Department of Energy
Review Committee Report

on the

Technical, Cost, Schedule, and
Management Review

of the

SPALLATION NEUTRON SOURCE (SNS) PROJECT

Phase I, October 2000
Phase II, December 2000

EXECUTIVE SUMMARY

A Department of Energy (DOE) Office of Science review of the Spallation Neutron Source (SNS) project was conducted in two phases at Oak Ridge National Laboratory (ORNL), Phase I during October 31- November 2, 2000, and Phase II during December 6 - 8, 2000. The review was conducted at the request of Dr. Patricia M. Dehmer, Associate Director for Basic Energy Sciences. The purpose of this review was to evaluate progress in all aspects of the project (i.e., technical, cost, schedule, management, and environment, safety and health), with special emphasis on the SNS pre-operations plan and cost estimate. Phase I of the review covered the line item project scope (i.e., Total Estimated Cost), while Phase II focused on the pre-operations plan and its cost estimate. In addition, Phase II evaluated proposed scope revisions that had been developed to address cost issues identified during the first phase of the review.

By the end of Phase II, the Committee concluded that the project plans support completing the SNS within the Level 0 cost, schedule, and technical baselines: Total Project Cost (TPC) of $1,411.7 million; project completion date of June 2006; and at least 1 megawatt of proton beam power on target. As revised, the project's internal working schedule is consistent with the FY 2001 Project Data Sheet out-year funding profile. The Committee also observed that there had been a smooth transition from Lockheed Martin to University of Tennessee-Battelle as the new ORNL Management and Operating contractor, and that good progress was being made in R&D and design of technical components, including the superconducting linac. The Committee felt that the project's installation and commissioning milestones were reasonable, and deemed the proposed FY 2006 pre-operations staffing level to be appropriate.

Over the course of the two review phases, three major issues were identified and addressed. First, the initial estimate (completed in September 2000) of the pre-operations cost by the current SNS management team reflected a overly aggressive staffing plan that greatly exceeded the baseline cost estimate. After extensive discussions with DOE, a revised estimate was presented to the Committee in Phase II that exceeded the pre-operations baseline of $111 million by approximately $16 million, which can be accommodated by adjustments within the existing TPC.

Second, the Architect Engineer's initial Title I cost estimate for conventional facilities greatly exceeded the baseline. By December 2000, a number of actions had been developed by

SNS management to address this potential cost growth. These included: returning the scientific instrument budget to near its conceptual design level; reducing the amount of office and laboratory space; reducing the proton beam energy and current; shifting some procurement and installation oversight functions from the partner laboratories to SNS; and reducing the size and capabilities of several conventional facilities. The Committee was generally supportive of these steps and encouraged further internal reviews to find cost savings that could be used to increase the contingency, and hopefully avoid some of the above proposed reductions. A revised project estimate that incorporates the results of these reviews will be provided to DOE for further discussions in mid-February 2001.

Third, the project's internal working schedule was examined in Phase I and was noted as overly aggressive. Although it provided 14 months of schedule contingency, the use of cost contingency over the past several months had caused annual budget authority requirements to exceed the funding profile in the FY 2001 Project Data Sheet. Activities have now been replanned to match the available funding, while still providing six months of schedule contingency.

The SNS was authorized as a line item construction project in FY 1999, and DOE approved the start of construction (Critical Decision-3) in November 1999. The SNS technical design has continued to mature and R&D activities are progressing with favorable results. Title I design is essentially complete, Title II design is well underway, and site excavation is complete. Foundation work for the Target Building has begun and other major site construction will start in the spring of 2001. The project is about 17 percent complete overall.

During Phase I of the review, the Committee was very concerned about cost growth (contingency use) that had occurred since the March 2000 DOE review, and also with the potential for future cost growth as indicated by many pending project change requests that might require the use of contingency. Most of the pending changes involved conventional facilities. The Committee therefore recommended that SNS management take immediate steps to generate cost savings throughout the project, including pre-operations, in order to maintain a healthy contingency level.

In response to DOE guidance following Phase I, the SNS Project Office provided a draft "SNS Pre-Operations Plan and Revised Project Baseline" proposal in November 2000 for evaluation during Phase II. This proposal described specific actions to generate cost savings across the project, including pre-operations, while still adhering to the SNS Level 0 baseline criteria. With certain reservations, the Committee endorsed the overall strategy proposed in this document for completing the project within the TPC of $1,411.7 million. These reservations concerned proposals to reduce linac output energy and current, and returning the instrument budget to its conceptual design level. The Committee ultimately agreed that the linac change, which could be easily reversed later if the necessary cost savings (about $10 million) could be found, was not unreasonable considering the cost pressures on the project. Although the proposed instrument budget of $53 million would only provide for three to four of the previously planned ten "best-in-class" instruments, the project intends to make additional instruments a high priority in allocating any future cost savings. The Committee also recommended that adequate laboratory and office space be provided convenient to the SNS facility.

It was noted that the contingency on the remaining line item work would be about 22 percent if all pending project change requests were approved. The Committee therefore strongly recommended that further efforts be made to identify additional cost savings to enhance contingency and provide for more instruments. The Committee recommended that Engineering, Design, Inspection, and Administration (EDIA) costs (at approximately 48 percent of construction costs) be examined and reduced to no more than 40 percent.

In summary, the project presented a plan that was acceptable to the Committee, and that met the Level 0 cost, schedule, and technical baseline criteria. However, the Committee emphasized that continued diligent effort by SNS management is required to keep this project on track. In addition, the project accepted an action item to complete implementation of the proposed scope revisions in the detailed cost and schedule baselines to enable earned value reporting against them by February 12, 2001. The Committee strongly urged the project to finish developing resource-loaded installation and commissioning plans by the next review in April 2001.

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Phase I Report

1. INTRODUCTION

1.1 Background

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

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

Phase II Report

1. INTRODUCTION

The Phase I portion of the review found that good overall progress was being made in R&D and technical design of technical components, including the superconducting linac. There were serious concerns, however, about whether the project would be completed within the $1,411.7 million total project costs (TPC) given the recent high rate of contingency use and the potential for cost growth as represented by the Architect Engineer's (AE) Title I conventional facilities cost estimate, which the project had received just prior to Phase I. If all project change requests (those already in the system and those anticipated) were approved, the Committee projected that contingency could fall to just under ten percent. Although pre-operations had not been reviewed during Phase I, the Committee had the general impression that the pre-operations cost estimate could exceed the baseline by as much as $100 million. Lastly, it was observed that the project's accelerated schedule, which forecast an "early finish" in May 2005, could not be achieved within the funding profile in the most recently approved (FY 2001) Project Data Sheet.

In light of the above findings, the Committee made three key recommendations in October 2000 Phase I review that required immediate responses from the project prior to Phase II:

1. SNS management should complete an extensive review to identify potential scope reductions and cost savings throughout all WBS elements, including pre-operations. The project should then prepare a plan for implementing sufficient scope reductions to restore contingency to at least 20 percent, while preserving the Level 0 cost, schedule, and technical baselines (TPC of $1,411.7 million, project completion by June 2006, and minimum proton beam on target of 1 MW).

2. Prepare a resource-loaded schedule that is consistent with the funding profile contained in the FY 2001 Project Data Sheet.

3. Aside from site work currently underway, hold the award of all other construction packages until project scope reduction activities are completed, and a revised schedule is established that can be accomplished within the DOE-approved funding profile.

Shortly after Phase I, DOE concluded that significant rescoping of the project would be necessary in order to offset potential increases to the cost baselines for a number of elements, primarily in conventional facilities and pre-operations, while preserving an adequate cost contingency. DOE therefore directed the project to provide a plan for accomplishing this rescoping, that would not impact the Level 0 cost, schedule, or technical baselines, in time to be reviewed and approved by DOE and then evaluated by the Committee during Phase II. Based on discussions between DOE and UT-Battelle, it was expected that the plan would include two major descoping actions: 1) remove the Central Laboratory Office building from the project scope, while still providing for the minimum functionality needed by the project, and 2) return the instrument budget to the January 1999 baseline proposal level of $45 million.

Pending the outcome of Phase II and implementation of a DOE-approved rescoping plan, DOE directed the project to suspend all new field construction activities and place a hold on all instrument-related procurements. In the meantime, the project launched an intensive effort to develop potential cost savings by revisiting all aspects of the project, with special emphasis on conventional facilities and pre-operations staffing plans. The SNS Technical Director was tasked to conduct an in-depth analysis of the AE's Title I estimate of conventional facilities and determine the root causes of difficulties in this area.

Senior ORNL and SNS management promptly organized and carried out two successive internal reviews during November 2000 to help the project address the Committee's key Phase I recommendations. The first was a review of the SNS pre-operations cost estimate by a panel of independent experts from other DOE laboratories, chaired by ORNL's Associate Laboratory Director for Physical and Computational Sciences. It provided several good recommendations for minimizing the cost of pre-operations. Next, a review of the project's potential line item rescoping and cost saving measures was conducted by a separate outside panel of experts, chaired by the ORNL Laboratory Director.

On November 29, 2000, the project delivered to DOE a draft "SNS Pre-Operations Plan and Revised Project Baseline," based on the results of the two above mentioned internal review exercises. The draft document was reviewed and approved by DOE for release to the Committee in advance of Phase II. This document contained the pre-operations cost estimate (the original focus for Phase II), as well as the project's proposal for achieving the cost savings needed to satisfy the Committee's Phase I recommendation on restoring contingency to at least 20 percent. It satisfied the boundary condition of preserving the project's Level 0 baselines. The pre-operations cost estimate had been reduced to the extent that it only exceeded the project pre-operations cost baseline of $111.5 million by $15.8 million. The rescoping proposal included several significant changes in project scope:

1. Deleting the Central Laboratory and Office Building (as directed by DOE) while providing for necessary functionality. This was estimated to yield a net savings of $37.5 million from the Central Laboratory and Office Building's $52.7 million estimated cost.

2. Restructuring the instrument plan to provide three to four "best-in-class" instruments (down from ten previously), and designs for common components of future instruments. This plan would cost $53 million, and hence save the project $40 million from the baseline instrument budget of $93 million.

3. Reducing the linac output energy (from 950 to 842 million electron volts or MeV) by eliminating the last three cryomodules of the superconducting linac. Space in the linac tunnel would remain to allow the possibility of adding these cryomodules back at some point in the future. This measure was estimated to save about $10 million, while still providing about 1.3 MW of beam power on target.

The entire Committee was invited to provide findings, comments, and recommendations on the draft "SNS Pre-operations Plan and Revised Project Baseline," and those have been included in the Phase II Report that follows.

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2. PROPOSED PROJECT SCOPE REDUCTIONS

2.1 Accelerator Systems

2.1.1 Findings

The Committee was shown three proposed scope reductions within accelerator systems.

The first was to defer the installation of a cryomodule processing facility within the superconducting radio frequency (SRF) building (a cost reduction of $3.9 million). The Committee had discussed this during Phase I and had no issue with this portion of the descoping.

The next was to eliminate three R&D items (a cost reduction of $2.0 million). Three R&D efforts using proton beams at Brookhaven National Laboratory, Los Alamos National Laboratory, and the Institute for High Energy Physics in Protvino have been pursued by the project to study e-p instabilities and ring collimators and to bench-mark simulation codes. It is now proposed to closeout these efforts for a cost reduction of $2 million since the outcome of the studies is not expected to affect the design or construction, or potentially pose a threat to successful project completion at Critical Decision-4.

Last was the removal of three cryomodules from the linac, along with the associated radio frequency (RF) systems and controls (a cost reduction of $10.7 million). This item, which would lower the linac energy from a nominal 950 MeV to a nominal energy of 840 MeV, is highly controversial, and was discussed at length.

2.1.2 Comments

The R&D studies to be dropped are very well motivated and have already provided important information. The Committee agreed that the termination of the studies would not affect the project's ability to reach Critical Decision-4. However, these studies will be essential to the commissioning effort beyond Critical Decision-4, and should be continued during the commissioning or early operations period of SNS. It is expected that the studies on e-p instabilities will most likely be continued by Los Alamos National Laboratory.

The reduction of the linac energy strongly impacts the performance of the ring. It was noted during Phase I that this approach should be considered only as a last resort. However, the Committee was told that difficult decisions had to be made, and this was one of them.

One of the reasons presented for defending this choice is the SNS design level for power on target, which was previously 2.0 MW and would now be about 1.3 MW. This is based on conserving a “comfort factor” quantified by the space charge tune shift equation. The scaling goes as the number of particles divided by β squared times γ cubed. Both factors in the denominator are reduced by reducing the energy, so the number of particles must be correspondingly reduced. The power level associated with maintaining the space charge tune shift is about 1.3 MW.

It was also noted that the accelerator physicists working on the ring have become “uncomfortable” with 2.0 MW at 1.0 GeV, and correspondingly they are not comfortable with 1.3 MW at 840 MeV. Simulations, which have an uncertain margin of error in predicting beam losses at the level needed at the SNS, indicate that 1.3 MW might not be achieved without additional hardware. However, the Committee noted that there would be some technical contingency between the minimum Level 0 baseline power requirement of 1 MW and an SNS design level of 1.3 MW. Accelerator physicists estimate that, at 840 MeV, it might take a year to reach 600 kW and several years to reach 1 MW. Several technical options exist to shorten this interval, such as achieving higher cavity gradient in the SCL cavities or adding more cryomodules to increase the energy, or adding sextupole correction magnets to decrease energy dependent time spread. It will become apparent during commissioning whether any of these options need to be exercised before the end of the construction period.

Time is available to best understand how to increase the power among the various technical options. Options are available to increase the linac energy and to increase the ring’s current capabilities (i.e., loss minimization). The project has plans for doing both, and there will be time during construction and commissioning to consider and implement the most cost effective method(s).

The accelerating gradient that the SRF cavities can support may a higher than what is presently promised. If the cavities can support the higher gradient, this would allow the linac to provide a higher energy beam at the needed current. It is not known what energy the linac will be able to provide with the reduced number of cryomodules being proposed, but it is felt by many on the project that it will be greater than 840 MeV, perhaps even as great as 1 GeV.

