the Research Accelerator Division, both long-term and over the two years since the last AAC meeting. The numbers speak for themselves: the accelerator has improved in reliability, number of hours scheduled for users, and number of hours delivered to users. All of the DOE metrics were exceeded. Both Stuart Henderson (the previous RAD Director) and Kevin Jones, as well as the entire RAD staff, can take pride in these results.

Since the last committee meeting, there has been a major reorganization of the Neutron Sciences Directorate, designed to focus attention on Neutron Science. This reorganization almost doubled the size of the Research Accelerator Division from 200 to 400, due to the addition of facility management and instrument slow controls responsibilities, along with the staff that carried out these functions. This means that almost all of the engineers, technicians and craftsmen now reside in the Research Accelerator Division, initially creating a dozen groups, which are organized into four distinct business lines.

The largest Department is Accelerator and Target Operations under George Dodson, which has the majority of the engineering and technical support groups. Next largest is now Data Operations under Karen White, due to the addition of the responsibility for the Instrument Controls. Improving this area is one of the top priorities of the SNS Director, and therefore will need a lot of support from RAD. The third Department is Instrument Operations, which is the most visible interface to the users. Finally, Facility Operations supports all of the site and buildings work at SNS.

In the near-term future, the Division's goal is to ramp up the machine's power to 1.4 MW over the next five years, primarily using operations or AIP funds. A straw man cost and schedule for this upgrade was made available to the Committee in a very preliminary form, but was not ready for wide distribution. There is a hope that BES will later fund the Second Target Station project, that would also include an upgrade of the accelerator to 3 MW. The areas that could be targeted for upgrade were enumerated but not prioritized.

4.2 Comments

The organization is rational, putting like skills together, and the managers (at least all that we were introduced to) are both competent and experienced. What is somewhat less clear is the role that RAD should play in improving neutron science output, whether measured in number of unique users, number of proposals, number of experiments run, or less quantitative measures such as the quality of the neutron science. Given the excellent performance of the accelerator, perhaps the focus of the accelerator experts should be on helping the users to be successful. This suggestion appears to be contrary to the self-interest of the accelerator scientists and engineers but actually their livelihood depends on making the users successful. It is the task of RAD management to make everyone aware of the importance that RAD puts on users; this would include the staff, the Neutron Science Directorate, the users and DOE.

The future directions for accelerator R&D for the power ramp-up are ill defined, which is understandable given the very recent re-organization, the indefinite suspension of the PUP, and current funding uncertainties. However, it will be important to prioritize the R&D directions rather soon. It is when funding is tight that a clear strategic vision is really valuable. The RAD management team should finalize the strategic plan for the power ramp-up to 1.4 MW, defining which areas should be accelerated, which should be delayed, etc. The prioritization should also consider how the short-term improvements prepare the way for the long-term improvement to 3 MW, but this should not be the only criterion.

4.3 Recommendation

Finalize the strategic plan for the accelerator power ramp-up, and initiate high-impact items in FY12.

5 Ion source and LEBT

5.1 Findings

The Ion Source group has made good progress over the past two years. Although the downtime from source failures is now the highest among accelerator systems, good progress with the source and LEBT has been made, improving source reliability over the years. Additionally, progress is being made in understanding the performance of the source, which indicates a path toward achieving the needed performance.

SNS has been able to implement a ∼6-week source service cycle which eliminates one source change per run.

5.1.1 Reliability Issues

The primary cause of source downtime has been antenna failures. The Ion Source Group believes the failures are at the leg bends which penetrate into the plasma. A new design has been implemented and will be tested in early 2012. Source leak and contamination issues have been investigated, and solutions include careful handling of sources in a class 10,000 clean room, and more rigorous procedures.

RF issues have been addressed by installing a high-voltage insulated RF transformer. A production 2 MHz high voltage isolation transformer has been in operation since July 2010, and there is a plan to provide a 13 MHz transformer to allow operation of the 13 MHz amplifier system at ground potential.

LEBT reliability has been improving; an ongoing carefully proceduralized approach to maintenance has been implemented and should be tracked to ensure that the trend continues.

5.1.2 Performance Issues

Ion sources have performed at the levels needed for present operation, and for the 1.4 MW ramp-up. However, performance is not predictable, and the different sources, which ostensibly are the same design, behave differently. A carefully developed program to understand these issues is needed, and in fact is being pursued by the ion source group. The components of the program include:

- Careful understanding and documentation of any differences among the existing sources. This includes not only observable differences, but also differences in the way the sources have been handled, which could lead to different surface properties.
- Ongoing careful understanding of LEBT alignment issues. Alignment issues may be behind the differing beam and electrical performance.
- Development of test stands to support the above.

5.2 Comments

With substantial improvements to the reliability of the High Voltage Converter Modules, the ion source has become the leading contributor to downtime in the period from FY2011 to date. While the ion source and LEBT are now the most significant contributor to downtime, this metric masks the fact that improvements have been made in source reliability over the last few years, and the committee acknowledges this progress.

Additionally, of the three factors which must be addressed to accomplish the power ramp up to 1.4 MW, one is the stable and predictable operation of the source, at current levels already achieved, but not demonstrated by more than one of the sources over a period of time. Thus fundamental improvements must be made to the sources.

5.3 Recommendation

We note that there are a number of well thought out, important R&D items for the source that are being considered. In the short term we recommend focusing on the more limited program of thoroughly understanding the issues with the present sources as noted above, as this will address issues related to present operation and lay the foundation for proposed future developments.

6 Front End and Normal-Conducting Linac

6.1 Findings

The performance of the front end and the warm linac has been significantly improved since the last AAC (2010). The chopper was a major source of downtime and this has been successfully resolved by a targeted series of improvements. A decision was made to keep the slow chopper ramping time slow, as it was not causing any problems as is. A spare RFQ has been ordered and will be used in the test stand while also serving as a hot spare.

The overall performance of the MEBT is good. All 4 rebunchers have new solid-state RF amplifiers and a 5th amplifier is a hot spare.

The DTL has made some availability improvements that have reduced downtime. Recently, there was a leak into a tank due to a braze failure in the window. There are plans to replace all of these windows with locally made replacements.

