SNS 102000000-TR0004 - R00

# The Spallation Neutron Source: Operational aspects and reliability in the transition from commissioning to fully committed User Operation

February 2002

Discussion Paper

February 6, 2002
Thom Mason/Norbert Holtkamp

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## Introduction

The purpose of this short note is to provide the Spallation Neutron Source (SNS) management perspective on the approach and timescale necessary for the SNS facility to realize its ultimate goals of scientific productivity based on high power, reliability, and availability. The SNS complex includes a front end, 1 GeV $H^-$ linac, compressor ring and a target station that includes the research instruments. In addition, support facilities on site provide cooling water; electrical utilities; 2K helium; shop, laboratory and office space for staff and users; and storage space. This scientific infrastructure represents an investment of $1.4 B in support of research into the structure and dynamics of materials. In addition, a Nanoscience center, the Joint Institute for Neutron Sciences (JINS) and possibly, at some time later, a second target station and a Superconducting RF development facility are planned.

Experience at other major neutron and x-ray user facilities that serve the materials community has shown that high reliability and availability are crucial metrics of facility performance in terms of the ability to deliver a robust scientific program. Successful accelerator based user facilities have been able to deliver reliability with respect to schedule approaching 95% and availability up to 5000 hours per year. This is true for both synchrotron x-ray facilities and spallation neutron sources such as IPNS and ISIS. Because of the unprecedented power levels of the SNS 5000 hours per year at 95% represents a challenging goal that will not be met immediately on completion of the construction phase of the project (defined by meeting the criteria for Critical Decision 4 (CD-4)). However, following a two-year period of commissioning and ramp up of the power level we anticipate being able to operate in user mode (defined as >90% availability) at ~MW level power levels. As experience with operation is gained we plan to asymptotically approach the ultimate goal of 5000 full power hours per year at 95% reliability.

How is this user requirement integrated into the design of the facility? On what schedule can SNS achieve an availability of 90% and what can be can be done as the construction of the facility progresses to facilitate success? Several review committees have struggled with these questions. This document is intended to give guidance on what the route should be to define successful operation after initial commissioning beyond CD-4 and after the final approval for Operational Readiness Review (ORR) in ’06. For the purposes of this document we have measured time from the late finish date of ’06 since that represents the external commitment for the project in the Data Sheet. The Project is working to an early finish date of Dec. ’05, which, if met, would accelerate the schedule by six months.

**Operation Mode for the SNS**

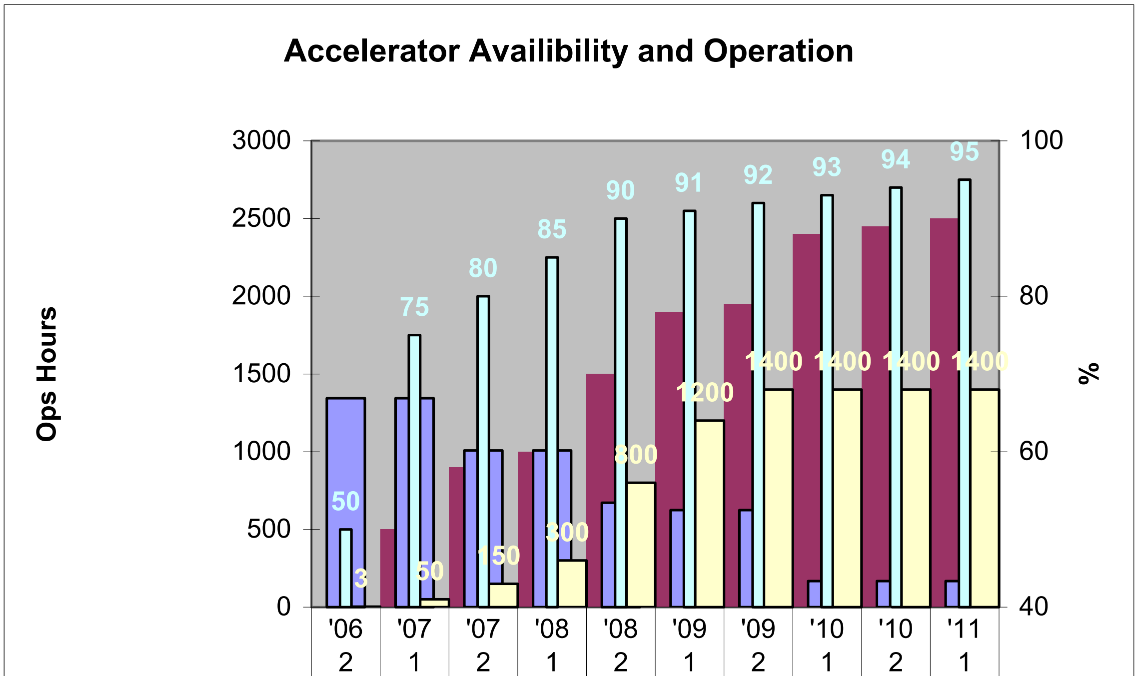
Ultimately the typical mode of operation for the SNS is similar to synchrotron radiation light sources, where each week allows for a short break to organize preventive maintenance (PM) and setup of the accelerator and experimental equipment:

| Activity | Hours | %Up | %Down |
|---|---|---|---|
| One week run cycle | 168 | | |
| One shift of PM per week | 8 | | 4.7% |
| Two Recovery/AP Shifts | 16 | | 9.5% |
| Assumed unscheduled downtime | 14.4 | 90% | 10% |
| **User Beam Availability** | **129.6** | **77%** | **23%** |

It is important to note that reliability is measured with respect to scheduled user beam operation, i.e. scheduled downtime for maintenance etc. does not impact reliability since it can be planned around. Scheduled downtime does affect overall availability, but in general the user community will prefer to have planned as opposed to unplanned outages even if it implies somewhat lower availability overall. Similarly the user community will be willing to accept reduced power of operation if it yields improved reliability even at the expense of overall reduced integrated beam current. These two factors mean that SNS will optimize user mode operation to achieve at least 90% reliability with the number of scheduled beam hours and power level chosen, based on operating experience that is anticipated to meet the reliability constraint. In doing so it is important to understand that the duration of downtime events is also important. Generally, very short beam interruptions are not a problem, except in specific time sensitive experiments that are not typical although they do occur. In fact, some facilities exclude short duration trips from their reliability statistics since they do not adversely impact users. Since typical experiments are a couple of days to a week or two in duration it is shut downs that become significant on that scale that are important, i.e. an hour or so to days. A shutdown of very long duration becomes, in effect, scheduled downtime since experiments are rescheduled.

The figures above do not reflect reliability for individual instruments (which are generally not tabulated in facility statistics) due to the fact that a failure in one instrument does not usually impact the whole facility. However, instrument reliability is every bit as important as beam reliability and the same goals apply, which implies instrument reliability on the order of 98%.

The figure below shows what we believe represents a reasonable planning basis for the early years of operation for SNS. It tabulates, hours of user operations, accelerator physics studies, beam power, and reliability following CD-4 shown in six-month intervals flowing project completion.




| | '06 2 | '07 1 | '07 2 | '08 1 | '08 2 | '09 1 | '09 2 | '10 1 | '10 2 | '11 1 |
|---|---|---|---|---|---|---|---|---|---|---|
| User Ops hours | 0 | 500 | 900 | 1000 | 1500 | 1900 | 1950 | 2400 | 2450 | 2500 |
| Accel. Phyics | 1344 | 1344 | 1008 | 1008 | 672 | 624 | 624 | 168 | 168 | 168 |
| Beam Power/kW | 3 | 50 | 150 | 300 | 800 | 1200 | 1400 | 1400 | 1400 | 1400 |
| Reliability (%) | 50 | 75 | 80 | 85 | 90 | 91 | 92 | 93 | 94 | 95 |

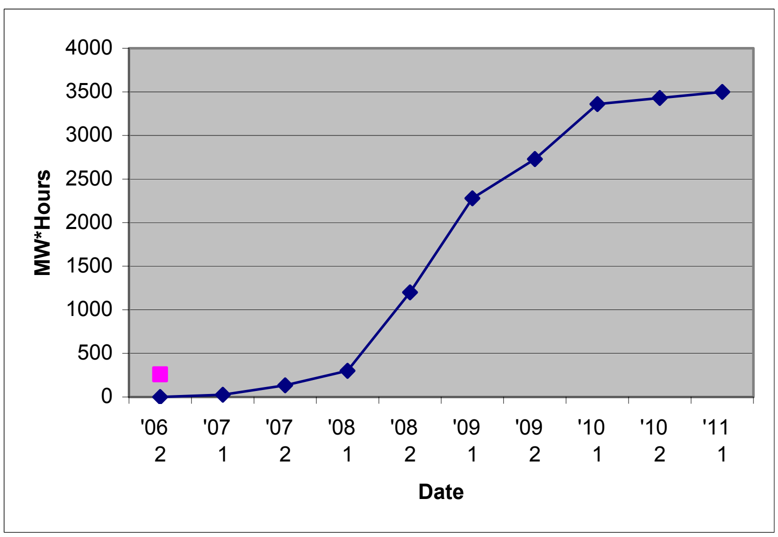
The gradual increase for the three user parameters is based on the presently foreseen program in which the commissioning of the instruments, as well as the continuous development, construction and installation of instruments, will require significant time especially in the first two years of operation. At the same time there is the necessity to approach the beam power design goal carefully, in order to guarantee safe and well controlled operation of the first of a kind liquid mercury target. Nevertheless, it is well understood that the lifetime is inversely proportional to beam power.

