SNS 102000000-TD0001-R04

Fiscal Year 2007 Operating Budget Plan for the Spallation Neutron Source

MAY 2004

SPALLATION NEUTRON SOURCE

A U.S. Department of Energy Multilaboratory Project

Argonne National Laboratory • Brookhaven National Laboratory • Thomas Jefferson National Accelerator Facility • Lawrence Berkeley National Laboratory • Los Alamos National Laboratory • Oak Ridge National Laboratory

SNS

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FISCAL YEAR 2007 OPERATING BUDGET PLAN FOR THE SPALLATION NEUTRON SOURCE

Date Published: May 2004

Prepared for the
U.S. Department of Energy
Office of Science

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managing
Spallation Neutron Source activities at
Argonne National Laboratory
Brookhaven National Laboratory
Thomas Jefferson National Accelerator Facility
Lawrence Berkeley National Laboratory
Los Alamos National Laboratory
Oak Ridge National Laboratory
under contract DE-AC05-00OR22725
for the
U.S. DEPARTMENT OF ENERGY

CONTENTS

Page

ACRONYMS vii

1. MISSION 1

1.1 MISSION 1
1.2 GUIDING PRINCIPLES 1

2. EXPERIMENTAL FACILITIES DIVISION 5

2.1 DIVISION MANAGEMENT 5
2.1.1 Effort 5
2.1.2 Materials and Equipment 5
2.2 OPERATING BUDGET FOR INSTRUMENT SYSTEMS 5
2.2.1 Management and Administrative Support 6
2.2.2 Operation/Development 6
2.2.2.1 Staff 6
2.2.2.2 Replacement Spares and Consumables 8
2.2.2.3 Effort for Development 8
2.2.2.4 Materials and Equipment for Instrument Upgrades 8
2.2.2.5 Materials and Equipment for New Component Development and Procurement 8
2.3 OPERATING BUDGET FOR TARGET SYSTEMS 9
2.3.1 Target Systems Operations 9
2.3.1.1 Target Systems Management 9
2.3.1.2 Operations and Maintenance Support 9
2.3.1.3 Instrument Support 9
2.3.1.4 Materials and Equipment 9
2.3.2 Target Systems Development 10
2.3.2.1 Target Development Effort 10
2.3.2.2 Target Development Materials and Equipment 10
2.4 USER COORDINATION OFFICE 11
2.4.1 Functions 11
2.4.2 Effort 12
2.4.3 Materials and Other Expenses 12
2.4.4 Risks 12
2.5 OPERATIONS 12
2.5.1 Effort 12
2.5.2 Materials and Equipment 13
2.5.3 Risks 14
2.6 PERSONNEL PROTECTION 15
2.6.1 Effort 15
2.6.2 Materials and Equipment 15
2.6.3 Risks 15

3. ACCELERATOR SYSTEMS DIVISION 17

3.1 DIRECT ASD STAFF 17
3.1.1 Division Management 17
3.1.2 Accelerator Physics Group 18

3.1.3 Operations Group 18
3.1.4 Ion Source Group 19
3.1.5 Linac RF Group 19
3.1.6 Cryomodule and Cryogenics Group 20
3.1.7 Power Supply Group 21
3.1.8 Mechanical Group 21
3.1.9 Survey and Alignment Group 22
3.1.10 Diagnostics Group 23
3.1.11 Controls/Personnel Protection Group 23
3.2 MATRIXED STAFF WORKING FOR ASD 24
3.3 MATERIALS, SUPPLIES, AND SHOP SUPPLIES 24
3.4 OPERATING MAJOR EQUIPMENT COSTS 24
3.4.1 Replacement Spares and Consumables 25
3.4.2 Cryogens 26
3.4.3 Waste Disposal 26
3.4.4 Laboratory Capital Equipment 26
3.4.5 Accelerator Capital Equipment 26
3.4.5.1 Ion Source and Front-End Upgrades 26
3.4.5.2 Linac RF System Upgrades 27
3.4.5.3 Cryomodule Maintenance and Upgrades 27
3.4.5.4 Ring Upgrades 27
3.4.5.5 Power Supply Upgrades 28
3.4.5.6 Beam Diagnostics Improvements 28
3.4.5.7 Control System Upgrades 29
3.4.5.8 Shielding and Remote Handling Upgrades 29
3.4.5.9 Accelerator Utility Systems Upgrades 29