The existing linac has an excellent set of diagnostics tools, and it can (and should) be used as a test bed for accelerator physics studies. There are developments that can improve the performance of the warm linac.

6.2 Comments

The front end seems to be performing well and is not a cause for concern.

7 Superconducting Linac Performance

7.1 Findings

Ever since first operation of the SNS, beam loss in the SC linacs has been considerably greater than foreseen. Empirically, it was found that reducing the quadrupole focusing strength improved the beam loss. Valeri Lebedev (FNAL) proposed a mechanism for beam loss in the superconducting linac: intrabeam stripping of the H^- ions, and theoretical calculations support this hypothesis. A nice experiment was carried out at SNS to use a foil to strip the H^- ions and create protons, which showed significantly lower losses under identical focusing conditions. This result convincingly confirms the mechanism.

There are significant discrepancies between the measured beam optics in the SC linac and the various models. This has been traced to variations in RF focusing in the cavities which are used during operation but not included in the models.

A nice experiment was carried out to show that the accelerator could operate at a fixed 60 Hz frequency instead of being slaved to the electrical grid, which has significant frequency variability. This will become standard operating procedure as it facilitates synchronization of the beam with the Instrument rotating collimators.

Halo studies continue and show that some improvement of halos in the SC linac can be obtained by collimating in the MEBT. The present collimation suite in the MEBT does not allow for full collimation of the beam.

7.2 Comments

Now that the dominant mechanism for beam loss in the SC linacs has been confirmed, efforts should turn to mitigation strategies such as controlled emittance enlargement. This may (or may not) require improved halo control. However, properly collimating the beam in the MEBT should be a priority as it makes everything downstream easier.

The optical effects of variable RF focusing due to off-crest operation of the cavities to reduce beam loss should be incorporated in the online model. This will facilitate understanding of the beam loss and perhaps lead to an improved focusing strategy that is more robust.

7.3 Recommendations

1. Develop and implement mitigation strategies for particle loss and errant beams in the superconducting linacs.
2. Design and implement a full collimation scheme in the MEBT that eliminates halo produced in the Injector.

8 High Voltage Converter Modulators

8.1 Findings

The committee recognizes the accomplishments of the HVCM system in reliability. Improvement in the HVCM down time was the major contributor to meeting the SNS availability goal. The down time of the HVCM system in 2009 was 338 hours. It was reduced to 72 hours in 2011. The majority of the down time in 2011 was due to High Voltage Cable failures.

The replacement of the oil-filled capacitor on the IGBT switch plate with dry type capacitors and the adjustment of the timing to eliminate over voltages during the pulse termination have reduced the fires and explosive IGBT failures which were prevalent in 2009. Improvement in the timing controller wiring has eliminated timing fault trips.

The availability of an IGBT test stand and the formation of a development group has allowed for development of an improved IGBT gate drive circuit, with current limiting, fault detection, and improved EMI shielding. An IGBT snubber to eliminate overvoltage on the IGBT's has been developed and tested. A new generation of controller is being investigated to eliminate the pulse termination overvoltage problem, change the modulation method to allow for voltage droop control, compensate the flux in the transformer core, and provide for waveform capture and logging to detect first faults.

8.2 Comments

Without these improvements, it is not clear that the pulse width can be increased to accommodate > 1 MW operation without encountering substantial degradation in availability. Reliable 1.4 MW operation seems impractical without implementation of the fourth IGBT switch plate and topology change.

8.3 Recommendations

The committee recommends for immediate action the following items to help insure an improved availability:

1. Implement the replacement of the new tested IGBT gate drives as soon as possible. The present gate drivers provide the IGBT with too high of a voltage, which results in an excessively large fault current.

In addition, the present drivers have no internal projection against noise or triggering errors, which would cause faults.

2. Complete the design and testing of the IGBT snubber network and install it as soon as practical. Over voltages on IGBT's are the main cause of IGBT failure and should be prevented by the addition of snubber networks.

3. Complete the design and implementation of the new controllers to allow for the pulse voltage droop control and pulse termination over voltages. The inability to adjust the pulse voltage droop severely limits the use of the RF system. The present system does not control voltage saturation of the transformer core flux and the commutating current amplitude.

The committees also recommends that for the longer-term development for 1.4 MW operation the following be implemented:

4. Undertake the implementation and testing of the series fusing switch to prevent explosive events under most fault conditions.

5. Design, develop and test the alternate topology with the addition of a fourth IGBT switch plate. It is not clear that the longer pulse length needed for 1.4 MW operation can be reliability maintained without the fourth switch plate.

9 RF systems

9.1 Findings

The Committee finds that the RF system has made substantial progress in reducing down time from 226 hours in FY09 to 103 hours in FY11.

The MEBT rebuncher amplifier, the largest contributor to the RF down time in FY09, was dramatically improved by replacing a high voltage supply and implementing a Solid State amplifier.

The RFQ has had improvements and its frequency has remained stable.

There have been several QEI driver amplifier failures, which were replaced with Tomco amplifiers, the type used in the new Ion Source.

Vacuum leaks in the DTL, due to poor workmanship, have been a problem.

The low level RF equipment is becoming obsolete and needs to be replaced.

The "errant beam" events are a significant limit on the RF availability of the SCL.

The number of spare klystrons is adequate for the near future.

9.2 Recommendations

1. The sources and remedies for the errant beam events should be investigated to insure improved operation of the RF systems.

2. Obsolescence in the low level RF system should be addressed before it becomes a problem.

3. A more robust data acquisition and logging system should be implemented on the klystrons to determent when performance is being compromised.

.

10 Electrical systems

10.1 Findings

The Electrical Systems down time has improved from 40 hrs in FY09 to 20 hrs in FY11. The main improvements have been adjusting motor trip levels and transferring critical equipment to UPS supplies to avoid interruption due to lighting events. An AC wiring inspection program has also been introduced to insure that the electrical wiring is in proper operating condition and that the breakers are in working order.

11 Superconducting linac cryomodules and cryogenics

11.1 Findings

The management has formed a new SRF team which consists of the personnel of the former cryogenic and SRF groups. This team is led by S-H. Kim.

