*Department of Energy*
*Review Committee Report*

on the

Technical, Cost, Schedule, and
Management Review

of the

# SPALLATION NEUTRON SOURCE (SNS) PROJECT

May 2002

# EXECUTIVE SUMMARY

A Department of Energy (DOE) Office of Science review of the Spallation Neutron Source (SNS) project was conducted at Oak Ridge, Tennessee during May 7-9, 2002, at the request of Dr. Patricia M. Dehmer, Associate Director for Basic Energy Sciences, Office of Science. The purpose of the review was to evaluate progress in all aspects of the project: technical, cost, schedule, management, and ES&H. Special emphasis was given to evaluating whether the project's status was consistent with the cost, schedule, and technical baselines.

Overall, the Committee found that the SNS project remains on track to meet its Level 0 Baseline objectives: Total Project Cost (TPC) of $1,411.7 million; project completion by June 2006; and $\geq$ 1 megawatt proton beam power on target. Technical progress has continued to be excellent, and as of March 31, 2002, the project is 41.0 percent complete (versus 40.8 percent planned). Over 60 percent of all procurements have been placed under contract. The Front End has been assembled, tested, and will be shipped to the SNS site for installation beginning in June 2002. Other accelerator components have also begun arriving in Oak Ridge. In the area of Conventional Facilities, the Front End Building and Klystron Hall are nearing completion, and the Linac and Ring tunnels are well along. These construction activities (over 600,000 work-hours to date) have been accomplished without a lost workday injury. Most of the recommendations from the November 2001 DOE review have been implemented.

The SNS project is a multi-laboratory partnership led by the SNS Project Office in Oak Ridge, Tennessee. The partners are Argonne National Laboratory, Brookhaven National Laboratory, Lawrence Berkeley National Laboratory, Los Alamos National Laboratory, Oak Ridge National Laboratory, and Thomas Jefferson National Accelerator Facility. Relations among the SNS partner laboratories are excellent and communications are good. With the arrival of a new Experimental Facilities Division Director in March, all key management positions are again filled with permanent staff.

While the Committee expressed confidence that the project could be completed on schedule and within the TPC, it urged SNS management to judiciously conserve contingency funds (currently 21.6 percent of the remaining work). This contingency level is considered to be tight, especially considering that pending awards of the last two large conventional construction subcontracts (due in July) are anticipated to significantly exceed their baseline estimates. The Committee recommended that a quantitative, risk-based contingency analysis be prepared for the next DOE review.

There is also a lingering technical issue having to do with target window material pitting that could threaten the ultimate viability of the liquid mercury target concept. Materials testing is ongoing, and the project has set a "Go/No-Go" decision date of October 2002 for deciding whether to keep the liquid mercury target as the baseline design, or switch to a solid target (at least for commissioning). Although a solid target would still support achieving the $\geq$ 1 MW beam power objective, it would limit SNS from reaching higher power levels. Regardless of the decision to be made in October, the Committee recommended that the project keep options open for switching target configurations after CD-4 and assigned an action for it to provide DOE with a status report by July 31, 2002.

In summary, the Committee found that the SNS project is well prepared to meet its Level 0 Baseline objectives, and management is on top of the issues. There is no room for complacency, however, as substantial challenges lie ahead in maintaining adequate contingency while solving the target window material pitting problem, starting accelerator installation and commissioning, and safely completing conventional construction.

# CONTENTS

# 1. INTRODUCTION

## 1.1 Background

When completed in 2006, the Spallation Neutron Source (SNS) will be the world's foremost neutron scattering facility. It will be an important scientific tool for basic research in materials science, life sciences, chemistry, solid state and nuclear physics, earth and environmental sciences, and engineering sciences. The design calls for a beam of negatively-charged hydrogen ions ($H^-$) to be generated and accelerated to an energy of one billion electron volts (1 GeV) using a linear accelerator (Linac). The $H^-$ beam will then be transported to an accumulator ring, where it will be injected by stripping away the electrons to leave the desired protons and bunching them into a short (under one microsecond) pulse 60 times per second. Finally, the proton beam will be directed onto a liquid mercury target, where pulses of neutrons will be created through spallation reactions of the protons with the mercury nuclei. Inside the Target Building, the emerging neutrons will be slowed or moderated and channeled through beamlines to instrumented experimental areas where users will carry out their research. Figure 1-1 shows a pictorial view of the facility.

The SNS project is being carried out as a multi-laboratory partnership, led by the SNS Project Office at Oak Ridge, Tennessee. Besides Oak Ridge National Laboratory (ORNL), the other laboratory partners include: Argonne National Laboratory (ANL), Brookhaven National Laboratory (BNL), Los Alamos National Laboratory (LANL), Lawrence Berkeley National Laboratory (LBNL), and the Thomas Jefferson National Accelerator Facility (TJNAF). This collaborative approach is being used to take advantage of the best expertise available in different technical areas and to make the most efficient use of Department of Energy (DOE) laboratory resources. As indicated in Figure 1-1, and defined in the SNS Project Execution Plan (PEP), each laboratory is responsible for a specific scope of work. Design and construction management of the conventional facilities is being handled by a commercial architect engineer/construction management (AE/CM) team (Knight-Jacobs) under a task order contract to ORNL.

A Final Environmental Impact Statement (FEIS) for the SNS was issued in April 1999. On June 18, 1999, the Secretary of Energy signed the Record of Decision to proceed with construction of the SNS at ORNL. A Mitigation Action Plan (MAP) was prepared, identifying actions taken by DOE and the project to avoid or minimize environmental harming building and operating the facility. All actions identified in the MAP have now been properly implemented and closed out.


**Figure 1-1. The Spallation Neutron Source**

The SNS conceptual design was carried out during FY 1996 and FY 1997, at a cost of about $16 million, and evaluated by a DOE review committee in June 1997 (report DOE/ER-0705). At the same time, a DOE Independent Cost Estimate was performed. In response to recommendations from these reviews, the project schedule was extended from six to seven years, and other adjustments were made that increased the Total Project Cost (TPC) from $1,226 million to $1,333 million (as spent[1]).

Critical Decision (CD) 1, Approval of Mission Need, and CD-2, Approval of Level 0 Project Baseline, for the SNS were approved by the Secretary of Energy in August 1996 and December 1997, respectively. The SNS PEP, which governs how the project is managed, was initially approved by the Secretary at the time of CD-2; it was most recently updated in July 2001 and another update is planned for June 2002. The Level 0 cost and schedule baselines set at CD-2 comprised a TPC of $1,333 million and a seven-year design/construction schedule, with facility commissioning to occur at the end of FY 2005. The approved Level 0 technical baseline stipulated that the accelerator complex would produce a proton beam on target of $\geq$ 1 megawatt (MW). Receiving $23 million in FY 1998, the project carried out advanced conceptual design and further R&D activities in anticipation of starting Title I design in FY 1999.

A DOE Technical, Cost, Schedule, and Management Review of the project was conducted in June 1998. Its principal finding was that the project's management organization and systems were sufficiently mature to initiate the construction project at the beginning of FY 1999. Further work was deemed necessary, however, to complete a detailed cost and schedule baseline, and to restore project contingency to at least 20 percent. A strong recommendation was made to hire a permanent Project Director as soon as possible and to continue building the Accelerator Systems Division at ORNL.

The FY 1999 SNS project construction line item was approved and funded by Congress to start Title I design and initiate long-lead procurements, but only at a level of $130 million, as compared to $157 million requested in the President's FY 1999 Budget Request. As a result of the $27 million funding shortfall in FY 1999, the project schedule was extended by three months (completion due in December 2005), and the TPC was increased to $1,360 million. The President's FY 2000 Budget Request for the SNS project was $214 million ($196.1 million of line item construction funds and $17.9 million of operating expense funds).

[1] All cost figures throughout this report are in "as-spent" (i.e., escalated) dollars.

In November 1998, ORNL competitively awarded an AE/CM contract to a joint venture led by Lester B. Knight and Sverdrup Facilities, Inc. (Sverdrup has since been acquired by Jacobs Engineering Group, Inc.). The AE/CM team is responsible for design and construction of all conventional facilities.

At a DOE review of the SNS project in January 1999, the review committee determined that the SNS collaboration was continuing to work well together, and technical progress was generally good, however the baselines were still not judged to be ready for DOE approval. The main reason was lack of technical leadership and project-wide ownership by the relatively inexperienced SNS Project Office management team then at ORNL. The committee strongly recommended that a new Project Director be recruited with extensive experience in construction of large technical/scientific facilities and with the technical background, including accelerators, needed to make major design decisions. Overall, the $1,360 million TPC was deemed to be adequate to complete the facility as designed. The committee, however, urged a further increase in contingency.

As an immediate result of the January 1999 DOE review, a new Project Director was brought on board from ANL in early March to lead the project for a two-year term. He brought with him a strong track record in managing large scientific construction projects and a user perspective as a neutron scientist. Between April and June 1999, the SNS Project Office at ORNL was reorganized and additional technical and management staff members were recruited to fill key positions. The partner laboratories were directed to optimize and fully integrate the technical design, and to strengthen the business and project management systems to support construction activities. The SNS technical parameters were revised to include an average proton beam power on target of up to 2 MW, enhanced ("Best-in-Class") instruments, and expanded laboratory and office space for users and staff.