One of the more important deliverables to the users is accelerator reliability. Regardless of the maximum available average power, the useful power for operations is the energy that can be delivered at high reliability (greater than 90 percent). Pushing either the beam energy or the current higher does carry reliability risks, of which the increased current risk is by far the greater. The commissioning plan should balance a push for higher power with early availability of a lesser flux of neutrons for the users.

The Committee felt that lowering the linac energy would be a painful descoping action that would delay the delivery of 1 MW beam on target. However, when compared with other descoping actions such as an instrument budget reduction, it is not unreasonable.

2.1.3 Recommendations

1. Provide a plan, initiated by the SNS Experimental Facilities Division, of accelerator requirements for the first three years of SNS operation. This plan should contain hours of operation, power levels, and needed reliability, as a function of time, that will match instrument commissioning and users needs. This should be done by the next DOE review, now scheduled for April 2001.

2. Continue to evaluate all means of raising the linac energy within the proposed reduced scope of cryomodules. This is potentially an inexpensive means of raising the energy, but needs to be done in the context of high reliability operation.

2.2 Experimental Facilities

2.2.1 Findings

The Experimental Facilities Division staff level, funded by both line item and pre-operations funding, is adequate for the current commissioning plan. This plan, however, includes operating the target at low power prior to completing the Operational Readiness Review that is required before it can be operated as a Category 2 Nuclear Facility. If DOE does not approve this approach, there is a significant risk that the Experimental Facilities Division staff level will not be sufficient to complete the Operational Readiness Review requirements before Critical Decision-4, missing the Level 1 project completion milestones.

The proposed scope reductions include shortening the Target Building by 35 feet. This reduction has been optimized to maximize the amount of savings with minimal impact on operations, but further reductions in this building would not be appropriate. This change in the target building provides the second largest savings identified in conventional construction.

The proposal also deletes funding for the Central Laboratory Office Building from the baseline. This change would provide sufficient contingency to achieve the Critical Decision-4 milestones within the current TPC.

The proposal would eliminate a number of construction spares for the target system. In some cases, the components are unique, and fabrication would require six to eight months. While most of the spare components to be eliminated are relatively robust and simple, the inner core reflector assembly is both complex and more prone to failure in the early stages of testing. This introduces significant schedule risk to the project in the event of an early failure.

In an effort to increase contingency, the instrument budget would be reduced to $53 million. At this level, the project could not deliver the ten instruments previously foreseen. The project has developed a plan that will allow continuation of the effort on common components, and also provide for construction of the first three instruments selected for construction. In addition, the project is working to descope these three instruments in a way that allows for future upgrade, while recovering some of the money needed to allow construction of a fourth instrument.

2.2.2 Comments

Although the project's proposal relies on use of a User Conference and Residence Facility (to be constructed with $8 million of Tennessee State funds) and available space on the instrument floor of the Target Building to satisfy early user program needs, this is not a long-term solution. The functionality of the Central Laboratory and Office Building for the user program, including the provision of labs and offices convenient to the facility, must be provided.

The project should seriously consider procurement of a spare target inner core reflector plug that uses heavy water rather than Beryllium. This would provide a lower neutron flux, but would allow commissioning to continue while the first failure was analyzed and a replacement plug was fabricated. The cost of such a spare would be substantially less than the $1 million for a Beryllium system, thus providing most of the benefit of the original reduction, while removing a significant schedule risk.

While the Committee expressed regret at the reduction in scientific scope that would result from a reduction in instrument funds, it endorsed the strategy adopted to cope with this action by the project. The shared component development is a prerequisite to later completion of the full suite of instrumentation that is required to properly exploit this source. The Committee also endorsed the decision to add a fourth instrument by descoping all instruments, while allowing for future upgrades. However, it was noted that until the subsequent upgrades are completed, the four instruments thus provided would not be the "best-in-class" instruments that were promised.

The choice for the fourth instrument should be based on meeting the needs of the broadest possible user community, considering all four instruments, and cost should be a lesser consideration.

2.2.3 Recommendations

1. Find additional savings throughout the project, and use the funds to restore the full scientific scope of ten "best-in-class" instruments to the extent possible.

2. Ensure that adequate user and staff laboratory and office space is provided convenient to the facility to support a robust user program. This should be done in close consultation with ORNL.

2.3 Conventional Facilities

2.3.1 Findings

Title I designs are complete and Title II designs are underway. Site preparation work is nearing completion.

The project has identified about $37 million of cost reductions, relative to the Title I design estimate, to meet the project baseline in addition to a $37.5 million net reduction deleting the Central Laboratory and Office Building. The 89 reductions proposed by the project would bring the conventional facilities cost down to $306.8 million compared with the baseline level of $300.3 million. The Central Laboratory and Office Building is a 250,000 square foot building designed to house the SNS control room, support laboratories, and site personnel (administration, operation, and users). As previously mentioned, this facility would be deleted from the project scope as a cost control measure to free additional budget. While the Central Laboratory and Office Building carried a budgeted cost of $52.7 million, Title I and II design ($5.1 million) are essentially complete leaving a net reduction of $47.6 million. However, essential functions from the Central Laboratory and Office Building would have to be provided by alternate means. A new control room ($3.8 million), incremental project management office space ($4.3 million), and extended occupancy of the RATS (Receiving, Assembly, Test, and Storage) building ($2.0 million) lower the net reduction for elimination of the Central Laboratory and Office Building to $37.5 million.

A $3.3 million cost savings is being proposed for eliminating the crane in the ring tunnel and reducing the tunnel height from 18 to 11 feet. The remainder of the identified cost reduction measures is being prepared for implementation as project change requests. The AE has been directed to prepare cost proposals for proceeding with the designs.

The conventional facilities schedule has been extended to adjust the commitment profile to the available budget authority. This was accomplished by slipping Beneficial Occupancy Dates by eight months. The analysis to support these Beneficial Occupancy Dates will not be available until February 2001.

As previously discussed, the project made a significant cost reduction effort after receiving the Title I conventional facilities cost estimate. The effort was lead by the SNS Technical Director, who is familiar with cost trade-off issues associated with the technical program objectives and the construction costs of conventional facilities.

Revised Title II designs to reflect the proposed cost reduction initiatives are awaiting the negotiation of related AE fixed price design contracts.

2.3.2 Comments

The Committee was unable to evaluate the impact of the conventional facilities cost containment changes on the schedule, and consequently on the annual funding profile. The initiatives must be incorporated into the resource-loaded Integrated Project Schedule before these impacts can be evaluated.

Some of the functions consolidated into the Central Laboratory and Office Building are essential for productive operation of SNS. While supporting the deletion of the Central Laboratory and Office Building to contain costs, the Committee cautioned that essential SNS functions must be provided in the absence of the Central Laboratory and Office Building.

Actual contract costs need to be tracked against Title I estimates. The AE should be encouraged to propose cost reductions as a routine matter.

Substantially more than $37 million of cost reductions in conventional facilities are possible. The identification of additional savings are of the highest priority. This will continue to require the leadership of a senior technical accelerator person to make the technical trade-off judgments.

As part of cost reductions for civil construction, the project is considering the elimination of the crane in the ring tunnel. This could lead to significant cost savings because of the reduced tunnel height and the lower load requirements on the structure. Since the performance level of the SNS is expected to be limited by component activation from beam losses, reductions in the collective radiation dose during the repair and replacement of ring components need to be considered during the design stage. The design specification calls for limiting residual dose to components to allow “hands-on” maintenance. By their nature, the cores of the beam collimators will become highly radioactive. The failure modes and replacement frequency for these components need to be evaluated. As an alternative to the crane, in-situ storage or provision of a shielded hatch at the collimator location need to be evaluated. Component handling in the tunnel for normal maintenance needs to be re-evaluated in the absence of a crane.

2.3.3 Recommendations

1. Continue to evaluate the requirements on conventional facilities driven by the technical systems with a view to further cost reductions and simplification of design. Keep in view operations requirements.

2. Include at an appropriate management level, an advocate for conventional facilities who has recognized credentials on both the technical and conventional facilities sides to buffer and evaluate conventional facilities change requests.

3. Incorporate accepted cost containment design changes into the resource-loaded Integrated Project Schedule by February 2001.

4. Process expeditiously the project change requests related to cost containment actions.

5. Continue to review all the conventional facility tasks for cost savings, with an aim to restore a minimum $20 million more back into project contingency.

3. INSTALLATION and PRE-OPERATIONS

3.1 Findings

This section addresses both component installation (a construction-funded activity) and pre operations (an operating-funded activity). The SNS pre-operations plan has recently undergone substantial modifications. The component testing and installation efforts are also undergoing reevaluation. The original plan contained very little construction scope at ORNL, with the predominant effort being assigned to the participating laboratories. The SNS management has assessed that the accelerator installation and pre-operations budget is inadequate to have the core accelerator workforce in place so as to assure success in early operation.

The newly proposed plan consists of a new accelerator equipment testing and installation strategy, which would transfer most responsibility from the partner laboratories to the SNS Accelerator Systems Division at ORNL, a $25 million transfer of budgeted costs, and would increase the cost estimate for this activity by $15 million. There is also a proposed increase of $4 million to support increased Davis-Bacon installation labor. In addition, the pre-operations estimate would be increased by $15.8 million to meet a "minimum reasonable" interpretation of the Level 0 milestone for project completion. The Committee was not able to verify the details of the $34.8 million increase. The $15 million would come from contingency funds and would be used to support Accelerator Systems Division field coordination for the linac and ring systems. The $15.8 million increase in the pre-operations estimate would provide for the Accelerator Systems Division staff needed to continue into the operations phase. This effort was underestimated for Accelerator Systems Division by approximately 110 full-time equivalent (FTE) years in the early years of the SNS project. The field coordination is in the area of power supplies (22 FTE years), linac RF (26 FTE years), mechanical structures (34 FTE years), vacuum systems (13 FTE years), and beam diagnostics (15 FTE years).

The Committee found that the installation planning process is well conceived and moving along. Staffing levels in FY 2006 are appropriate, and the installation and commissioning milestones are well matched at this point in the development process.

In order to stay within the TPC, SNS management has proposed to relax various Level 1 milestone requirements and reduce the instrument budget (by $40 million) amongst other items, in order to accommodate the above mentioned increases in installation and pre-operations ($34.8 million) and to provide increased contingency funds. The Experimental Facilities Division's pre-operations budget is to be reduced ($2 million) due to reducing the number of instruments (from ten to three or four) to be operational at Critical Decision-4.

3.2 Comments

The Committee was concerned that at this advanced stage of the project the question of the magnitude of pre-operations staffing has become such a substantial problem. This is introducing a significant paradigm shift in the laboratory collaborative effort and adds substantial risk in the delivery of meeting technical component and operating systems specifications by the partner laboratories. The proposed changes necessitate a review of the Project Execution Plan between the participating laboratories.

The Committee noted that the basic structure of a collaborative effort between the laboratories and ORNL is changing towards one of a vendor-supplier relationship to the project. The re-engineering goals have been generally established, with the installation approach more mature than the commissioning plan. The Committee was concerned that an increased dependence upon commercial suppliers to perform magnetic measurements and power supply evaluation could easily lead to unidentified errors, delays, costly rework, and an unappreciated (i.e., much larger) oversight requirement by the project. An extremely close evaluation of vendor performance is of the highest priority before full implementation of the vendor model. The "lead, mentor, consult" model is likely to be appropriate for subsystems with a large number of identical components and, therefore, highly repetitive. Subsystems consisting of many singleton items could be negatively affected in cost, time, and performance. The project must evaluate the risks and cost effectiveness of the newly proposed approach, and have the flexibility to respond appropriately. The Committee was concerned that one will likely learn that modifications to the plan will be required, and that the project will not have enough resources to quickly change to stay on time and within budget. The expectation is that the partner laboratories will rapidly reassign or reduce force as this new paradigm is implemented, and that an enhanced effort by the laboratories, after they have reduced their efforts and staff, would be problematic.

The Accelerator Systems Division is being built up to provide a critical mass for the commissioning and operation of SNS. This is accomplished, in part, by transferring the responsibility and budgets for installation labor and supervision to the SNS Project Office at Oak Ridge. A strong and capable organization at Oak Ridge is clearly critical to the success of SNS. At the same, time funds should remain allocated to allow physicists and engineers from the partner laboratories to participate and help to organize the commissioning of their systems.

The Committee was not presented with a staff and budget plan for operations following the construction period. In order to provide for an orderly transition into operations, one must match the construction and pre-operations staffs into a robust operations staff.

3.3 Recommendations

1. Evaluate the effectiveness of the new component and systems testing approach that de-emphasizes the partner laboratory efforts. There is a serious concern that the equipment performance may be compromised.

2. Complete the development of a resource-loaded accelerator installation plan prior to the next DOE review (April 2001).

3. Complete the development of a resource-loaded accelerator commissioning plan prior to the next DOE review (April 2001).

4. Scrub the $34.8 million installation and pre-operations cost increase and civil construction areas for savings that can be applied to other parts of the project, such as additional user needs and increased proton beam energy.

5. Complete, in conjunction with the Instrument Systems team, the installation and commissioning plans of the baseline instruments.

6. Complete the target facility installation and commissioning plan prior to the next DOE review (April 2001).

7. Develop an operations budget and staffing plan for the first year of SNS operations.

8. Evaluate the cost effectiveness of increased use of purchased services for the Site Operations Division from ORNL services, instead of full-time SNS employees.

9. Evaluate the transfer of responsibility and effort from the partner laboratories so as to maximize the value of their work. Define the role of the partner laboratories so as to retain their involvement for complex systems as long as possible so that the associated risk is minimized.