The SCL operated at high reliability: the total downtime of the linac due to SRF trips in FY11 was 90 hours (98% availability). 70% of the 90 hours were due to errant beam conditions.

The SCL supports neutron production at 925 MeV, up to 1 MW. But 80 MeV is missing to run at 1000 MeV in the future. The gradient setting is limited by collective (field emission) effects.

Several cavities lost performance (due to errant beam loss, bad vacuum, 2K CB trip, irregular vibrations, and other causes) but could partially be recovered (by RF conditioning, warm up, etc.). The plan is to replace the worst-performing high beta module, CM20, by the new spare.

In general two spare modules (high and medium beta) are foreseen for ready replacement of a failed module. One high beta module is nearly finished; a medium beta module is in planning.

There has been considerable progress in operation and development of the SRF Test Facility. Recent activities include installations for clean-room assembly, high pressure rinse cleaning, and cryogenic cooling. The design and assembly of cavity and module have been improved. There are plans for module rework, electro-polishing, plasma cleaning and horizontal cavity testing.

Short term funding has been provided for assembly of a HB spare module, test cavity development, installation of VTA, RF, HPR and CTF. No funding has been allocated for assembly of a spare MB module, R&D for plasma processing, HTA and Chemistry.

11.2 Comments

In the past the committee expressed its concern about the highly multiplexed structure of the former SRF group. SC accelerator technology for electrons has just been industrialized (EXFEL) after more than one decade of R&D at laboratories (e.g. TTF, FLASH). SC proton accelerator design and operation is not based on such broad experience. To guide a SC proton accelerator project, it is highly advisable to establish an experienced and permanent team knowledgeable in cryogenics and SC technology.

The committee is pleased to see that such team is now organized at SNS.

11.3 Recommendations

1. Additional funding would support assembly of a MB spare module to assure linac operation in case of a MB failure, and/or R&D for Plasma processing to explore in situ module processing. Priority should

go to assembly of a MB spare.

2. Work with a partner laboratory (e.g., JLab) to develop plasma cleaning R&D.

12 HEBT/Ring/RTBT, foil development, laser wires and laser stripping

12.1 Findings

The committee is gratified to find that the ring is operating very well at ∼1 MW with high availability and acceptable beam losses thanks to several improvements in last 2 years including:

1. A new and improved air-cooled momentum dump with adequate capacity (5 kW).
2. Increased injection dump line apertures to lower losses along with added diagnostics to speed up tuning.
3. Correction of the injection kicker waveform distortion caused by noise getting into the Voltage Isolation Board.
4. Various stripper foil improvements including corner cut shapes that have resulted in significantly longer foil lifetimes (greater than 1 month at 1 MW). One foil has lasted an entire run cycle at mostly 1 MW.

Foil flutter and shaking is an intermittent issue, which is not well understood but may be due to charging. Higher conductivity foils may help. Better collection of the convoy electrons by the new catcher design with larger acceptance and proper placement may also help.

A multi-pronged approach to development of stripper foils with improved reliability and adequate lifetime has been ongoing for several years and is a priority for reaching 1.4 MW. It includes development of more conductive foils, new corrugation patterns, development and testing new foil technologies (e.g. Hybrid Boron Carbide developed at KEK) and construction of an electron beam test stand (with energy deposition equivalent to 1.5 MW operation of the ring). The test stand will be a valuable tool for the stripper foil development effort.

There is no reliable model for extrapolation of foil lifetime from the present 1 MW operation to 1.4 MW. Several hours of successful operation obtained with the foil inserted further into the beam to approximate the total heat load estimated at 1.4 MW is encouraging, but it is not the same as operating with the beam hit density on the foil expected at 1.4 MW operation for weeks on one foil. Extensive testing under the most realistic conditions expected at 1.4 MW is most prudent.

Significant (up to 40%) discrepancies in measurements of proton beam density on target between TIS & RTBT Wizard are not understood and efforts to resolve them not funded in the present budget picture.

We find very commendable progress to date with laser-based diagnostics including the SCL laser wire profile, a laser emittance scanner (HEBT), and a laser bunch shape monitor (MEBT). These are very useful capabilities for beam studies as well as for operational beam monitoring.

SNS is a world leader in R&D on laser stripping for injection. Proof-of-principle has been demonstrated experimentally by the SNS team. However, many practical issues must be addressed before it can realistically replace stripper foils. Continued development is a worthwhile long-term program.

12.2 Comments

Laser stripping may not be required for the 1.4 MW goal, but it is a long-term option of considerable interest to the high intensity proton accelerator community.

The installation of an improved primary stripper foil mechanism and new electron catcher is tentatively planned to take place in 2012 but resolution of design issues with the primary stripper foil mechanism may delay implementation. The new electron catcher should significantly reduce the reflection of convoy electrons back to the stripper foil region.

12.3 Recommendations

1. Further foil development is a high priority for 1.4 MW and needs to continue at a pace that is sufficient to keep ahead of the needs of power ramp up.
2. Many other worthwhile development efforts are going to be impacted by the impending budget cuts. A cost-benefit approach to development decisions is recommended where risk reduction is one of the benefits considered.
3. Laser stripping is a potential game-changing technology for high intensity accumulator rings in which SNS is a world leader; therefore the committee recommends that laser stripping R&D be continued at a level consistent with other resource-limited intermediate and longer-term development priorities.

13 Ring beam dynamics

13.1 Findings

An issue presented at the last AAC meeting was the observed beta beating in both planes of the ring. This data had been taken using a Model Independent Analysis (MIA). Since then, the standard (but time consuming) technique of looking at tune variation as a function of quadrupole strength was employed. These measurements revealed beta functions deviations less than 15% from design.

Collective effects are not limiting SNS ring intensity. However there is an intensity dependent effect that is not understood, namely the coupling between horizontal and vertical beam size, resulting in reduced ability to control beam shape on the target. A graduate student is being assigned this project.

The e-p instability is visible in the ring at present production intensities, but does not impact operation. There have been some studies of instability dependencies on various machine parameters, but recently there have been few studies at higher currents where these instabilities are likely to be a problem.

13.2 Comments

The Ring Beam Dynamics effort is well organized, providing good insight into the performance of the ring at the present energy level.