In July 1999, another DOE review was conducted for the purpose of evaluating the project's proposed technical, cost, and schedule baselines. The review committee judged the baselines to be credible and consistent with the FY 2000 Budget Request funding profile, and recommended their approval by DOE. Confidence was expressed that the new SNS Project Office team could lead the project to success. The committee felt that the management team had moved aggressively to take full ownership of all technical, cost, and schedule aspects of the project, and defined a clear vision and a disciplined management approach.

In order to strengthen the commitment among the partner laboratories, the 1998 inter-laboratory Memorandum of Agreement (MOA) was revised, and signed by the laboratory directors in October 1999. It replaced the original MOA in the SNS PEP, and is also included by reference in the laboratories' management and operations (M&O) contracts. The latter step had the effect of making the MOA a legally binding agreement.

At $117.9 million, the FY 2000 appropriation for SNS was $96.1 million less than the $214 million request. This, coupled with the project's restructuring under new management, led to an estimated delay in project completion of six months (to June 2006), and a corresponding increase in the TPC of $80 million (to $1,440 million including Tennessee taxes, see below). In addition, the House report (Report 106-253, pages 113-114) accompanying the FY 2000 Energy and Water Development Appropriations Act prohibited DOE from obligating FY 2000 funds to SNS until seven conditions had been satisfied. The project was able to make continued progress, however, by using uncosted obligations remaining from FY 1999 while efforts were made to satisfy these conditions. In particular, DOE approved CD-3, Start Construction, on November 5, 1999, and site preparation work on Chestnut Ridge began soon thereafter. A formal groundbreaking ceremony for SNS was held on December 15, 1999. By February 2000, DOE and the project had satisfied the seven congressional conditions and all FY 2000 construction funds were released to the project. Later in FY 2000, the project managed to complete most Title I design activities, as well as nearly all site clearing, excavation, and road work.

One of the conditions in the FY 2000 House report was for the cost baseline and project milestones for each major SNS construction and technical system activity to be reviewed and certified by an independent entity as the most cost effective way to complete the project. In order to satisfy this condition, DOE tasked an External Independent Review (EIR) contractor (Burns & Roe) who then conducted such a review during September through November 1999. The final Burns & Roe EIR report (December 1999) stated: "Burns and Roe's view is that the planned approach to executing the SNS project, as reflected by the baseline documents that support the FY 2000 Budget Request, is the most cost effective approach to project completion."

Another condition imposed by Congress was that the General Accounting Office (GAO) had to certify that the total taxes and fees on SNS paid to the State of Tennessee or its counties/municipalities would be no greater than if SNS were located in any other state that contains a DOE laboratory. In response, the Tennessee state government enacted a law to completely exempt SNS from state and local sales and use taxes (estimated at $28.3 million). This tax exemption addressed the last remaining condition in the House report, and GAO provided the necessary certification.

In April 2000, the M&O contract for ORNL was turned over from Lockheed Martin Energy Research Corporation to a team led by the University of Tennessee and Battelle Memorial Institute. From the SNS project perspective, the transition went smoothly—there were no adverse impacts.

The President's FY 2001 Budget Request for SNS was amended to reduce the TPC from $1,440 to $1,411.7 million to account for the Tennessee tax exemption. Congress appropriated the entire requested amount for FY 2001 (minus a $512,000 rescission) and DOE provided the project with $258.9 million in construction funds and $19.1 million in operating expense funds.

In October and December 2000, a two-phase DOE review was conducted that included an initial evaluation of the SNS pre-operations plan and cost estimate. Three major issues were identified in the first review phase, two of which had to do with the potential for significant cost growth in different areas, one in conventional facilities and the other in pre-operations. It was also noted that the project was using contingency at an alarming rate. The cost growth concerns stemmed from the AE/CM's preliminary Title I design estimate for Conventional Facilities, which was about $80 million over the cost baseline, and an overly aggressive pre-operations staffing plan. The third issue was that the Integrated Project Schedule (IPS) required more Budget Authority than that contained in the FY 2001 Project Data Sheet's annual funding profile.

SNS management took immediate steps to resolve these issues, and by December, the committee found that the project had developed workable plans to address them. The overall approach to dealing with the cost concerns involved value engineering and selective scope reductions that still allowed the project to meet its Level 0 Baseline objectives. There were significant scope reductions in conventional facilities that included deleting the Central Laboratory and Office (CLO) Building (while retaining a minimum level of functionality) and reducing the size of the Target Building, and the instrument budget was reduced from $93 million to $53 million (still more than the conceptual design level of $45 million). In addition, the last three cryomodules of the Superconducting Linac were deleted to save money, resulting in a lower Linac output energy of 840 MeV, while still providing a proton beam power on target of over 1 MW. The pre-operations staffing level was reduced to the minimum level necessary to commission the machine. Lastly, the IPS was re-planned to be consistent with the Budget Authority in DOE's annual funding profile and still provide six months of schedule contingency.

SNS management met with DOE in February 2001 to finalize the actions needed to resolve the cost and schedule issues described above. As a result, a reduced-scope CLO was retained in the baseline; the instrument budget was adjusted to $60 million to provide for at least five instruments plus design of common components for future instruments; certain DOE milestones were relaxed to conform with the revised IPS; and the energy specification for Linac output energy was restored to 1 GeV (while retaining the proton beam power on target requirement of $\geq$ 1 MW). Although there was a net shift in baseline installation scope from the partner laboratories to SNS to allow the necessary buildup of Accelerator System Division staff, there was no change in the Total Estimated Cost (TEC) or TPC.

In February 2001, the Project Director had reached the end of his two-year term as leader of the SNS project, and rather than extend, he elected to return to Argonne National Laboratory. After an extensive search by the Director of ORNL, the SNS Experimental Facilities Division Director (Dr. Thomas Mason) was selected to take charge as SNS Project Director. Having been with the project since its inception, he is thoroughly familiar with SNS and is also well known in the neutron scattering research community. Other changes in the senior management team were completed over the following months with the permanent appointment of new personnel to the three SNS Division Director positions (Accelerator System Division, Experimental Facilities Division, and Conventional Facilities Division).

The FY 2001 and 2002 congressional appropriations for SNS have met the levels contained in the President's Budget Requests ($278.0 million and $291.4 million, respectively). Accordingly, the project's TEC and TPC have remained constant at $1,192.7 million and $1,411.7 million, respectively. The FY 2003 appropriation is the peak of the project's annual funding profile.

During FY 2001-2002, construction activities at the Chestnut Ridge site have included extensive structural work on the Front End Building, Linac and Ring Tunnels, Klystron Hall, Target Building foundation, and site utilities and support buildings. In fact, the Front End Building is now essentially complete. As of March 31, 2002, the overall project was 41 percent complete, had awarded over $300 million in procurements, completed 76 percent of all design work and 92 percent of all R&D. Only two large Conventional Facilities procurements remain (CLO and Target Building General Construction) and these are planned for award in July 2002. The Front End System has been mostly completed at LBNL and is scheduled for shipment to ORNL beginning in June with commissioning to start in fall 2002. Other technical components have also begun to arrive in Oak Ridge at the Receiving, Assembly, Test and Storage (RATS) Building. The overall size of the project work force, including construction workers, has exceeded 1,000 full-time equivalents (FTE), which is near its peak level.

## 1.2 Charge to the DOE Review Committee

In a March 15, 2002 memorandum (see Appendix A), Dr. Patricia M. Dehmer, Associate Director for Basic Energy Sciences, Office of Science, requested that Daniel R. Lehman, Director, Construction Management Support Division lead a review to evaluate all aspects of the project, including technical, cost, schedule, management, and ES&H. In addition, the Review Committee was asked to verify that the project's technical, cost, and schedule baselines are consistent with the current DOE-approved SNS PEP and FY 2003 Project Data Sheet.

## 1.3 Membership of the Committee

The Review Committee (see Appendix B) was chaired by Daniel R. Lehman and James R. Carney. Members were chosen on the basis of their independence from the project, as well as for their technical and/or project management expertise, and experience with building large scientific research facilities. Continuity and perspective were provided by the fact that many of the members served on one or more of the previous eight DOE review Committees. The Committee was organized into eleven subcommittees, each assigned to evaluate a particular aspect of the line item project corresponding to members' areas of expertise.

## 1.4 The Review Process

The Review was accomplished during May 7-9, 2002, at Oak Ridge, Tennessee. The agenda (Appendix C) was developed with the cooperation of the SNS Project Office, DOE Headquarters, and DOE Oak Ridge Operations Office staff. Comparison with past experience on similar projects was the primary method for assessing technical requirements, cost estimates, schedules, and adequacy of the management structure. Although the project requires some technical extrapolations, similar accelerator projects in the United States and abroad provide a relevant basis for comparison.

The morning of the first day was devoted to a plenary session with project overview presentations by members of the SNS Project Office staff, followed by a tour of the construction site. In the afternoon and throughout the second day, there were presentations by the partner laboratories with subcommittee breakout sessions to discuss detailed questions from the Committee. The third day was spent on Committee deliberations, report writing, and drafting a closeout report. The preliminary results were discussed with SNS management and staff at a closeout session on the last day.

# 2. TECHNICAL SYSTEMS EVALUATIONS

## 2.1 Accelerator Physics

### 2.1.1 Findings

The Accelerator Physics work being performed is excellent, both on the SNS site and at the partner laboratories. The Accelerator Physics group at ORNL continues to enhance its lead role. At the November 2001 DOE review it was recommended to:

> "Resolve how to control the halo of the beam distribution, as it emerges from RFQ, for example by putting collimators in DTL tank 1."

