EXECUTIVE SUMMARY

A Department of Energy (DOE) peer review of the Spallation Neutron Source (SNS) project was conducted at Oak Ridge, Tennessee, during July 13-15, 1999, at the request of Dr. Patricia M. Dehmer, Associate Director for Basic Energy Sciences, Office of Science. The main purpose of this review was to evaluate the proposed technical, cost, and schedule baselines and their consistency with the President's FY 2000 Budget Request to Congress. The Review Committee was specifically asked to judge whether these baselines are reasonable, self-consistent, and credible, and whether the cost and schedule contingencies are adequate for this stage. Lastly, the Committee was charged to determine if the project is being managed as needed for its proper execution.

Overall, the Committee judged the project's proposed baselines to be credible and consistent with the FY 2000 Budget Request, which includes the funding profile, and recommended that they be approved by DOE. The Committee expressed confidence that the SNS Project Office team, under Executive Director David Moncton, can lead the project to success. While only in place for about four months, this management team is experienced and has moved aggressively to take full ownership of all technical, cost, and schedule aspects of the project. The management team has defined a clear vision for the project and a disciplined management approach, both of which are on target.

The SNS will be the world's most powerful spallation neutron source. With an initial complement of about ten highly advanced, state-of-the-art experimental systems, this facility will be unsurpassed for many years in its ability to utilize neutron scattering for a wide range of research applications. It was first authorized as a line item construction project in FY 1999 and will be based on modern accelerator technology. Its most important parameters have been approved by the Secretary of Energy and are contained in the President's FY 2000 Budget Request to Congress: completion of a facility with the capability of operation at a power level of at least 1 million watts (MW) by the end of 2005, for a Total Project Cost of $1.36 billion (as spent). To ensure that these goals are met, the SNS Executive Director has developed a cost plan that includes a 28-percent contingency for the construction cost, a compressed schedule with a ten-month contingency, and technical parameters for a linac-accumulator ring system capable of delivering a 2-MW (average power) pulsed proton beam onto a liquid-mercury target for high-flux neutron production. The Project Office is to provide DOE with an updated Project Execution Plan by October 1, 1999, to reflect the changes in project leadership and the new management structure and systems, as well as the proposed baselines.

The SNS project is being carried out as a multi-laboratory partnership, led by the SNS Project Office at Oak Ridge, Tennessee. The five partners are Argonne National Laboratory, Brookhaven National Laboratory, Los Alamos National Laboratory (LANL), Lawrence Berkeley National Laboratory, and Oak Ridge National Laboratory (ORNL). As defined in the SNS Project Execution Plan, each laboratory is responsible for delivering a particular subsystem for installation and commissioning at the construction site. In June 1999, the Secretary of Energy signed a Record of Decision, based on the analysis in a Final Environmental Impact Statement, to build the SNS at the preferred site on the Oak Ridge Reservation. Design and construction management of the conventional facilities is being handled by a commercial architect engineer/construction management team under a task order contract to ORNL.

The Committee shared the strong concerns of the SNS management team over the risks involved with LANL's current management approach for delivering the linac within budget and on schedule. This is an important issue because the linac lies on the critical path that defines the overall project schedule through design and construction. The Committee recommended that LANL and the SNS project immediately take steps to mitigate this risk. The LANL Director and the SNS Executive Director, jointly, should select the leadership of a new LANL SNS Linac Division to be established at LANL. LANL should develop a staffing and management plan for this Division for the concurrence of the SNS Executive Director. Finally, by September 1, 1999, the SNS Executive Director is to provide to DOE a management plan that will ensure that the linac is delivered as required by the project.

The Committee also recommended that the SNS project management should rapidly build up linear accelerator expertise at ORNL to assist in monitoring and assessing progress of the linac. This step should also facilitate a smooth transition to ORNL ownership of the linac once it is installed at the SNS site and ready for commissioning. It should also help to build trust and communication between LANL and SNS management at all levels. The Committee emphasized that in the end, it is the SNS Executive Director who must decide what steps must be taken to ensure successful delivery of the linac.

The SNS project has improved its conventional construction strategy and procurement plans, and is poised to award task orders for Title I design and site preparation work. The Committee viewed the project's compressed conventional construction schedule as extremely aggressive due to its heavy reliance on conducting many design and construction activities in parallel. This approach will require extraordinary project management skills and execution, and a freeze on design changes that would affect fixed-price tasks. These requirements underscore the need to permanently fill the Conventional Facilities Deputy Project Director position as soon as possible.

Although there is not yet a completely integrated, bottoms-up schedule, the Committee felt that the project's proposed top-down schedule will support completion by December 2005. The conventional facilities schedule, as noted above, entails a degree of risk that will require diligent management oversight. Contingency in the cost estimate has significantly increased to $255 million (as spent). This is an improvement on the $220 million presented at the January 1999 DOE review. While commending the project for this accomplishment, the Committee urged SNS management to continue in its efforts to raise the contingency further before construction activities begin to ramp up in the months ahead.

The Committee was pleased to note that the multi-laboratory project team has made some outstanding accomplishments in recent months. For example, the construction site at ORNL has been technically qualified, ion source tests have exceeded the original (1-MW) performance goals, prototype components for the linac and proton storage ring have been fabricated, and tests have confirmed the feasibility of the liquid mercury target concept. No unsolvable technical issues were found by the Committee and the facility's design is expected to meet all performance requirements.

In summary, the Committee recommended that the proposed baselines be approved by DOE, while recognizing that they can be successfully achieved only if the risk associated with the linac is rapidly mitigated by management and cultural changes at LANL. The Committee found that there is a credible, self-consistent cost estimate for the whole project, the technical design is on track, and the project can be completed by the end of 2005 with the planned funding profile and the strong, experienced leadership now in place at the SNS Project Office.

Intentionally Blank

CONTENTS

1. INTRODUCTION

1.1 Background

When completed in 2005, the Spallation Neutron Source (SNS) will be the world's foremost neutron scattering science facility for conducting basic research in material science, solid state physics, engineering, chemistry, and structural biology. The design calls for a beam of negatively-charged hydrogen (H^-) ions to be generated and accelerated to an energy of one billion electron volts (GeV) using a linear accelerator (linac). The H^- beam will then be transported to an accumulator ring, where it will be converted to protons by stripping away the electrons and bunched into a short (less than one microsecond) pulse. Finally, the pulsed proton beam will be directed onto a liquid mercury target, where 60-Hz 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. Section 2 provides a more extensive overview of the facility.

The SNS project is organized as a multi-laboratory partnership under the leadership of the SNS Project Office at Oak Ridge, Tennessee. The five partners are: Argonne National Laboratory (ANL); Brookhaven National Laboratory (BNL); Los Alamos National Laboratory (LANL); Lawrence Berkeley National Laboratory (LBNL); and Oak Ridge National Laboratory (ORNL). This collaborative approach is being used to take advantage of the best expertise available in different technical areas, and make the most efficient use of Department of Energy (DOE) laboratory resources. Each laboratory is responsible for a particular part of the project, as shown in Figure 1-1.

A Final Environmental Impact Statement (FEIS) for the SNS was issued in April 1999. It analyzed the potential environmental impacts of constructing and operating the facility at four sites: ANL, BNL, LANL, and ORNL (the preferred site). The FEIS concluded that construction and operation of the SNS is not expected to result in any unacceptable environmental consequences at any of the four candidate sites. In particular, the analysis indicated that building the SNS at ORNL would have the least negative impacts. On June 18, 1999, the Secretary of Energy signed the Record of Decision, based on the analysis in the FEIS, to proceed with construction of the SNS at ORNL (Chestnut Ridge). A Mitigation Action Plan (MAP) has been prepared that identifies actions to be taken by DOE and the project to avoid or minimize environmental harm in building and operating this facility. The Department will monitor progress against the MAP to ensure that the plan is properly implemented.

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).

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. A DOE approved SNS Project Execution Plan (PEP) is in place and governs how the project is to be managed. The Level 0 cost and schedule baselines set at CD-2 comprised a TPC of $1,333 million (as spent) and a seven-year design/construction schedule, with facility commissioning to occur at the end of FY 2005. 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 Physics Group 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 (as spent). The President's FY 2000 Budget Request for the SNS project is $214 million ($196.1 million of line item construction funds and $17.9 million of operating expense funds).

In November 1999, ORNL competitively awarded an architect engineer/construction manager (AE/CM) contract to a joint venture led by Lester B. Knight and Sverdrup Facilities, Inc. The AE/CM team is responsible for design and construction of all conventional facilities, as well as installation of major technical components (front end, linac, ring, and target) supplied by the laboratories.

A further DOE review of the SNS project occurred as planned in January 1999. Although the review committee determined that the SNS collaboration was continuing to work well together, and technical progress was generally good, 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 Oak Ridge. The committee strongly recommended that a new Project Director, reporting directly to the Director of ORNL, 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, Dr. David Moncton, who led the successful construction of the Advanced Photon Source facility at Argonne, was brought on board in early March as SNS Executive Director. He brought with him a strong track record in managing large scientific construction projects and a user perspective as a neutron scientist. Over a period of several weeks, he led a team of experts in conducting a thorough project assessment and developed a comprehensive course of action for completing the project safely, on budget, and on schedule. Since April 1999, the SNS Project Office at Oak Ridge has been reorganized and additional technical and management staff has been recruited to fill key positions (e.g., Project Director, Technical Director, Accelerator Systems Division Director, and Procurement Manager). The five partner laboratories have been directed to optimize and fully integrate the technical design, and strengthen the business and project management systems to support construction activities.