4. MANAGEMENT 31

5. SNS COMPLEX FACILITIES AND SUPPORT ORGANIZATION 33

5.1 MANAGEMENT 33
5.2 TECHNICAL INFORMATION SYSTEMS (TIS) 34
5.3 COMPLEX FACILITY (CF) MANAGEMENT 34
5.3.1 CF Model for Fiscal Year 2007 34
5.3.2 CF Organization 34
5.3.3 CF Staffing 35
5.3.4 Facilities Engineering (additional funded from projects) 35
5.3.5 Facilities Maintenance and Site Support 36
5.3.5.1 Facilities Maintenance 36
5.3.5.2 Facility Operations 37
5.3.6 Plant Maintenance and Operations 37
5.3.6.1 Space Charge for CLO 37
5.3.6.2 Electric Power Operating Spares 37
5.3.6.3 Materials, Supplies, Consumables and Travel 37
5.3.6.4 Capital Equipment 38
5.3.6.5 Grounds and Equipment Subcontracts 38
5.3.6.6 Electric Power 38
5.3.6.7 Utilities 38
5.3.6.8 Wastes 38
Appendix A LABOR COST A-1
OVERHEAD RATES A-1

CRAFT LABOR SUMMARY A-2
XFD BUDGET TABLE A-3
ASD BUDGET TABLE A-4
CFSO BUDGET TABLE A-5
MANAGEMENT BUDGET TABLE A-6
SUMMARY BUDGET TABLE A-7
Appendix B TECHNICAL INFORMATION SYSTEMS B-1
ENVIRONMENT, SAFETY, HEALTH AND QUALITY B-2
Appendix C THE SPALLATION NEUTRON SOURCE: OPERATIONAL ASPECTS AND RELIABILITY IN THE TRANSITION FROM COMMISSIONING TO FULLY COMMITTED USER OPERATION C-1
Appendix D A BEAM POWER UPGRADE TO 3 MW AND BEYOND FOR THE SNS COMPLEX D-1

ACRONYMS

AC	alternating current
ALARA	as low as reasonably achievable
ANL	Argonne National Laboratory
APS	Advanced Photon Source
ASD	Accelerator Systems Division
BCM	beam current monitor
BES	Office of Basic Energy Sciences
BESAC	Basic Energy Sciences Advisory Committee
BPM	beam position monitor
CAD	computer-aided drawing
CCL	coupled-cavity linac
CCR	central control room
CD	Critical Decision
CF	Conventional Facilities (Division)
CFD	computational fluid dynamics
CFSO	Complex Facilities and Support Organization
CHL	central helium liquefier
CLO	Central Laboratory and Office Building
CNMS	Center for Nanophase Materials Sciences
CSO	Complex Facilities and Support Services Organization
CUB	Central Utilities Building
CVS	Concurrent Version System
DC	direct current
DCC	Document Control Center
DI	deionized
DOE	U.S. Department of Energy
DSP	digital signal processing
DTL	drift-tube linac
ES&H	environment, safety, and health
ESH&Q	environment, safety, and health and quality assurance
EPICS	Experimental Physics and Industrial Control System
ERWM	Environmental Restoration and Waste Management
F&O	Facility and Operation
FE	front end
FPC	fundamental power coupler
FTE	full-time equivalent
FWP	field work proposal
FY	fiscal year
GL	group leader
H-	negative hydrogen
HEBT	high-energy beam transport
HFIR	High Flux Isotope Reactor
Hg	mercury
HP	health physics
HPTS	High Power Target Station
HR	Human Resource
HV	high-voltage
HVAC	heating, ventilation, and air conditioning