Accelerator Physicists at ORNL, Brookhaven National Laboratory (BNL), and Los Alamos National Laboratory (LANL) have made a careful simulation study of this issue, summarized in the extensive report "Linac Halo Mitigation." One scenario considers inserting scrapers in the first ten empty drift tubes in Drift Tube Linac (DTL) tank 1. A second scenario places a collimator next to the chopper target in the middle of the Medium Energy Beam Transport (MEBT) section. A last scenario considers optics changes in the MEBT, designed to make the beam rounder, and therefore less susceptible to the generation of halo tails.

The report concludes that a hybrid solution is optimal, with a collimator in the MEBT chopper target box and modified MEBT optics. When nominal beam parameters are used, simulations suggest that there is a result of 97 percent reduction in the halo. This proposal has been accepted, and will be implemented when the Front End is re-commissioned at SNS in fall 2002.

Real beam distribution measurements are becoming available, now that the commissioning of the Front End at Lawrence Berkeley National Laboratory (LBNL) is entering its final stages. For example, the beam emittances at moderate beam currents appear to be consistent with nominal specifications.

The other Accelerator Physics recommendation at the November review was:

> "Prepare, for Front End re-commissioning at ORNL in fall 2002, a diagnostic system in the MEBT to demonstrate beam gap cleanliness, as well as to measure transverse halo."

There is a plan to put instrumented, isolated scrapers in the chopper target box that will support beam gap cleanliness. It is hoped that this diagnostic will be able to measure the beam distribution, including halo, over 4 orders of magnitude. Also present in this plan is an in-line emittance measurement device.

The interfaces between Accelerator Physics, Controls, and Diagnostics groups are strong, and are developing in a healthy fashion. This is necessary for efficient and rapid beam commissioning. The "global database" is a central repository for the well-regulated maintenance of public data owned by these three groups and others, including the survey, magnet measurement, power supply, and radio frequency (RF) groups. There are two versions of this database, which are development and production. The first production release is about to take place. While it is clear that this database will expand over the next few years, the present effort is going very well.

A list of approximately 200 application codes has been generated, in the process of writing the SNS Commissioning Plan (there are two plans: 1) high-level for DOE called the CPP and 2) lower level, detailed for the contractor called the CP). Individuals within the ORNL Accelerator Physics group will write the majority of these codes. Some scope has been transferred from Controls to Diagnostics, with the shift to Network Attached Devices. The ORNL Diagnostic group has significant operational and physics experience. Currently there are 5.8 full-time equivalents (FTEs) in the ORNL diagnostics group, seven at BNL, 7.5 at LANL, and one at LBNL. There are two open requisitions at ORNL, with more to come.

The Accelerator Physics, Controls, and Diagnostics groups will also be centrally involved in the full system integration tests that the four WBS managers from the Accelerator Physics group will lead. These WBS managers represent accelerator sections: the Front End, Warm Linac, Cold Linac, and Ring and transport lines. The goal of these dry runs is to save precious beam-time. The philosophy is to set readiness deadlines some weeks ahead of beam, to enable the broad exercise of the next accelerator section as if it were fully operational, with enough time to fix problems before actual beam commissioning.

Remote operations proved very useful during initial MEBT commissioning, for example in debugging Network Devices, and in testing applications. Long-term benefits of remote operations include the enhancement of continued long-term involvement of specialists at the partner laboratories. For example, when the Front End is re-commissioned at ORNL, the remote operations connection will enable specialists from LBNL to remain closely connected.

An abnormally large spread in transfer functions has been observed in ring dipoles, as delivered. About 70 percent of this effect comes from variations in the iron, and 30 percent from dimensional errors. It is simple to correct these errors for operation at 1.0 billion electron volts (GeV) by shimming the magnets.

The neutron back scattering and Ring to Target Beam Transport (RTBT) aperture problems that arose since the November 2001 DOE review have been resolved. There is now a close collaboration between Accelerator Systems Division (ASD) and Experimental Facilities Division (XFD), enhanced by the assignation of a liaison between the two divisions. For example, XFD performs shielding calculations for ASD.

The Critical Decision 4 (CD-4), Approve Start of Operation Criteria document includes the statement that "the SNS must have in place all capital facilities to achieve a proton power on target of $\geq$ 1 MW" but goes on to state that "these tests will consist of demonstrating that particles can be stored in the accumulator ring to a level of 1 x $10^{13}$ protons in a pulse (and) can be extracted…and transported to the target." This is consistent with the "Operational Aspects and Reliability" white paper that describes the evolution from CD-4 to full operation over a two-year period. In particular, operation at average power beyond 10 kW is only possible after the Operational Readiness Review, scheduled for six months after CD-4.

Many other important Accelerator Physics studies are also making good progress at ORNL, in collaboration with the partner laboratories. These include:

- the fate of partially chopped beams
- sources of beam loss in the linac
- linac mismatch
- missing superconducting cavity
- drift tube linac tuning results
- Ring/Target integration, aperture, fault studies, and target parameters
- collective effects and impedance budgeting
- negatively-charged hydrogen ion (H-) laser stripping
- electron cloud code development and data analysis

### 2.1.2 Comments

Great advances have been made in Front End commissioning at LBNL since the November 2001 DOE review. The data becoming available for input into halo evolution simulations is more realistic, now that MEBT commissioning is in its final stages. Enhanced understanding can be gained from continued, more accurate, beam halo studies.

It is vital that the accelerator system groups "buy-in" to contributing and maintaining public data that they own, in the global database. This necessitates the full support of management, including the provision of appropriate database administration support.

The four WBS managers in ASD need adequate management support in planning and implementing broad system integration tests without beam, before beam-commissioning each of the accelerator sections.

Other partner laboratories such as LANL can expect significant benefits from remote operations, and should carefully observe its ongoing use in the Front End activities.

### 2.1.3 Recommendations

1. Prepare a diagnostic system in the Medium Energy Beam Transport to demonstrate beam gap cleanliness, as well as to measure transverse halo, for front end re-commissioning at ORNL in 2002.

2. At the next DOE review, present refined beam dynamics simulations down the accelerator chain, using the latest beam distribution input information from the commissioning and re-commissioning of the Front End.

## 2.2 Front End Systems (WBS 1.3)

### 2.2.1 Findings

Virtual completion of the Front End work scope at Berkeley has been achieved by LBNL/ORNL since the November 2001 DOE review. Significant progress was also made in the following areas:

1. Improved RF antenna coatings developed.

2. “24 x 7” performance test conducted.
3. Beam through all four modules of the radio frequency quadrupole (RFQ) (32 milli Amperes (mA)—93 percent transmission).
4. MEBT fully installed and commissioned one day ahead of schedule.
5. Output current of 36 mA achieved with the Ion Source Extractor configured for lower currents.

LANL and BNL contributed substantially to the success at LBNL. The recommendation from the November 2001 DOE review has been addressed and implemented by LBNL/ORNL. That recommendation stated, “Clarify to all participants the availability of and budgeting for partner lab performance in Front End System (FES) installation and commissioning.” Engineering oversight by LBNL staff at ORNL during the Front End shipment will be provided. Significant SNS/ORNL participation has occurred at LBNL and will continue until shipment of the FES takes place. Twelve FTE-weeks were budgeted for LBNL staff to participate in FES commissioning at ORNL. Additional LBNL effort was not budgeted, but could be arranged within the existing post-handoff memorandum of agreement (MOA).

Some of the recommendations from the Accelerator Systems Advisory Committee (ASAC) review have been implemented and the remainder will be addressed at ORNL. The ASAC Committee made six recommendations in February 2002. One of the recommendations was implemented at LBNL, taking into consideration the laboratory’s project schedule constraints. The other five will be considered for implementation at ORNL.

The shipment of the FES is expected to occur as scheduled. The testing at LBNL will conclude on May 31, 2002. Shipping is scheduled to be complete on July 15, 2002. The FES budgets remain unchanged from December 2001. The cost and schedule performance shows less than one percent variance through March 2002.

The source antenna reliability has made substantial progress. One antenna, with a 0.3 mm coating was tested to 107 hours of uninterrupted operation. New coatings, 0.75 mm thick, have been developed and are expected to provide substantially longer life. A second extended lifetime test of the FES will begin May 2002. Backup efforts, that include an external RF antenna or a microwave drive, are being examined.

Since the November 2001 DOE review, all MEBT and RFQ components have been completed, installed, and commissioned. Only three major tasks remain: 1) operation at full six-percent duty factor, 2) a 24 x 7 performance test of the full FES with beam, and 3) the final acceptance test.

### 2.2.2 Comments

Interaction between LBNL, ORNL, LANL, and BNL continues to be very positive. The relationship between LBNL and ORNL FES personnel continues to be a very positive benefit to the project. Both sides have contributed to the effort, both at LBNL and at ORNL. The atmosphere of cooperation has amplified the effort in a way that has more than paid for itself. The contributions to the MEBT hardware and diagnostics by LANL and BNL have also been a very positive contribution to the recently achieved success at LBNL.

The schedule is on target, but some details may have to be resolved at ORNL. While there is full confidence that the FES will be shipped as scheduled, several items of lesser importance will not be fully demonstrated at LBNL. Therefore several items such as operational reliability will need continued attention after the FES is re-commissioned at ORNL. The integration of the final RF system will be a major change in hardware from that used at LBNL. Several minor systems such as the Personnel Safety System, the timing system, Machine Protection System, and closed loop control of various FES systems will not occur until commissioning at ORNL. No measurements of FES longitudinal properties have been included in the scope of testing at LBNL. Similarly, full MEBT chopping performance will not be tested at LBNL. The items to be resolved at ORNL are not considered to be major risks.