4. COST, SCHEDULE, and FUNDING

4.1 Project Cost and Schedule Baselines

4.1.1 Findings

The SNS project has assembled a very talented team of cost and schedule specialists. Considerable effort was dedicated by the entire project to developing the cost estimates and schedules provided during the review. The project uses Primavera as its cost and scheduling tool. Two sets of resource-loaded, integrated project schedules were developed and presented at the review. Both the budget authority and budget obligation profiles were factored into the resource loading. These schedules were:

1. Early finish of December 2005/late finish of June 2006 (which supports the Level 0 baseline schedule), and

2. Early finish of September 2005/late finish of December 2005 (which supports an accelerated funding option).

These schedules were developed to achieve the June 2006 or earlier project completion date within the TPC of $1,411.7 million. In addition, project cost contingency had to be at least 20 percent, the Level 0 technical baseline had to be met, and the pre-operations funding needs had to be resolved within the existing TPC. The SNS project had to identify significant cost savings from the October 2000 (Phase I) cost estimates to achieve the project TPC under the stipulated conditions. This required some internal strategy changes. For example, the transition of construction work from the partner laboratories to the SNS is now planned to occur earlier than presented during Phase I. The Draft SNS Pre-Operations Plan and Revised Project Baseline document was provided to the Committee before Phase II. This document describes the essential changes in the SNS project that would allow the TPC to be maintained.

An additional assumption for both of these schedules includes maintaining the ongoing R&D (with the exception of $2 million in R&D that was deleted) and design schedules. For both schedules, construction starts were delayed, construction durations were slipped, and beneficial occupancies were delayed. These delays affect the installation of technical components and commissioning. An exception is the Central Laboratory and Office Building that would be removed from the baseline. These schedules were prepared using much of the existing information and logic that were developed for the schedules presented during Phase I. Because of the short time available between Phase I and II, the partner laboratories did not complete their confirmation of the schedules for their activities, and verify that budget authority and budget obligation profiles were accurately reflected in the schedules.

4.1.2 Comments

A number of valid cost savings measures were identified by the SNS project through a variety of reviews and value engineering processes. The SNS project was strongly encouraged to continue to methodically identify cost savings to ensure that adequate funds are available to complete the project as planned, and to provide as many instruments (greater than four) as possible. In addition, it remains important that the partner laboratories review and confirm the revised project schedules and the budget authority and budget obligation profiles for their respective activities to provide additional credibility. Completion of this review is still required for the ring, conventional facilities, and target.

While continued assessment of alternative schedules remains part of the SNS management approach, the SNS project needs to focus attention on the present project baseline (FY 2001 Project Data Sheet funding profile and June 2006 completion date) to ensure that the existing project baseline plan retains its credibility. The current baseline Project Summary Schedule and FY 2001 Project Data Sheet funding profile are contained in Appendices E and F, respectively.

4.2 Change Control Process

4.2.1 Findings and Comments

The SNS change control process was discussed in some detail during the review. It appeared to the Committee during Phase I that some changes in the change control process are warranted. A number of recent changes in the process were presented by the SNS project during the Phase II presentations. For example, change control approval thresholds have been reduced, the change control process has become more formal, and senior SNS management is more involved in the changes. Change control criteria that discourage cost increases (other than necessary changes) have been established. For example, cost increases in the conventional facilities now require offsetting reductions from the change control actions. A review of the change control process has been planned for January 2001 by the SNS project using a number of distinguished outside consultants.

The Committee supported the changes made by the SNS project and the planned review of the change control process. It was recognized that the large number of project participants makes the change control process more difficult, so efficiencies are encouraged. More senior management attention to this area should aid in the integration process.

4.3 Specific Baseline Changes from October 2000 to December 2000

4.3.1 Findings

During Phase I, the Committee identified potential cost increases on the scale of $200 million. At the end of Phase I, the SNS project was charged to identify cost reductions that would provide at least 20 percent contingency while resolving cost problems in conventional facilities and pre-operations. UT-Battelle took immediate steps in November 2000 to work with the SNS project to examine the cost issue and recommend cost savings or cost avoidances through the work of two committees, as previously described in the Introduction Section of this (Phase II) report. The SNS project identified significant cost changes, and identified other cost issues that could be avoided, particularly in the area of conventional facilities. The significant cost reductions proposed by SNS management were:

1.	Reduce instrument budget	-$40.0 million
2.	Delete Central Laboratory and Office Building	-$37.5 million
3.	Remove three linac cryomodules and related RF	-$ 9.9 million
4.	Defer SRF equipment	-$ 3.8 million
5.	Remove target spares and reconfigure target Mock-Up Test Stand	-$ 2.8 million
	Total	-$94.0 million

The significant cost increases proposed by the SNS project to reflect the pre-operational needs of the project are:

1.	Additional staff for Accelerator Systems Division construction/installation	$15.0 million
2.	Additional staff for Accelerator Systems Division pre-operations	$15.8 million
3.	Escalation related to schedule changes	$ 8.2 million
	Total	$39.0 million

The escalation related to schedule changes resulted from adjustments needed in the cost profiles to reflect delays in project activities from the overly aggressive May 2005 early finish schedule. The net effect of the above changes would be to return $55.0 million to project contingency.

4.3.2 Comments

Overall, the Committee supported the ongoing SNS project effort to identify and implement cost savings. So far, this effort has successfully demonstrated that cost savings can be found through cost savings measures. Continuation of this effort is critical because additional funds are needed to increase the number of instruments and the ability of the SNS project to support the user community. Of those changes presented by SNS management and discussed in section 4.1.3 above, the Committee believed that if additional cost savings measures were identified, then the instrument budget could be restored accordingly. This would result in more instruments being installed on the completed SNS at Critical Decision-4. Deleting the Central Laboratory and Office Building would result in some SNS staff inefficiencies, and at the same time would remove the capability to provide user support, but the Committee deemed this to be a lower priority than adding instruments.

4.4 Contingency

4.4.1 Findings and Comments

As recommended by the Committee during Phase I, the SNS project baseline now includes about $220 million in contingency. SNS reports that this contingency is over 29 percent of estimate to complete. The SNS project reported that proposed change control actions, if approved, could lower that contingency to about 22 percent.

The Committee felt that a contingency of $220 million and over 29 percent would be adequate for the project at this stage of development. While this contingency level may appear high, there are several project change requests pending approval (as noted earlier) that could reduce it to around 22 percent. In addition, this level of contingency reflects the additional risk imposed through the implementation of cost reductions. For example, some construction spares were removed from the project scope.

4.5 Project Support Costs (WBS 1.2)

4.5.1 Findings and Comments

The SNS project reported cost savings due to revised overhead agreements with ORNL, but additional staffing and requirements for direct funding of SNS staff resulted in some overall cost increases to this WBS element since October 2000. The SNS project has undertaken some cost-savings reviews to minimize this impact. The Engineering, Design, Inspection, and Administration (EDIA) for the SNS project is reported at 48 percent of construction costs.

Project support costs for SNS remain high. The large number of project participants has led to a complex management structure. The SNS project also recognized that EDIA is higher than for an average project. Many of the Committee recommendations will require additional management attention. The SNS project has underestimated its space needs at ORNL before construction completion. In addition, the decision on office space was closely linked to the fate of the Central Laboratory and Office Building. The absence of the Central Laboratory and Office Building would continue to add to this problem. Another initiative is the cooperative examination of ORNL and SNS resources to develop opportunities for cost savings through shared resources. Integration with ORNL and examination on shared resources may result in some cost savings to the project.

4.6 Recommendations

1. Identify funds that can be used to ensure that the project's Level 0 baselines can be achieved and to increase the ability of the SNS to perform its science mission by increasing the number of instruments beyond the three to four proposed.

2. Continued senior SNS management attention is needed for the change control process to aid in integrating the required changes into the project in a more timely manner.

3. Continue the methodical review of the project to identify funds for increasing contingency. The contingency account needs to be protected.

4. Continue to examine project support costs and Engineering, Design, Inspection, and Administration costs.

5. Work closely with ORNL management to identify opportunities for cost savings through shared resources.

Figure 1-1. The Spallation Neutron Source

A Final Environmental Impact Statement for the SNS was issued in April 1999, and on June 18, 1999, the Secretary of Energy signed the Record of Decision to proceed with construction of the SNS at ORNL (Chestnut Ridge). A Mitigation Action Plan (MAP) was prepared that identifies actions being taken by DOE and the project to avoid or minimize environmental harm in building and operating this facility. The Department is monitoring progress against the MAP to ensure that the plan is properly implemented.

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-1, Approval of Mission Need, and Critical Decision-2, Approval of Level 0 Project Baseline, for the SNS were approved by the Secretary of Energy in August 1996 and December 1997, respectively. The Secretary initially approved the SNS Project Execution Plan, which governs how the project is managed, at the time of Critical Decision-2; it was most recently updated in October 2000. The Level 0 cost and schedule baselines set at Critical Decision-2 comprised a TPC of $1,333 million and a seven-year design/construction schedule, with facility commissioning to occur at the end of FY 2005. The approved Level 0 technical baseline stipulated that the accelerator complex would produce a proton beam on target of at least 1 megawatt (MW). Receiving $23 million in FY 1998, the project carried out advanced conceptual design and further R&D activities in anticipation of starting Title I design in FY 1999.

A DOE technical, cost, schedule, and management review of the project was conducted in June 1998. Its principal finding was that the project's management organization and systems were sufficiently mature to initiate the construction project at the beginning of FY 1999. Further work was deemed necessary, however, to complete a detailed cost and schedule baseline, and to restore project contingency to at least 20 percent. A strong recommendation was made to hire a permanent Project Director as soon as possible and to continue building the Accelerator 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. The President's FY 2000 Budget Request for the SNS project was $214 million ($196.1 million of line item construction funds and $17.9 million of operating expense funds).

In November 1998, ORNL competitively awarded an AE/CM contract to a joint venture led by Lester B. Knight and Sverdrup Facilities, Inc. (Sverdrup has since been acquired by Jacobs Engineering Group, Inc.). The AE/CM team is responsible for design and construction of all conventional facilities, that will contain the major technical components (front end, linac, ring, target, and instruments) supplied by the partner laboratories.

At the January 1999 DOE review, the committee determined that the SNS Collaboration was continuing to work well together, and technical progress was generally good, however the baselines were still not judged to be ready for DOE approval. The main reason was lack of technical leadership and project-wide ownership by the relatively inexperienced SNS Project Office management team then at Oak Ridge. The committee strongly recommended that a new Project Director be recruited with extensive experience in construction of large technical and 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 1999 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, within budget, and on schedule. Between April and June 1999, the SNS Project Office at Oak Ridge was reorganized and additional technical and management staff members were recruited to fill key positions (e.g., Project Director, Technical Director, Accelerator Systems

Division Director, and Procurement Manager). The partner laboratories were directed to optimize and fully integrate the technical design, and to strengthen the business and project management systems to support construction activities.

Under Dr. Moncton's leadership, the SNS technical parameters were revised to include an average proton beam power on target of up to 2 MW, enhanced (best-in-class) instruments, and expanded laboratory and office space for users and staff. This was achieved, along with increased contingency, through aggressive scrutiny of all subsystem cost estimates by the SNS Project Office management.

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

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

At $117.9 million, the FY 2000 appropriation for SNS was $96.1 million less than the $214 million request. This, coupled with the project's restructuring under new management, led to an estimated delay in project completion of six months (to June 2006), and a corresponding increase in the TPC of $80 million (to $1,440 million including Tennessee taxes, see below). In addition, the House report (Report 106-253, pages 113-114) accompanying the FY 2000 Energy and Water Development Appropriations Act prohibited DOE from obligating FY 2000 funds to SNS until seven conditions had been satisfied. The project was able to make continued progress, however, by using uncosted obligations remaining from FY 1999 while efforts were made to satisfy these conditions. In particular, DOE approved Critical Decision-3, Start Construction, on

November 5, 1999, and site preparation work on Chestnut Ridge began soon thereafter. A formal groundbreaking ceremony for SNS was held on December 15, 1999. By February 2000, DOE and the project had satisfied the seven congressional conditions and all FY 2000 construction funds were released to the project. Since that time, the project has managed to complete most Title I design activities, as well as nearly all site clearing, excavation, and roadwork.

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

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

The President's FY 2001 Budget Request for SNS was amended to reduce the TPC from $1,440 million to $1,411.7 million (as-spent) to account for the Tennessee tax exemption. Congress appropriated the entire requested amount for FY 2001: $259.5 million in construction funds and $19.1 million in operating expense funds.

1.2 Charge to the DOE Review Committee

In a September 6, 2000 memorandum, Dr. Patricia M. Dehmer, Associate Director for Basic Energy Sciences, Office of Science, requested that Daniel R. Lehman, Director, Construction Management Support Division lead a review to evaluate all aspects of progress, including technical, cost, schedule, management, and environment, safety and health, with a special emphasis on the SNS pre-operations plan and cost estimate. The review scope also included verification that the project's cost and schedule baselines are consistent with the President's FY 2001 Budget Request to Congress.

The entire review was originally planned to take place during October 31-November 2, 2000. However, the charge was modified on October 6, 2000 (see Appendix A) to have the review conducted in two phases—Phase I (on the original dates) to cover the line item project scope, and Phase II (December 6-8, 2000) to focus on the pre-operations plan and cost estimate. This change was needed to allow the project more time to prepare the pre-operations plan and cost estimate in a meaningful level of detail. As a result of cost issues identified during Phase I, the second phase also evaluated proposed scope revisions that had been developed to address them.

1.3 Membership of the Committee

The Review Committee (see Appendix B) 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. Continuity and perspective were provided in that many of the members served on one or more of the previous five DOE review committees. For Phase I, the Committee was organized into nine subcommittees, each assigned to evaluate a particular aspect of the line item project corresponding to the members' areas of expertise. In order to cover the pre-operations aspect of Phase II, the Committee was augmented (and the subcommittees reduced to four) with several experts who have experience in commissioning new research facilities.

1.4 The Review Process

As mentioned above, this review was accomplished in two phases during October 31-November 2, and December 6-8, 2000, at Oak Ridge, Tennessee. The agendas for both phases (Appendix C) were developed with the cooperation of the SNS Project Office, DOE Headquarters, and DOE Oak Ridge Operations Office (ORO) staff.