HVCM	high-voltage converter modulator
HVPS	high-voltage power supply
I&C	instrumentation and controls
IGBT	Integrated gated bipolar transistor
IH	industrial hygiene
IOC	input/output controller
IPNS	Intense Pulsed Neutron Source
IS	Industrial Safety
IT	information technology
JINS	Joint Institute for Neutron Sciences
JLab	Thomas Jefferson National Accelerator Facility
kg	kilogram
LANL	Los Alamos National Laboratory
LANSCE	Los Alamos Neutron Science Center
LEBT	low-energy beam transport
LHe	liquid helium
Linac	linear accelerator
LLRF	low-level radio frequency
LLW	low-level waste
LLLW	liquid low-level waste
LLRF	low-level radio frequency
LOTO	lockout/tagout
LV	low voltage
LWTS	Long-Wavelength Target Station
MEBT	medium-energy beam transport
MIS	Management Information Systems
MOA	Memorandum of Agreement
MPS	machine protection system
MSDS	material safety data sheet
MTBF	mean time between failures
MV	medium voltage
MW	megawatt
NEPA	National Environmental Policy Act
NIST	National Institute for Standards and Technology
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
PC	personal computer
PIE	postirradiation examination
PLC	programmable logic controller
PM	preventive maintenance
PNNL	Pacific Northwest National Laboratory
PPS	Personnel Protection System
PSAR	preliminary safety analysis report
PSR	proton storage ring
QA	quality assurance
R&D	research and development
RAM	reliability, availability, and maintainability
RCRA	Resource Conservation and Recovery Act
RF	radio frequency
RGA	residual gas analyzers

RTBT	ring-to-target beam transport
SAIC	Science Applications International Corporation
SANS	Small-angle neutron scattering
SINQ	Spallation Neutron Source at the Paul Scherrer Institute
SLAC	Stanford Linear Accelerator Center
SNS	Spallation Neutron Source
SRF	superconducting radio frequency
TDR	time-domain reflectometer
TiN	titanium nitride
TIS	Technical Information Systems
TTF	Target Test Facility
TVA	Tennessee Valley Authority
UHV	ultrahigh voltage
U.S.	United States
WNR	weapons neutron research
XFD	Experimental Facilities Division

1. MISSION

The Spallation Neutron Source

1.1 MISSION

The mission of Oak Ridge National Laboratory's (ORNL's) Spallation Neutron Source (SNS) Directorate is to operate and maintain the SNS as the world's leading neutron-scattering facility for studying the structure and dynamics of materials. The SNS will number among the world's finest user facilities.

1.2 GUIDING PRINCIPLES

If the science produced at the SNS is to be maximized, then key elements (such as proton beam current, neutron flux, reliability and predictability, number and performance of instruments, number and caliber of staff, performance of ancillary equipment, and strength of the user community) must be maximized with respect to each other. This report contains the planned operating budget for the SNS's first full year of operation, FY 07.

The U.S. Department of Energy (DOE) is expected to provide the operating funds for the SNS; DOE or other organizations may provide significant upgrades or additional equipment, instruments, and facilities. Operating funds identified in this budget support the reliable production of neutrons for users with the appropriate levels of research determined through consultation with the DOE program office. Although the operating budget supports incremental improvements in the accelerator and target, significant upgrades are assumed to be funded separately. The operational goal is 5000 hours per year, with neutrons produced for more than 90% of the scheduled hours. We expect this ambitious goal to require readily available spares; a dedicated maintenance and operations staff; a robust, programmed maintenance effort; and a full complement of specialty shops and support facilities.

The SNS will operate under the ORNL business and financial rules and within the ORNL division and directorate models (see Fig. 1). Maintenance of the Central Laboratory and Office (CLO) building will be supported through the ORNL space charge-back program, whereas maintenance and refurbishment of all other SNS facilities will come directly from operating funds, and no ORNL space charge will be levied. SNS will use a landlord/tenant model that will permit building occupants to focus on their research and support activities, while controlling associated facility management and upkeep costs. Utilities (electricity, natural gas, and potable water) will be metered at the SNS and will be funded by the SNS operating budget. Wastes will be handled by the ORNL Waste Management organization, based on the *ORNL Waste Management Plan*, with waste disposal costs borne by the facility generating the material and funded by the operating budget. The residential facility for the Joint Institute for Neutron Sciences will be managed through an operating contract.