MEBT modification will be completed at ORNL. Halo reduction, previously discussed in terms of scrapers in the DTL, is envisioned to be accomplished in the MEBT. This effort will be carried out by the SNS/ASD at ORNL. The current budget appears adequate to complete the FES effort at Berkeley.

## 2.3 Linac Systems (WBS 1.4)

### 2.3.1 Linac Overview

The Linac structure is unchanged since the November 2001 DOE review. As shown in Figure 2-1, the Linac structure is a conventional DTL to 87 million electron volts (MeV), a coupled cavity linac (CCL) from 87 to 186 MeV, a “medium-β” (β=0.61) superconducting linac

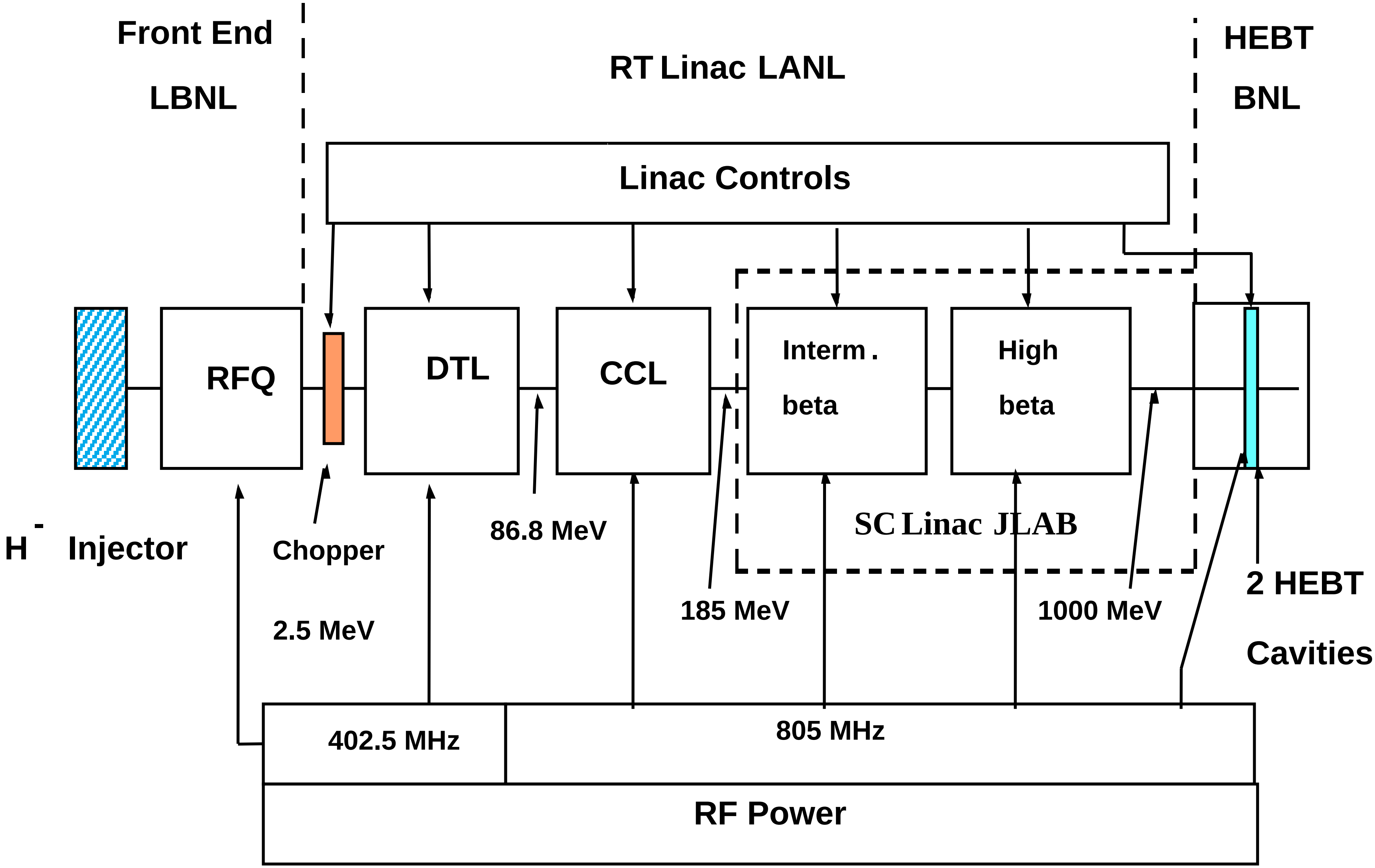


Figure 2-1. Linac Structure

(SCL) from 186 MeV to 379 MeV, and a "high β" (β=0.81) SCL from 379 MeV to approximately 1 GeV. The medium β SCL has 33 cavities in 11 modules and the high β SCL has 48 cavities in 12 modules.

#### 2.3.1.1 Findings

Good progress has been made in most areas since the November 2001 DOE review. The first DTL section (unit #3) has been assembled at LANL and will be ready for shipment to SNS/ORNL soon. Temporary RF systems (needed for the Front End) were delivered to LBNL for power tests of the Front End RFQ through MEBT systems; the first production system will be delivered to ORNL later this year. First item klystrons for the 402 MHz DTL were delivered and are being used in a test configuration for the high voltage converter modulator (HVCM) prototype system at LANL. With the placement of a second source order (by SNS/ORNL) for the 402 MHz klystrons (as recommended at the November 2001 DOE review) and the initial delivery of units from the first vendor, much of the uncertainty surrounding this klystron procurement has been removed.

Parts for the rest of the DTL are being received. The vendor building the CCL has made many pieces, and is reported on schedule for fabrication and later assembly of CCL modules. SNS/ORNL staff have concluded that collimation in the MEBT is much more effective than in the DTL for the removal of beam halo, which satisfies an issue from the November 2001 DOE review.

The low-level RF (LLRF) system (Field Resonance Control Module) is designed to be able to be used for control of all the linac RF systems (warm and cold). The present status appears to be about two months behind schedule. About 25 percent of the $14 million of this element is costed or committed. Prototype systems are scheduled for delivery to ORNL for the RFQ and DTL-3 in June. A limited production run of four systems is planned for June or July. One of these systems should be available for the superconducting cavity test stand at TJNAF in September 2002.

A prototype Converter Modulator built by LANL has been undergoing tests and has been used to test RF components and superconducting cavity couplers. Full peak power capability of the modulator has been demonstrated at low duty factor. An average power of 400 kW (out of 1 MW required) has been reached. But failures of the Insulated Gate Bipolar Transistor (IGBT) switches have occurred at high average power. Testing continues with different switches and possibly increased switch gate drive may cure the problem. Recent tests have been favorable.

Also, an alternate design using double IGBTs is being developed. The HVCM units were ordered as several "build to design" sub-components, at a significant savings versus the first request for complete "build to specification" units.

An action item from the May 2001 DOE Review, installation of a 1 MW RF source for prototype cryomodule tests at TJNAF, was completed on schedule. Assembly of the prototype cryomodule with three medium-β cavities has also been completed, however, tests of the prototype medium-β cryomodule have been significantly delayed from the original plan. This is largely due to problems with vacuum seals and various mechanical assembly problems with the prototype cryomodule. These have now been solved, and design changes incorporated in a timely fashion for the production cryomodules.

Procurement of cavities and cryomodule elements, and preparation for production assembly of cavities and cryomodules is proceeding well. The first production module is scheduled for complete assembly in November 2002 and installation at the end of this year.

The cryosystems are mostly committed. There is a large quantity of equipment awaiting installation. Major component deliveries are on schedule. Installation of 80-foot sections of transfer lines has already started. Cold box installation should start this summer. Commissioning of the plant is planned to start in March 2003 and to finish by October 2003 with limited 2.1° K capacity available. Full availability will be achieved by April 2004. At the October timeframe, 11 medium-β cryomodules will also have been installed.

A significant transfer of responsibility for installation of the majority of the DTL, CCL, and RF systems from LANL to SNS/ORNL has been mutually accepted. The value of the transferred effort is approximately $7.5 million. LANL retains responsibility for several "initial" installation tasks, as well as for "mentoring" of the SNS-ORNL staff during the installation of some other items.

#### 2.3.1.2 Comments

Overall, the progress on the Linac continues to be encouraging. The expected delivery of the first DTL structure to ORNL, as well as progress with prototyping of major systems such as the HVCM is commendable. This is especially important, as the prototype HVCM operation has revealed a few problems that are being addressed in an appropriately responsible fashion. These problems are not believed by engineering staff or managers to represent a serious threat to technical performance or schedule, and when discovered at an appropriately early date can be rectified, as is happening. This history indicates the importance of lifetime testing of such new designs, in addition to the identification of start-up failures. The Committee therefore noted an urgency to pursue remaining development of items such as the LLRF system, and the necessity to test concepts, as well as final engineering in test beds whenever possible.

The Committee noted, in response to a concern expressed at the November 2001 DOE review, that a good working relationship has been developed with vendors of components for the HVCM and the CCL modules. These and similar close working relationships with other vendors should continue to be carefully developed. The Committee also noted, with approval, the continued growth of the working relationships between the partner laboratories.