Comparison with past experience on similar projects was the primary method for assessing technical requirements, cost estimates, schedules, and adequacy of the management structure. Although the project requires some technical extrapolations, similar accelerator projects in the United States and abroad provide a relevant basis for comparison.

Members of the SNS Project Office staff largely devoted the first day of each phase of the review to a plenary session, with project overview presentations. On the second day, there were presentations by the participating laboratories (ANL, BNL, LANL, LBNL, ORNL, and TJNAF) with subcommittee breakout sessions to discuss detailed questions from the Committee. The third day was spent on Committee deliberations, report writing, and drafting a closeout report. The preliminary results of each phase were discussed with SNS management and staff at a closeout session on the last day.

The Committee identified some cost issues during Phase I, and the project was provided with recommendations on how these could be addressed. Progress was made in responding to the Committee's recommendations during the month leading up to Phase II, and this was documented in a draft "SNS Pre-Operations Plan and Revised Project Baseline" proposal. It was provided to the Committee in late November for evaluation during Phase II. The proposal described specific actions to generate cost savings across the project, including pre-operations, while still adhering to the SNS Level 0 baseline criteria. The project's presentations to the Committee during Phase II were based on the plans contained in that document.

Although a number of Committee members were not physically present at each phase of the review, all members were involved by reviewing and commenting on the relevant documentation, and in one instance, a member participated in Phase II via a videoconference link.

2. TECHNICAL SYSTEMS EVALUATIONS

2.1 Accelerator Physics

2.1.1 Findings

Excellent progress has been made in the understanding of the accelerator physics of the whole SNS facility since the March 2000 DOE review. The SNS team has carefully considered and studied all recommendations given in that review. The Committee analyzed several topics in detail in the relatively short period of time available.

The introduction of a superconducting linac (SCL) was addressed at the March 2000 DOE review. It was then commented that "close Accelerator Physics coordination is required between LANL and the SNS Project Office in order to work together quickly and efficiently in evaluating and responding to the superconducting linac issues." It is a pleasure to see how well the laboratories have worked together along these lines since then, and to note the impressive Accelerator Physics efforts which have been made at both LANL and TJNAF. These efforts continue, for example with a linac Beam Dynamics workshop to be held in November.

Essential progress has been made in the SCL design (see Figure 2-1). A radio-frequency (RF) architecture with one cavity per klystron has been adopted. In addition, the optimization of the two-β cavity architecture has been completed. As a result, the number of cryomodules required to reach the design energy of 950 million electron volts (MeV) has been reduced from 29 to 26, resulting in improved beam dynamics performance. The phase and amplitude control of the accelerating field in each cavity has become much simpler and more effective.

Enormous progress has been made in beam dynamics simulations using several different multi-particle codes. One code is used to simulate the Ion Source itself, another to model the RF, and a third to model the drift tube linac (DTL), the coupled-cavity linac (CCL), and SCL portions of the linac. A fourth simulation is used to model the ring. There is continuous effort in improving these codes. However, further studies are required to more thoroughly establish the dependence of the beam parameters at the stripping foil on the particle phase space distribution, beam current, and emittance at the entrance to the RF.

Figure 2-1. SC Linac Configuration

Issues of beam distributions input to the simulations continue to be addressed. A waterbag beam distribution is often used as input into the RF simulation, although this is unlikely in practice. It was stated that, in the future, the RF simulation input distribution would be derived from the Low Energy Beam Transport performance, when such data become available. Simulations of RF transport with anomalously large input emittances show that, as expected, the RF exit emittance is filtered down to a maximum acceptance value.

Transient beam loading can produce distortions of the electrical field in any cavity. The influence of this effect on the beam parameters can be enhanced by the space charge fields of the beam. The physics of Higher Order Mode (HOM) excitation and the possible evolution of beam instabilities are now well understood. The upper limit for the quality factor of the HOMs has been established. The use of HOM dampers is necessary.

A standard set of realistic SCL parameters has been established, and is used by all parties involved in analyzing the accelerator physics performance of the SCL. The "Proton Storage Ring instability" is still not fully understood, despite continuing progress. The next e-p workshop is being planned. A productive study of the collimation systems in the transport lines and in the ring is under way. Experimental studies on operational machines are being performed.

The Accelerator Physics role is evolving from being primarily involved in addressing engineering issues, to playing an integral role in the preparations for commissioning, in coordination with the controls and beam diagnostics groups. At this stage of the project the engineering designs are being frozen so that the flexibility for engineering changes in response to Accelerator Physics analysis is rapidly diminishing.

SNS Accelerator Physics is becoming more centralized at ORNL, while at the same time becoming better integrated across the laboratories. The healthy relationship between ORNL Accelerator Physics and the controls group continues to improve, especially while the controls group also becomes more centralized at ORNL. Application code development plans are being jointly developed, with the Accelerator Physics group playing a leading role. The Committee supported and encouraged this activity. The first applications are expected be exercised in the on-site commissioning of the front end in January 2002.

2.1.2 Comments

Continued close Accelerator Physics attention is required in support of engineering decisions, notwithstanding the fact that the Accelerator Physics effort is naturally moving towards commissioning preparations.

The trend towards a tighter relationship between Accelerator Physics, beam diagnostics, and the controls group is very encouraging. This integration is made easier by the increasing centralization of these three groups at ORNL, and by the significantly improved project-wide integration of their activities. There is no shortage of issues to be jointly addressed. For example, how will multi-disciplinary systems like the Beam Position Monitor/Closed Orbit system be commissioned? How will the beam distribution be monitored and matched in each accelerator section during phased commissioning?

The development of a strategy for linac commissioning with beam is just starting. The tuning of the linac with high-pulsed current beam, even for low repetition rate must be done very carefully in order to avoid any extra activation of the accelerator equipment. There is no previous experience with tuning an SCL with a proton (H^{-}) beam. This task should be carefully studied with the goal of identifying possible impacts on the RF system, and on beam instrumentation requirements.

The Committee was concerned with the extent to which linac simulation studies concentrate almost solely on root mean square emittance values to represent the beam distribution. Comparatively little attention is paid to the relatively few particles in the beam halo, which nonetheless cause many of the problems.

Halo studies, although necessary, are demanding, and push the simulation codes to their performance limits. It is very desirable to validate simulation code halo predictions, either by comparison with data from an existing accelerator, or by side-by-side comparison between independent simulation codes.

Semi-analytical models of beam halo growth take into account higher order resonances, both structural and space charge. In particular, the frequencies of the transverse and longitudinal oscillations are close to parametric resonance along the SCL. Even if this resonance is weak in first order, it can be serious in higher orders, and can cause significant beam halo development.

It might be possible to improve the linac beam dynamics performance by shortening the space between the SCL cryomodule tanks. This distance is nominally 1.60 meters, but after slight modifications it seems that the space could be reduced to less than one meter. For example, the focussing quadrupoles between cryomodules could be shortened by increasing their pole tip fields. The shorter length of the focussing period results in stronger focussing. This could be important in avoiding the parametric resonances between transverse and longitudinal motion that may drive halo development in the present configuration. The length of the tunnel also becomes shorter. If the SCL is designed for 26 cryomodules, then the shortening of the focussing period could save about 15 meters of tunnel length.

The presentation of beam halo simulation results should be made in accordance with the latest developments in the field. For example, it is desirable to use the halo distribution parameters recently introduced by Gluckstern and Wangler, along with the root mean square and 99.9 percent emittance parameters. The goal is to identify the underlying physics processes that drive halo development. Such studies should be pursued even past the time when engineering designs are frozen, since they are vital in preparing commissioning strategies.

Beam dynamics simulations indicate that a main source of emittance growth and halo formation in the front end is in the long drift spaces in the Medium Energy Beam Transport where the chopper is placed. Therefore, front end commissioning and acceptance is important. The list of acceptance parameters should include not only root mean square parameters, but also other longitudinal and transverse beam distribution parameters representing the beam halo. In addition, the measurement of the beam parameters as a result of chopper operation should be considered during the off-site commissioning of the front end. The planning of such measurements and the development of necessary equipment (within the existing budget) is important.

The ring team reported stripping foil lifetime estimates. The SNS storage ring is designed for the highest beam intensity ever accumulated with a stripping technique. With a (potential) future increase of the beam intensity, the stripping foil lifetime could result in frequent down times during foil cartridge changes. The most critical issue is the foil heating. Similar problems exist in connection with the development of the Rare Isotope Accelerator Facility, where high-intensity heavy ion beams will be stripped. The solution proposed at ANL involves the development of a liquid lithium target. A similar technique appears promising for H^- stripping at SNS. The technical aspects of such stripping are reasonably well understood.

Further studies of the beam losses and beam-induced activation around the collimators are required. It is particularly important to optimize the collimation system to make its performance independent of the incoming beam emittance and particle distributions.

2.1.3 Recommendations

1. Continue the recent excellent and diverse work on the beam dynamics performance from source to foil. Study the sensitivity of beam delivered to the foil with respect to variations in the beam distribution and current output from the front end.

2. Consider ways to validate the linac simulation codes, either by comparison with real data from existing linacs, or by independent code evaluation of the same SNS model.

3. Continue experimental and theoretical studies of the Ion Source and Low Energy Beam Transport, in order to minimize the ion beam steering and emittance growth due to the large number of electrons coming from the source.

4. Prepare a commissioning plan on how to measure and correct the beam distribution characteristics at multiple points along the accelerator system, especially in the context of phased commissioning.

5. Consider extending the front end beam diagnostics in the off-site commissioning, to include measurements of the longitudinal emittance and other distribution parameters of the chopped beam.

6. Continue to support investigations to understand the "Proton Storage Ring instability." This instability, which is still not fully understood, could limit the performance of the SNS.

7. Continue the good work on beam losses and collimation, with the goal of reducing spurious beam losses in other areas.

2.2 Front End Systems (WBS 1.3)

2.2.1 Findings

Compliments to LBNL for significant technical progress on the Front End Systems (FES) since the March 2000 DOE review. LBNL is to be complimented for:

- Completion and initial RF conditioning of the Alpha module of the radio-frequency quadrupoles (RFQ).
- Fabrication of the first production Ion Source.
- Fabrication of a Low Energy Beam Transport designed for 65 milliamperes (mA).
- Achievement of 42 mA at the Low Energy Beam Transport exit.
- Acquisition of a large number of components for the RFQ and Medium Energy Beam Transport.

The project has made good progress toward the implementation of the recommendations of the March 2000 DOE review.

1. The new klystron was delivered during September 2000, and it has been installed in the Integrated Testing Facility.

2. Considerable attention has been given to the recommendation to clarify installation responsibilities, however this issue needs continued attention.

The Schedule Performance Index (SPI) for the FES construction effort (WBS 1.3) is 0.84 and the Cost Performance Index (CPI) 1.01. The schedule has slipped almost uniformly throughout the year. The primary reason for this slip is due to problems experienced in the fabrication of the RF modules. Currently about two months of slippage has accumulated. The schedule slippage is expected to level off, and possibly reverse, as brazing problems experienced with the RF modules are being solved.

The FES project costs seem to be on track so far, and the contingency seems to be adequate. However, performance problems with the Ion Source, if not solved in about six months, could have a cost impact.

The Ion Source achieved 42 mA at the end of the Low Energy Beam Transport in April 2000, but has not reliably repeated that performance. Problems in Cesiating the source and the anomalous steering of the beam present challenges that remain to be solved.

2.2.2 Comments

Reliable and repeatable production of the agreed upon FES acceptance current (40 mA) remains to be demonstrated. The difficulty in reproducing the beam current achieved last April underscores the challenge of reaching an eventual current of 65 mA required to achieve 2 MW of beam on target. The achievement of the 2 MW current should take a lower priority to reliably achieving the baseline acceptance current for 1 MW. Any specification changes concerning the baseline current should be clarified quickly and full attention applied to achieving those goals as expeditiously as possible.

The performance of the FES and the Ion Source in particular cannot be reliably calculated. Computer codes applied to the Ion Source, particularly concerning plasma aspects of the source, are not reliable. The performance of the FES must be demonstrated and one time performance should not be considered as a proof of operational performance. This demonstration is somewhat dependent on the delivery of components to LBNL by the partner laboratories (diagnostics, low- level RF, choppers, etc.). Until the required performance can be demonstrated reliably and repeatedly, there is a danger that the schedule will drag out, and costs increase.

Early emittance measurements indicate that the beam is asymmetric. Calculations of RF performance indicate that it acts as an emittance filter. Therefore, it cleans up the beam emittance as presented to the DTL. However, cleaning up the emittance occurs at the expense of losing beam. Early calculations indicate that the RF transmission drops from 96 to 75 percent based on a recently measured emittance.

There are three line items in Work Breakdown Schedule (WBS) 1.3 for installation, 1.3.1.3.1, 1.3.2.3.2, and 1.3.3.3.2 totaling $258 K. The extent of commissioning envisioned in that amount is unclear, and compared to similar projects elsewhere, this amount may be too small by a factor of two.

2.2.3 Recommendations

1. Aggressively pursue demonstration of required beam performance.

2. Give priority to completing an installation plan and revise the installation estimates accordingly. The plan should not only clarify roles and responsibilities, but should clearly define commissioning and the boundary between commissioning and pre-operations.

2.3 Linac Systems (WBS 1.4)

2.3.1 Linac Overview

2.3.1.1 Findings

The design work reflecting the incorporation of a SCL structure approved prior to the March 2000 DOE review has continued. The details of the design have been modified and refined since that time. At this time, the linac structure is now a conventional DTL to 87 MeV, a CCL from 87 MeV to 186 MeV, a "medium-β" SCL ($\beta = 0.61$) from 186 MeV to 379 MeV, and a "high-β" SCL ($\beta = 0.81$) from 379 MeV to approximately 1 GeV. The Linac configuration is shown in Figure 2-1.