Under Dr. Moncton's leadership, the SNS technical parameters have been revised to include an average proton beam power on target of up to two million watts (MW), enhanced ("world-class") instruments, and expanded laboratory and office space for users and staff. This has been achieved, along with increased contingency, through aggressive scrutiny of all subsystem cost estimates by the SNS Project Office management.

In order to strengthen the commitment among the five partner laboratories, the 1998 interlaboratory Memorandum of Agreement (MOA) has been revised, and plans are to have the new MOA signed soon after the baselines are approved.

Current plans, subject to appropriation of funds from Congress, are to begin physical construction of the facility in FY 2000. This will include site preparation and excavation, and fabrication of long-lead hardware (e.g., magnets, klystrons, and power conditioning equipment).

1.2 Charge to the DOE Review Committee

In an April 27, 1999, memorandum (Appendix A), Dr. Patricia M. Dehmer, Associate Director for Basic Energy Sciences, Office of Science (SC) requested that Daniel R. Lehman, Director, Construction Management Support Division lead a review to evaluate Level 1 (SC) project technical, cost, and schedule baselines to reflect the President's FY 2000 Budget Request to Congress. In so doing, the Committee was asked to address questions regarding the appropriateness and credibility of the baselines, cost and schedule contingency, and the management needed for proper execution.

1.3 Membership of the Committee

The Review Committee was chaired by Daniel R. Lehman. 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. In fact, many of the members served on one or more of the previous three DOE review committees. The Committee was organized into eight subcommittees (see Appendix B), each assigned to evaluate a particular aspect of the project corresponding to members' areas of expertise.

1.4 The Review Process

The Review took place on July 13-15, 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 (ORO) staff.

The first day was largely devoted to a plenary session, with project overview presentations by members of the SNS Project Office staff and the participating laboratories (ANL, BNL, LANL, LBNL, and ORNL). On the second day, members of each subcommittee met with their SNS counterparts in working sessions to discuss details of the scope, cost, schedule, and management of the various systems. The third day was spent on Committee deliberations, report writing, and drafting a close-out report. The preliminary results of the Committee were discussed with SNS management and staff at a close-out session on the last day.

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.

Intentionally Blank

2. OVERVIEW OF THE SNS PROJECT DESIGN AND BASELINES

2.1 SNS Design Overview

The SNS project is aimed at constructing a world-class basic research center on Chestnut Ridge within the DOE Oak Ridge Reservation. It will provide scientists from universities, laboratories, and industry with the world's most powerful facility for investigations using neutrons to explore new frontiers in materials science, life sciences, chemistry, solid state and nuclear physics, earth and environmental sciences, and engineering sciences. The facility will consist of an accelerator-based, short-pulsed, spallation neutron source, and the research and user support facilities needed to create a fully operational research center. A block diagram of the facility is shown in Figure 2-1, and the site layout on Chestnut Ridge is portrayed in Figure 2-2. A summary of the major technical parameters is given in Table 2-1.

The SNS design calls for an accelerator system consisting of an ion source, full-energy linac, and an accumulator ring that combine to produce short, powerful pulses of protons. These proton pulses strike a mercury target to produce neutrons through the spallation nuclear reaction process in which neutrons are knocked out of the mercury nuclei. For every proton interacting in the target, 20 to 30 neutrons are produced.

The following overview of the facility and how it will be used has been excerpted and updated from the brochure "Spallation Neutron Source—The next-generation neutron scattering facility for the United States" (this brochure and further details of the project can be accessed from the web-site www.ornl.gov/sns).

The Front End. LBNL is responsible for designing and building the front end, which includes an ion source, beam formation and control hardware, and low-energy beam transport and acceleration systems. The ion source produces H^- ions—hydrogen atoms with an additional electron attached—that are formed into a pulsed beam and are accelerated to an energy of 2.5 million electron volts (MeV). This beam is delivered to a long linear accelerator.

The Linac. LANL is responsible for the linac, which accelerates the H^- beam from 2.5 to 1000 MeV (1 GeV). The linac is 465 meters long and made up of three successive sections of radio frequency (rf) cavities that accelerate the beam: a Drift Tube Linac, a Coupled Cavity Drift Tube Linac, and a Coupled Cavity Linac. These structures will be made from copper, and

Figure 2-1. SNS Level 1 System Diagram

Figure 2-2. SNS Site Master Plan

Table 2-1. Summary Parameters for the Spallation Neutron Source

Proton beam power on target	2.0 MW
Proton beam energy	1.0 GeV
Average proton beam current on target	2.0 mA
Pulse repetition rate	60 Hz
Peak ion source H^- current	70 mA
Peak linac H^- current	56 mA
Chopper beam-on duty factor	65 percent
Linac length	465 meters
Linac rf frequency	402.5/805 MHz
Number of 402.5 MHz, 1.25-MW klystrons	3
Number of 805 MHz, 5.0-MW kylstrons	30
Linac beam duty factor	5.8 percent
Accumulator ring circumference	220.7 meters
Ring orbit rotation time	841 nsec
Number of injected turns	1160
Ring fill time	1.0 msec
Ring beam extraction gap	240 nsec
Protons per pulse on target	2.08E+14
Proton pulse width on target	600 nsec
Target material	Hg
Number of ambient/cold moderators	2/2
Number of neutron beam lines	18
Initial number of instruments	11

fitted with devices known as klystrons, which provide the rf power needed to accelerate the ions in the beam. Diagnostics and rf power supplies, as well as vacuum and water cooling systems are included to support linac operation.

The Accumulator Ring. BNL is responsible for the accumulator ring, which bunches and intensifies the beam for delivery onto the mercury target to produce the pulsed neutron beams. The intense beam from the linac must be sharpened more than 1,000 times to produce the extremely short spike of neutrons needed for optimal neutron scattering research. To accomplish this goal, the H^- pulse from the linac is brought into the ring through a stripper foil that removes the electrons from the negatively charged hydrogen ions to produce the protons (H^+) that circulate in the ring. Approximately 1,200 turns are accumulated and then all these protons are kicked out at once, producing a pulse less than one millionth of a second (10^{-6} seconds) in duration that is delivered to the target. In this way, short, intense 1-GeV proton pulses are produced at a rate of 60 times a second to bombard the target.

The Target. ORNL is responsible for the coordination, installation, and operation of the SNS; for project management; for conventional construction; and for design and construction of the liquid mercury target. Because of the enormous amount of energy that the short, powerful beam pulses will deposit in the spallation target, it was decided to use a liquid mercury target rather than a solid target such as tantalum or tungsten. The SNS will be the first scientific facility to use pure mercury as a target for a proton beam.

Mercury was chosen for the target for several reasons: it is not damaged by radiation, as are solids; it has a high atomic number, making it a source of numerous neutrons (the average mercury nucleus has 120 neutrons and 80 protons); and, because it is liquid at room temperature, it is better able than a solid target to dissipate the large, rapid rise in temperature and withstand the shock effects arising from the rapid high-energy pulses.

The neutrons coming out of the target must be slowed to energies suitable for research—that is, they must be moderated to room temperature or colder. The neutrons emerging from the target are slowed down by passing them through cells filled with water (to produce room-temperature neutrons) or through containers of liquid hydrogen at a temperature of 20 K (to produce cold neutrons). These moderators are located above and below the target. Cold neutrons are especially useful for research on polymers and proteins.

The SNS is an inherently safe way to produce neutrons because the neutron production stops when the proton beam is turned off. It also produces few hazardous materials. To maximize the safety of the facility, the SNS will be designed to have many levels of containment to keep potentially hazardous material from getting into the environment.

Instrumentation and Experiment Facilities at SNS. ANL is primarily responsible for developing the neutron scattering instrumentation for SNS and for working closely with ORNL to develop the experiment facilities. The SNS will initially have one target station with beam at a frequency of 60 Hertz (Hz). Two "thermal" moderators and two "cold" moderators will be used to service 18 beam lines, and a variety of world-class instruments will be constructed on these beam lines.

Once in operation, it is anticipated that the SNS will be visited by 1,000 to 2,000 users each year from all walks of science and industry. Because not all these users will be expert in neutron scattering, the SNS will provide scientists and technicians to maintain and operate the instruments and work closely with the user community. The broad user community has been and will continue to be involved in the selection, design, construction, and operation of the instruments.

Scientific Research at SNS. The instruments at the SNS, such as neutron spectrometers, will be used to determine the positions, or arrangements, of atoms in crystals, ceramics, superconductors, and proteins. A neutron spectrometer works as follows. A pulse of neutrons generated by the spallation source follows a flight path to the sample. Because the neutrons have varying energies and wavelengths, these spread out in time presenting a continuous spectra to the sample. When the distance between atoms in a crystal matches the wavelength of an incident neutron, that neutron is scattered into a multi-detector that records the position (scattering angle) and time of arrival of the scattered neutron. The result is a pattern of peaks showing the different positions and arrival times of various numbers of neutrons reaching each point in the multi-detector. This pattern tells scientists how different atoms are arranged in the crystal.