As stated in the November 2001 DOE review report, "The timely completion of tests of the prototype cryomodule is needed to establish the adequacy of the system designs to cope with the electromagnetically-induced mechanical vibrations resulting from pulsed operation of the superconducting cavities." A substantial risk of design changes needing to be retrofitted to the cavity and cryomodule configuration will exist until RF phase and amplitude control is demonstrated in pulsed operation at the design gradient in the prototype cryomodule.

It is critically important that the prototype production LLRF system be installed and operated with a cryomodule as soon as possible, so that cavity amplitude and phase can be controlled and the issue of Lorentz and microphonic detuning can be laid to rest. As studies of the prototype low-$\beta$ module are about to begin now, the planned delivery of the LLRF in September 2002 is already later than desirable.

The modulator developed at LANL and planned for the linac klystron systems has many unusual or unique features. Though the IGBTs are having complications at this time, there are other untried components (transformer rectifier units). It is critical that the modulators be life tested. Long-term testing should be carried out, not only on the prototype, but also on production units.

It appears that the procurements and installation of the cryosystems are off to a very good start. However, cryoplant commissioning is scheduled for completion by October 2003, when a considerable number of cryomodules have been installed. Some temporary cryo-capability (dewars) should be considered for an earlier time, so that integrated systems tests can be performed on RF systems and modules.

Testing the first production cryomodules is very important in order to be assured that all aspects of the cavity preparation and assembly are under control, and that the module system can be operated as expected with RF. Measurements of cryo load, Lorentz and microphonic detuning will be important, as well as with the prototype module. The first production module should be tested with the planned LLRF with phase and amplitude control. Generally, cost and schedule issues do not represent a major concern except in the few particular areas noted.

#### 2.3.1.3 Recommendations

1. Expedite the prototype cryomodule testing at TJNAF. In particular, demonstrate full control of RF phase and amplitude in pulsed operation at design gradient for one or more cavities before concluding the prototype tests.

2. Life-test a production modulator unit at the earliest possible time.

3. Ensure that the delivery of the low level RF system is on schedule, and if possible, advance it in order to integrate with cryomodule tests as soon as possible. Additional resources, including experts from across the collaboration, should be considered as a means of speeding up the development.

4. Incorporate internal milestones for cryomodule production and testing into the schedule and report on progress against these at the next DOE review.

5. Develop a plan by the next DOE review for the integrated testing of a cold module with the RF system at SNS. This will require a temporary cooling system.

6. Continue to closely monitor klystron production at the various vendors.

## 2.4 Ring Systems (WBS 1.5)

### 2.4.1 Findings

Considerable progress has been made in all areas in the Ring. The observed progress is consistent with expectations to this point in the project. Technical challenges, which are few, are being addressed; and cost and schedule goals are being met.

**Magnets:** An appropriate number of magnets have been purchased, and delivered indicating no problems in delivery that would impact either installation or overall schedule. Measurements of the ring dipole magnets have taken place. The magnets have been shimmed to integral field specification and the measurements are repeatable after shimming and re-assembly. The quadropoles and other magnets will be cycled to insure repeatability during reassembly.

The magnets and girders are being budgeted to aid in installation. The SNS alignment people have provided location input for the fiducials.

Several quadrupoles being built in Russia (BINP) will require close monitoring until they can demonstrate the ability to provide a quality magnet. The use of a European quality assurance firm is useful, and project presence might be required.

**Vacuum Systems:** High Energy Beam Transport (HEBT) and Ring chambers have been ordered and all have been received. Orders have been placed for ion pumps, and all have been received. A first article ion pump controller has been tested, and the production order placed. Assembly of the ring arc half-cell vacuum chambers is 75 percent complete, and 30 percent of the chambers are coated with Ti-N.

**Collimators:** HEBT collimator specifications are set and detailed design is 95 percent complete. Ring collimator specifications are now set. In the RTBT line, the first article collimator has been built and is being tested. It will be delivered to ORNL in August 2002.

**Power supplies:** The power supplies for the Ring and Transfer Lines are going very well. All of the 255 power supplies have been ordered or are in procurement. All of the Power Supply Controllers (PSC) and Power Supply Interfaces (PSI) units have been received and tested. The corrector power supply (162 total) prototype has been tested successfully. The first extraction kicker supply prototype (14 total) has been extensively load tested. The 69 medium power supplies are under contract and have undergone successful design review. The 2 MW main dipole supply procurement is ready for release in May 2002. The only problem has been the first article Injection Bump supply (eight total) acceptance tests which are about one year late. The prototype was expected to be tested in April 2002. However, all of the supplies are within budget, seem to be on schedule, and are not on the critical path.

**RF Systems:** Component testing has been underway. A first article systems test is scheduled for May 2002. The RF systems are on schedule and not on the critical path.

**Diagnostics:** See comment below.

**Commissioning/Installation:** Activities are further addressed in Section 4.

### 2.4.2 Comments

An early operations plan, outlining reliability and beam power expectations for the first two years after CD-4 was presented.

The Committee was shown responses to the Ring recommendations from the November 2001 DOE review. Recommendations (italicized) and discussion follow:

*Present a plan, at the next DOE review, of how to proceed with commissioning if the surface field goal of 37 megavolts per meter (MV/m) in the SCL cavities cannot be met. This plan should include a firm deadline for installation of additional RF, or for lower energy commissioning, leading to full-energy operation.* The Ring can operate for low power commissioning at 850 MeV. The date for making the decision regarding the additional linac RF is April 2003. The Committee was satisfied with this response.

*Present a plan, at the next DOE review, for spares of all devices that will be in high radiation areas. The project is encouraged to obtain spares for these devices before beam is introduced in order that these devices can be replaced in-situ, in a "dry run" scenario. This would provide the one chance to work out unforeseen problems before these devices become activated, and should be made part of the installation schedule.* The spares for these regions have been identified, a number of them are in the baseline, and others are proposed. However, the Committee felt that it was not presented with a plan to develop in-situ dry run replacements in the high radiation areas. The Committee encouraged SNS to incorporate this into their installation plans utilizing any special handling equipment necessitated by the high radiation environment. This plan should be extended to repairs in all areas in the interest of availability.

Working relations between the BNL Ring team and the SNS Project Office are good. The hand-off documents and the commissioning and installation documents are excellent, and the Committee encouraged both groups to continue to refine and execute them.

A reliability analysis was presented with greater detail than what was shown in the past. SNS/ASD and BNL are encouraged to continue to refine the analysis with vendor data and operational experience from other accelerators.

SNS is encouraged to investigate alternate thyratron/switches for the fast kicker system and any mechanical impact on the modulator, in case EEV/Marconi gets out of the thyratron business.

Because the Injection Bump supply is technically difficult, it should be put on life test under all operating conditions as soon a possible to find any latent problems.

The design and implementation of the Magnet Protection needs more definition. Double redundancy for the turn off of the Ring and Transfer Line power supplies by the Personnel Protection System (PPS) should be considered.

To improve reliability and reduce spare parts cost, BNL should consider changing the design for the Main Ring Power Supply to four 750 kW power supply (rather than two 1000 kW supplies) in parallel and arrange them so that any three supplies can run the ring to 1.0 GeV. This provides for a three out of four redundancy with the fourth, a hot spare. The cost should not be more than a single supply with full rated spare transformer/rectifier, and the availability should improve by nearly an order of magnitude.

In the May 2002 project baseline, the estimate at completion for WBS 1.5 is $150.9 million. There are two main components to this number, the BNL portion, and the SNS/ASD portion. The BNL portion has increased from $112.7 million to $113.3 million due to project change request (PCRs) that have added spares. The SNS/ASD portion of WBS 1.5 is now $37.6 million. The contingency assigned to WBS 1.5 by the project is 14 percent. Since recent performance has been favorable and this level appears acceptable, a thorough a contingency analysis based on a bottoms-up approach would be credible.

The Committee had asked for a report on diagnostics at this review. The report that was presented focused on project-wide diagnostics progress and not on Ring-specific problems. The Committee would like to see a Ring-specific diagnostics talk at the next review. Although the Diagnostic Group to Controls Group interface is functioning well, there are some unique problems in the Ring such as turn-by-turn Beam Position Monitor (BPM) data collection and circulating beam profile monitors that are challenging.

### 2.4.3 Recommendations

1. Address the recommendation from the November 2001 DOE review concerning spares in high radiation areas, concentrating on the development of procedures and tooling for rapid, low-exposure replacements in high radiation areas.

2. Present, at the next DOE review, a specific report on all ring diagnostics.

3. Collect, at ORNL, all component and subsystem drawings from the partner laboratories and include them in the Document Control Center in preparation for installation.

4. Create a complete set of installation documents (e.g., drawings) in support of installation.

## 2.5 Target Systems (WBS 1.6)

### 2.5.1 Findings

The recommendations from the prior review were adequately addressed and the Committee concurred with the project's decisions. The Committee welcomed Ian Anderson and commended him for the leadership to this point. The Committee also thanked Tony Gabriel for his outstanding work as Acting Division Director. In general, Target Systems have progressed very well on all fronts. The cost and schedule variances, to date, are minimal.

As noted in the past two DOE reviews, the project has been investigating the causes and possible remedies for pitting damage in the stainless steel target window surfaces that are in contact with mercury. This concern arose from the results of tests first performed in Japan during the fall of 2000, and then duplicated at LANL in July 2001. The latter tests showed that, at least for the materials and configurations used, pitting damage occurred for proton beam intensities comparable to SNS operation at almost 3 MW. It is believed that the damage mechanism is the collapse of bubbles created as part of a mercury cavitation process. Further tests of samples (exposed to 200 beam pulses) were conducted at LANL in December 2001, and another round of tests are scheduled for June 2002.