We concur with SNS that the linear dynamics are well understood and agree with the design values. It would be nice to know why the MIA indicates a discrepancy, but this is not necessary for moving forward.

Based on experimental work and simulations, the ring will perform well at 1.4 MW, but uncertainties exist at the projected future linac power level of 3 MW.

We encourage SNS to resume higher power beam studies in the ring. This has not been done for several years, and can be done at relatively small expense to the facility. These studies should:

- verify the operation of the ring at 1.4 MW, which can be achieved during studies;

- experimentally evaluate the onset of instabilities (e-p), and other issues, which may effect performance at higher power;
- address basic accelerator R&D issues. The SNS ring is a high intensity proton ring, in many ways, unique. SNS accelerator physicists should evaluate experiment topics that can benefit the broader accelerator community and be given appropriate time to carry these out.

SNS recognizes its roll in training the next generation of accelerator scientists and engineers. However the number of graduate students and post-docs has dropped. We encourage SNS to explore opportunities to attract and fund graduate students and post-docs.

13.3 Recommendations

1. Resume high power beam studies in the ring.
2. Explore ways of bringing more accelerator science and technology graduate students and post-docs to SNS.

14 Target systems

14.1 Target development

14.1.1 Findings

The problem of mitigating the effect of pressure waves on the target shell is still unresolved, although very good R&D progress was made in the past. Off-line work carried out in collaboration with the JSNS team - with beam in Los Alamos and without beam at ORNL and JAEA - has contributed significantly to the understanding of the mechanism of cavitation erosion and potential mitigation routes. Another very important front is the PIE-work on spent targets in conjunction with computer simulations of the pressure and flow conditions in the target. Although the opportunities of carrying out PIE are very limited, the team was able to gain important information which seems to support the following observations:

- Cavitation damage on the target shell does not appear to reflect the intensity distribution in the proton beam.
- Flow along the target wall, which was found to have some mitigating effect in offline experiments, may be less effective in the real target. At least the damage distribution found does not correlate in an obvious way with the calculated velocity distribution. In particular the cracks along the center line found in target shells # 2 and 3 run through regions of reasonably high flow velocity.
- The concept of "saturation time", which considers the duration during which the mercury is at a level of tension which it cannot sustain and hence forms cavities, appears to be highly successful in describing the damage pattern observed on Target 1, which is the one that received most of its beam load at low pulse power. The calculated distribution of this saturation time also reveals regions outside the beam where damage is likely to occur, which is in qualitative agreement with observations.

These results suggest that the most prominent feature determining cavitation damage on the target shell is the pressure wave interference pattern which results from the thermal expansion of the mercury due to the energy deposited by the protons in the volume and which is largely dominated by the structure mechanics of the target shell. Once 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. An important feature might be the weakening of the structure by erosion and hence an increased stress during the pressure pulse. 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 in Targets 2 and 3. It is quite possible that, apart from fatigue, also other effects such as some form of stress corrosion cracking or liquid metal embrittlement add to rapid crack propagation. (The tiny inclusions found in the fracture surface of tensile specimens fabricated from a disk from Target 1 are probably not a driver in damage creation or propagation.) This explanation is admittedly rather speculative at this point, but if it has some truth to it, the most promising method of mitigating cavitation damage seems to be gas injection into the mercury, which has been the subject of intense development efforts of the SNS team in close collaboration with JSNS in the past.

However, given the current budget limitations which do not allow to continue the full scope of the R&D for the time being, the division management was forced to set priorities and decided to

- support analysis of samples already irradiated at WNR;
- support development of a "jet flow" target with an additional inlet channel on the bottom of the target volume which is expected to eliminate flow stagnation zones and provide adequate mercury flow over the whole target window inner surface (ESS target design);
- design a removable (bolted on) water shroud for new targets in order to facilitate examination of used targets;
- give priority to PIE of spent targets; and
- put any other target development (in particular gas injection) on temporary halt.

14.1.2 Comments

Even in view of what was said above about the most promising damage mitigation mechanism, this is a defendable decision for the following reasons:

- All 4 targets used so far have survived of the order of 3000 MW-hr. Although none of them was consistently used at 1 MW, the team counts on being able to use no more than 2 targets per year at 1 MW (2500 MW-hr per target). In this way the number of targets currently on stock or on order will take them until mid-2016. Although there is still some uncertainty about the target service life at or above 1 MW, there is no reason not to use targets already procured.
- Immediate PIE of spent targets, albeit of limited scope due to existing boundary conditions, is of high priority because of the need to send used targets to final disposal quickly, since there is no space to store them on site. It is also the only way to obtain realistic damage information and hence holds the greatest promise of finding a clue for future design improvements.
- Although Target 3 - the only one which reached the end of its service life by developing a leak into the interspace - could not be examined in sufficient detail to identify the position and nature of the leak, it is probably not worthwhile to store it for later examination, since there is no indication that the leak was the consequence of a target design feature. If this was the case, one of the other targets will also develop a similar leak.
- In this context the plan to build the " jet flow" target with a removable (bolted on) outer water cooled shroud is a very positive move, since it will make possible (optical) examination of the whole outer wall of the mercury target.
- R&D on bubble injection is being continued at J-PARC with whom SNS is in close information exchange. In fact, the target currently installed at JSNS already has provisions for gas bubble injection. (Its design provided for cross flow along the target window from the beginning). Thus it may be expected that results on the effectiveness of gas injection will accrue in the not too distant future.

Although the positive effect of cross flow along the wall is not fully established for the real target geometry and operating conditions, the " jet flow" target is a worthwhile effort, since it means a comparatively small change (relative to a target with gas bubblers) and has a potential to help clarify this issue. The fact that the leak in Target 3 seems to have developed elsewhere is not an argument against this effort because the cause and nature of the leak are completely unknown.

In summary, the ongoing and planned activities which SNS is pursuing can still be expected to provide clues on future development needs in preparation for higher power (1.4 MW and above) on a useful time scale.

14.1.3 Recommendations

1. Aggressively pursue the development of the jet flow target in combination with the removable water shroud and put it to use as early as possible.
2. Run this target to the end of its service life (leakage into the interspace to the water shroud) in order to establish whether or not the jet flow has the anticipated positive effect.
3. If this is not the case, work on pressure wave mitigation must be resumed as quickly and as aggressively as possible. In order to be able to do this, existing equipment and know-how in the group must be preserved.