In the initial six-month period following CD-4 the target facility will be undergoing an Operational Readiness Review (ORR) and until that is complete will be under regulatory constraint of both the power level and duty factor to stay below the isotope inventory threshold for a nuclear facility. During these very low power operations the neutron production will be sufficient for beam tests of instruments to verify detector performance and timing etc. but not a full suite of experimental capability. Facility staff will carry out this work, and there is minimal need for reliability although advance notice of beam availability on a weekly scale will assist in making good use of the time.

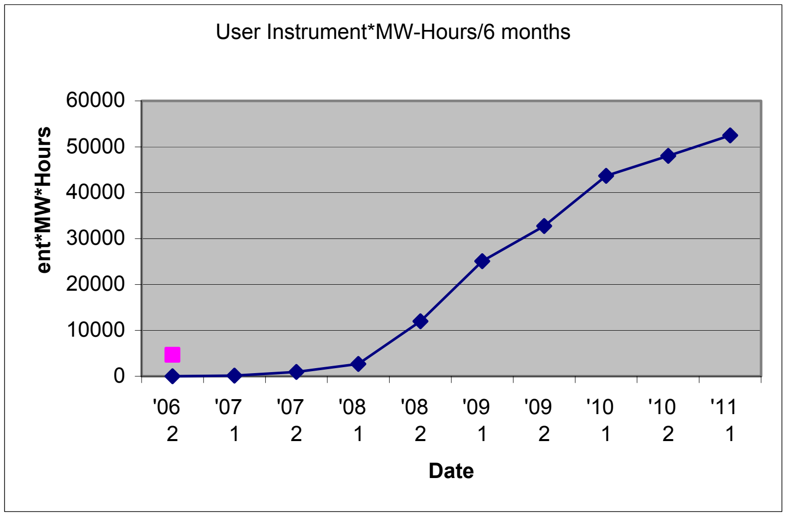
Once the ORR is complete, the facility will be able to initiate high power operation. The first six months of high power operation will also be used by facility staff for test experiments and debugging instrument control and data analysis software. The beam power should be sufficient to permit testing of the full range of experimental capability (including inelastic scattering), which implies at least 50 kW or so at 75% reliability.

This plan foresees that in the second half of 2007 the facility will deliver 900 hours of beam time with a beam power comparable to the best in the world (150 kW). Within these 900 hours (over six months) the availability of the complex should come close to 80 percent to permit conducting experiments with external scientists in a "friendly user" mode and further refinement of data analysis software. The first half of 2008 should see progress to beam power beyond that available at any other facility (300 kW) with continued progress in reliability. By the second half of 2008, two years after project completion, the user program will commence with 90% reliability at ~MW power levels.

The data above can be used to project the integrated beam power delivered in each six-month interval as shown below. For comparison the corresponding data for ISIS in 2000 is shown at the left hand side of the figure. By adding in the expected growth of the instrument suite (approximately nine by the start of user operations and two per year after that) the growth of overall scientific capacity can be gauged (again ISIS 2000 is shown for reference). This figure of merit will continue to grow as beyond the time frame of the current projection as an additional nine instruments (for a total of 24) are completed and the power is increased to upgrades to the accelerator and target over the operating life of the facility.




In addition to attention to reliability issues in design and provision for adequate spares in the construction project this plan implies robust operational funding during the early years of operations (which is reflected in the Operation Budget that has been presented to the Department of Energy). Typical improvements of the rf systems, debugging of components and infant mortality of equipment being replaced by new hardware will be done. At the same time a well trained operations crew, which is supported by the technical groups of the division and the accelerator physics group, will be available since all of them are very familiar with the equipment installed by them and operated for more than two years.




**Summary**

A multiyear plan for the Spallation Neutron Source has been described in which the ultimate goals of the facility (beam power, availability, and reliability) can gradually be achieved over a time period of approximately two and a half years. The plan allows for installation, testing, and commissioning of instruments as well as for careful commissioning for the ultimate power on a one of a kind liquid mercury target. It should provide the basis for a successful initiation of research at SNS and the basis for planning to achieve this.