Estimates of levels of operating staff are based on a bottoms-up evaluation of tasks. When appropriate, staff levels are compared with ORNL activities and other scientific accelerator and neutron-producing facilities. If a function will be paid by ORNL overhead, costs beyond this level of service will be paid by the SNS project only for demonstrated need. Engineering and technical staff requirements are at the levels estimated to operate the facility in a safe and efficient manner for the hours planned but are not the levels required to plan and develop significant upgrades. Labor costs have been estimated using the ORNL functional wage pool system. These rates are identified in Appendix A-1.

Shop space will be provided at SNS to perform most routine and special maintenance tasks in a timely and efficient manner. Other tasks requiring large shop areas will be performed at ORNL, with

estimated costs for these services based on information provided by ORNL. Crafts for the SNS shops will be members of the ORNL bargaining units, with rates for these services provided by ORNL. Individual craft members are generally assigned to specific shops and areas for maximum efficiency and effectiveness. Anticipated divisional requirements are listed separately for each function, but it is expected that resources will be shared among SNS organizations as workload requirements dictate; therefore, a summary of all craft labor is provided in Appendix A-2.

Maintenance and refurbishment costs are based on engineering estimates and were subsequently validated through an ORNL laboratory study for Building 4500N (a main laboratory and administration building at ORNL), using a Pacific Northwest National Laboratory (PNNL) model. This study was performed to help the laboratory, including SNS, transition to a new model for facilities management proposed for ORNL beginning in October 2001. A single shipping and receiving point and limited general stores will be staffed through laboratory overhead. Required engineering support for building infrastructure is estimated and is included in the Complex Facilities and Support Services Organization (CSO) budget.

Services to users will be provided to support world-class research. Staff and materials have been based on comparisons with similar facilities worldwide. SNS will adopt policies and review procedures consistent with those relating to users of the High Flux Isotope Reactor (HFIR). SNS users will have access to office space, support laboratories, ancillary equipment, and information technology needed to facilitate their research. Technical and scientific support will enable users of varying levels of experience to successfully carry out their research programs. Although it is expected that much of the research at the SNS will be made publicly available, proprietary research will be possible at the SNS at rates commensurate with ORNL and DOE policies.

Materials and travel requirements have been detailed, but cost estimates are shown based on the following:

- Materials for crafts and technicians—20% of fully burdened craft and technician labor cost.
- Materials for professional and support staff—10% of fully burdened professional and support staff labor cost.
- Travel for professional staff—3% of fully burdened professional staff labor cost.

The operations budget for FY 07 has been planned using the current organizational structure represented by the Experimental Facilities Division (XFD), the Accelerator Systems Division (ASD), and the CSO. These organizational entities may change as the project moves from construction to operations, but the functions represented by this budget are expected to appear within the directorship of the SNS and therefore are budgeted. XFD will be responsible for operation of the target facility, target development, neutron-scattering instrument development and operations, and the user program. ASD will be responsible for operations of the SNS accelerator complex, including future upgrades. CSO will be responsible for building support, site infrastructure, and utilities for reliable operations of the SNS facility. Management is provided through the office of the Associate Laboratory Director for SNS, which is responsible for overall management of the SNS facility and research program.

A summary of the FY 07 request is shown in Appendix A-7.