14.2 Moderator and reflector improvements

14.2.1 Findings

On top of ramping up the beam power to design level, SNS is continuously striving to improve the source performance on all fronts. This is done by a combination of computational modeling and experimental work using test set-ups at a low power source (LENS). An important prerequisite for this is the assessment of the precision with which the performance of a whole beam line can be predicted. To this end, flux studies have been performed on most of the beam lines and have been compared to the results of calculations. Currently the team believes that the simulations represent the real situation with a precision of 10-20 %. This is important to bear in mind when the likely improvement by proposed changes is judged on the basis of simulations. Of course, the relative effect of changes to individual beam line components can be predicted with better precision.

Currently two possible options of improving moderator performance are being studied:

- “advanced” moderator concepts to provide for directionally focused beam extraction and
- increase of the fraction of para-hydrogen in the coupled hydrogen moderators.

The “advanced” moderator concept consists of a sequence of layers of moderating material interleaved with thin silicon wafers. It turned out that this system in fact shows some preferential neutron escape in or near the horizontal direction, but the effect could be shown to be mainly geometric, i.e. the silicon acts as escape channels for moderated neutrons. The option of increasing the para-hydrogen fraction in the coupled moderators by adding an ortho-para converter in the hydrogen loop is contemplated in conjunction with a re-design of the inner reflector plug, since it requires a larger moderator volume than currently available. The present inner reflector plug is too bulky to fit into a TN-RAM cask and hence is very difficult to dispose of. Since its life time is limited by burn-up of the poison in the poisoned moderator, regular exchange of the whole plug is an unnecessarily expensive legacy for the facility. This will even be true if the lifetime can be increased from 6 MW-yr to 8 MW-yr by switching from gadolinium to cadmium as a poison material and by increasing the thickness of the decouplers and liners. The SNS team is therefore preparing to create a two-piece inner reflector plug composed of an inner sector containing the moderators and the beryllium (lifetime limiting components) and the steel shielding as outer ring component with increased lifetime of 40-50 MW-yr.

14.2.2 Comments

The finding that the effect of the silicon layers in the "advanced" moderator concept is mainly geometric means that this configuration is essentially the same as the moderators with extraction grooves or holes, studied extensively during the late 1970's in the context of the joint SNQ-SINQ R&D work. Most of this has been published in the proceedings of the ICANS collaboration. While such concepts are relatively easy to implement on solid (polyethylene) moderators or even on water moderators, the increased amount of structural material required makes it difficult to realize in a cryogenic moderator of this design due to the extra heating. This does not mean, however, that no further improvement over present designs is possible, and it is certainly a potentially rewarding effort to continue this kind of study. In this context, the committee would like to commend the SNS team for having agreed to take on a leading role in the recently established IAEA-supported effort on directionally enhanced cold neutron beam production.

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. Clearly, the attempt to incorporate larger volume coupled moderators under the existing boundary conditions is an added challenge but is worth the extra effort if the anticipated gain in intensity of about 30 % can actually be realized.

14.2.3 Recommendations

1. Proceed with the nested inner reflector concept to have it ready for the upcoming reflector plug replacement (in 4 years from now, with 2.5 years lead time for procurement). Try to simplify the manufacturing process and do not push improvements to the moderator concept to a point where they might hold up or compromise the deployment of the new plug.
2. Conduct a detailed review of the plug design at the earliest possible point in time.

14.3 Fusion Material Irradiation Test Station

14.3.1 Findings

In an attempt to cater to the needs of the fusion community for materials irradiation facilities and at the same time to broaden the utilization of SNS, the target team has conducted a study to add a Fusion Materials Irradiation Test Station (FMITS) to the outside of the mercury target. In the target region the installation would consist of two sets of three concentric tubes each to contain a water cooling jacket, a gas layer for temperature control and the irradiation samples proper. The two loops would sit on the outside of the target water cooling shroud above and below the target center plane like a bridle. By virtue of an inflatable seal bolted to the target flange they could be removed separately for re-use over more than one target cycle. Running the pipes to the hot cell would require a re-design of the rear part of the target water shroud, a modified insert in the target bulk shield, and connections to be made in the jumper region behind the target flange.

According to the design team the study was completed on Dec. 31, 2011 and included all tasks and systems needed for installation and operation, as well as an evaluation of potential impacts to safety and reliability. The design was well received by a review committee. The ultimate decision path will be based on a balance of mission need of DOE Fusion Energy Sciences and risk to scattering mission of DOE Basic Energy Sciences.

14.3.2 Comments

Irradiation of fusion materials in or near spallation targets has been under discussion for several spallation sources planned or designed in the past. Such proposals have met with great skepticism on the part of the fusion community, because of an alleged lack of representativeness of the damage created, and of low damage levels achievable during the life of a spallation target which does not allow the desired accelerated irradiation experiments. In particular the generation of transmutation products not present in a fusion spectrum has caused concerns.

In this context it may be noted as an example that the He/dpa and H/dpa values given for the SNS-FMITS even for the 5 cm position (20 and 100 appm/dpa) seem to be at least a factor of 2 higher than anticipated in the DEMO first wall where they have been assessed as 11 and 46 appm/dpa.

Of course, in the absence of any other irradiation facilities such discrepancies might be acceptable to the US fusion community, but the pros and cons of adding this facility to SNS certainly require careful analysis.

Although not enough design detail was given in the present review to judge all technical implications, it is clear that adding the device as studied would constitute a significant complication of the system design and handling. Target exchange times would certainly be affected as would be operational risk. It should be clear that a fault on the irradiation rig must not be allowed to affect target operation for the primary mission of SNS, namely neutron scattering.

14.4 Proton beam window

14.4.1 Findings

The committee noted with satisfaction that SNS has finally decided to replace the inconel window in the proton beam by one made from aluminum alloy. This bears the promise of longer life time and reduced activation and heating in the downstream components. The concept foresees an aluminum window internally cooled by water flowing through narrow bores. The aluminum window will be joined to the surrounding stainless steel structure by explosion bonding, which is a complicated procedure but seems to be under control.