Instrumentation based on the same principles can be used to determine the atomic structure of glasses and complex fluids or to determine the residual stresses in industrial parts. Instruments to measure inelastic scattering will require measurement of the time of neutron travel over paths leading to and from the sample. In this way, scientists can determine the excitation spectra of materials of importance and thus the nature of the forces that hold the atoms in place. The time-of-flight technique makes it possible to collect a large number of data points for each neutron pulse.

Recent Design Changes. As noted in Section 1.1, several significant design changes have recently been made by Dr. Moncton and the new SNS Project Office team. These are reflected in the technical parameters in Table 2-1, and include:

- Accelerator specifications sized for 2-MW beam power on target (increased from 1 MW)
- Goal for beam availability increased from 85 to 95 percent (for "mature operation")
- Number of instruments increased from ten to eleven, and scientific quality of the instruments enhanced to "Best-in-Class"
- Laboratory, office, and shop space significantly increased to benefit users (visiting scientists) and facility operations staff

The primary goal behind these changes is to provide the neutron science community with the most capable facility possible at project completion, while remaining within the $1,360 million TPC.

2.2 Project Baselines

There are three levels of project baselines (Level 0, 1, 2) used by DOE to manage laboratory contractor performance on its Strategic Systems, which include construction projects such as the SNS. Level 0 corresponds to those aspects of a project that are directly controlled by the Secretary of Energy; Level 1 are those under the responsible Program Office (for SNS, this is the Office of Science); and Level 2 are under the responsible DOE Project Manager, at ORO in this case.[1] Level 3 and 4 baselines are managed by the laboratories performing the work. For the SNS, Level 3 baselines are managed by the SNS Project Office at Oak Ridge, and Level 4 baselines are managed by the partner laboratories' Senior Team Leaders. The top four levels of project baselines (Levels 0, 1, 2, and 3) are described in the SNS PEP along with their respective change control thresholds.

As mentioned in Section 1.1, the SNS Level 0 baselines were approved by the Secretary of Energy in December 1997. These represent the top level agreement between DOE and the SNS project on what is to be delivered, its cost, and when the facility will be ready for operation. They are consistent with the President's FY 2000 Budget Request for the SNS, and consist of three components:

Technical — The SNS will be an accelerator-based neutron scattering facility providing at least 1-MW proton beam on target.

---

[1] The Level 2 Baselines for SNS were approved by ORO in October 1998, and have been updated to reflect the TPC and schedule in the President's FY 2000 Budget Request. Similarly, those at Level 3 were approved by the SNS Project Office and have been updated.

Cost The TPC will not exceed $1,360 million (as spent, based on the President's FY 2000 Budget Request).

Schedule The project will be completed and SNS will be placed into operation (CD-4) by December 2005.

The next tier of baselines, Level 1, corresponds to the various subsystems of the SNS project (i.e., Front End Systems, Linac Systems, etc.). The SNS Project Office has proposed the following baselines to DOE for management control by the Director of the Office of Science:

Technical The facility will be equipped with a suite of approximately ten instruments for research applications.

Final Safety Documents for the facility will meet DOE and other applicable regulatory requirements.

Cost In addition to the TPC limit in Level 0, the Total Estimated Cost (TEC) will not exceed $1,160 million (as spent, based on the President's FY 2000 Budget Request).

Schedule The line item project will start in October 1998 [already accomplished].

The project will be ready for approval of CD-3 (Start Construction) by December 1999. [The PEP currently plans for this to occur in March 2000.]

The first proton beam will be produced and directed onto the spallation target by January 2005.

In order to support proposed Level 2 and 3 baselines, the SNS Project Office has issued an SNS Parameters List that specifies the design objectives set by SNS management for the overall SNS facility, as well as those for each of the subsystems. (Table 2-1 is an excerpt from that document.) In addition, the Project Office has issued WBS Descriptor Forms, System Requirements Documents, and Interface Definition Documents that, once approved, will be used to define and control the lower level baselines. The proposed cost and schedule baselines are contained in a Cost and Schedule Book, which also provides the methodologies used to produce the cost estimates and schedule details. The proposed SNS Integrated Project Schedule is a top-down, resource loaded schedule that has been compressed to provide an increased contingency of ten months (compared to about six months in the schedule reviewed by DOE in January 1999).

3. TECHNICAL SYSTEMS EVALUATIONS

3.1 Accelerator Physics

3.1.1 Findings

As a result of studying historical data from existing machines, the SNS Project Office has raised the overall availability goal for the SNS facility from 85 to 90 percent for early operation, increasing to 95 percent for mature operation. This corresponds to over 98 percent availability for each of the major subsystems.

End-to-end simulations from the radio frequency quadrupole (RFQ) to the target have been done. These include random rf phase and amplitude errors in the linac.

The ion source has demonstrated 45 mA, well above the original specification for 1-MW operation, but lifetime and emittance measurements at this current level have yet to be made. The new ion source current specification, corresponding to 2-MW operation, is 70 mA.

A comprehensive error analysis has been completed for the RFQ. The specification for risetime of the chopping system has been relaxed to 10 nsec. This has resulted in a cheaper, simpler Medium Energy Beam Transport (MEBT) and chopper system.

The goal of “hands-on” maintenance for the linac appears to be achievable with the proposed four-centimeter diameter bore. A comparison has been made with the losses observed at the Los Alamos Neutron Science Center (LANSCE) linac, but this is hampered by unknown details of the operation of this linac, particularly at high energy. So far, in simulations of the SNS linac, the apparent 100 percent size of the beam has grown without saturating as the number of macro-particles was increased.

A cost reduction has been achieved by shortening the High Energy Beam Transport (HEBT) system length by 47 meters, but at the expense of losing two of the four collimators. The simulation with a realistic (output from the simulation of the linac) distribution suggests that there is still effective momentum and transverse collimation, with ideal absorbers. Two cavities are now planned to compensate for linac energy jitter and to sweep the linac beam over a larger energy band downstream of the achromat.

A truly impressive amount of work has been carried out since the management change in the SNS Project Office and in particular, since April. A complete alternative design scenario based on a Rapid Cycling Synchrotron, generally believed to be more cost-effective than a high-energy linac, has been performed. The study, however, led to the conclusion that the stringent loss limits of a 2-MW source could not be met with this design.

Following the October 1998 recommendations of the SNS Accelerator Systems Advisory Committee (ASAC), an alternative lattice was designed that not only provides better matching and longer straight sections for injection, extraction, and loss collimation, but most importantly increases the total ring acceptance to 480 π mm-mrad (up from 360 π mm-mrad in the former lattice). A welcome byproduct is a shift in the natural working point to (6.3, 5.8), i.e., to a region in which high-current machines such as ISIS operate successfully with low loss. Consequently, this working point has been chosen for ambitious projects like the European Spallation Source (ESS) 2.5-MW rings. The increased acceptance allows either larger emittances, which could reduce the space charge tune shift at 2 MW to about 0.1, or alternatively, provide an acceptance four times larger than the design emittance of 120 π mm-mrad. The lattice allows for chromaticity correction, if required.

Following the sense of a recommendation from the January 1999 DOE review, and for the first time in the design study, quantitative estimates of the limits of loss control have been made with a computer code developed at CERN for the design of the Large Hadron Collider collimator insertion. Not unexpectedly, the results show that collection efficiencies of over 95 percent can only be achieved with acceptances at least 400 π mm-mrad and at least four collimators.

A new scheme has been developed for clearing the beam gap in the ring.

The LANSCE Proton Storage Ring (PSR) instability is now being pursued more vigorously. Experiments are being carried out together with PSR staff, and R&D is being planned, to be funded by SNS at the $2-3 million level, to resolve the instability.

3.1.2 Comments

The accelerator physics design is progressing toward self-consistency and is now being controlled by the SNS Project Office. Better communication between participating laboratories is evident in the way simulation data are being shared between subsystem groups.

A bottoms-up reliability, availability, and maintainability (RAM) analysis has not been done for any of the major subsystems. This is needed for evaluating cost/availability tradeoffs.

As computing power becomes available with massively parallel computers, simulations using the actual number of particles per bunch in the linac should be pursued, since this can reduce risk and perhaps economize the design of the linac. This approach is excluded for the ring, but the development of space charge tracking codes should continue.

Results, presented by the SNS LANL linac design team, indicate that an induced activity of less than 10 mrem/h, required for hands-on maintenance, corresponds to a beam loss of 0.13 nA/m at 1 GeV. This is much less than the goal of 1 nA/m used so far. This new criterion is not accepted unanimously, and the disagreement must be reconciled.

A benchmark of losses to be expected in a high-current accumulator ring is given by the observed average loss rate of 3×10^{-3} at the upgraded PSR. There may be reasons to reject this datum as a relevant comparison for SNS, but if it is applicable, together with the reinforced limits on uncontrolled loss, it presents an almost insurmountable challenge to the beam-loss collimation system. A way to handle the problem is indicated by the results of simulation and from existing machines showing that the residual uncontrolled loss is confined to a limited region downstream of the collimators.