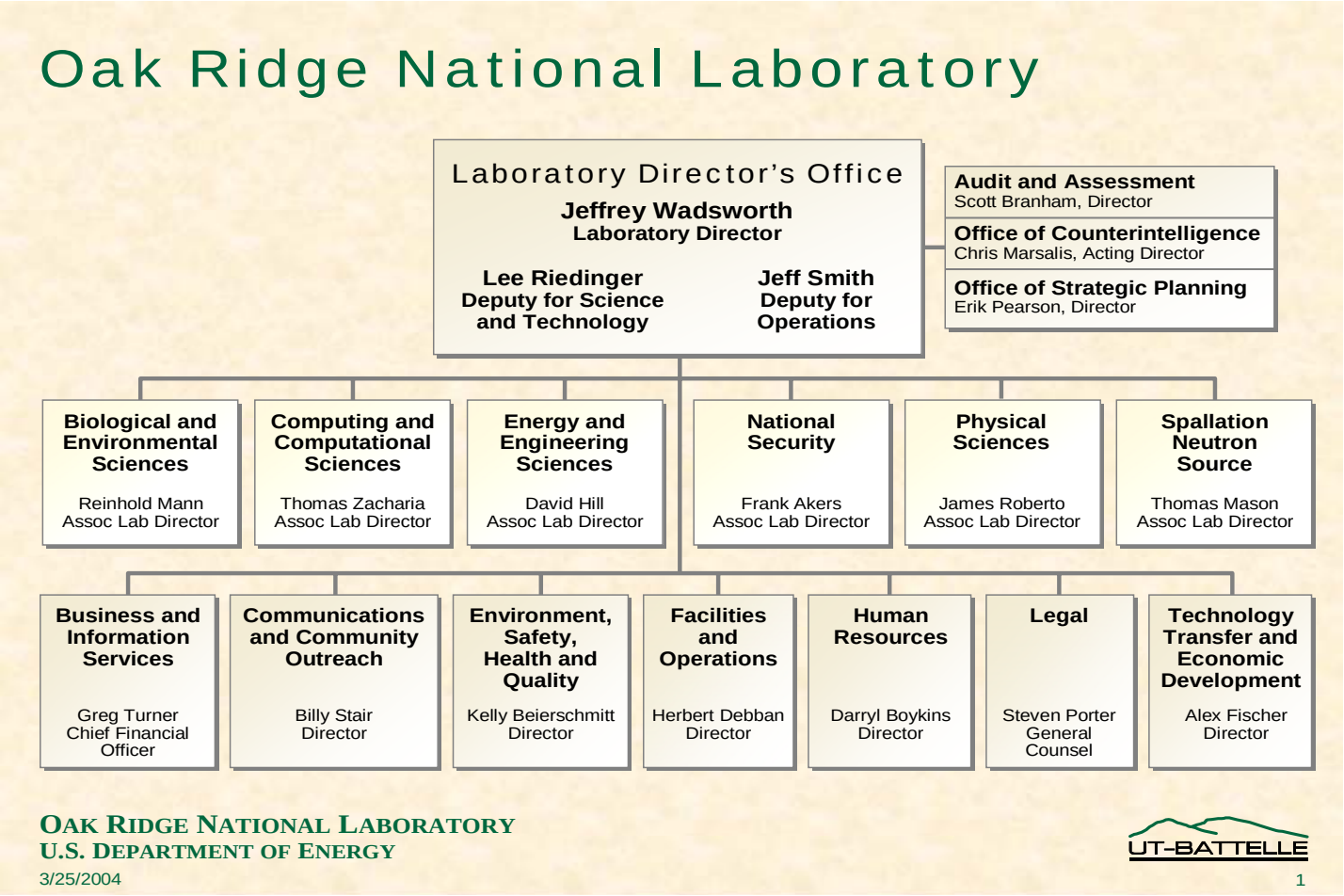


Figure 1. ORNL Organization Chart.

2. EXPERIMENTAL FACILITIES DIVISION

2.1 DIVISION MANAGEMENT

This section provides backup and details for the Experimental Facilities Division (XFD). The prime scope of the XFD is to

- manage a users program of approximately 1000 to 2000 scientists per year;
- operate neutron-scattering instruments and supply support to the users;
- develop neutron-scattering instruments for all beam lines;
- carry out research and development (R&D) for future neutron-scattering instruments;
- generate properly tailored neutrons with high reliability and safety;
- carry out R&D for the future development of targets that can operate above 2 MW and improve the performance of the neutron-scattering instruments, moderators that can increase the performance of the neutron-scattering instruments, reflectors that can increase the source brightness, and shielding; and
- operate the target facility.