14.4.2 Comments

Changing from inconel to aluminum alloy as a window material is clearly a move in the right direction. The design and fabrication of the window was not discussed in detail during the review. Therefore it did not become clear why the window has to be of such relatively complex design and why explosion bonding has to be used rather than a bolted connection with a metal seal.

14.4.3 Recommendation

Consider simplifying the window design at least in the long run.

15 Control systems

15.1 Findings

A new group has been formed within RAD called Data Operations. This group brings together "skills": controls, IT, database; and "responsibilities": accelerator, the instruments (including data acquisition) and enterprise systems at SNS. This is a large group consisting of about 70 people.

Issues discussed at the last AAC have been resolved, and control system availability is meeting expectations.

The SNS has adopted Control Systems Studio (CSS) as its EPICS system toolset. Thus it benefits from developments at many participating laboratories, while at the same time making contributions. These capabilities are being extended to the instruments.

15.2 Comments

The committee is pleased to see that this merging of groups has gone well, and is addressing appropriate challenges.

The reorganization was done in part to make more resources available to science and instrument support. Controls is the one area in which these changes were most visible to the committee.

We simultaneously encourage this effort, as we know it is needed at SNS, while at the same time suggest close monitoring of the utilization of controls resources. We were not presented with the mechanism through which decisions will be made regarding the allocation of resources to the various customers of this group. It is important that this process be transparent, and well communicated to all relevant parties.

16 Beam instrumentation systems

16.1 Findings

Beam instrumentation at the SNS has continued to mature and is providing the needed diagnostic tools for operation and for many of the beam studies. We were presented with a talk that summarized what has taken place in the last several years, which will be briefly noted here.

Beam Loss Monitors (BLMs) are a primary diagnostic tool used in many locations throughout the accelerator and tied to a number of interlock systems. Some conceptual work has begun to address obsolescence issues.

Beam Position Monitors (BPMs) are functioning well, but are also facing obsolescence issues. Additionally, the 6 Hz trigger rate is a limitation in the linac, and this will be addressed in the BPM development project, which will be 60 Hz capable. The first of these units is expected to be installed in the summer of FY12.

An out-of-tunnel camera imaging system for the stripping foil has been developed. This will provide greater reliability as well as enhanced resolution, update rates and other features. Foil temperature monitoring is also being developed.

The ring transverse feedback system is well developed, but progress has slowed with the loss of personnel, and the need to develop a low level system that can accommodate the tune splitting that is observed in the presence of the e-p instability. Tune splitting in the data has led to inconsistent results.

Other diagnostics, particularly those used for beam studies, are being developed or upgraded to provide greater dynamic range, reduced beam perturbations, faster data collection and improved GUIs.

16.2 Comments

The committee is pleased to see the developments that are taking place, and the implementation of a number of state-of-the-art diagnostic tools that will be extremely important as SNS pushes to higher power. In particular the 60 Hz capabilities in the linac will be beneficial.

16.3 Recommendations

1. The ring transverse feedback system work should be pursued, particularly at intensities corresponding to 1.4MW operation. If this cannot be done due to limited resources, a cost projection should be made so that it can be planned in the context of other priorities.
2. The committee was presented with a wish list of mostly unfunded diagnostic development projects. SNS is encouraged to indicate which accelerator performance goal is associated with each diagnostic in order to help prioritize these projects.
3. We encourage SNS to make a near term goal of understanding unidentified errant linac beam losses. The Beam Instrumentation Group would have the capacity to do this job.

17 Availability and maintenance planning

17.1 Findings

There has been an impressive improvement in availability, number of beam hours and MW-Hrs (integrated power) delivered since the last review, culminating in the outstanding 94% avail at 0.8-1 MW so far in FY2012. In the past 2 years, availability has been a higher priority than increasing beam power, with availability increasing from 82% in early FY2010 to 94% in the first 3 months of FY2012, all at beam powers between 800 kW to 1 MW.

A number of factors have contributed to the vastly improved availability. The operational, maintenance and accelerator improvement priorities established during the last two years have been have been instrumental in focusing efforts where they are most needed for improving availability. For example, the focused efforts on HVCM and ion source issues have clearly made a difference. However, it is unclear just how much of the improvement was due to limiting power to 800 kW. In addition, a robust and highly effective maintenance management system has been implemented.

A number of tools are being used effectively to address and manage reliability issues and to aid in maintenance planning and execution, including:

- MIS (Oracle)
- RAMI modeling via ReliaSoft BlockSim7
- Vulnerability Assessment
- Configuration control
- Data Stream Maintenance Management System

These tools are complemented with suitable Spares Management Policies and an Obsolescence Management Plan.

The reliability modeling and vulnerability assessment tools are used to identify system components with high risk for causing long downtimes. MIS and Configuration Control documents are used effectively to track asset/component installation, upgrade and maintenance history.

Maintenance planning and execution have been very successful to date. The maintenance period allocation is a careful balance between costs, availability goals and neutron production time. The availability during recovery from outage periods has greatly improved since the last review. The Data Stream Maintenance Management System is used extensively and effectively to plan and manage the longer maintenance periods.

Good use was made of the opportunity for maintenance during long unplanned downtime during the April target failure.

18 Reliability Modeling, Vulnerability Analysis and Spares Management

18.1 Findings

A formal approach to evaluating spares needs and obsolescence has been established using industry best practices. Beam time accounting data is obtained from the Operations Accounting System and the shift-by-shift account of downtime as well as the Electronic Logbook. Failures are assigned to an asset in CMMS DataStream. The entire machine has been put into ReliaSoft BlockSim7 to create a structure where every component is tagged with all the information available. This has been used for Monte Carlo predictions of availability, which compare favorably with previous work using a Markov chain model. It has also been used to predict the klystron lifetime.

Vulnerabilities were evaluated by seeking assets that had a high risk of failing in a way that would bring the accelerator down for a significant period of time. The system owner scored these assets for likelihood and consequence of failure, and the result was a severity score. This enabled the project to identify many non-standard components with no spares.