The Committee encourages the adoption of the ESS philosophy regarding losses: loss reduction is more important than capital cost reduction. After exploring all possible physical improvements, the efficiency of the collimator system determines the ultimate performance of the SNS. To this end, the team should carry out careful collimator system optimization in the accumulator ring without restricting the number of elements, aiming at an efficiency greater than 99 percent.

3.1.3 Recommendations

1. Investigate, at the level of individual components, the design and cost implications of the goal of eventually reaching 95 percent availability.

2. Increase the number of macro-particles in linac tracking studies towards real numbers of particles.

3. Re-evaluate beam-loss criteria and methodically incorporate them into the accelerator systems designs.

4. Study the effect of realistic collimators in the HEBT with the simulated linac distributions, including expected errors, in particular, understanding the potential loss increase in the injection process.

5. Pursue methods of achieving hands-on maintenance in the accumulator ring by carrying out careful collimator system optimization without restricting the number of elements, and address equipment designs in locations where radiation levels are anticipated to be high.

6. Provide additional R&D funding in order to satisfactorily understand the mechanism behind the PSR instability.

3.2 Front End Systems (WBS 1.3)

3.2.1 Findings

Increasing the H^- current requirement from 35 to 70 mA challenges the ion source and the Low Energy Beam Transport (LEBT) system, however, the RFQ and the MEBT were already both designed for 70 mA. Specifying 10 nsec rise/fall times will reduce the risks in the MEBT chopper design.

The Front End baselines are acceptable, with minor cost and contingency adjustments (see Cost Estimate Comparison table in Appendix D). The Committee found only minor issues with details. It would be appropriate to add a risk-based component to some contingencies.

3.2.2 Comments

The Front End team at LBNL is to be congratulated for achieving 45 mA in tests of the R&D ion source, exceeding the initial (1-MW) requirement of 35 mA. All of the Front End components (ion source, LEBT, RFQ, MEBT, MEBT chopper) need early demonstration at LBNL to verify their performance, including reliability/availability.

The Front End cost estimate is acceptable "as is," but should not be subjected to further reductions. SNS management's effort to compress the overall project schedule in order to create more schedule contingency has increased the schedule risk in the Front End.

3.2.3 Recommendations

1. Approve the proposed baselines for Front End Systems.

2. Demonstrate integrated Front End Systems performance, including LEBT and MEBT chopping, at LBNL as soon as possible. Do not reduce the planned scope of these integrated tests.

3. Send about four SNS project staff members from Oak Ridge to LBNL at the appropriate time for Front End testing, packing, and shipping (about six months duration), and provide the additional associated funding (about $400,000).

4. Provide an adequate funding profile for the Front End to support the aggressive project schedule. This is crucial for reaching the project's ion source current objective of 70 mA on time.

3.3 Linac Systems (WBS 1.4)

3.3.1 Findings

The Linac Systems will provide acceleration of H^- ions produced in the Front End to an energy of 1 GeV for multi-turn injection into the accumulator ring. The linac will accelerate H^- ions from 2.5 MeV through three types of linear accelerator structures: the Drift Tube Linac (DTL) to 20 MeV, the Coupled Cavity Drift Tube Linac (CCDTL) to 79 MeV, and a Coupled Cavity Linac (CCL) to 1,000 MeV (1 GeV). The rf frequency of the DTL is 402.5 mega hertz (MHz), and the rest of the linac operates at a rf frequency of 805 MHz. The most demanding criteria of this system are: 1) 60 Hz pulsed operation, 2) one msec pulse length, and 3) a beam power of 2 MW (a recent increase in specification as noted in Section 2). The design and production of the Linac Systems have been assigned to LANL since the inception of the SNS project. This has included the accelerator physics associated with the design, for example, the focusing structure and the definition of the physical apertures. The accelerator design is mature, and the associated design and specification of the rf accelerating systems are well advanced.

Over three years of design work are now reflected in a recently completed and thorough cost estimate. The 60-Hz pulse rate of 1-msec beam pulses has required the development of an rf modulator system based upon the insulated gate bipolar transistor (IGBT) technology for which the R&D is sufficiently advanced that the technology has been incorporated into the cost estimate. The SNS Project Office has provided guidance and encouragement for the LANL linac team to perform a significant cost re-estimation effort for the linac, which has produced an estimate of some $222 million (as spent; about 17 percent below the corresponding estimate presented at the January 1999 DOE review). This revised estimate has provided SNS project management with a significant source of funds for scope improvements in Experiment Systems (WBS 1.7). The estimate was presented along with backup data sufficient to support a judgment that the linac can be built at this cost. The design now incorporates approximately thirty 5-MW klystrons for the rf power in place of the approximately sixty 2.5-MW klystrons previously in the design.

3.3.2 Comments

The recently completed cost estimate was presented to the Review Committee with significant accompanying backup information. The Linac Systems cost estimate is of sufficient quality for baselining. It is reasonable for the methods of construction assumed. It is self-consistent and of sufficient detail with backup data to be credible for a project at this stage. The Committee found the cost estimate, when subjected to a series of relatively random probes to the lowest levels, to be complete and informative when compared to other known projects at a similar stage of development. The information in the cost estimate has not yet been inserted into a bottoms-up resource-loaded schedule, so both obligations and cost profiles are imposed rather than derived at this time.

The summary-level Integrated Project Schedule developed by SNS project management does show the linac to be on the overall project critical path, a conclusion in which the Committee concurs. While the SNS high level schedule seems reasonable, the Committee cannot comment in detail in the absence of a bottoms-up resource-loaded schedule for the linac. The Committee does, however, concur with the SNS Project Office's assessment that the klystron and cavity structure production are on the SNS critical path. The production of more than 30 5-MW klystrons and the production of the CCL accelerating structures are both certainly very long duration efforts, and will require the attention of all levels of management to complete the work consistent with the overall SNS requirements.

The CCDTL accelerating structure design is relatively new to proton or H^- linacs. None has been tested with beam yet, although a high power test, off-project, of such a structure is underway. Given the relatively new design of this accelerating structure, early fabrication of the SNS CCDTL structure for high power tests seems prudent.

The cost contingency estimate, also developed top-down, presented by the LANL team, was stated at 31 percent (this had not been carried into the SNS project summary cost worksheets, however, where the estimate was listed as 23 percent). Accepting the 31-percent figure for the linac at this stage is reasonable and the Committee has shown this value in Appendix D.

A feature of the new cost estimate is an increasing reliance on commercial vendors for accomplishment of the work. The Committee supports this decision. This outsourcing approach will also be necessary to achieve the SNS Integrated Project Schedule. For example, the use of multiple commercial manufacturers of klystrons, and well developed plans for commercial production of accelerator cavity modules and for rf modular power supplies are expected to be critical to meeting the schedule.

Despite the success of the new cost estimate (or perhaps unavoidably accompanying that success), some tension between the LANL linac team and the SNS Project Office is evident. The rapid addition of a strong linac group at the SNS Project Office to work with the LANL team, while helping to plan for the receipt of components and final rf tuning and testing at Oak Ridge, should help to alleviate this tension through better communications.

3.3.3 Recommendations

1. Approve the proposed baselines for Linac Systems.

2. Develop a resource-loaded schedule for the linac.

3. Build mutual trust and encourage the free exchange of ideas between SNS project management and the LANL team. SNS management should accelerate the creation of a strong linac group at the SNS Project Office to help build that trust, smooth communication between LANL and SNS management at all levels, and to review designs and construction plans.

4. Optimize the basic construction designs of the critical path items such as the CCL cavities, modulator power supplies, and klystrons, using a series of reviews organized by SNS management and the LANL team as part of the Title I design efforts. Both the designs and the construction methods, including the extent of commercial participation and fabrication, should be carefully studied as part of the Title I design effort.

3.4 Ring and Transfer Line Systems (WBS 1.5)

3.4.1 Findings

Design changes to the Ring and Transfer Lines Systems (since the January 1999 DOE review) have come from two sources:

- The identification of 2 MW as the project design goal for proton beam power, resulting in putting a fourth rf cavity back into the design and coating the vacuum chamber. There is now greater technical risk associated with the H^- stripper foil.

- Implementation of cost saving measures, including shortening the HEBT line, simplifying the vacuum system, reducing the number of collimators, and other miscellaneous items.

Cost saving measures resulted in a total reduction of five percent from the January 1999 DOE review to $125.3 million (as spent) at this review. This reflects reductions of $11.6 million on the part of BNL, and the inclusion of $1.9 million for Oak Ridge Field Coordination. The cost estimate is clear, detailed, and well organized. It was derived in a bottoms-up fashion. The estimate is credible, except as noted in the comment section below. The schedule for the Ring and Transfer Lines Systems has not changed since the January 1999 DOE review, and the Committee believes that the project can meet this schedule.

Technical progress has been made in many areas; significant among these are efforts associated with the reduction of uncontrolled beam loss. There is a new scheme of electron collection at the injection stripping foil that has increased the acceptance of the ring from 280 π mm-mrad to 360 π mm-mrad. There has been good progress made in understanding the loss distribution in the collimators, and in devising a system of removing (within the ring) any remaining protons in the beam gap as a controlled loss.