This effort will require the total funding as shown in Appendix A-3. The budget includes all necessary items (i.e., personnel, spares, equipment, and tools) to accomplish the scope just outlined. Note that by 2007, not all neutron scientists and support staff will be on board. These individuals will be added annually over approximately a five- to ten-year period.

2.1.1 Effort (7 FTEs)

- The management staff shown is typical for a technical division at ORNL.
- A note is made for the environment, safety, and health (ES&H) specialist. It is expected that Target Systems operation will require industrial hygiene (IH) expertise, which has not been included in staffing plans for the XFD sections. It may be prudent for the division specialist to be IH qualified. Otherwise, the capability will need to be purchased on an as-needed basis. Additionally, HR support and procurement support staff have been included.

2.1.2 Materials and Equipment

- As one of the major international promoters of SNS, the division manager's travel will be greater than other monthly employees. The $60K noted on the spreadsheet is based on history for the division director's travel.
- Supply and support expenses of 10% are used for all staff. This may be underestimated for the division management office because of some of the support charges that accumulate in the division office accounts (e.g., seminar expenses, postage, copying, and general office supplies).

2.2 OPERATING BUDGET FOR INSTRUMENT SYSTEMS

Resources are required for the operation of the neutron scattering instruments and for development of new instruments and/or instrument components.

2.2.1 Management and Administrative Support (6 FTEs)

This includes management, secretarial support, project management support (for instrument development), budget and financial support, etc.

Staff for management & administrative support	
Leader	1
Secretary	2
Group administration (budget, etc.)	2
Project administration (instrument upgrades, etc.)	1
Total	6

2.2.2 Operation/Development

2.2.2.1 Staff (86 FTEs)

A Report from the Assessment Team for SNS Instruments was prepared in March 1999 by Dan Neumann and Kent Crawford. This report documents the level of staffing required to support a vigorous world-class user program at the top neutron scattering facilities. Scaling from experience at both ISIS and National Institute for Standards and Technology (NIST) indicates that such a user program at SNS would require about six-seven staff per instrument. Since that time it has become increasingly evident that the higher power at SNS and the increased sophistication of the SNS instruments may require SNS staff to carry out some operations, such as certain aspects of sample changes, that have typically been done by the users at other neutron scattering facilities. This will necessitate some round-the-clock (shift) floor support for the instruments (covered in the XFD Operations Group budget) and some additional extra-hours coverage accounted for in the staffing levels indicated here.

On average, each instrument would be operated by two Ph.D. scientists with two scientific associates also dedicated to that instrument, for an average of four staff whose entire effort is dedicated to that particular instrument. Other technical staff and technicians would be assigned to support groups, such as data acquisition and computing, neutron choppers, etc. that support all of the instruments. Some would also be needed to provide support for the user laboratories and shops (sample prep, sample characterization, etc.). Experience at a number of neutron-scattering facilities indicates that the user program will be severely curtailed if the level of support falls much below this. It is now fairly clear that there should be ten neutron scattering instruments in commissioning or operation by the end of FY 2007 or early FY 2008, so SNS support for operation of ten instruments has been assumed for this FY 07 operating budget. In addition, this budget includes support for instrument-related development, where this is taken to mean upgrades of operating instruments, development of new components or capabilities, and occasional development of SNS-funded new instruments,. Tables 1 and 2 show the types of staff and the distributions of staff among the various areas. Management and administrative support is described above and is not included in Tables 1 and 2.

Table 1
Planned FY 07 staffing distribution for science, instrument operation, and instrument development

Staff category	Tot	Inst	Dsn	DAS	Det	Chp	Smp	Opt	Soft	Lab
Scientist	23	17			2		2	2		
Scientific assoc./ technical support	23	10			2	1	5	2		3
Mech. Engineer	4		3			1				
Elec. Engineer	4			4						
Software	9			3					6	
Mech. Designer	4		3		1					
Technician	19			4	5	2	5	1		2
Total	86	30	6	11	10	4	12	5	6	5

Here "Inst" are staff directly assigned to the operation of specific instruments, "Dsn" are pooled mechanical design staff shared across a variety of activities as needed, "Det" are detector support and development staff, "DAS" are data acquisition support and development staff, "Chp" are neutron chopper support and development staff, "Smp" are sample environment support and development staff, "Opt" are neutron optics support and development staff, "Soft" staff for support and development of data analysis software and infrastructure, and Lab" are staff to support the user laboratories.