The pitting phenomenon is not yet understood well enough to explain all of the experimental findings, let alone develop predictive capabilities based on computational modeling. Estimating target lifetime using data from the 200-pulse tests requires an enormous extrapolation (by more than a factor of one million), and activation issues make it difficult to obtain a high number of proton beam impacts. The relevance of surrogate experiments has not been fully established.

The project is generally optimistic that a technical design solution will be found, but there is still a fallback plan to switch to a solid target design. SNS management has identified October 2002 as a "Go/No-Go" decision point for retaining the liquid mercury target as the baseline design. Even if the decision were made to switch to a solid target for commissioning, an international R&D program would continue to pursue a technical solution to the pitting problem. SNS management asserted that the target design would still accommodate a changeover to a liquid mercury target at some future point beyond CD-4.

Hiring an Installation Engineer was a good move. Installation planning of the Target Systems is adequately detailed for the present status of the project. The proposed installation schedules are tight throughout, but not unrealistic. The cost impact of a decision for a solid commissioning target is estimated at $6 million minimum. The need to negotiate a significant part of the installation activity with the contractor already on board may weaken the project's position.

### 2.5.2 Comments

The position of installation engineer is very important and needs to be a strong one.

The Committee concurred with the October 2002 date for the decision on the commissioning target. This decision may still be a question of risk management. A clad tungsten target is presently considered a smaller technical risk than a liquid mercury target, though this is not a fully proven concept at SNS load levels.

Operating costs for a solid target including waste handling and disposal, are likely be markedly higher. This may limit the upgrade options of SNS unless suitable provisions for transition to mercury are made initially. There is approximately five years to find a dependable solution for the mercury target. Concepts developed on theoretical grounds for mitigation of the pressure pulse effect in liquid metals, by injection of non-condensable gas bubbles of suitable size, have not yet been tested.

### 2.5.3 Recommendations

1. Provide DOE with a status report on target window material development by July 31, 2002 that reviews the current situation and proposed actions (this is also an Action Item—see Appendix H). Identify opportunities, worldwide, to complete meaningful pitting tests in the multi-million pulse regime and on a prototypical target configuration during the next three years.

2. For the mercury target option, evaluate in detail, the procedures, time and cost required for changing to a solid target soon after CD-4, (i.e., before significant activation has occurred that would make extensive remote handling necessary) in case the pitting problem is not resolved by then. For the solid target option, identify the provisions and associated costs necessary up front to facilitate a later transition to a liquid metal target, once its feasibility for high power operation has been established.

## 2.6 Instrument Systems (WBS 1.7)

### 2.6.1 Findings

The Instrument Systems team, under the guidance of a new XFD Director, is making good progress on all tasks, and their response to the previous recommendations has been quite positive.

The recommendations at the November 2001 DOE review were to prepare an integrated plan for instrument installation for the initial SNS spectrometers and to consider how to install future instruments. There was also concern about identifying an appropriate installation manager. In response to the latter point, an Installation Engineer has been hired, and Instrument Systems has prepared a draft Integrated Instrument Installation Plan. The analysis indicates that it should be practical to install all seven of the currently funded spectrometers by the end of the construction project. The funded instruments include the five in the SNS project baseline (the high-resolution back-scattering spectrometer, the magnetism and liquids reflectometers, the third-generation powder diffractometer, and the extended-Q-range small-angle scattering instrument), together with two instruments being constructed by university-led, DOE/BES-funded Instrument Development Teams (IDTs), the Cold-Neutron Chopper Spectrometer (CNCS) and the Atomic-scale Resolution Chopper Spectrometer (ARCS). It should be noted that the baseline scope includes only installation of three SNS-funded instruments and that the installation of the last two SNS-funded instruments is not yet funded as part of the construction project. The installation plan is only a draft, and it is recognized that it needs considerable optimization.

The design work on the SNS instruments continues to be on schedule. Significant procurements are being initiated. For those few where contracts have been awarded, the costs are, on average, consistent with expectations. The budget appears reasonable.

There is a recognized need to enhance the effort on detector development in order for a number of proposed instruments to eventually reach their full potential. One proposed mechanism for doing this is to develop strong collaborative connections between existing detector groups at the national laboratories and universities. Such an effort would leverage a substantial, existing talent base. Such efforts are to be applauded.

Planning has been initiated for the transition from construction to commissioning, with the longer-range plan of supporting users during regular operation. Within Instrument Systems, the transition will bring a reduced need for design and engineering staff, but an increased need for technicians and for computer and electronics support staff. In order to accommodate users, there will be a need for an enhanced sample-environment support group and for increased numbers of scientific support staff (such as instrument scientists and/or post-doctoral research associates) dedicated to each instrument. The Committee concluded that it is essential that such planning continue and be documented.

User Programs is doing a great job of reaching out to the existing and potential user communities. The upcoming American Conference on Neutron Scattering will bring more than 250 interested participants to Knoxville in June and give them an opportunity to tour the SNS site. The conference, organized by the Neutron Scattering Society of America and the SNS/High Flux Isotope Reactor User Group, has received substantial support from the SNS, as well as the other national neutron centers. There have also been several workshops in Oak Ridge within the last year organized by the Joint Institute on Neutron Scattering, and more will occur in the future. These workshops are aimed at exposing non-users to the benefits of applying neutron scattering techniques in their research.

The Committee noted with satisfaction that the Center for Nanophase Materials Sciences (CNMS) has been approved for construction adjacent to the CLO building. The proximity of CNMS should lead to a valuable symbiotic relationship with the SNS.

### 2.6.2 Comments

The installation plan developed by Instrument Systems is an excellent start. Committee members raised several points that should be considered in optimizing the schedule and in developing more detailed plans. SNS recognizes that, in the preliminary plan, the cranes in the Target Hall are over-allocated during a two-month period, requiring usage in excess of three eight-hour shifts per day. In one possible resolution of the situation, the peak demand might be reduced to three shifts per day, requiring the use of three different installation crews. Such a choice should be considered with care, as it could lead to unintended inefficiencies. For example, an unexpected problem could occur during any shift, requiring a critical decision by the lead engineer. Unless a suitable decision maker is available during each shift, unanticipated delays could result.

One concern is whether "Ready-for-Instruments" status is clearly defined and, if so, is it compatible with early installation of sensitive instrument components. A related concern involves possible incompatibility between concurrent tasks, an issue that may already be under consideration. An important example concerns the installation of neutron guides. Such work involves precision surveying, which is incompatible with significant air disturbances, such as might be caused by open roll-up doors, or building vibrations. The Committee recognized that there must be a transfer of technology for the installation and alignment of the neutron guides from the manufacturer to the SNS personnel. Appropriate staff will need to be identified. Finally, as the actual time for installation approaches, it will be important to involve the installation technical specialists in any design reviews to raise any practical installation questions or issues that he or she recognizes. Such issues are better addressed before installation on the floor and can avoid possible lost time and money.

As previously mentioned, the installation of two of the SNS instruments is not currently funded under the construction project. Given the challenge of all seven funded instruments being installed by construction's end, it may be premature and overly optimistic to be concerned over this issue at the moment. Nevertheless, the Committee encouraged reconsideration, at an appropriate time, of the priority for funding to ensure installation of the maximum possible number of instruments.

Each beam port will require a target-vessel insert. Optimized inserts will be designed and procured for each of the funded instruments, and blank inserts are currently planned for beam ports without funded instruments. Procurement of vessel inserts will begin in FY 2003 for installation in FY 2004. The blank inserts will eventually have to be replaced with ones having optimized beam openings as instruments are funded. Once the facility starts producing neutrons, the inserts will become highly activated. Replacing inserts after commissioning begins will be expensive. There is a window of opportunity to design and procure optimized inserts for proposed, but not yet funded, instruments. (For example, there are five instruments that have been approved by the Experimental Facilities Advisory Committee (EFAC), and at least two others that have approved letters of intent. More letters of intent are likely to be submitted to EFAC within the next six months.) Such an effort on inserts would require funding beyond what is included in the baseline, but could provide substantial savings in the long run. It seems highly desirable to evaluate the costs of these two alternatives so as to allow an educated decision in the near future.

The success of the initial suite of instruments at the SNS will strongly depend on the sample environment equipment that is available for experiments and the analysis software used to interpret the data. Flexible control of sample temperature, pressure, and magnetic field would broaden the science addressed by the instruments and broaden the user base. Instruments such as the powder diffractometer should be not only Best-in-Class for intensity and resolution, but should also have outstanding capabilities for sample environment. New IDTs will likely cover important variables such as pressure. The present plan is for procurements of sample environments to be deferred to the beginning of operations. While understanding the reasoning behind this plan, members of the Committee expressed some concern about the level of priority given to the sample-environment effort.

The Committee commended the project for preparing the discussion paper on the transition from commissioning to user operation–this is a good step in the right direction. Along these lines, it is not too early to begin serious planning for the commissioning of the instruments. This will probably result in the identification of future (presently unknown) issues, and will enable the operational phase to be initiated in the most efficient manner. For example, there is concern about possible background problems between instruments. Clearly this problem will be assessed at the time of commissioning of the two reflectometer instruments. Perhaps a policy should be developed regarding an instrument configuration plan to deal with inter-instrument background problems.