Related to these issues, the Committee was shown a new lattice design, which employs a matching quadrupole doublet in the straight sections. This lattice is not presently in the cost estimate, but will be put into the change control process soon. The new lattice is not expected to change the cost estimate, but it does provide several advantages: an increase in ring acceptance (to 480 π mm-mrad), and more flexible injection and collimation arrangements.

The SNS team at BNL continues to make progress on the fabrication of initial production components. This is evident in the areas of magnets, the stripping foil assembly, and kicker pulse forming networks.

The SNS Parameter List, discussed in Section 2, indicates interface control points.

The BNL staff conducted a design study of a Rapid Cycling Synchrotron (RCS) for the SNS project. The study concluded that the cost savings of the RCS, as opposed to the present linac plus accumulator ring design, are not significant. The RCS design is, therefore, not being pursued any further.

The Ring and Transfer Lines Systems availability budget has been increased from 95 to 98 percent. SNS management made a presentation to the Committee addressing reliability issues that consisted of showing availability numbers from existing, similarly sized accelerators. Similar engineering standards will be used in constructing the SNS ring and transfer lines. Based on past experience, the availability of 98 percent is not expected in the first two years.

3.4.2 Comments

The Committee believes that the changes made to the Ring and Transfer Lines Systems in the cost cutting effort have not compromised the technical goals, with a possible single exception associated with the change to the HEBT collimators (see Recommendation 4 in Section 3.1.3, Accelerator Physics).

The Ring and Transfer Lines Systems cost estimate, which has been considered high in past reviews, still appears to be high. The Committee pointed out specific examples where it felt that costs could be reduced. The Committee, during the course of the review, identified savings of six percent on the project base estimate and shifted that amount to contingency (see Appendix D). Accordingly, the Committee advised an increase in the contingency level for the Ring and Transfer Line Systems from 25 to 32 percent, which is considered appropriate. It is felt that more savings can be found with further effort.

Many accelerator components are being procured, delivered to BNL, bench tested, shipped to SNS, installed, and field tested. The Committee feels that cost savings (without incurring a reduction in ultimate reliability) can be achieved by direct delivery to the SNS site followed by field testing.

3.4.3 Recommendations

1. Approve the proposed baselines for Ring and Transfer Lines Systems.

2. Coordinate closely between Ring and Transfer Lines Systems and Conventional Facilities on those areas in the ring tunnel where tritiated water might be present, and design for the possibility of spills.

3. Reduce the cost baseline in all WBS Level 6 elements for a total savings of up to 15 percent. In doing this, the following guidelines should be considered:

   - Deliver components directly to ORNL rather than to BNL.
   - Acquire additional vendor quotes.
   - Obtain more components as complete systems, thereby reducing BNL engineering costs.
   - Maintain technical baseline specifications.

3.5 Target Systems (WBS 1.6)

3.5.1 Findings

Target Systems, which appeared to be on track in the January 1999 DOE review, has made further significant progress in establishing and detailing the technical content, as well as the cost basis, for this part of the project. Detailed and extensively referenced WBS descriptions exist and responsibilities are assigned in an unambiguous manner. R&D results successfully indicate the viability of a liquid mercury target and this approach forms the basis of the baseline design. Good progress has also been made in refining the design of crucial parts of the target and in incorporating flexible design features in the target shielding to satisfy users' demands that are likely to emerge as instrument concepts progress. This eliminated one of the main concerns expressed during the January 1999 DOE review. Extensive interactions with existing spallation neutron facilities (ISIS in the United Kingdom, SINQ in Switzerland), as well as with the ESS project team, have also helped to establish a sound technical basis that fully accounts for experience existing elsewhere.

The Target Systems cost estimate has been completely redone, based on design data whose detail adequately reflects the complexity of the respective subsystems. Vendor quotes were obtained for a large part of the hardware components, in particular those for which prior historical costs were not available due to their novelty. Although the new evaluation produced appreciable deviations from previous estimates in detail, partly also due to the design modifications mentioned above, no significant change resulted in the overall estimate, now $79.9 million (as spent). Reductions in cost came from identifying opportunities to obtain lower cost material for the shielding and from compressing the overall SNS project schedule to create more schedule contingency. Some reduction in the scope of the R&D program, in line with recommendations from advisory committees, also helped in the cost-cutting effort without compromising the credibility of the program. Contingency now amounts to 29 percent of the base cost estimate and is adequate for the present level of design.

The schedule for the installation and testing phase of the Target Systems was already tight before increasing overall project schedule contingency to ten months. Consequently, the Target Systems schedule cannot be compressed further without serious risks. Virtually all of the schedule compression to date has gone into the design and procurement phases. This is not without risk, especially since a tight schedule for installation and testing requires very careful planning and intensive coordination with other parts of the project. No schedule contingency could be identified for Target Systems within the compressed project schedule.

Dr. Moncton's reorganization of the SNS project has resulted in the creation of an Experimental Systems Division that formally unites Target Systems with Experiment Systems under one competent leader. The Committee commends this move because it will lead to strengthening the ties between these two subsystems, as previously recommended.

3.5.2 Comments

With the beam power goal set at 2 MW, a study was initiated to back-up the present liquid metal target with a solid target concept, with a date for a decision set in March 2000. The Committee believes that the SNS Project Office should:

- Eliminate this decision point since no date will be available by that time that would cast doubt on the feasibility of the liquid metal target.

- Develop a forecast as to when information would be required to keep the option of a transition to a solid target open without jeopardizing the readiness of the target to accept beam on day one.

- Reduce the effort for the solid target backup study to a level that is commensurate with this forecast and the progress of the work on the liquid metal target, and that takes into account both the existing experience with solid targets elsewhere (ISIS at 200 kW; SINQ at 1 MW), as well as information generated in earlier spallation source studies (Intense Pulsed Neutron Source Upgrade, etc.).

These steps will significantly reduce the burden on the target design team in the months ahead and will probably also result in much lower design expenditures.

While the Committee fully endorses the decision to unite Target Systems and Experiment Systems in one project division, this will increase the workload on the Division Director. The Division Director will have to spend much of his efforts in coordinating the users' input to the project and ensuring proper actions to optimize the scientific potential of the SNS facility.

3.5.3 Recommendations

1. Approve the proposed baselines for Target Systems.

2. Consider adding a staff member who reports directly to the Experimental Systems Division Director and is responsible for project management matters. This will help to ensure that all subsystem elements remain on schedule and within budget while allowing the Division Director to extend his efforts to ensure the maximum scientific output of the facility.

3.6 Experiment Systems (WBS 1.7)

3.6.1 Findings

The additional funds allocated to this element by the SNS Executive Director are critical to the development and implementation of an instrument suite that will provide a science capability commensurate with the scale and promise of this facility. The Committee notes and approves of the decision to use the additional funds to enhance the science capability of the instruments, rather than the number of instruments. The new level of funding ($97.3 million, as spent, an increase of slightly over a factor of two since January 1999) will permit development of up to eleven world class instruments by project completion. The instrument development team has established a process by which instruments are selected for development. The Instrument Oversight Committee (IOC) is a crucial element in this process. Workshops are used to solicit and develop instrument concepts, which the IOC then recommends to the SNS project for development to the point at which they can be evaluated and prioritized for deployment. This process will ensure that maximum science benefit is derived from the SNS.

The team has made an excellent start on staffing up, and has already attracted a number of outstanding scientists to the project. The Division Director, Dr. Thomas Mason, has established a good scientific atmosphere and this is reflected in the recruiting success. The structure of the Division, which combines Target Systems and Experiment Systems in the same organization, has led to much improved communication between the two teams, to the significant benefit of both.

The technical baseline is appropriate for this stage of the project. The IOC is meeting at the time of this review to evaluate the first “physics” designs of advanced instrumentation for detailed development. Decisions on concepts to be deployed are essential to ensure that the instrument development remains on schedule. The IOC review process, which the Committee believes is a good one, must be conducted in a timely fashion. This will allow engineering concept development to be started on several instruments in the very near future, as is required to meet schedules.

The Experiment Systems team has developed a good basis for estimating the cost of instruments as they are selected for deployment. Thus, although there are not yet designs with sufficient detail on which definitive cost estimates could be based, the Committee is confident that the necessary information is at hand, and that the funds available are sufficient to provide up to eleven world class instruments.

3.6.2 Comments

It is essential that the increased level of funding for instruments remains available, and should be increased if possible. These funds are being used to ensure that every instrument is optimized for scientific impact, as is appropriate for a facility of this magnitude. The early physics design process has already yielded designs that will provide up to an order of magnitude greater improvement over current instruments than would be available from the source neutron flux alone. It is precisely these designs that will enable true scientific breakthroughs to be made at the SNS, and each success will stimulate greater efforts from all involved.

The IOC process has worked well to date, and has produced some promising physics designs that are now being reviewed. However, the Committee suggests that the Experiment Systems team and the IOC also consider establishing some numerical goals for instrument performance based upon the enablement of new science (e.g., an instrument that would allow measurement of real time processes on some scientifically interesting time scale). In any case, the Committee notes and applauds the fact that the process is focused on maximization of scientific impact.