The details of the SCL have been modified since the March 2000 DOE review, with the medium-β SCL having 33 cavities in 11 modules and the high-β SCL having 59 powered cavities in 15 modules. At the time of the March 2000 DOE review, the method to provide individual RF phase and amplitude control to each cavity was the subject of an engineering development program, which was urgently endorsed by the March 2000 DOE review committee. Since that time, the RF engineering staff has recommended, and SNS project management has accepted, the technical solution of providing an independent 550 kilowatt (kW) klystron (total number 92) for each of the medium-β and high-β SCL cavities. The Committee was shown the results of the engineering efforts that rejected the "phase shifter" options that were considered as a potentially cheaper (but ultimately impractical) alternative to the "single klystron per cavity" approach now accepted. The "single klystron per cavity" approach (together with other required changes) has required a further increase in the linac baseline cost of approximately $19 million, consistent with the expectations found in the March 2000 DOE review report.

A program to undertake end-to-end beam simulations from the Ion Source to the stripping foil at the accelerator ring injection point has made good progress. This was also a joint recommendation in the Linac and Accelerator Physics sections of the March 2000 DOE review report. The Committee was shown a computerized "movie" of the beam throughout the linac. It showed that no halo reached the beam tube walls under the conditions simulated (only 10^4 particles).

Work on the DTL and CCL designs has continued to make good progress. "Cold models" of both the DTL and CCL structures have been built, and a prototype cavity coupler for the CCL is being used to refine the "slot shapes" prior to final machining of a CCL "hot model." The RF team has continued development of the modulator/power supply system. Favorable quotes have been received for the 550 kW klystrons. Mechanical engineering for the DTL and CCL has made progress, and requests for proposals are being prepared for commercial production of CCL modules and the RF modulator/power supplies (build to specifications with a design offered).

LANL and TJNAF staff have cooperated on the joint specifications of the SCL modules and RF requirements. A coherent and constructive team approach has evolved.

2.3.1.2 Comments

The Committee noted very good progress since the March 2000 DOE review. The RF architecture of "one klystron per cavity" for the superconducting RF has been defined and incorporated by accepted change control actions into the project baseline. Although somewhat expensive, this is a straightforward solution to a difficult problem for non-relativistic H^- acceleration. The Committee concurred with this decision. It is expected to be the last major cost driver associated with the incorporation of the SCL structure into the linac system. The Committee noted substantial progress with the DTL, CCL, and SCL. Taken as a whole, there is a viable, workable linac system design appropriate to the requirements of a world-class SNS facility.

Preparations for procurements are continuing, and some substantial orders have already been placed for both the conventional and SCL systems, and the associated RF systems including klystrons. On budget or even favorable pricing has been obtained.

There also appeared to be a unity of purpose between LANL and TJNAF staff. There appeared to be a good understanding of requirements, and LANL is supporting TJNAF RF needs. Much work is being done on the linac systems “as a whole.” The resignation of the LANL SNS Linac Division Director resulted in a new division director being appointed. The change in LANL management has been made smoothly without any visible adverse impact to progress. As demonstrated by LANL’s presentation to the Committee, the new management has clearly taken hold.

As seems to be the case for much of the SNS project, there is a need to restructure the linac schedule to reflect the actual funds available and revised cost estimates of work. Cost growth associated with detailed designs, and the incorporation of the SCL, have required the utilization of project contingency funds that were not originally budgeted in FY 2001 or FY 2002. Some work must be rescheduled to either later starts or slower rates of expenditure to compensate.

At this point SNS project management has assigned a 24 percent contingency ($50 million) to the linac. This is almost five percent higher than the SNS project as a whole. The Committee was not persuaded that the remaining risks for the linac are “above average” and suggests diligence to keep future net cost increases to an absolute minimum.

Some consideration has been given to commissioning and installation efforts as reflected in a few approved increases in the linac cost baseline in these areas. Further consideration of these requirements will be necessary.

2.3.1.3 Recommendations

1. Make an aggressive attempt to build the linac system to the present baseline cost.

2. Rework the schedule for completion of the linac to match the DOE approved project funding profile. Consider carefully the schedule impacts of any future net draw on contingency.

3. Delay the commitment of funds to the ORNL superconducting RF facility. These funds are a possible source of additional contingency.

4. Perform the hot model test of the CCL, finish the DTL and CCL designs, and undertake procurement to lock-in pricing.

5. Continue and complete the definition of and final cost estimates for all linac installation and commissioning activities.

2.3.2 Superconducting Linac

2.3.2.1 Findings

Cavity, Cryostat, and Cryogenics

Superconducting RF cavity design, prototyping, and procurement activities have proceeded well since the March 2000 DOE review. This is especially gratifying, as the effort was only launched last February.

Of special note was that the first 0.61 β cavity has been fabricated and tested. The cavity reached a gradient of 11 megavolts per meter (MV/m) and Q of 7×10^9 in the vertical dewar test. This is higher than the design specification of 10.4 MV/m (E_o times the transit time factor) and 6×10^9 Q. The measurement was limited by the external RF feedline, not by the cavity which may well go higher. The cavity will have stiffening rings welded in place and will be tested further.

Three additional 0.61 β cavities are about 40 percent complete and are awaiting HOM couplers before complete assembly. Two 0.81 β cavity prototypes are about 60 percent complete. The overall prototyping effort is on schedule.

The cavity input power coupler is a key part of the overall cavity development, and it is on the critical path. Initial fabrication is being done in collaboration with KEK, the original designers of the coupler. As there is considerable potential risk in this component until prototypes can be completely tested, particular attention is being given to it. The first tests should take place early in 2001 at LANL. A RF power source will be needed at TJNAF to carry out coupler conditioning, but it is not planned to be available until 2002. The HOM coupler requirements and design are just now being completed. This coupler is also on the critical path, but does not have the technical risk of the input coupler.

Other activities include the cryomodule design and bid package procurement (on schedule), the refrigeration procurement (ahead of schedule, most major procurements placed), and the transfer line (behind schedule, but should be recovered with expected manpower buildup).

Project change requests include a place holder for the RF source at TJNAF.

Superconducting Linac Accelerator Design and RF Power Source

The linac design team carried out a energy optimization study to select the β of the high-β structures. This study resulted in a selection of 0.81 for the β and a reduction of the number of cavities needed.

An architecture of one klystron per cavity was adopted. This architecture, though more costly, has less technical risk than a system with more cavities driven by one klystron, or than a system using high-power phase shifters. Ninety-two 550 kW klystrons and 26 modulators are now required for the SCL sections. This has resulted in a $18.8 million cost increase in the linac estimate since the March 2000 DOE review.

Other areas of study include optics matching at the transitions between the various linac types, selection of design phase of the individual cavities to preserve longitudinal dynamics and continuous-smooth phase advance per cavity down the linac, studies with gradient and phase errors and higher gradient (five percent) cavities showing final energy limited by RF power in the mid region of the high-β section. Multiple particle beam simulations with errors (except alignment) have been carried out from the entrance of the RF to the entrance of the ring at the stripping foil. These simulations show jitter in energy and position, the development of beam tails, and the effectiveness of the energy compensator. The fraction of particles found to miss the stripper
(0.7 percent) is less than the minimum required by the design and jitter appears to be acceptable.

Simulations (using the TRANS code) are also underway to model the initial procedure for calibrating and adjusting the individual cavities' phase and amplitude using the beam to excite the cavities one by one. This procedure assumes that the beam is initially transported through the SCL without acceleration. The procedure appears to work with realistic error assumptions and with RF feedback only (no feed-forward).

RF Power

First delivery of 805 mega Hertz (MHz) 550 kW power systems is scheduled for June 2002. The klystron contract award is in progress. Full power tests of the prototype high voltage converter modulator system are scheduled for December 2000 and January 2001. Control margin for the available RF power to the beam has been evaluated. It is assumed that saturated power is 33 percent above that required for beam acceleration. Of this, nine percent is in losses before reaching the cavity. Microphonics and Lorentz detuning variations of 300 to 400 Hz consume 12 percent (worst case), leaving 11 percent for other errors. This is not an overly generous power margin.

The power requirement is only severe for cavities at the high-energy end of the linac where the acceleration becomes most efficient. If the achievable cavity gradient is more that the specified gradient, higher energy beam could be obtained, but only if sufficient power were to be available. This power could be supplied by higher power klystrons installed at a later time as long as the high voltage converter modulator system could be upgraded easily for sufficient power capability. Otherwise an upgrade might be very disruptive and expensive.

2.3.2.2 Comments

The SNS team's work and accomplishments on the SCL design, prototyping, and initial procurements have been excellent over the past six months. This part of the project seems to be in excellent technical shape. Of particular note is the fabrication and successful test of the first 0.61 β cavity. This success is encouraging indeed. Congratulations are well deserved.

The power input coupler was identified as a critical path and high-risk component. Emphasis on and close attention to the development and test of this coupler component is highly appropriate.

A RF system will be needed at TJNAF. This should be obtained as quickly and cost effectively as possible in order to carry out coupler tests and conditioning.

The planned high power tests of the High Voltage Converter Modulator at LANL is important as it will be proof of some of the innovative engineering in this power supply.

The amount of available RF power in the 550 kW systems appears to be marginal in the high energy end of the linac. It would be unfortunate if it turned out that cavity-operating gradients were higher than specification, but this capability could not be used for lack of power capability.

2.3.2.3 Recommendations

1. Continue the good work presented at this review.

2. Obtain a RF system for TJNAF as quickly and cost effectively as possible.

3. Continue to refine and develop further accelerator analysis and simulations of the linac, its commissioning, and operation.

4. The plan for interaction between installation and RF commissioning and conditioning must be worked out.

5. Find a consistent way to express the gradient in the cavities, be it E_o or E_{acc} or some way to clearly identify the difference.

6. A strategy should be developed to allow for possible RF power upgrade of the 550 kW systems at a later date. Such a plan might provide for excess converter modulator capability or at least the dedicated space for additional capability.

2.4 Ring Systems (WBS 1.5)

2.4.1 Findings

The SNS project has made considerable progress in design and fabrication of the ring. The quantity and quality of work is impressive. All scheduled design reviews except the project-wide diagnostic review (scheduled for December 2000) have taken place.

There has also been notable progress in accelerator physics issues, particularly those associated with collimation and supporting code validation. Other physics issues including injection, beam loss management, impedance budget, and beam-in-gap have been aggressively pursued and adequately addressed. Work is ongoing to understand the "Proton Storage Ring instability."

A number of procurements have been completed, and costs are closely matching the baseline estimates.

Seven project change requests have been processed since March 2000 accounting for a $2.9 million increase in the ring cost estimate. Effectively, this is a $2.35 million increase in Ring

Systems because the diagnostic consolidation reduced the overall project Total Estimated Cost (TEC) while increasing the WBS 1.5 portion by $593 K. The other project change requests involve R&D directed at the collimation process, R&D on foils, and acquisition of some spare components.

An installation review is planned for April 2001 that will address all aspects of receiving, acceptance, testing, and installation. A 60,000 square foot building, the Receiving, Acceptance, Testing & Storage (RATS) building will be temporarily leased by the project in support of this function. Possible cost reductions may be realized as this process continues. An installation coordinator has been hired.

Foil lifetime remains a concern. ORNL/SNS has hired a scientist to work on foil R&D.

WBS element 1.5 includes all funds for installation and equipment testing, but not beam commissioning (this is part of WBS 1.10 Pre-Operations).

2.4.2 Comments

Accelerator components are being designed to produce 2 MW on target. The DOE Level 0 baseline requirement is at least 1 MW. The project is presently working on a number of problems related to adequately handling the current levels associated with 2 MW. These problems become more difficult if the same current levels are to be accumulated at a lower energy. If the beam power on target is to be reduced below 2 MW, this should not be done simply by reducing beam energy.

The Ring Senior Team Leader has requested $35 million of budget authority for FY 2001. This amount is needed to meet early completion milestones. As of the time of this review, the ring has been allocated $24 million for FY 2001. It was estimated that this will result in a schedule slip against the accelerated ("early finish") schedule of approximately four months. Based on budget authority of $24 million for FY 2001, the work plan should be re-evaluated, with a goal of further reducing Engineering, Design, Inspection, and Administration (EDIA) costs.

Overall, there are very few technical concerns in the ring. The foil lifetime issue is mentioned above. Two other areas warrant design attention: the foil cartridge and associated vacuum chamber assemblies, and the remote handling of the vacuum flange assembly planned for the collimator region. Progress on these issues should be presented at a future DOE review.

Project change requests in excess of $8.2 million are pending approval, and one of these has further implications for conventional facilities. These would consume about one-half of the remaining contingency associated with this WBS, and leave it with about nine percent contingency on a WBS element that is only 14 percent complete. The majority of these project change requests are project improvements beyond the Level 0 technical baseline requirements. This issue is addressed in the recommendation.

2.4.3 Recommendation

1. Approve only the project change requests absolutely necessary for meeting the Level 0 technical baseline requirement.

2.5 Target Systems (WBS 1.6)

2.5.1 Findings

The project has responded positively to the recommendations made in the March 2000 DOE review, and has hired the staff necessary to keep progress in technical planning consistent with the extremely tight schedule for procurements in the following years. This goal has been fully met and some long-lead procurements have already been released.

Progress on the technical level is excellent, with Title I design completed for all WBS 1.6 elements. Independent reviews approved of all decisions made and cost estimates have been revised to incorporate Title 1 design changes. Title II design has started throughout WBS 1.6, and design development and optimization is in progress and has generated visible results. Improvements of the design were incorporated on various levels, the most notable ones being:

- A stepped upper edge of the beam shutters, to reduce neutron streaming in the closed position of the shutter, and thus minimizing the need for extra shielding at a location where it is difficult to implement.

- Elimination of the composite moderator that, in experiments carried out within the R&D program, showed some undesirable pulse shape properties, although it yielded the anticipated extra intensity in the 0.2 nanometer wavelength range.

- Combination of the two cryogenic moderators above the target into one single vacuum housing, thereby moving the downstream moderator into a position where its coupling to the target, and hence its neutron output, increased by nearly 40 percent.

- An improved target module design that not only facilitates remote replacement of the target shell, but also minimizes the amount of movable shield, thus improving the reliability of the transport system.