The spares policy places responsibility for ordering spares on the system owner. Eventually the ReliaSoft program will provide information on failure rates and time to repair, and even remind the system owner to place an order for spares, although this functionality is not available yet.

Finally, a Configuration Management System has been put in place to ensure that every component placed in the machine, either as a new installation or as a spares replacement, occurs in a controlled fashion.

18.2 Comments

It is tempting to believe that this methodology has, at least partially, contributed to the marked improvement in downtime. However, at this time the structured maintenance program has probably more to do with it.

It will take some effort to get the system owners to buy into using the system, but in the opinion of the Committee this approach has great merit. To be fully adopted, the system needs to generate a result that was not obvious. Forecasting the lifetime of the klystrons at this stage will not generate any useful information, so this was not a good example to pick. Some examples that are likely to provide actionable recommendations should be evaluated.

The Vulnerabilities process was good, although the input data is suspect. A good Group Leader will automatically inflate the risk of not having a spare for a valuable asset to try and ensure that budget is applied to procuring it. The data therefore needs to be carefully vetted by independent experts, to ensure that no biases are present.

The ground rules should be that in the case of a major failure that shuts down the accelerator for a long period, there would be no financial or staffing limitations for the repair. In most cases, applying a focused effort by the lab and the DOE would significantly reduce the predicted repair or replacement time.

In addition, the concept of “bang for the buck” should be rigorously applied. In many cases, keeping an expensive inventory of rarely required spares is not the best use of scarce maintenance funds and alternate solutions should be found for these items (e.g. procuring some of the long-lead sub-components to speed up repair rather than having a complete replacement).

The Configuration Management System should be maintained, as it is a really useful and effective tool, albeit sometimes constraining.

18.3 Recommendation

Re-evaluate the input data to the Vulnerabilities Matrix and apply ground rules for repair priority.

19 Power Upgrade Project

19.1 Findings and Comments

The Power Upgrade Project (PUP) goal is an energy increase to 1.3 GeV, with a consequent beam power increase to 1.8 MW. The scope includes 9 new cryomodules with associated rf power (36 klystrons, 4 modulators). In the ring, the project includes upgrades to chicane magnets and the injection/extraction kickers.

CD-1 was approved in January, 2009. The PUP had advanced almost to the CD-2 stage in 2011 but was indefinitely suspended by DOE.

In the future, a linac energy increase to 1.3 GeV and power increase to 3 MW may be supported as part of a Second Target Station upgrade.

RAD has continued to refine its concepts for the best way to implement the linac energy upgrade and the related current upgrades (e.g, the concept of constant-power operation of the SCL).

19.2 Recommendations

1. Modifications to the machine should not preclude the capability to go to 3 MW in the future.
2. At a low level of effort, the design concepts for a power upgrade to 3 MW should continue to be refined, so that a final design can be more quickly developed when the funding environment improves.

20 Conclusion

The committee applauds the dedicated and careful work that RAD has done which has resulted in the world-record availability performance over the past two years.

We understand the constraints which recent funding limitations have imposed on plans for future upgrades. Our comments and recommendations have been given in the context of a tightly constrained budget.

SNS recognizes its role in training the next generation of accelerator scientists and engineers. However the number of graduate students and post-docs at SNS has dropped. We encourage SNS to explore opportunities to attract and fund graduate students and post-docs.

We strongly support the concept of a power ramp-up to the design level on the proposed 5 year time-scale, and urge SNS to begin this effort in FY12 with the most cost-effective elements of the plan.

21 SNS Accelerator Advisory Committee Charter

- Committee Charge and Responsibilities

  The Accelerator Advisory Committee (AAC) will report to the Oak Ridge National Laboratory (ORNL) Associate Laboratory Director (ALD) for Neutron Sciences and will advise the Research Accelerator Division (RAD) and Neutron Facilities Development Division (NFDD) Directors on the operations and performance of the Spallation Neutron Source accelerator complex, which includes the target systems and the site conventional systems. The Committee will assess and provide advice on accelerator performance, performance limitations, proposed improvements to overcome those limitations, operation of the facility, the on-going program of accelerator science and technology development, and plans for future upgrades to the accelerator complex.

- Committee Membership

  The Chair and Members of the Committee will be appointed by the ALD for Neutron Sciences in consultation with the RAD and NFDD Directors. Members will be appointed to three-year terms with possible renewal by mutual consent.

- Operations

  The AAC will meet regularly, approximately once per year, but may be called upon at other times, via email or teleconference to address specific issues.

  A specific charge for each meeting will be developed by the RAD and NFDD Directors, and transmitted to the Committee in advance. The Chair, in consultation with the RAD and NFDD Directors, will set the meeting agenda.

  A verbal report will be presented at the end of each meeting followed by a written report to the ALD for Neutron Sciences submitted within 4 weeks. The AAC will also be asked to provide an oral briefing to the Neutron Sciences Advisory Board which meets yearly.

22 Committee Membership

- Günter Bauer
  Forchungszentrum Jülich (ret.)
  Wolfsackerweg 8,
  D-79761 WALDSHUT
  Germany
  Email: guenter@bauer-wt.de

- Richard Cassell
  Stangenes Industries, Inc.
  1052 East Meadow Circle
  Palo Alto, CA 94303
  Email: rlcassel@pacbell.net

- Alexander W. Chao
  Stanford Linear Accelerator Center
  2575 Sand Hill Road
  Menlo Park, CA 94025
  Email: achao@slac.stanford.edu

- Gerry Dugan, Chair
Newman Laboratory
Cornell University
Ithaca, NY 14853
Email: gfd1@cornell.edu
- Masatoshi Futakawa
Japan Proton Accelerator Research Complex (J-PARC)
Tokai-mura, Ibaraki-ken, 319-1195
Japan
Email: futakawa.masatoshi@jaea.go.jp
- Roland Garoby
CERN
European Organization for Nuclear Research
CERN CH-1211 Geneve 23
Switzerland
Email: Roland.Garoby@cern.ch
- Rod Gerig
Argonne National Laboratory
9700 S. Cass Avenue
Lemont, IL 60439
Email: rod@aps.anl.gov
- Stephen D. Holmes
Fermi National Accelerator Laboratory
105 (WH 2E)
P.O. Box 500
Batavia, IL 60510
Email: holmes@fnal.gov
- Andrew Hutton
Thomas Jefferson National Accelerator Facility
12000 Jefferson Avenue
Newport News, VA 23606
Email: andrew@jlab.org
- Roderich Keller
Group Leader, AOT-ABS
Los Alamos National Laboratory
P.O. Box 1663- MS H817
Los Alamos, NM 87545
Email: roderich@lanl.gov
- Robert J. Macek
Los Alamos National Laboratory
P.O. Box 1663
Los Alamos, NM 87545
Email: macek@lanl.gov
- Dieter Proch
MHF-SL
DESY-Deutsches Elektronen-Synchrotron (ret.)
Notkestr. 85
22603 Hamburg
Germany
Email: info@dieterproch.de