3.6.3 Recommendation

1. Approve the proposed baselines for Experiment Systems.

3.7 Control Systems (WBS 1.9)

3.7.1 Findings

In the first DOE review of the SNS project (June 1997), the Committee found, "no areas of high technical risk in the [Control Systems] proposal." This finding remains true. New scope has been added to the Control Systems WBS element, namely the Personnel Protection System has been transferred from Project Support (WBS 1.2). There is a consistent technical, cost, and schedule baseline, however, schedule and linkages between global systems and user systems need to be updated. In addition, there is adequate cost and schedule contingency. The Committee, therefore, considers the Control Systems to be ready for DOE baseline approval.

The Control Systems portion of the project is well managed. The Control Systems Senior Team Leader and his team have been successful at reducing the cost estimate for this system with little to no negative technical impact. Standardization efforts in areas such as diagnostics, power supply control interfaces, and vacuum control interfaces are underway and should be encouraged, and the project needs to restart the project-wide workshops in this area. The Committee noted that the Timing System proposal needs a conceptual design review.

3.7.2 Comments

The excellent controls teamwork across laboratory and system boundaries seen in previous DOE reviews has continued. The cost estimate has matured, and shows the positive impact of the interlaboratory collaboration and a standardized, global approach. Assigning budget authorization control to the Control Systems Senior Team Leader, as was previously recommended, has worked well.

The SNS Project Office should consider building a "rack factory." The rack factory would be an on-site SNS facility to assemble and test integrated electronics racks comprising, for example, power supplies, vacuum equipment, diagnostics, and controls. The idea here is to deliver completed racks for installation in the field.

3.7.3 Recommendations

1. Approve the proposed baselines for Control Systems.

2. Hold a conceptual design review for the Timing System. The goal of this conceptual design review should be to confirm that the proposed system meets the functional requirements of all its users.

3. Investigate the cost effectiveness of an on-site "rack factory."

Intentionally Blank

4. CONVENTIONAL FACILITIES (WBS 1.8)

4.1 Findings

One of the first activities of the new project management team, after coming on board in February 1999, was to conduct a thorough internal assessment of the project. While this assessment was absolutely necessary, it did prevent Title I design of the Conventional Facilities from proceeding as previously scheduled and Title I design is now further behind schedule. The new management team and the pre-existing SNS project staff have established new working relationships. They have made a concerted effort to resolve open issues, identify appropriate alternatives, and prepare the necessary documentation to support an integrated cost, schedule, and technical baseline. This is a commendable effort given the time available to them, and the experience and insight of this project team is evident in the results discussed below. However, there are still areas for continued improvement.

The Committee noted that the SNS project has made several significant accomplishments in Conventional Facilities since the January 1999 DOE review:

- The Chestnut Ridge site has been technically qualified as appropriate for SNS construction following extensive geotechnical analysis and a re-evaluation of the technical requirements related to the concerns over differential settlement.

- The project made appropriately conservative determinations regarding the facility hazard class determination and this removed a significant level of design uncertainty.

- The project resolved issues surrounding potential technology changes and remained focused on the system requirements for the Linac and Ring Systems.

- The Title I design work packages have been consolidated into fewer AE/CM task orders and plans are in place to have the AE/CM start Title I design in August 1999.

- With the exception of filling the position of Conventional Facilities Deputy Project Director, recommendations made by the January 1999 DOE review committee, have either been closed out or have near-term closure dates with achievable implementation objectives.

- The new SNS management team has energized project efforts in Conventional Facilities around beneficial occupancy dates, which have been “integrated” (see comments below) with the rest of the project.

Additional findings are discussed below which illustrate the significant effort put forth by the project team. They still require future work, as is appropriate for a project that is only six percent complete.

The Conventional Facilities schedule has been integrated with the Integrated Project Schedule as recommended at the January 1999 DOE review. However, to accomplish this, the design and construction activities have been significantly compressed with most activities now occurring in parallel. There is no schedule contingency for Conventional Facilities apparent in the proposed compressed baseline schedule. This parallel approach increases both cost and schedule risk.

The technical scope has been recorded in the following documents: The Physics Parameters List, the WBS Descriptor Forms, and the System Requirements Documents (SRD). The Interface Definition Documents (IDD) are being incorporated in the SRDs. The SRDs will be approved by the appropriate Senior Team Leaders and the Project Office prior to implementation of AE/CM task orders. It is the Committee’s understanding that these documents, once approved, will be placed under configuration change control.

In the January 1999 DOE review, the committee concluded that the TPC was sufficient, but at this early stage there was inadequate contingency. The committee, therefore, recommended that the Project Office optimize the cost estimate and conduct a bottoms-up contingency analysis to provide the necessary level of additional contingency. The Conventional Facilities cost estimate has been reformatted by the AE/CM into Construction Standards Institute (CSI) code of accounts to match the format that will be used for future estimates. The estimate was reviewed to correct errors and omissions and was validated by the AE/CM contractor against established benchmarks, parametric estimating values, Means Construction Data, and relevant commercial information.

The Conventional Facilities team was given a cost reduction target of $60 million by the SNS Project Office, and at the same time was required to accommodate additional project scope for more office, laboratory, and shop space for users and operations staff. The team was able to incorporate the additional scope and achieved a $23 million (as spent) cost reduction from the

January 1999 estimate, to give the present estimated cost of $256.6 million (as spent). There has been no separate verification of design assumptions; operations impact; environment, safety and health (ES&H) design impact; or evaluation of special technical requirements since the recent cost estimating efforts.

The Committee concluded that the assumptions made for Conventional Facilities for Engineering, Design, and Inspection (ED&I) costs resulted in a low estimate for design, and recommended that these costs be reviewed and revised.

While there is still some uncertainty in the details of the technical requirements and in the aggressive compressed Integrated Project Schedule, the cost, schedule, and technical baselines have advanced to the point that they are ready for DOE approval, subject to the recommendations below.

4.2 Comments

To date, the SNS project technical designs (Front End, Linac, Ring, and Target) were significantly ahead of the Conventional Facilities design effort. This will change very quickly with the release of fixed price AE/CM design task orders, and the entire SNS project must be prepared to respond accordingly.

The AE/CM performance in assisting the SNS Project Office has been productive and of acceptable quality. It is clear that the AE/CM key managers are senior and experienced, and can contribute significantly to the definition, planning, and success of Conventional Facilities, if provided opportunity and incentive. The Project Office revised the construction procurement strategy by establishing a more robust Construction Management role, removing the conflict of General Contractor responsibilities that previously existed. This has positioned the AE/CM to better represent the SNS project’s interests.

The Conventional Facilities portion of the SNS Integrated Project Schedule has assumed the use of parallel scheduling techniques to minimize the duration of overall activities with the expectation that the shorter duration of project overhead will save money. This approach requires extraordinary project management skills and execution, and a freeze on design changes that would affect the Conventional Facilities fixed price design and construction scopes. The cost estimate for the Conventional Facilities AE/CM design effort must address the manpower inefficiencies of aggressive schedules.

The seven open Conventional Facilities action items from the January 1999 DOE review should be completed on the current schedule, and the IDDs should be incorporated into the SRDs as planned.

4.3 Recommendations

1. Approve the proposed baselines for Conventional Facilities.

2. Validate that the missing and current Integrated Project Linkages represent an adequate level of completeness in technical component design.

3. Approve the SRDs, including the associated technical parameters, prior to AE/CM task order release; this includes approvals by appropriate Senior Team Leaders, Division Directors, and the SNS Project Office.

4. Validate the bid/award durations for task order and construction package procurement based on current plans to pre-qualify subcontractors, assumptions on availability of local labor, and leveling of the current construction resource distribution.

5. Validate the contingency analysis and risk mitigation methods necessary to implement the proposed aggressive parallel approach to design and construction.

6. Review and revise Conventional Facilities ED&I costs to better account for SNS type facilities and for the compressed schedule that has been imposed to meet the beneficial occupancy dates.

7. Reconsider special requirement needs such as vibration isolation for the target building, pollution prevention requirements, and energy efficiency requirements. These requirements must be included in the SRDs.

8. Proceed aggressively to implement AE/CM task orders 1 and 2 for site work, land improvements, offices, and shops.

9. Conduct an independent technical, operations, and ES&H review of the Conventional Facilities design to identify and optimize physical parameters prior to release of AE/CM task orders 3–Ring, 4–Front End & Linac, and 5–Target.

10. Institute, immediately, a comprehensive configuration management process for the project that adequately supports cost/schedule/technical control, change control threshold approvals, and the aggressive schedule implementation needs for successful Title I and Title II design implementation.

11. Work aggressively to fill the necessary leadership positions for Conventional Facilities, with emphasis on the Conventional Facilities Deputy Project Director.

Intentionally Blank

5. COST ESTIMATE

5.1 Findings

The SNS TPC remains unchanged since the January 1999 DOE review, at $1,360 million (as spent). A breakdown of the cost estimate can be found in Appendix D. Briefly, it contains $1,159.5 million for construction funded activities (TEC), $161.5 million for R&D and pre-operations, and $39 million for prior year costs.