Final assembly and developmental testing procedures have been defined for the most critical subsystems, and necessary ancillary systems are being developed. The most notable one is a Design Validation Test Stand (DVTS), which will be erected in the immediate vicinity of the already existing Target Test Facility. This will enable early validation of complicated assembly and mounting procedures of the target environment and neutron shutter systems with their incorporated neutron-optical components (a novelty on SNS never realized elsewhere before).

Substantial progress was also made in the planning of the remote handling procedures required in various locations of the target system. This is important in view of the high cost often associated with remote handling needs.

The R&D efforts in support of the target design are largely complete. They have given valuable input to many design issues, such as flow optimization in the target module, and life time assessment for construction materials under the anticipated loads. They have also helped to solve critical remote handling issues, particularly in relation to replacement of the target shell. Some important R&D efforts are still continuing, in accordance with the initial schedule for this work. Examples are the completion of the thermal-hydraulic loop tests with the recently installed heat exchanger, final analyses of an irradiation test carried out in the SINQ (Swiss Spallation Neutron Source) target, and analyses of thermal shock experiments performed at LANL.

In addition to the $11 million worth of project change requests approved prior to the March 2000 DOE review, which resulted in substantial improvements to the user-relevant features of target systems, another $6 million worth of project change requests have been approved since then. These were largely a result of Title I design reviews related to the target utility systems and changes in the Preliminary Safety Analysis Report associated with the toxicity of mercury and fire safety.

Cost and schedule performance indicators are satisfactory. Thus far, there are no systematic deviations from the planned progress that might be a concern. Contingency has remained at 25 percent of the estimate to complete, which is appropriate for part of the project.

2.5.2 Comments

As a consequence of the accelerated staffing realized in response to the recommendations in the March 2000 DOE review, the project is now in a position to be able to commit funds in accordance with the progress required to meet the present accelerated early finish date of May 2005. This would imply committing a total of $35 million in FY 2001, whereas there is budget authority of only $25 million. The shortfall of $10 million to be carried into FY 2002 will mean that if the projected budget authority remains at $20 million in FY 2002, no new procurements are possible in FY 2002 because $10 million is needed to pay for the staff cost, and $10 million is used to service the phased procurements from FY 2001. Without corrective measures, this would mean a one-year delay in the Target Systems early finish date. Possibilities to make up for some of this delay by procurement management has been identified, but the bottom line is that the present budget authority plan would leave Target Systems with a schedule delay of five to six months.

It was noted that SNS management needed to identify significant cost reductions in order to remain within the approved TPC. The Committee, together with the project team, therefore tried to analyze opportunities for cost reductions and their possible consequences. The following possibilities were examined:

- Eliminating all further R&D, since Target Systems R&D is nearly complete. The remaining funds are roughly estimated at $2 million and are, to a large part, already committed to analysis of experiments carried out elsewhere. The potential savings would be less than $1 million—this was not recommended.

- Omitting procurement of construction spares. The spare parts planned for procurement are of a long lead time nature, difficult to come by, and/or crucial for the availability of the target station. Delaying this procurement would not immediately affect the Level 0 or Level 1 baselines, but would increase the risk of an extended outage in the event of a relevant failure. The cost reduction would be of the order of $3 million, but these spare parts would need to be purchased early on during operations.

- Delaying implementation of the Mockup Test Stand (MTS). The significance of the MTS has been reduced with the decision to implement the DVTS in the near future. Much of what the MTS was designed for can be achieved with the DVTS with some replanning and restrictions. The DVTS could ultimately be moved to the target building and upgraded. The potential savings would amount to $0.5 million.

- Delaying implementation of the cryogenic moderator system. In exploring this option, the Committee discovered that the cryogenic system currently budgeted would not be sufficient for full power operation of the source. This is based on reusing a refrigerator from ANL that needs refurbishing. This reduces the cost savings of delaying the implementation of the cryogenic moderator system to the early operations phase to about $1 million. This option was not recommended at the present time.

- Replacing the Beryllium in the reflector with heavy water. Best reflector performance is obtained with an inner reflector of Beryllium, but a heavy water reflector would be nearly as good. Since the inner reflector is designed to be replaceable, a Beryllium reflector can be substituted at a later stage during operations. The potential short-term cost savings would be about $0.5 million.

- Reducing the amount of shielding. Shielding design always involves considerable uncertainties. As a consequence, there is a risk of over-design. Since the accelerator will take some time after Critical Decision-4 to reach scientifically useful performance on a routine basis, deliberate under-shielding might be an option, particularly in view of potentially reduced beam energy. This would allow adding exactly the right amount of shielding at the locations where it is needed, based on measurements of the dose levels. Since this requires suitable provisions to be made up front, the actual cost savings potential is not obvious.

Target Systems has a potential for near-term cost reductions of about $5 million, $2 million of which were not recommended at the present time. The remainder would mean that items, the procurement of which has been delayed during the project phase without affecting the Level 0 baseline, would have to be bought during the initial phase of operations to bring the source up to scientifically relevant performance and the desired availability.

The potential effects of reduced proton beam energy were examined from the perspective of Target Systems. Such a reduction is acceptable to a certain level, but certainly not to a level below 800 MeV. One consequence of reduced energy (with a compensating increase in current) would be a poorer coupling of the downstream moderators to the target, with a concurrent loss in performance of the source. In this case, the effects of pulsed beam input into the target would be somewhat more serious than at 1 GeV, but no insurmountable difficulties are anticipated.

2.5.3 Recommendations

1. Maintain the present pace and quality of work, even under cost restraints. This is crucial in dealing with the challenges still ahead.

2. Revise the present accelerated schedule because it is not consistent with the approved funding plan. The project should take into account delivery and commissioning times of components or redistribution of the budget authority in the out years in such a way that Target Systems can adequately proceed in its procurements. A new plan should be established that is consistent with the anticipated budget authority, taking into account all options to recover from delays in procurements which Target Systems now will have to face.

3. Consider postponing the construction spares and the Mockup Test Stand as the preferred cost saving options. The other reductions should be considered only as a last resort. While not necessarily affecting the Level 0 baseline, they are a big burden on the ability of Target Systems to serve instruments properly.

2.6 Instrument Systems (WBS 1.7)

2.6.1 Findings

The Instrument Systems team is making excellent progress. They have responded to all previous recommendations of DOE Review Committees with vision, enthusiasm, and technical competence. Within understandable fluctuations, they are proceeding on schedule and on budget. They are to be commended for their accomplishments.

The first three instruments, a backscattering spectrometer, a magnetism reflectometer, and a liquids reflectometer, have been selected by the project's Instrument Oversight Committee (IOC) and added to the baseline. These cost and schedule baselines were reviewed by a Baseline Review Committee (BRC) on July 27-28, 2000. Their report, which was released on August 13, 2000 was quite favorable and confirmed that the costs and schedules were realistic. In particular, the BRC reported its pleasure with the availability and quality of the staff allocated to these three instruments. The Committee agrees with the conclusions of the BRC report.

The IOC has approved the second set of three instruments, a chopper spectrometer, a small-angle scattering instrument, and an engineering diffractometer. Project change requests are being prepared and will be submitted in early 2001.

These first six instruments meet the desired performance criteria; that is, they will be the best-in-class in their respective areas of science.

The Committee noted that, as was envisioned, the design of a basic suite of instruments within the project has fostered efficient coordinated work on instrument design tools and instrument components that are shared between several instruments, such as neutron guide tubes, choppers, shutters, advanced detectors, shielding, etc. These are being combined into "Shared Design Baselines" (WBS 1.7.3). This approach will contribute significantly to superior instrument performance and will reduce cost.

The hiring of staff, both scientists and engineers for the instrument design effort, noted as lagging in the March 2000 DOE review, is now on schedule. Present staff levels (53 full-time equivalents) are consistent with the design and construction of ten best-in-class instruments. The Instrument Systems leadership is to be commended for assembling an excellent instrument design team. This team has the correct mix of talents to accomplish the vision for SNS neutron scattering instrumentation. They are also capable of evolving into an instrument operations staff that will be invaluable when the SNS is operational, while at the same time enabling an ongoing instrument design effort.

Detailed procedures for instrument integration, safety reviews and approvals, and conditions for approval of Instrument Development Team (IDT) proposals, as recommended in the March 2000 DOE review, have been produced.

Environment, Safety and Health (ES&H) issues involved with instrument design and construction are being addressed properly for this stage of the activity.

There is no contingency in the Instrument Systems cost estimate. Thus, as instruments are baselined, the number of instruments that can be built may change to reflect the available budget. The Committee was concerned that there may not be sufficient funds to build ten instruments of the level of performance that makes them best-in-class unless design features of some instruments (e.g., full detector compliments) are deferred.

2.6.2 Comments

The early and aggressive work of the Instrument Systems design team has substantially benefited other aspects of the SNS project, with the result that large increases in scientific productivity will be achieved. For example, the SNS would not have moved beyond the ISIS target/moderator concept without strong interactions with an instrument group that was thinking about detailed requirements of the instruments. Early detailed input from the instrument design team has also strongly impacted the plans for conventional facilities such that the instruments desired by the scientific community can be accommodated without costly changes at a later date. Shielding, especially in the area closest to the target, is being designed to achieve safety requirements without compromising instrument performance, and building support columns are being located so as not to block beam access or detector arrays. Careful attention to such issues has already yielded an increase in the number of instrument beam lines from 18 to 24. This close interaction between instrument design and other parts of the project must continue throughout the project.

At the beginning of the SNS project, neutron scattering scientists in the United States had not been involved in broad-scale, state-of-the-art instrument design for many years. There is a need for the creativity and sophistication of instrument design to evolve very rapidly if the SNS is to have next-generation instruments. The organization of a comprehensive instrument design team, with a strong R&D component, is fostering this rapid evolution. Sophisticated design tools are being developed and common elements of instruments (e.g., guide tubes, choppers, advanced detectors, neutron polarization techniques, shielding, etc.) are being given appropriate attention, yielding increases in the performance of all instruments. An effort should be made to extend the strengths of this unique core of expertise to any groups that may become involved in SNS instrument design. This is critical to achieving best-in-class instrument performance and also maintains the needed compatibility (e.g., in software interfaces, data structure, etc.) for a viable user facility.

In the United States, the "neutron drought" is worsening with the permanent closing of the High Flux Beam Reactor at BNL. Thus, it is increasingly critical to have spectrometers operating as quickly as possible after the startup of the SNS. Additionally, these instruments must serve the broadest possible research community.

Strategies, perhaps involving instrument funding from outside the project, should be explored for having more instruments operating at startup. The SNS project should explore ways it can foster involvement of the scientific community in seeking other funding sources.

2.6.3 Recommendations

1. Direct the Experimental Systems Advisory Committee (consisting of two previous groups: the Instrument Oversight Committee and the Target Instrument Advisory Committee) to consider the breadth and balance of the instrument suite in making their final instrument selections.

2. If the instrument suite is descoped, instrument design and construction commitments must be as part of the next SNS rebaselining.

2.7 Control Systems (WBS 1.9)

2.7.1 Findings

There has been excellent technical progress since the March 2000 DOE review. Preliminary design reviews have been completed for the timing system, machine protection system, and personnel protection systems.

The WBS 1.9 cost estimate and need for contingency are normal for this stage of the project. Now that the preliminary design reviews mentioned above have been held, the Committee supports the 25 percent contingency estimated for Control Systems.

Cable plant design and coordination systems and a rack factory are being put in place. Previous DOE reviews had recommended that the applicability of such systems to the SNS should be investigated. It was recommended that the cable installation effort should be run as a shop during construction. At the end of construction, the project should look at the long-term needs of the facility for cable installation, and make a conscious decision whether or not to continue providing such a service at a reduced level. Other laboratories have found such a service to be very useful during operations.

Cryogenic plant and linac cryogenic module control system design are proceeding well. This is a significant increase in the scope of the Control System.

The Committee supported the project's decision to implement the conventional facilities controls using Experimental Physics and Industrial Control Systems.

The Committee was very encouraged by the development of a project-wide, coordinated effort in the area of beam diagnostics.

2.7.2 Comments

The accelerator physics application software cost estimate is still based on a level of effort. In addition, this work is distributed across a number of WBS elements. Some project coordination is needed. The Committee supports the Accelerator Physics group's plan to develop a set of application programs for use during the commissioning of the front end at LBNL and SNS.

Meeting the staffing plan is problematic. This is no surprise, given the national employment market conditions for electronic and software engineers. The Committee is encouraged by the ability of SNS to attract high-quality staff with accelerator and other relevant experience. The Committee continues to be impressed with the quality of the Control Systems team.

There may be an opportunity to reduce the control system cost by automating checkout and/or development functions. There would be some investment required for the development of the automated routines or procedures, but the cost to benefit ratio may be favorable. This point was discussed with the SNS Control System team, who agreed to "slice" the cost estimate by category of labor (e.g., software development, checkout, etc.) to see where the money is and if it is enough to warrant an investigation of ways to reduce cost.

2.7.3 Recommendations

None.

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3. CONVENTIONAL FACILITIES (WBS 1.8)

3.1 Findings

Since the March 2000 DOE review, considerable progress has been made in both design and site excavation. Revised System Requirement Documents have been approved which reflect the most current requirements for the technical components. Title I design is mostly complete, and Title II design is underway with overall progress at about 50 percent complete. Site work is well underway and progress is commendable. Unit price contracts have been awarded for concrete material, concrete installation, and fabrication and installation of structural steel. It is important to note that the progress to date must be balanced against the changes experienced since the March 2000 DOE review. Although site design and construction activities have continued with acceptable progress, the cost and schedule baseline and all contingency estimates that result are not supported by current project planning.

Changes from the March 2000 DOE review include:

- The conventional facilities cost baseline is currently $300.2 million. This is an increase of $34 million from the baseline presented in March. The increase is due to 27 approved project change requests that were funded by allocation of contingency. However, the status of conventional facilities activities does not support this project cost baseline.

- The Title I cost estimate identifies approximately $82 million, in escalated dollars, of cost estimate increases. About two-thirds of the increases are due to scope changes. Examples include: the linac tunnel has increased in length by 200 feet, the Central Utility Building has increased from 5,400 to 20,000 square feet, and the target facility has increased in size and has greater shielding requirements.