Figure 1: Agenda for the fourth meeting

Tuesday January 10, 2012
Room C-156

Length	Time Start	Time Stop	Talk	Speaker	Content
0:30	8:00	8:30	Gathering and Greeting		
0:30	8:00	8:30	Executive Session		
0:30	8:30	9:00	SNS Overview	K. Beierschmitt	Overview of SNS, Organizational Changes
0:40	9:00	9:40	Accelerator Systems Overview and Plans	K. Jones	New RAD Organizational Structure, Accelerator System, 1.4MW Ramp Up Plan, Challenges and Progress
0:30	9:40	10:10	Instrument Systems Development Overview and Plans	P. Fergusson	ISDD, Target Systems, Target Systems Challenges and Plans
0:20	10:10	10:30	Discussion		
0:20	10:30	10:50	Break		
0:20	10:50	11:10	SNS Operations Performance and Downtime	G. Johns	Metrics, Performance plots, downtime results
0:40	11:10	11:50	Accelerator Physics Overview	J. Galambos	Ramp Up progress and challenges, beam loss overview, key AP topics
0:20	11:50	12:10	Discussion		
0:50	12:10	13:00	Lunch		
0:35	13:00	13:35	Ion Source and LEBT Performance and Plans	M. Stockli	IS and LEBT Performance, limitations, challenges
0:25	13:35	14:00	Front-End and NC Linac Overview	A. Shishlo	Front-end performance, chopper systems, emittance, NC Linac performance, losses, challenges
0:10	14:00	14:10	Discussion		
0:35	14:10	14:45	Superconducting Linac Operations and Performance	S-H. Kim	SC Cavity and Cryomodule performance
0:15	14:45	15:00	Discussion		
0:15	15:00	15:15	Break		
0:45	15:15	16:00	HEBT/Ring/RTBT Overview	M. Plum	Overview, challenges, Idmp, Injection, Rings, RTBT/Target interface, Stripper Foils
0:35	16:00	16:35	Mechanical Systems Performance and Plans	M. Baumgartner	Target Systems overview
0:25	16:35	17:00	Discussion		
1:00	17:00	18:00	Executive Session		
	19:00		Review Dinner		

Wednesday January 11, 2012
Room C-156 Accelerator Breakout

Length	Time Start	Time Stop	Talk	Speaker	Content
0:30	8:00	8:30	Gathering and Greeting		
0:30	8:30	9:00	Superconducting RF Activities and Plans	S-H. Kim	Spare CM, CM/Cavity Development, RFTF, Facilities progress, plans
0:20	9:00	9:20	Linac Modulator Operations and Performance	V. Peplov	Modulator downtime, failure modes and performance
0:40	9:20	10:00	Linac Modulator Upgrades	D. Anderson	Modulator development and upgrade plans
0:15	10:00	10:15	Discussion		
0:20	10:15	10:35	Break		
0:20	10:35	10:55	RF System Performance	T. Hardek	RF System performance and issues
0:25	10:55	11:20	Linac Beam Dynamics Progress	J. Galambos	Linac performance, matching, acceptance, SCL algorithms, $H^{+/}$ H^{-} Beams
0:20	11:20	11:40	Ring Beam Dynamics Progress	S. Cousineau	Lattice, tunes, collective effects, high intensity, collimation, etc.
0:15	11:40	11:55	Discussion		
0:50	11:55	12:45	Lunch		

Room C-152 Target Breakout

Length	Time Start	Time Stop	Talk	Speaker	Content
0:35	8:30	9:05	Neutron Source Development	F. Gallmeier	Cryo moderator, advanced materials, next gen IRP
0:45	9:05	9:50	Target Development	B. Riemer	R&D progress and plans, PIE
			Target Action Items	B. Riemer	
0:15	9:50	10:05	Discussion		
0:20	10:05	10:25	Break		
0:40	10:25	11:05	Target Engineering	P. Rosenblad	Limits on present target, planning for next target, leak detection system + other diagnostics
0:35	11:05	11:40	Remote Handling	M. Dayton	Experience with target/PBW change out, PIE preparations, CVI procedures, waste handling
0:15	11:40	11:55	Discussion		

Room C-156 Full Committee

Length	Time Start	Time Stop	Talk	Speaker	Content
0:30	12:45	13:15	Beam Instrumentation Performance and Plans	A. Aleksandrov	BI systems overview, new systems under development
0:20	13:15	13:35	Laser Based Beam Instrumentation	Y. Liu	Laser Wire, Emittance Measurement, Laser Stripping
0:40	13:35	14:15	Controls System Performance and Plans	K. White	Controls systems overview, machine protection, performance issues, challenges and plans
0:20	14:15	14:35	Discussion		
0:20	14:35	14:55	Break		
0:35	14:55	15:30	Reliability, Vulnerability and Spares Management	Dodson	Reliability Modeling, Vulnerability Analysis and Spares Management Policy
0:25	15:30	15:55	Maintenance Management	M. Giannella	Maintenance Planning and Execution
0:10	15:55	16:05	Beam Power Upgrade Project	Galambos	Status of PUP/CUAIPs
0:40	16:05	16:45	Discussion		
1:00	16:45	17:45	Executive Session		

Thursday January 12, 2012

Length	Time Start	Time Stop	Talk
0:30	8:00	8:30	Gathering and Greeting
3:00	8:00	11:00	Executive Session
1:00	11:00	12:00	Closeout
12:00			Lunch