There are numerous systems that are common to most, if not all, instruments. These include data acquisition, detectors, choppers, sample environments, and vacuum systems. These areas can benefit from an early identification of the staff requirements for the operational phase of the SNS project. Consideration of such requirements now will allow a smoother transition to the operational phase of the SNS.

There is concern about the readiness of the neutron optics test station (NOTS) at the HFIR reactor.  This is required for testing not only for various neutron optical systems, but also for the detector and data acquisition systems, before the SNS facility is operational.  While an Intense Pulsed Neutron Source (IPNS) beam line might be the fallback position, every effort should be made to have such a facility close at hand.

### 2.6.3 Recommendations

1. Evaluate the incremental costs of designing and procuring optimized target-vessel inserts for proposed, but not yet funded, instruments in time for initial installation versus the costs of replacing activated blank inserts with optimized ones after commissioning has begun.

2. Prepare a written plan covering staffing changes and requirements for an efficacious transition from construction to commissioning—looking towards eventual user support.

## 2.7 Control Systems (WBS 1.9)

### 2.7.1 Findings

The overall status of Control Systems, as well as the cooperation between Controls, Beam Diagnostics, and Accelerator Physics Applications Programming, is excellent.  All three teams have been delivering excellent products.  The functionality provided by those products to the FE commissioning gave wonderful results. The tools put in place and proven there will work for the rest of the accelerator.  Remote Operations—in the sense of people from ORNL supporting the process at the Front End Commissioning at the partner lab (LBNL)—went well. This bodes well for the future commissioning efforts where the relationship will be reversed; that is, the commissioning will take place at ORNL for the Linac and the Ring, and support will be from the partner labs (LANL, TJNAF, and BNL, respectively).

Control Global Systems—Timing, Machine Protection System (MPS), Network, EPICS, Database, PPS—are all well along.  MPS and Timing are being deployed at the partner labs for testing.  The database design and schema are in associated tools developed by that team resulted in programs that were commissioned and working in a remarkably short time for the Front End commissioning effort.

Progress in the PPS continues to be steady. Coordination and planning between the PPS team and the Radiation Safety Officer are well developed. The detailed project schedule has proven to be an effective tool for identifying interfaces between the PPS and the installation process. Administrative procedures or engineering solutions are then developed and agreed upon. This work is mainly within the Accelerator Systems Division. However, XFD will also become involved in this area, since there are clearly circumstances in which the Target Systems will need to control access via the PPS. This is foreseen in the engineering plan.

The project has designed a rack and Accelerator Controls (AC) infrastructure. This includes a design for grounding. The Committee did not fully appreciate until late in this review that there are technical concerns from the controls team with regards to the grounding design. The concerns need to be studied. This is a difficult technical question. Experience with the efficacy of grounding designs to decrease radio-frequency interference is not consistent. One common, non-controversial guideline is to decrease interference at the noise source. The expected noise source of concern here is the SNS klystrons. The present design provides a general grounding point. Any subsystem specific needs are expected to be paid for by the sub-system team and implemented as part of the subsystem. Thus, Controls Systems is being asked to solve its own grounding problems. In general, the Committee agreed with this policy. However, Controls Systems correctly pointed out that there are other SNS groups (e.g., diagnostics and low-level RF) that might also benefit from a more unified approach. The Committee suggested that this issue be reviewed one more time by a team of engineers from the Accelerator Systems Division, the Conventional Facilities Division (CDF) and possibly some external experts.

A recent ASAC recommendation was that the project should investigate the applicability of Fast Feedback techniques to the SNS. Fast Feedback, in this context, refers to software based feedback systems that are capable of reading data from various instruments (e.g., Beam Position Monitors (BPMs)), performing a matrix inversion, and sending corrections to actuators which can adjust beam parameters on the next pulse. Experience at Stanford Linear Accelerator Center (SLAC) and other laboratories show that operation at 60 Hz is realistic. This option was discussed in a roundtable discussion with Beam Diagnostics, Accelerator Physics Applications Programming, and Controls personnel. The Beam Diagnostics System Architecture is the critical element. It is optimized for throughput (long messages of processed data), not response time (short messages); short messages are needed for Fast Feedback. The conclusions of the roundtable discussion are that the present system is capable of supporting Fast Feedback at:

- 1 Hz—Possible with the present system.
- 10 Hz—Possible with the minor modifications to the present Network Attached Devices (NADs) communication software.
- 60 Hz—Possible, but significant upgrades to the present NAD software would have to be done. The SLAC experience indicates that links for NAD to the Input-Output Controller communication with short turn-on time will also be necessary at this frequency.

There is no SNS requirement for such feedback identified at this time.

### 2.7.2 Comments

The Beam Diagnostics System Architecture of NADs works and was very effective in the Front End commissioning process. There is a Project Change Request (PCR) transferring scope from Controls to Beam Diagnostics. This is in response to a change in the Beam Diagnostics system architecture for some systems (e.g., BPMs), which makes each such device itself a network node with its own Experimental Physics and Industrial Control Systems (EPICS) channel access interface.

The success of the database design and schema was mentioned previously. That success comes with a price—there is a great deal of database entry. The project should find some way to support this temporary staffing issue during the next few years.

There are many functions and tools available for users of the device database; e.g., cable plant wiring diagrams, rack profiles, etc. Some groups are using the device database and its associated tools more than other groups.

### 2.7.3 Recommendation

1. Support the use of the device database as a project-wide tool.

**Intentionally Blank**

# 3. CONVENTIONAL FACILITIES (WBS 1.8)

## 3.1 Findings

Overall, cost and schedule are in good shape. The project remains on track to deliver against the cost and schedule baseline approved in December 2001. The Conventional Facilities (CF) cumulative cost performance index (0.98) and schedule performance index (SPI) (0.96) are based on reasonable earned value to date. Additionally, the current month SPI of 0.70 was adequately explained as weather related and does not reflect the overall project schedule performance.

The manpower issue identified at the previous DOE review has been resolved. The Committee found that there are sufficient manpower resources to support the current planned work, and the current construction sequence identifies peak manpower requirements in the remainder of FY 2002 and FY 2003.

The integration approach is not strong enough. The SNS project is using an Integrated Systems approach in a distributed team relationship. As a result, accountability and ownership are difficult to conceptualize. The Committee found that the level of integration between CFD and the ASD is adequate for an initial project turnover stage. However, the level of management discipline needs to increase to deal with the anticipated increase in project turnover complexity between CFD and ASD/XFD as the project continues.

## 3.2 Comments

The Committee noted that the CF team has completed a seismic design standard review by DOE that compares existing SNS civil structural design requirements to emerging requirements sponsored by DOE at other Oak Ridge locations. Based on this review, there are no apparent benefits or significant impacts to current design caused by the emerging standards, however, the process of certifying a completed design to a new or otherwise imposed standard is expensive and time consuming.

As noted in previous reviews, and reinforced here, equipment installation poses a near-term issue as beneficial occupancy and equipment installation occur in parallel with continuing construction. The project must ensure adequate field engineering and installation coordination between CF forces and technical installation staff.

## 3.3 Recommendations

1. The SNS project has completed a seismic design margin analysis of emerging United States Geological Survey standards that concludes the current design, based on DOE standards in effect at the initiation of design, is adequate. The DOE Federal Project Manager should verify that the standards are therefore appropriate for current design and construction prior to the Target Building general construction contract award in July 2002.

2. Clarify and implement the project-wide integrated systems management team approach to equipment integration tasks, and verify that equipment component installation designs are being integrated with the CF design media and project earned value system by the next DOE review.

# 4. INSTALLATION/PRE-OPERATIONS PLANNING

## 4.1 Findings

All recommendations of the November 2001 DOE review have been implemented.

The ASD has produced a subproject schedule based on a detailed component delivery schedule, a schedule for assembly activities to be done in the RATS building an installation schedule, a commissioning schedule, and a field coordination schedule. The ASD subproject schedule is part of the SNS Integrated Project Schedule (IPS). An Installation Services Group has been formed to coordinate installation with the technical groups being responsible for the actual installation.

The installation schedule is very tight and relies on installing equipment before the "Beneficial Occupancy Dates" of the Conventional Facilities. Intermediate dates when the facilities are "Ready for Equipment" are being negotiated with the CF contractor. The conditions for "Ready for Equipment" and the responsibilities for ASD and CFD have been defined in signed documents. The actual situation is then negotiated at the division level.

As of December 2001, component and subsystem hand-off agreements are in place for all partner laboratories. Post-hand-off MOAs have been signed with LBNL and BNL to provide the framework for commissioning support by the partner laboratories. A draft MOA already exists with LANL.

Additional intermediate storage space will be required during the installation process. This is being addressed with the existing ORNL building 7039 and a new building (RATS II) at the SNS site that was included in the baseline.

The beam commissioning organization consists of WBS area managers for the four main accelerator systems (Front End, DTL/CCL, SCL, and Ring) that are members of the Accelerator Physics Division. They are responsible for the overall commissioning process, as well as system integration tests ("dry runs"). They are also responsible for components meeting the required physics parameters.

The installation schedules for the Target Systems and the Instruments Systems are well developed for the present stage of the project.

## 4.2 Comments

The Committee heard comments on the possibility of off-site (partner laboratory) commissioning and/or troubleshooting help. SNS management should ensure that this capability is available in case special expertise is needed. The ORNL controls group has already successfully demonstrated remote measurements of parameters on the Front End System operating at LBNL.