- The FY 2001 budget authority to accomplish the March 2000 conventional facilities baseline scope was reduced from the conventional facilities team's request of $121 million to $105 million by SNS management.

- The project has not replanned to accomplish work in accordance with the revised budget authority, and the project did not present a schedule and budget reflecting the lower budget authority.

- At the current pace of construction, conventional facilities will expend all authorized funds prior to the end of FY 2001.

The Committee reviewed current and pending project change requests that indicate that the revised conventional facilities baseline estimate at completion would be approximately $393 million if all the pending project change requests were approved. This would be a $127 million increase from estimate presented at the March 2000 DOE review.

Management and oversight costs associated with conventional facilities tasks are increasing at a rate disproportionate to the direct cost of the work. The conventional facilities team should conduct a review of overall staffing needs to ensure that there is an appropriate level of management for the planned work.

The management tools are in place to monitor and analyze trends in the construction estimates as they are developed. The Committee observed that the increase in the Title I estimate was a surprise to the conventional facilities staff. This implies that either:

- The project management team is not communicating or consolidating key cost data for timely and appropriate management action, or

- The project management team is receiving the information but not taking appropriate action.

The conventional facilities team is attempting to maintain an earned value approach to an overall project schedule that is not supported by allocated funds. Under these circumstances, while useful to indicate progress, this approach is not an accurate indicator of performance. The conventional facilities CPI of 0.98 and SPI of 0.89 indicate progress during the month of September. However, these indicators cannot be used to quantify an integrated approach to the parallel-path activity management technique being employed by SNS management.

3.2 Comments

The Committee recognized the conventional facilities team's tremendous effort in aggressively moving forward with design and site construction activities. Completion of Title I design has provided a more accurate estimate from which credible scope reduction efforts required by the budget shortfall can proceed.

The Committee reaffirmed the philosophy of holding the AE costs to the established budget by appropriate planning using the established baselines; i.e., design to cost. Current conventional facilities cost performance results include:

- AE design costs are approximately 37 percent above the March 2000 baseline estimates.

- Completed site work costs are approximately eight percent above the March 2000 baseline estimates.

- The Title I cost estimate has not been included in the current $300.2 million conventional facilities baseline estimate (without contingency).

- The AE/CM fee is not included in the baseline estimate.

- Engineering, Design, and Inspection (EDI) costs are approximately 16 percent, which is on the low end of the 15 to 25 percent acceptable range set by DOE G430.1A (DOE Cost Estimating Guide).

- EDIA costs are 32 percent, which is considered high but appropriate due to the parallel design, construction, and integration requirements of the project. The Committee noted that this includes ORNL oversight, as well as AE/CM project management, and believed that this percentage is in the expected range for this stage of the project.

It is noted that equipment installation may pose a new problem in the near future, as beneficial occupancy and equipment installation occur in parallel with continuing construction. The project will need to ensure adequate field engineering to provide installation coordination between conventional facilities forces and technical installation staff.

The conventional facilities team has developed a proposed list of descope items. SNS management has agreed with approximately $28 million of these savings. The planning to support the accepted $28 million is well done, and in sufficient detail to clearly quantify impacts and identify the path forward for implementation. However, the planning is inadequate to address the overall issue of scope management in conventional facilities activities and the actual status of the project.

The project presented cost information in mixed formats (both escalated and non-escalated). This made it very difficult to analyze and sort between mixed applications of overhead and escalation.

3.3 Recommendations

1. Descope conventional facilities to help restore credible project contingency estimates to 20 percent, while maintaining the project TPC. No less than $100 million in potential scope reductions should be identified with the goal of reaching the March 2000 conventional facilities cost baseline level of $266 million.

2. Continue with design as planned; however, do not accelerate design activities to achieve early completion milestones that are not supported by the approved funding profile.

3. Complete site work currently underway and review the necessary site utility infrastructure to prepare the site for ongoing construction.

4. Hold the award of all other construction packages until project descope activities are completed, and a revised plan is established that can be accomplished within the approved funding profile.

5. Reinforce the project management change controls to prevent continued scope creep and requirement changes. Conventional facilities management needs to be supported by SNS management, and the SNS Project Office needs to be more proactive and accountable for rejecting project change requests based on convenience and for challenging the technical requirements.

4. COST ESTIMATE

4.1 Findings

The SNS TPC remains unchanged since the March 2000 DOE review at $1,411.7 million. A breakdown of the cost estimate can be found in Appendix D. Briefly, it contains $1,192.7 million in construction funded (TEC) activities, $180.5 million in R&D and pre-operations funded activities, and $38.5 million in prior year (e.g., prior to FY 1999) costs. Cumulative costs through September 2000 amount to $224.9 million ($186.4 million for the period since September 1998 and $38.5 million for the period prior to FY 1999).

Contingency is now estimated to be $167.2 million (20.2 percent of the estimate to complete). The EDI and EDIA reported for the project are 28 percent and 48 percent respectively.

The estimate to complete does not include commitments for placed contracts and procurements that are not yet delivered, and the contingency calculation is based on this definition.

4.2 Comments

The contingency presented at the July 1999 DOE review was $255.2 million (28.2 percent); the contingency presented at the March 2000 DOE review was $235.6 million (26.4 percent). A recommendation was made at each of the last two DOE reviews for SNS management to look for opportunities to identify additional contingency funds in order to help ensure project success. Since last March, contingency use has been very high. Seventy-six revisions to the baseline have been made during the last seven months totaling $68.4 million. These revisions represented ninety-two separate project change requests. The allowance for contingency is now estimated to be $167.2 million (20.2 percent) and SNS management has suggested that contingency could soon fall below ten percent if all of the pending project change requests were to be approved. The Committee agreed with SNS management that at this stage in the project, when all Title II design activities are yet to be completed, this level of contingency is dangerously low.

At the March 2000 DOE review, the SNS estimates for EDI and EDIA were observed to be somewhat different from other DOE projects of a similar size and complexity. It was recommended that the project review the calculation of EDI and EDIA to ensure consistency across the project cost estimate. This review was accomplished, but the results were not what was expected. Instead of an increase in EDI and a corresponding decrease in project management costs, both EDI and EDIA have now increased. The project's review uncovered the incorrect categorization of $24 million of EDI in the Instrument Systems that had initially been coded as construction labor. While this item accounted for almost half of the 33 percent increase in this category, the extraordinarily high level of EDIA across the project as a whole is of great concern.

The Committee was able to assimilate and review the financial data presented at this review with relative ease compared with previous DOE reviews. As a general rule (with conventional facilities details being the lone exception), data were formatted and displayed in a consistent and easily traceable manner from one spreadsheet to another.

4.3 Recommendations

1. Develop a plan to restore project contingency to more than 20 percent by the Phase II portion of this review in December 2000.

2. Reduce EDIA to no more than 40 percent by the next DOE review in April 2001.

5. SCHEDULE and FUNDING

5.1 Findings

The project's current overall cost baseline is a TEC of $1,192.7 million and a TPC of $1,411.7 million. These amounts are identified in the President's FY 2001 Amended Budget Request. The cost baseline in the FY 2001 request is based on the following TPC funding profile: $278.5 million in FY 2001 ($278.6 million was appropriated), $291.4 million in FY 2002,
$224.5 million in FY 2003, $143 million in FY 2004, $112.9 million in FY 2005, and $75 million in FY 2006.

SNS management has been operating since March 2000 with an accelerated schedule that calls for project completion by May 2005 (14 months ahead of the Level 0 Baseline Schedule in Appendix E). However, due to contingency use over the past several months, the accelerated schedule now requires an accelerated funding profile. The difference between the planned budget authority required (not including expenditure of contingency) and the available funding is a shortfall of $99 million in FY 2001. An estimate of a five-month delay in project completion was provided in order to meet the approved funding profile specified in the FY 2001 Project Data Sheet (see Appendix F); however, this estimate did not take into account the expenditure of contingency throughout the project.

A summary project schedule was derived from the detailed schedules provided by each WBS manager, and the detailed schedules are now resource-loaded with both effort and material resources. The current integrated detailed schedules are comprised of approximately 10,700 activities with 15,000 relationships. There are also 450 inter-project links that tie activities among the individual partner laboratory schedules. The SNS Project Office has set a goal for activities in the current year to be, on average, four to six months in duration.

The project management documents have been updated and improved. A web-based project change request system has been deployed. The planned implementation of an integrated cost performance module (MicroFrame Project Manager) is well underway, with start-up to begin in November 2000 and complete implementation scheduled for January 2001. A new Project Controls Manager joined the SNS Project Office in spring 2000. She communicates regularly with project controls staff at the partner laboratories through biweekly videoconferences.

5.2 Comments

Since the project schedule is not consistent with the FY 2001 Project Data Sheet funding profile, many of the activities currently planned for FY 2001 will have to slip past their projected start dates. The SNS management team recognizes the problem and agrees to prepare new schedules: one that matches the FY 2001 Project Data Sheet, and one that matches an accelerated funding profile that they propose to DOE. One of the contributing factors to the mismatch between the schedule and the funding profile was the project's decision not to account for contingency usage throughout each year of construction. Instead, the assumption was made that all scheduled activities would be completed on budget. Thus, any call on contingency would reduce the funds that had been planned to start new activities and would necessarily delay the accelerated schedule.

In the March 2000 DOE review, the committee noted the long duration of many activities contained in some of the project's detailed schedules and recommended that the SNS project adopt a two- to three-month median duration for activities within the next 12 months. Alternatively, it was recommended that the project establish median milestones at least every two months by the next DOE review. Instead, the project adopted four to six months as a median duration for activities in the next 12 months. While this is certainly a move in the right direction, the Committee feels that the project should continue to push for shorter duration activities to further strengthen earned value measurement.

The Project Management Systems have further matured since the March 2000 DOE review. The already excellent project controls staff has been strengthened, and significant improvements have been incorporated since the last review. For example, a web-based change control process has been implemented, appears to be very easy to use, and saves in paper, copying, and mailing expenses.

Quite a bit of work has already gone into the implementation and integration of the new MicroFrame Project Manager cost processing system. This software will allow the project team to integrate all the costs, calculate the burdened and escalated cost baseline, generate the performance reports, and provide visibility at the activity level. The team has migrated the baseline data, and has iterated the comparison of resultant schedule and cost data with the participating Laboratories to resolve any outstanding discrepancies. The "backbone" of the process is now established.

Once MicroFrame Project Manager is implemented, the methods for earning value for reporting purposes should be evaluated for each activity as planned.

5.3 Recommendations

1. Prepare a resource-loaded schedule that is consistent with the approved funding profile contained in the FY 2001 Project Data Sheet by December 2000 (Phase II of the review).

If SNS wants DOE to consider a revised funding profile:

2. Prepare a second resource-loaded schedule that is consistent with the project-proposed accelerated funding profile for FY 2003-FY 2005 by December 2000 (Phase II of the review).

Both schedules should reflect a realistic plan for year-by-year contingency usage for the duration of the project.

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6. MANAGEMENT (WBS 1.2)

6.1 SNS Leadership

6.1.1 Findings

Considerable technical progress has been made on the SNS project, and it is now approximately 14 percent complete. The Title I design, which is essentially complete, represents about 50 percent of the overall design effort. Over 62,000 hours of site construction work has been performed on the project including about 1.3 million cubic yards of soil excavation, or about 98 percent of the grading and mass excavation work required for the site. Deep foundation work has begun. The construction work has been accomplished with no lost time accidents or reportable environmental incidents. To date, the project has committed $243 million, or about 98 percent of the available project budget authority (FY 2000, and FY 1999 uncosted obligations). About $37.4 million of procurements has been phased funded to maximize the ability to achieve the project schedule. About $100 million in procurements has been awarded for conventional facilities and components. Contingency was reported at 20.2 percent or $167.2 million, but several issues were identified. Cost and schedule variances were reported at less than ten percent, and are considered to be satisfactory. For FY 2001, the SNS project has received an appropriation of $278.6 million, equal to the President's Budget Request for the project.

The transition from Lockheed Martin as the management and operating contractor of ORNL to the team of UT-Battelle has gone smoothly. UT-Battelle has established an SNS Advisory Board to provide an assessment of SNS progress and advise UT-Battelle management to ensure that the project is completed as planned. The SNS project now includes the TJNAF as a full partner responsible for the superconducting RF components of the linac. The project management structure reflects the integration of all project organizational elements under the SNS Project Office at ORNL.

Formal project management and business systems are in place and continue to improve in effectiveness. These project management systems provide a common language to ensure that communication among the project participants, located at a variety of National laboratory sites, is enhanced. Regular monthly project reports are prepared to provide an official project status and progress report. The Committee focussed on the project results through September 2000.

Good technical progress has been made in all Level 2 WBS elements of the project. The linac now includes a superconducting RF section, being developed by the TJNAF. A recent review by the SNS Accelerator Systems Advisory Committee indicates that the technical quality and progress of the linac is satisfactory. Project planning has developed steadily. A review of the pre-operations cost estimate that was originally planned as a part of this review will now be deferred until December 2000 (Phase II of the review), when the SNS project will be better prepared to discuss the details of the estimate.

6.1.2 Comments

The Committee believes that the management of the UT-Battelle team has been aggressive in enhancing the capability of the SNS project and initiating construction work. The ability to integrate TJNAF into the technical capability of the SNS linac organization has been positive.

While cost and schedule variances are small, the SNS project has identified several issues including, for example, an increase in the Title I estimate for conventional facilities which could require considerable use of project contingency. The Committee also raised questions about the projected cost estimates and required contingency to complete the project. These issues include the amount of pre-operations funding required for the project.

To ensure that adequate funds are available for the remainder of the project, SNS management should identify cost saving measures and begin to implement them. At least 20 percent contingency of the estimate to complete needs to be preserved. This will require a considerable commitment on the part of SNS management to ensure that a reasonable plan is available to complete the goals of the project within the approved TPC.