Table 2
Staffing for instrument operation and development

	FY 07		FY 15	
	No. of instruments	**SNS staff**	**No. of instruments**	**SNS staff**
Staff attached to specific instruments	10	27	24	72
Instrument support and development staff				
Mechanical design		6		6
Data acquisition		11		15
Software		6		10
Detectors		10		14
Neutron choppers		4		8
Sample environment		12		20
Neutron optics/polarization		5		8
User laboratory support		5		8
Total	10	86	24	161

As more instruments become operational, the operating and support staff must be increased accordingly, as indicated in Table 2. Thus, staffing has been assumed to ramp at a rate to support operations for all operational instruments (see Table 2). This table also includes staff for development activities that will have to be maintained in order to sustain instrument upgrades, development of new instrument components and techniques, and development of new instruments into the future. Instrument development staff will be pooled with target development staff so that more staff can be brought to bear on particular development projects when warranted. Also, some of the instrument supporting technology groups will be called upon for particular phases of development.

2.2.2.2 Replacement Spares and Consumables

Replacement spares include spares for various equipment such as vacuum pumps, neutron choppers, detectors, data acquisition electronics modules, computers, etc. For more details, see the SNS Spares Plan. The spares list is based on a system by system assessment of major spares needed to ensure reliable operation of the known instruments with minimal down time, along with an extrapolation to currently undefined instruments. The list takes into account the reduction in needed spares because components are standardized among the instruments.

Consumables include items such as chemicals for sample preparation, gases of various sorts, furnace elements, etc. This must cover the needs of the users and the scientific staff (e.g., for sample preparation) and the operation of the neutron scattering instruments.

2.2.2.3 Effort for Development

Development will be required for new instruments and upgrades for operating instruments and for new technologies for neutron detectors, neutron optics, sample environments, and other infrastructure that benefits multiple instruments. Staffing estimates are based on experience at other neutron scattering facilities as well as on current experience in developing SNS instruments, and would contain a mix of scientists, engineers, software specialists, designers, and technicians. This staffing is included with the operations staff in Tables 1 and 2.

2.2.2.4 Materials and Equipment for Instrument Upgrades ($2M)

This assumes one instrument upgrade per year at a capital cost of $2M/year.

2.2.2.5 Materials and Equipment for New Component Development and Procurement ($4.5M)

Instrument development covers development of new instrument components and technologies, such as better detectors, neutron optics, and sample environment equipment. It also covers operation of a test beam line at SNS for such development purposes.

- *New detector development*—includes production of detector prototypes, and R&D contracts with other detector development laboratories; ~$1M/year.
- *New optics development*—includes production of prototype devices for neutron focusing, development of techniques for better guide coatings, new polarization capabilities, development of polarized 3He filters and production capabilities, etc. ~$1M/year.
- *Development of new sample environment equipment*—includes development of furnaces for higher temperatures, automated sample changers for more complex environments, etc. It also includes procurement of additional commercial sample environment equipment as new instruments become operational or as new capabilities become available; ~$2.5 M/year.

2.3 OPERATING BUDGET FOR TARGET SYSTEMS

2.3.1 Target Systems Operations

2.3.1.1 Target Systems Management (2 FTEs)

This group consists of the Target Systems manager and clerical support for the organization.

Staff	
Manager	1
Secretary	1

2.3.1.2 Operations and Maintenance Support (4 FTEs)

This group will provide engineering support for the XFD Operations Group in the maintenance and operations of utility systems and remote handling. This includes maintenance and trouble shooting for the target systems instrumentation and controls, development and definition of equipment maintenance programs and procedures, monitoring the technical aspects of ongoing maintenance activities, development of equipment upgrades and improvements, and updating as-built computer-aided design (CAD) models of the shielding monolith and associated systems.