The Front End System is well documented and the re-assembly and installation at ORNL is well prepared and supported. Follow-on systems will be assembled at a lower level at ORNL. It is important that documentation and expertise follow the equipment from the partner laboratories to ORNL. Effort is needed to transfer (and maybe translate) computer aided design files from the partner laboratories into the ORNL document system.

The commissioning plan is very comprehensive and the Committee felt that the allocated time for completing the various commissioning tasks would be adequate. A plan for phased Accelerator Readiness Reviews (ARR) has been generated and is presently under review. The ARR for the Front End System is scheduled to be completed within only 25 days. Since this is the first ARR, more time should be allocated to ensure timely completion.

## 4.3 Recommendations

1. Collect all component and subsystem documentation and drawings from the partner laboratories at ORNL and include them in the Document Control Center in preparation of installation.

2. Create a complete set of installation documents (i.e., drawings) in support of installation.

3. Present an updated installation plan including all necessary documentation and lessons-learned from Front End installation at the next DOE review.

# 5. ENVIRONMENT, SAFETY and HEALTH

## 5.1 Findings and Comments

All recommendations from the November 2001 DOE review have been satisfactorily addressed.

SNS management is involved in all safety audits and incidents. The Committee reviewed the "Headache Ball" incident and found that it reflects management's involvement with safety. The contractor "Expectation Letter" is an excellent example of management commitment to safety.

The SNS Safety Team is very professional and properly involved with guidance and consulting.

The Integrated Safety Management documentation is complete and included in the safety process. There is great safety morale in the field and this is a reflection of site leadership. The accumulation of safe work hours has reached 600,000 and the Total Recordable Incident Rate is 1.3 (7.8 is the national average).

## 5.2 Recommendations

1. Review the safety and health aspects of the Commissioning Program Plan at the next DOE review.

2. Review at the next DOE review "lessons learned" from construction incidents as they pertain to like work/equipment at ORNL.

**Intentionally Blank**

# 6. COST ESTIMATE

## 6.1 Findings

The SNS TPC has remained unchanged at $1,411.7 million. A breakdown of the cost estimate can be found in Appendix D. Briefly, it contains a TEC of $1,192.7 million (construction line item) and $219.0 million of operating expense funded activities (including R&D and pre-operations).

The actual FY 2002 costs through March 2002 amount to $131.4 million ($123.7 million for construction line item activities, and $7.7 million for R&D and pre-operations activities). Cumulative costs and commitments through March 2002 amounted to $711.9 million ($603.5 million for line item activities, and $108.4 million for R&D and pre-operations activities).

SNS management used the Estimate-to-Complete (ETC) presented at the November 2001 DOE review to re-baseline the project in December 2001. The project also presented a plan to prepare new ETCs in a phased manner over the next two years.

The Budget-at-Completion (BAC) presented was $1,088.1 million. This represents an increase of $16.4 million (use of contingency) over the December 2001 BAC. Total contingency remaining in the TEC is $104.6 million. The project calculated a contingency fraction of 21.6 percent (of the remaining effort) using the following assumptions:

- April 2002 costs: $26.7 million;
- April 2002 commitments: $10.0 million;
- Credit for contracts awarded but not funded: $30.3 million;
- Five percent contingency on both funded and non-funded contract commitments.

SNS management continues to use phased-funded procurements in the technical, as well as the Conventional Facilities portions of the project. Approximately 79 contracts with a total value of $154.6 million have been phase-funded. Of those, 38 with a total value of $78.1 million, have been completed.

The project controls staff presented their current process for entering information in the DOE Project Assessment Reporting System (PARS).

## 6.2 Comments

Following a recommendation from the November 2001 DOE review, the project updated the performance baseline in December 2001 with the new ETC prepared last summer. Responding to a second recommendation from the same review suggesting the preparation of new ETC every 12 to 15 months, the project has adopted a strategy to phase future ETC updates at WBS Level 2 starting this summer with Linac Systems, Instrument Systems, and Conventional Facilities. The second phase would begin in January 2003 for Ring and Transfer Systems, Target Systems, Control Systems, and Project Support. The choice of which systems to review first was based primarily on an assessment of likely value-added. The Committee concurred with this plan.

Since the November DOE review, the project has taken one step forward and one step backward with contingency management. Following the suggestion made by the Committee in the November, the project is currently setting aside contingency equal to five percent of outstanding commitments to cover future change orders. While this represents a step towards realism, the project's choice of a methodology for determining the amount of contingency to hold on work remaining is unfortunate. Using a top-down approach, the project has established uniform project-wide contingency levels for activities: ten percent on design and project management, 15 percent on construction, equipment procurement and fabrication, and 20 percent on installation, testing, and commissioning. This approach results in a calculated contingency level on remaining work of $67.1 million, or 15 percent. A separate $27.5 million "Management Reserve" is held to cover other key risk areas. While no details were presented, the Committee received assurance from SNS management that they have analyzed these key risk areas and are confident that the project carries adequate contingency funds to manage "risk of unknowns." However, in the future the Committee would like to see a quantitative, risk-based analysis of contingency needs.

As was stated in the November 2001 DOE report, "project activities are planned to peak over the next twenty-four months, it is especially important for SNS management to remain vigilant on the subject of contingency usage." As the project reported that the total value of new (pending) PCRs is already $5.7 million, this continues to be an area of concern for the Committee.

The information being entered in the DOE PARS is entirely consistent with the data being reported in the project's monthly reports. This data is collected through the project's Microframe Project Manager system and appears fully consistent with actual physical progress.

The project has adequately responded to recommendations from prior DOE reviews.

## 6.3 Recommendation

1. Prepare a quantitative, risk-based analysis of contingency needs by the next DOE review.

**Intentionally Blank**

# 7. SCHEDULE and FUNDING

## 7.1 Findings

As noted in the preceding section, the project's current cost baseline remains at a TEC of $1,192.7 million and a TPC of $1,411.7 million, which are both specified in the FY 2003 President's Budget Request and in the SNS Project Execution Plan. The FY 2003 Budget Request contains a Budget Authority (BA) profile of: $291.4 million in FY 2002, $225.0 million in FY 2003, $143.0 million in FY 2004, $112.9 million in FY 2005, and $74.9 million in FY 2006.

The IPS is consistent with the BA funding profile cited above, and calls for an internal goal for project completion of December 2005. Six months of project schedule contingency is provided relative to the CD-4, Start of Operations, commitment date of June 2006. Project performance continues to track well against existing DOE milestones. The IPS assumes that contingency is distributed throughout the duration of the project, with most of the available contingency allocated to the out-years.

The IPS (see Appendix F) is derived from the detailed schedules provided by each WBS manager. The integrated detailed schedules are comprised of a slightly higher number of activities (approximately 14,310 versus 13,500) and relationships (approximately 19,329 versus 17,850) since the November 2001 DOE review. Project elements that are on or near the critical path include: Front End System, DTL, CCL, SCL, Cryo Building, Ring components, Target installation, beneficial occupancy in some buildings, and commissioning.

The ASD has updated their subproject schedule to include the receipt, acceptance, testing, and storage of all accelerator components. They have also integrated all ASD subproject schedules into a more detailed ASD roll-up schedule.

Links between all of the subproject schedules, and the IPS are being done manually each month. While a tedious exercise, this seems to work effectively as it exposes variances to the IPS on a monthly basis. Significant variances are reviewed by the management staff monthly at a "metrics meeting."

## 7.2 Comments

The proposed schedule is consistent with the overall BA funding profile. The project's financial obligations are being effectively tracked and managed against available BA, with phased-funding of contracts used as an effective tool for maximizing flexibility.

Critical path (or near critical path) activities are distributed among many areas of the project, indicating that resources have been distributed appropriately across all WBS elements.

However, the Committee judged that the project's early finish goal of December 2005 will likely be difficult to achieve. Considering that the planned outlay over the next 30 months is approximately $500 million, with only $27 million in funding available for contingency between now and the end of FY 2004, it is quite likely that some project activities will slip into FY 2005 and beyond. This will put significant pressure on the project's ability to meet the December 2005 early finish date. This in itself is not a cause for concern, given the official DOE completion milestone of June 2006, but the project needs to ensure that adequate funds are available to fully fund all activities through CD-4, Approve Start of Operations.

The testing of the target window materials to resolve the pitting issue is extremely important. October 1, 2002 is established as the date that the decision needs to be made to minimize the cost and schedule impacts to the project. A detailed plan of the testing needs to be prepared to ensure that sufficient data is obtained by October to make an informed decision.

# 8. MANAGEMENT (WBS 1.2)

## 8.1 Findings

The SNS management team is fully in place and appears to be cohesive and effective. There is also good internal communication, as well as good working relations among the six partner laboratories. The deliverables and staff phase-down are well defined.

A draft commissioning plan has been developed that calls for a phased approach beginning with commissioning the Front End in the fall of 2002. Looking ahead, a White Paper has been drafted on performance expectations after CD-4.

ES&H performance has been excellent. Integration activities handled as part of work scope of the three divisions (ASD, XFD, and CFD), are appropriate for the current level of project activity.

## 8.2 Comment

Active project management support (clearly defined responsibility and resources) for timely resolution of integration issues is required as project activities continue to ramp up; responsibility for civil/technical and technical/technical interfaces should be assigned to specific individuals.

## 8.3 Recommendation

1. Assess whether the current methodology for addressing integration issues is adequate to handle the increased level of activity the project will experience between now and CD-4, Approve Start of Operations. If it is not, strengthen processes that address these needs and report at the next DOE review.

**Intentionally Blank**