Based on the Title I design estimate, approximately $100 million was identified as not presently covered by the TEC. Most of this increase occurred in conventional facilities. In addition, pre-operations costs of $100 million were identified to the Committee, which are not presently covered in the TPC. The latter will be reviewed separately in December 2000 (Phase II of the review). Projected contingency levels are precariously low and there is a significant risk that the TPC will be exceeded without corrective action.

SNS management provided some preliminary ideas for possible scope reductions. At this time, a complete review of all elements of the project for possible scope reductions has not been completed.

6.2 Effectiveness of the Multi-Laboratory Partnership

6.2.1 Findings

The multi-laboratory partnership, which forms the technical core of the SNS project, is functioning well. The addition of TJNAF to the project has occurred smoothly. The Director of LANL's SNS Linac Division has changed due to the previous director leaving to take a position with industry. The new SNS Linac Division Director was selected in concurrence with the SNS Project Office. LANL continues to work well with SNS/ORNL management and with TJNAF staff.

The SCL design, which was formally adopted just after the March 2000 DOE review, continues to demonstrate the expected promise for considerable flexibility. However, some cost estimate increases have occurred.

6.2.3 Comments

No significant issues have been identified with the effectiveness of the multi-laboratory partnership. This relationship will be tested with the need to develop significant cost savings measures.

An issue remains from the March 2000 DOE review that must be clarified as integrated planning is refined. The division of responsibility and accountability for delivery and performance of technical systems as they are designed, manufactured, delivered, and commissioned must be defined clearly. Resolution of this issue will be particularly important in the pre-operations phase because of limited pre-operations funding. Clear reconciliation of individual and joint responsibilities and accountabilities for the technical components of the SNS throughout their development cycle is needed. SNS management has taken ownership of the technical systems, assuring overall system performance.

The SNS project should further refine the roles and responsibilities for the installation and acceptance of facilities and equipment. SNS management should work with all WBS managers to ensure that an efficient installation process is in place. The details of the roles and responsibilities for each of the partner laboratories will need to be discussed at the Phase II portion of the review.

6.3 Project Support

6.3.1 Findings

The cost estimate for SNS Project Support (WBS 1.2) has increased by $5.3 million (or 8 percent) since the March 2000 DOE review. Project Support includes the staff for the project management and controls systems integration, management information, procurement, ES&H, quality assurance, and business management. The $5.3 million increase does not involve any new staff. About $2.5 million was needed for the rent of new office space for housing the entire SNS Project Office in one building, and the move to these new offices. In addition, after overhead negotiations with ORNL, costs for the SNS Executive Director's Office staff were assigned to WBS 1.2. This had been previously charged to ORNL overhead. Specific ES&H documents required almost $700 K. Some future costs, such as relocating the SNS Project Office staff to a new Central Laboratory and Office Building, were also identified.

6.3.2 Comments

The cost increases reflect uncertainties in project costs that are difficult to estimate and difficult to assign or inefficient to assign to individual WBS categories. Ten-percent contingency on the estimate to complete is adequate. The Committee compared the present cost estimate to the July 1999 (initial DOE baseline) estimate of $90 million. The present estimate is still about $15 million lower than the July 1999 estimate. The Committee judged that while the costs appear reasonable, additional efforts for cost savings should be pursued.

6.4 Overall Project Planning

6.4.1 Findings

Project planning for the construction work has progressed well. The SNS project reported that they believe the SNS design is much stronger and has a greater probability of success than the one presented at the January 1999 DOE review. For example, the project believes that the target, linac, ring, and instruments have twice the technical capability. The conventional facilities office space can accommodate approximately twice the staff and experimenters.

The project reported that conventional facilities were on the project's critical path, and a just-in-time approach was being used to construct these facilities. The limited project funding and a push to achieve the accelerated schedule drive this approach. Meeting the project schedule is key to achieving the project costs objectives. While there is about 14 months of schedule contingency, the funding profile does not appear to support this accelerated schedule.

All but about $4 million of the FY 2000 appropriated funding ($117.9 million) and FY 1999 uncosted obligations was either costed or committed by September 30, 2000. Many of the procurements were phased funded, which is a clear indication that more funding could have been committed. Although FY 2000 funding was not released to the project until the end of last February due to a constraint imposed in congressional report language, the project was able to effectively commit these funds. SNS management implemented this plan with only minor variances. FY 2001 planning is consistent with the FY 2001 appropriation, except in conventional facilities as noted in Section 3.1.

6.4.2 Comments

Construction efforts have been proceeding close to schedule. The project enhancements (SCL, additional funding for instruments, etc.) were discussed during this review. These enhancements exceed the Level 0 technical baseline requirements. The ability to achieve all of these technical enhancements, while meeting the cost baseline for the project, may not be possible.

Additional project planning is needed to ensure that the SNS project can be completed within cost. SNS management needs to ensure that the Level 0 baseline goals can be achieved first, and then enhancements should be included to the extent feasible. In some cases, this may mean that certain user capabilities may not be achieved until after the project has been completed and placed into operation. The Committee believes that scope reductions and cost savings should be identified to ensure that the SNS project can be completed within the approved TPC of $1,411.7 million.

6.5 Transition to a New Management and Operating Contractor

6.5.1 Findings

On April 1, 2000, UT-Battelle replaced Lockheed Martin as the management and operating contractor of ORNL. The new Director of ORNL attended this review and responded to questions. UT-Battelle has organized an internal review of the SNS project's pre-operations cost estimate, to take place in November before Phase II. Thus, they have been working cooperatively with DOE to help the project prepare for the next phase of this review. UT-Battelle considers the SNS project to be of the highest priority.

6.5.2 Comments

For the SNS project, the transition from Lockeed Martin to UT-Battelle continues to go smoothly. UT-Battelle has taken a very active role in helping the project minimize its pre-operations cost estimate.

6.6 Contingency

6.6.1 Findings

The project contingency figure (reported as 20.2 percent) represents a roll-up of the risk-based assessments of the WBS managers. It reflects a number of approved change control actions since March 2000 totaling about $68 million, including an allocation of about $34 million to conventional facilities. All Level 2 WBS elements experienced a cost increase. In addition, there are a number of pending project change requests, the largest involving conventional facilities costing about $100 million. SNS management made its own estimate of the required contingency which confirms the bottoms-up estimate of contingency developed by the WBS managers based on the remaining project risk. This estimate determined that approximately 19 percent should be adequate. This separate estimate was a confirmation that 20 percent contingency should be adequate to successfully achieve the project cost baseline. If all of the pending change control actions were to be approved, the project contingency would drop to less than ten percent. SNS management presented a preliminary list of goals for scope reductions that could be used to generate additional contingency.

6.6.2 Comments

Both SNS management and the Committee were concerned about the rate of contingency use and the potential for it to decline even further. A 20 percent contingency level is more appropriate for a project in the present stage of development. If all pending change control actions were to be approved, then project contingency would drop below ten percent. This level of contingency is not considered sufficient for the remainder of project construction.

SNS management should identify and implement scope reductions and cost savings now to ensure that adequate funding is available to complete the project within the TPC.

6.7 Recommendations

1. Complete an extensive review immediately to identify potential scope reductions and cost savings throughout all WBS elements of the project, including pre-operations. Specific items of scope should be identified and then removed from the project baseline so that the estimate to complete is reduced and project contingency is restored to more than 20 percent. This will require a considerable commitment of the SNS project to ensure that a reasonable plan is available to achieve the project goals within the approved TPC.

2. Defer all procurement actions on the Central Laboratory and Office Building until actions have been completed to implement the above recommendation.

3. Review the revised project scope and new base estimate, including the revised contingency estimate, as a part of Phase II in December 2000.

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7. ENVIRONMENT, SAFETY and HEALTH

The SNS ES&H team addressed the areas of construction safety and the ES&H planning, analysis, and documentation. The team has confidence that the policies, documentation, information systems, and staffing are sufficient to ensure that construction safety is properly addressed and adequately emphasized. ES&H is receiving appropriate attention for the current and near-term stages of project development. Plans to augment staff as construction activities increase in volume and complexity should be adequate to maintain a best-in-class construction safety record on the project. SNS management should ensure that the current level of effort is maintained and additional staff are brought on board in the next six months as planned.

7.1 Findings

No issues or weaknesses were found in the construction safety program documentation or on the site. Policies and initiatives found in benchmark private industry safety programs are being practiced by Jacobs management to ensure that a quality safety program is in place on the SNS project.

The review consisted of discussions on a number of topics to determine that plans and analyses were proceeding as previously discussed, and that scheduled documentation for the designs, analyses, and studies remain on track. The Committee found that these areas are receiving appropriate attention for the present stage of the project. The following is a brief summary the ES&H topics and status of salient issues.

The draft of the SNS Waste Management Plan was recently completed in October 2000. Project ES&H staff indicated that efforts to minimize waste are ongoing. Avoiding the use of ion exchange resins was an example of waste minimization success. A couple of items have been identified as potential "orphan waste" (as defined by DOE standards) and analysis is continuing.

SNS will track all chemicals arriving at the site by requiring all deliveries to be received at a centralized receiving point (the RATS building). The team noted that the software system is "off the shelf," which allows them to focus on data entry, and not on software maintenance. In particular, the planning for a location for chemical redistribution is an excellent strategy for minimizing waste. Plans include tracking the chemicals used by the research scientists during SNS operations, but such versatility cannot be assured at this early date.

Seismic data was still being obtained at the time of Preliminary Safety Analysis Report (PSAR) approval in March 2000. The Preliminary Safety Evaluation Report emphasized the importance of timely determination of the site specific acceleration values because they were needed to support target building design. Uncertainty in these values means that there is an inherent risk to the Target Building cost estimate. Design changes for the pilings to be imbedded in bedrock were noted, as they are important to assuring the PC-3 seismic design requirement is met. Timely design information needs to continue as building dimension changes are now being considered, which can affect the number of pilings.

The Preliminary Safety Assessment Document was submitted to DOE in October 2000 and is under review. An August 2000 update to the Target Building Preliminary Safety Analysis Reportwas submitted to DOE, and a formal update to the PSAR is scheduled for March 2001. At the time of PSAR approval, safety functions were often specified since specific equipment and systems to perform the desired safety functions were still evolving. System Design Descriptions and System Requirements Documents for the target are now being finalized and specific design criteria and standards are being specified. Those criteria and standards need to be reflected in the March 2001 update for the PSAR so that the Final Safety Analysis Report clearly identifies the design basis requirements.

The project uses its "Corrective Action" tracking system to track closure of issues raised by both external and internal project reviews, and actions flowing from project changes. There are secondary tier reviews with issues for resolution that are not being captured, such as ES&H Assist Visits, the Preliminary Safety Evaluation Report, etc. Such secondary items are being resolved, but such actions might benefit from tracking their closure more formally.

Tunnel width dimensions were being reconsidered during the March 2000 DOE review, as well as whether additional egress points should be added. The ES&H team supports the tunnel design width increase as important to improving personnel safety and realizing additional ALARA (as low as reasonable achievable) benefit. The Committee noted that concerns with exposure reduction were clearly being addressed. One particular example of this is reflected in widening the linac tunnel near the High Energy Beam Transport, and with the addition of a shield wall to reduce personnel exposure during routine sweeps.

Discussions included considerations for oxygen deficiency hazard, thermal burns, and oxygen enrichment. Lessons from TJNAF and BNL were being applied to SNS, and the Committee was favorably impressed with the attention. Addition of egress points, vertical orienting of cryogenic vents, and plans to address icing as potential frozen air reflect responsible planning for worker protection.

With completion of the Preliminary Safety Assessment Document, the Committee did specifically inquire whether there were any accidents identified in the PSAD that were not covered by the SNS Environmental Impact Statement. The project explained there were no accidents that exceeded the impacts analyzed in the SNS Environmental Impact Statement. The project did add that the Supplement to the Environmental Impact Statement for the linac design change to employ superconducting RF also serves to affirm that conclusion.

7.2 Comments

SNS and Jacobs safety policies and management safety statements are communicated to subcontractors regularly via memos, at meetings, and posted on job site bulletin boards.

The importance of ES&H is communicated during the bid process, through mandatory safety orientations for everyone working on site, weekly safety coordination and planning meetings, and reinforced and verified by DOE, SNS, and Jacobs project field reviews.

Managers are held accountable for safety performance: 50 percent of Jacob’s award fee is based on safety performance. Subcontractor employees and companies can be put on notice and terminated for poor performance (i.e., lost-time accidents). This is balanced with positive recognition for all workers when safety performance goals are achieved.

SNS has adequate staff to oversee present construction activities, and hiring an additional construction safety person in January 2001 has been authorized. In addition, ORNL is providing two experienced safety personnel to support the SNS project.

Jacobs currently has a full-time safety professional on staff, which is adequate at this stage of construction. He has authority to hire three more safety personnel over the next six months, and three more as the project grows.

ORNL, SNS, and Jacobs safety personnel have extensive training and experience in construction safety. Subcontractor safety personnel are required to have completed a minimum of the Occupation Safety and Health Administration (OSHA) ten-hour construction safety training course. Subcontractors with over 40 employees on site are required to have a full-time safety person who has completed the OSHA 30-hour course in construction safety. Daily safety orientation training is available for new workers coming on site. Upon successful completion, each attendee is issued a distinctive site access sticker for their hardhats.

Fire prevention is well integrated into the safety program. The ORNL Fire Department has conducted site familiarization tours, a hot-work permit system is in place, and strong fire prevention requirements are in effect.

Site access control of unauthorized personnel continues to be a potential problem, however it is being resolved through a contract for access security and construction of personnel stations at open entrances to the site.

7.3 Recommendations

1. Ensure that the Preliminary Safety Analysis Report update scheduled for March 2001 clearly captures the appropriate design criteria and standards.

2. Expand the Commitment Tracking system to pick up appropriate actions from second tier reviews.

3. Determine whether there is a lower level of actions that is appropriate for formal tracking.

4. Continue the excellent approach to addressing the full spectrum of ES&H hazards early on in project development so as to assure that ES&H is fully and optimally integrated into the SNS facility and its operation.