The SNS Project Office took charge of producing a new bottoms-up cost estimate for this review, which includes contingency of $255.2 million (as spent), or roughly 28 percent of the TEC. The estimate was summarized in a <u>SNS Cost and Schedule Book</u> that also included the Cost Estimate Requirements and Cost Estimate Guidance documents that provided the common methodology used by project personnel at the five partner laboratories to produce the estimate.

Project representatives presented detailed cost estimate information to each of the technical subcommittees at this review (see Sections 3 and 4 of this report for cost estimate comments on specific systems). These subcommittees evaluated the cost estimate base and contingency data, and in some cases then provided their own recommendations, which have been entered into the spreadsheet that appears in Appendix D.

5.2 Comments

The SNS Project Office clearly demonstrated ownership of the project cost estimate during this review. In fact, for the first time in the life of the SNS project, the Committee can refer to a single “project estimate,” as opposed to simply an assemblage of estimates produced by the various partner laboratories. There is a clearly recognizable coherence to the documents, which attests to a more effective level of management control than had previously been evident.

The Committee commends the SNS project for making significant progress in the last six months towards identifying a level of cost contingency that is adequate for the current stage of the project. The Committee notes that contingency has been increased from $167 million (as spent) in June 1998, to $220 million in January 1999, to the $255 million presented at this review. This represents real progress towards assuring satisfactory project completion. The SNS Project Office should continue to identify further opportunities for increasing contingency.

5.3 Recommendations

1. Approve the proposed cost baseline; it is consistent with the President's FY 2000 Budget Request.

2. Increase the level of contingency for the project, where appropriate, in order to further enhance the likelihood of success.

3. Review those areas in the cost estimate where the Committee advised adjustments be made.

6. SCHEDULE AND FUNDING

6.1 Findings

As explained in the preceding section, the project's TPC is $1,360 million (as spent) with completion scheduled for December 2005. This is reflected in the SNS Project Data Sheet contained in the President's FY 2000 Budget Request. The corresponding funding profile (see Appendix E) shows a substantial increase in funding (budget authority), from $130 million in FY 1999, to $214 million in FY 2000, to a peak of $281 million in FY 2001.

Title I design for the SNS project began in FY 1999 and the Record of Decision to proceed with construction at Oak Ridge was published in the Federal Register on June 30, 1999. Critical Decision 3, Start of Construction, is planned in March 2000 per the Project Data Sheet. The project has proposed to accelerate CD-3 to December 1999. The compressed construction schedule (see Appendix E) calls for ring design to be completed in January 2001, front end commissioning to begin in June 2002, and the start of target commissioning in January 2005. These internal project milestones have been established by SNS project management to provide an overall schedule contingency of approximately ten months as recommended in the January 1999 DOE review report.

The SNS Project Office held numerous project meetings during the last six months to develop a schedule strategy and a set of management scheduling tools to develop and manage schedule contingency. The Project Office has produced a summary level Integrated Project Schedule reflecting this schedule contingency and is in the process of updating and integrating the nine Subproject Networks into it. The summary Integrated Project Schedule (with Level 3 milestones) identifies the project's critical path.

6.2 Comments

The SNS Project Office has made significant progress since the January 1999 DOE review in developing schedule-based tools with which to manage the internal project milestones. The project scheduling meetings with all the laboratory participants appear to have been particularly effective venues for this work. In addition, the Project Office has been pro-active in helping to develop the increase in project schedule contingency, however, the ability to perform to these internal milestone will be dependent upon receiving the requested annual funding profile contained in the Project Data Sheet.

The development of this schedule contingency is particularly notable and timely. The work put into this effort is well spent as the project deals with the challenging schedule ahead. The Committee found that the baseline schedule is achievable and is ready to be baselined, recognizing that this schedule is dependent on obtaining the funding profile shown in the Project Data Sheet. The ability to meet the baseline schedule presented is highly dependent on managing to the internal milestones, which reflect schedule contingency.

Although the detailed subproject schedules have not yet been fully integrated with the summary Integrated Project Schedule at this time, this activity will be completed by October 1999. The Integrated Project Schedule has been resource-loaded with the latest information and is consistent with the Project Data Sheet's funding profile.

The project critical path runs through the linac and ring for the first five years of the project. But it is clear that there are many activities spread across other WBS elements, including Conventional Facilities and Target Systems that contain precious little float. The SNS Project Office should perform a sensitivity analysis on all activities falling within three months of the currently identified critical path. Such an effort should permit informed decisions for efficiently applying resources to minimize the need to use the schedule contingency developed for the internal project milestones.

6.3 Recommendations

1. Approve the proposed schedule baseline for the project, which is consistent with and dependent on the funding profile contained in the President's FY 2000 Budget Request.

2. Integrate the Subproject Network schedules into the summary Integrated Project Schedule.

3. Perform a sensitivity analysis of activities falling within three months of the currently identified critical path.

4. Complete the resource loading of detailed subproject schedules with current data.

5. Evaluate cost and schedule impacts for alternative appropriation amounts in FY 2000.

7. PRE-OPERATIONS AND OPERATIONS PLANNING (WBS 1.10)

7.1 Findings

Overall, planning for pre-operational activities leading to initial operation of the SNS as a research facility is progressing well and should result in a sound, realistic approach. Aggressive plans for staffing within the Accelerator Systems Division have been developed; it is not yet clear that these costs have been fully identified and allocated in the various WBS elements. Considerable uncertainty also exists because of issues related to interfaces with the linac systems.

7.2 Comments

The significant challenge for this multi-laboratory project is to transfer expertise developed during R&D, design, and component testing at the partner laboratories to ORNL for system testing, commissioning, and then full operations. This transition appears to be in good shape for Experiment Systems (the scientific instruments) where there are strong links and clear transition paths between ANL and ORNL. This joint development team is a project strength. The Target Systems team is already located at Oak Ridge and so the transition from development through operations should proceed smoothly in this area. The transition to operations appears to be much more problematic for the accelerator systems, where the type of joint participation occurring in Instrument Systems has not yet taken place and the future pre-operational interfaces with Linac Systems are not clear.

7.3 Recommendations

1. Continue the planned rapid staff build-up in the SNS Accelerator Systems Division and station appropriate people at the partner laboratories to assure the necessary transfer of expertise to the team that will test, commission, and operate all of the accelerator systems once they are installed at the SNS facility at Oak Ridge.

2. Re-assess the cost estimate associated with the planned buildup of pre-operations and operations staff in the Accelerator Systems Division.

Intentionally Blank

8. PROJECT MANAGEMENT (WBS 1.2)

8.1 Overall Management

8.1.1 Findings

The major management recommendation from the January 1999 DOE review was addressed by the successful recruitment of a new project leadership team. Dr. David Moncton, now the SNS Executive Director, and Dr. L. E. Temple, now the SNS Project Director, successfully managed the construction of the Advanced Photon Source (APS), a project of comparable scale to the SNS.

Dr. Moncton has installed a strong leadership team including members with experience from the APS project such as Dr. Yanglai Cho, now the Technical Director of the SNS, and Dr. Robert Kustom, now the SNS Accelerator Systems Division Director, and members of the previous SNS management team such as Mr. Carl Strawbridge, SNS Director for Administration, and Dr. Thomas Mason, SNS Experimental Systems Division Director (see Management Chart in Appendix F). Additional staffing changes are expected very soon including new leadership to strengthen the Conventional Facilities Division.

As Executive Director, Dr. Moncton reports to the Lockheed Martin Energy Research Corporation, in parallel with the Director of Oak Ridge National Laboratory. This gives him considerable latitude in adopting policies and procedures that are consistent with DOE regulations and orders and that can increase the effectiveness of SNS management.

In the four months that the new leadership team has been managing the project, they have made outstanding progress in assessing it at a detailed level, determining its strengths and weaknesses, and in recognizing the corrective actions needed to ensure its successful execution. The Committee has a great deal of confidence that this team will lead the project to success.

The new SNS leadership team has reviewed the previous project plans, cost estimate and schedule, and proposed a compressed Integrated Project Schedule that they believe can provide significant (ten-month) schedule contingency. They indicated that this schedule was developed in a top-down manner, based on an early delivery date for the accumulator ring, a strong overlap of Title I, Title II, and construction activities in Conventional Facilities, and fast-track schedule performance on the linac.

The new project cost estimate contains a significant increase in contingency, from the $220 million (as spent) shown at the January 1999 DOE review to the present $255 million, while providing for additional office and laboratory space for SNS users and staff, and for doubling the budget for end-use instrumentation. This was accomplished by adopting aggressive cost reduction goals that resulted in the identification of significant cost savings.

The new SNS leadership team has also articulated a unifying vision for the project to be shared by all of the partner laboratories and a set of key management principles to guide the overall approach to managing the project. The paradigm of a unified project that embraces all activities at all of the partner laboratories is essential for the success of the project.

At this time, the most significant management challenge for the SNS project is the linac, which is the responsibility of LANL. Previous review committees and the current SNS project leadership have indicated that major changes in the management approach at LANL will be necessary for success; not all of these changes have yet occurred. Senior management at LANL has also recognized this.

The LANL Deputy Director for Science, Technology, and Programs, Dr. William Press, described to the Committee his laboratory's commitment to the success of the SNS and to delivering the linac within the project's technical, cost, and schedule requirements. In order to accomplish this, LANL will create a dedicated SNS Linac Division reporting directly to the Office of the Laboratory Director. An accelerator specialist with significant project experience is being sought to either head this Division or to serve as its Technical Director under an administrative head. Dr. Press also recognized that a cultural change must take place at LANL and he pointed out that this change is an important part of the laboratory's strategic vision.

Recognizing the risk inherent in the LANL situation, the SNS leadership team has considered moving responsibility for the linac from LANL to ORNL, together with the rapid recruitment of a team of linac experts from the nation's accelerator community.

8.1.2 Comments

The new project leadership team has, in only a few months, demonstrated its ability to recruit quality management personnel, and to call on the active support of the scientific community for substantial efforts in support of their project assessments. This new team brings the ability, experience, drive, and commitment that are necessary for the SNS to succeed. This Committee is extremely impressed with this new team and their progress.

A challenge for the new leadership is to infuse the entire project team with their vision and management philosophy. This seems to be happening at ORNL, as well as at some of the other partner laboratories. LANL is a major remaining challenge.

The compressed Integrated Project Schedule is very aggressive and contains several significant risks. The overlapping of Title I, Title II, and construction activities in Conventional Facilities requires the application of private sector techniques to a government project with the use of strong configuration control. The concern is that the project does not yet have effective configuration control, while it expects to begin to assign Title I tasks to the AE/CM contractor within the next six weeks. In addition, the schedule requires fast-track delivery of the accumulator ring and linac. The linac, especially, is a concern in this regard. Until detailed bottoms-up, resource-loaded schedules are integrated into an overall project schedule, the feasibility of the compressed Integrated Project Schedule is in question.

The project schedule must be based on the funding profile contained in the FY 2000 SNS Project Data Sheet. The Committee believes that a bottoms-up, resource-loaded schedule would show a project completion date consistent with this Data Sheet but with little schedule contingency. Such a schedule would be aggressive, but could be achievable given the SNS management team now in place.

The Committee is very concerned that the current management approach at LANL may not lead to successfully delivering the SNS linac as required by the project. A change in management approach is considered necessary and should take place in very short order. LANL senior management has also recognized this.

The creation of a dedicated SNS Linac Division as described by LANL is a necessary, but not sufficient step. The staff of this division must be dedicated full-time to SNS, be of the highest quality, and be committed to the overall goals and approach of the SNS project leadership team. The division must be responsive to the overall SNS project direction, priorities, control, and management. The current strained relationship with the SNS management is a very serious issue. In a matter of weeks, a highly respected accelerator specialist should be selected by the LANL Director and the SNS Executive Director to serve as Linac Systems Senior Team Leader and should be in place within four to six weeks.

Even after a new Division is in place under the conditions described above, the Committee believes that a transformation of the current "culture" at LANL will be needed for the SNS effort to succeed. Although the need for a culture change is recognized by the LANL senior management, the Committee is concerned about whether such a change can take place as quickly as needed. This challenge has been exacerbated by the compressed schedule for the design, fabrication, and commissioning of the linac.

The Committee notes that the SNS management has developed a "back-up plan" for the linac management should it be determined that this responsibility should be removed from LANL. This "back-up plan" is only conceptual at this time, and does not yet address the realistic time scales for assembling a new team or the time scales necessary for the new team to assume responsibility for the linac effort.

In the end, it is the SNS Executive Director who must evaluate and decide whether conditions merit continuing the linac responsibility at LANL. This is consistent with his responsibility and authority.

8.1.3 Recommendations

1. Approve the project's proposed baselines, while recognizing that the project can be executed successfully only if the risk associated with the linac is rapidly mitigated by the management and cultural changes described above.

2. Select the leadership of the new SNS Linac Division at LANL; this should be done jointly by the LANL Director and the SNS Executive Director. LANL should also develop a staffing and management plan for this Division for concurrence by the SNS Executive Director. These actions should be completed by mid-August 1999.

3. Develop a management plan that will ensure that the linac is delivered as required by the project. This plan should be presented to DOE by September 1, 1999.

4. Build up linac expertise at Oak Ridge rapidly to assist the SNS Project Office in monitoring and assessing the progress of the linac. As part of the overall SNS linac team, these people would contribute to the design and execution of the linac and would form the nucleus of the eventual linac operations team.

5. Complete a full, bottoms-up, integrated resource-loaded schedule that is consistent with the current funding profile. This should be done by October 1, 1999.

8.2 Project Management Tools, Procedures, and Processes

8.2.1 Findings

Progress continues on the development and implementation of project management processes and procedures, which are necessary aids in managing the project. The SNS PEP and a Project Control Manual have both been approved, but will need to be updated.

The Configuration Management process is based on a detailed SNS Parameters List (dated July 8, 1999), WBS Descriptor Forms, and IDDs. The SNS Parameters List includes a summary of the significant project technical parameters, as well as defining the requirements of each SNS system. The IDDs define the interface requirements between the respective SNS systems. The WBS Descriptor Forms are similar to a WBS Dictionary, but contain additional information, such as references and cost and milestone information. Each of these three documents exists and is being used by the project participants. These documents ensure that system requirements are not changed without a thorough review by the affected Senior Team Leaders and the SNS management.

A project Change Control Process is in place. The technical, cost, and schedule change thresholds are being re-evaluated by the SNS Project Office. The proposed project baselines, consistent with the compressed Integrated Project Schedule and cost estimate, will be submitted for approval. These project baselines will serve as the formal basis for change control. Project contingency, the SNS Parameters List, WBS Descriptor Forms, and the IDDs will be managed by the project Change Control Process or directly modified as a result of controlled baseline changes. Other processes such as the control of System Requirements Documents ensure that the conventional facilities are designed and constructed to meet the needs of the technical/accelerator systems. Project cost and schedule contingencies are being managed at the SNS Project Office level, and will be tightly managed in a top-down fashion.

As recommended by the January 1999 DOE review committee, the SNS Project Office performed a detailed review of the project cost and schedule estimates to determine if additional contingency funds and schedule contingency could be generated from within the base project estimates. The SNS project team presented a modified cost and schedule baseline for this review. While the TEC, TPC, and project completion date remain consistent with the Project Data Sheet in the President’s FY 2000 Budget Request, the individual WBS cost estimates were reduced and the total project contingency account was increased. In addition, about ten months of contingency have been generated in this compressed schedule.

The project's scheduling and cost accounting systems have continued to mature. Presentations on SNS project accomplishments were provided to the Committee. Cost Performance Reports (CPR) have been generated for the construction project from October 1998 through April 1999.

A revised MOA between the SNS Project Office and the SNS partner laboratories has been developed to strengthen the project's management arrangements. Specifically, the revised MOA has clarified the agreement and commitment by the partner laboratories to adhere to project baselines. It will replace the interlaboratory MOA in the SNS PEP that was signed in 1998. This revised MOA is to be signed by the respective partner laboratory directors as soon as the project's baselines have been approved. No significant issues have been identified.

8.2.2 Comments

The SNS Project Office has a good understanding of the required project management controls and tools. Ownership of the project baseline and the development of effective management control processes were evident. The SNS Project Office staff also appears to have an excellent understanding of the need to effectively integrate the efforts of the partner laboratories. The development and control of the System Requirements Documents is a clear example of a process to ensure that the technical/accelerator systems and the conventional facilities are integrated.

The project-wide cost and schedule reviews, conducted by the new SNS leadership team to generate project cost and schedule contingencies, are an excellent example of an aggressive approach to ensure that project baselines are achieved. This management style was taken from the successful management techniques employed on the APS project. As a result of these reviews, which were similar to a value engineering exercise, the project cost contingency was increased and additional schedule contingency was generated.

While monthly project CPRs provide project cost and schedule status against the existing baseline, the recent CPR reports do not reflect a detailed cost performance review or a single earned value system. The cost performance collection and reporting systems have been given a lower priority during the past several months due to the Project Office staff focusing their attention on re-evaluating cost and schedule estimates. Because of the impending cost and schedule changes proposed by the new detailed baselines, little useful variance or predictive information could be generated.

The use of an interlaboratory MOA represents another management and communication technique between the SNS Project Office and partner laboratories to ensure that project baselines will be achieved.

8.2.3 Recommendations

1. Revise the SNS PEP by October 1, 1999, to reflect the new management structure and management systems, as well as the proposed baselines.

2. Complete the approval signature process for the revised interlaboratory Memorandum of Agreement by October 1, 1999.

3. Implement effective change control and configuration management by October 1, 1999 (or before Title I Conventional Facilities task order packages are assigned).

8.3 Relationship between the SNS Project and DOE

8.3.1 Findings

The DOE Basic Energy Sciences (BES) Program Office and the ORO Office continue to be strongly committed to the success of the SNS project. A positive working relationship, providing mutual support, has evolved among ORO, BES, and the SNS Project Office.

8.3.2 Comments

None.

8.3.3 Recommendations

None.

Intentionally Blank