Staff	
I&C engineer	1
Utilities engineer	1
Remote-handling engineer	1
Designer/drafting	1

2.3.1.3 Instrument Support (2 FTEs)

This group will perform neutronics and shielding analysis of the target/moderator/reflector systems and neutron-scattering instruments to support the needs of instrument scientists and users and modify shutter/shielding systems as needed.

Staff	
Neutronics analyst	1
Engineering support for shielding/shutters	1

2.3.1.4 Materials and Equipment ($5.4M)

The budget for Target Systems spares has been estimated for two cases, namely, (1) special process and other spares required to be purchased before or during the first year of operation (FY 07) and (2) the average budget required for spares after the facility is mature and operating at full performance. The required funding during mature operation is $5.18M (in FY 03 dollars including overhead).

Consumables are items that are spent or consumed when operating the facility. These include helium, hydrogen, other bottled gasses, chemicals, ion exchange resins, filters, lubricants, etc. Consumable costs are estimated at $300K (including overhead).

2.3.2 Target Systems Development

2.3.2.1 Target Development Effort (8 FTEs)

This group will design, develop, and test new concepts for target assemblies, moderator/reflector systems, remote-handling equipment, and target instrumentation and controls. This includes monitoring of the materials surveillance program that will be conducted in ORNL hot cells using ORNL materials scientists and technicians. Additional funds to pay for personnel and expenses related to the materials surveillance program and materials and testing expenses required to develop new target equipment to ensure reliable operation and maximum lifetime, are included as separate items in Section 2.3.2.2, "Target Development Materials and Equipment."

Staff	
Target development engineer	1
Advanced target design engineer	1
Engineering analyst	1
Neutronics analyst	1
Advanced moderator development engineer	1
Remote tool development engineer	1
Controls development engineer	1
Designer/drafting	1

2.3.2.2 Target Development Materials and Equipment ($2.2M)

The estimated budget for target development includes funds for materials and expenses, testing, and support for researchers in other ORNL divisions to develop advanced target/moderator/reflector concepts and extend the operating life of the target vessel. Because the SNS mercury target is a first-of-a-kind item, continued development and surveillance efforts are planned. This is necessary to ensure progressive improvements in next-generation target systems, optimization of target replacement frequency, and to avoid the occurrence of component failures where systematic data are unavailable to identify causes. In addition to advancing new target/moderator/reflector concepts, this funding is needed to monitor the damage accumulation in critical materials and components. Funding includes fabrication of standard miniaturized materials test specimens, dosimetry, and postirradiation examination (PIE) of the miniaturized specimens as well as PIE of sections of the target front face cutout of the target module in the mercury process bay. Because PIE activities will be performed in ORNL hot cells, the costs for packaging and transporting the material specimens and target cutouts from the SNS site to the ORNL hot cells are also included. The cost estimate is based on SNS target and moderator development efforts and extensive experience on similar activities for nuclear reactor–irradiated components at ORNL.

Software licenses and other computer costs. Funds are required to pay for licensing fees for special-purpose software used by Target Systems staff. Special-purpose software packages are required for CAD, structural and thermal analysis, computational fluid dynamics (CFD) analysis, and generating calculation meshes. The basis for the licensing fees is shown in Table 3.

Staffing Comparisons. This proposed staffing level can be compared with staffing levels at other neutron-scattering facilities, both operating and proposed. Table 4 is a 1999 look at the staff for target systems for ISIS and the proposed Intense Pulsed Neutron Source (IPNS-II) and a recent compilation of the professional staff at SINQ. A listing of the SNS Target Systems staff is included in this table for comparison.

Table 3. XFD license fees

Engineering workstations, cluster, and PCs (replace 1/3 of workstations and PCs and 1/7 of cluster = 3 × \$8K + 3 × \$3K + 1/7 × \$50K)	\$40,000
Support for specialized software	\$47,000
5 Pro-E licenses/maintenance fees	\$20,000
2 Mechanical licenses/maintenance fees	\$6,000
1 ABACUS license/maintenance fee	\$17,000
1 CFX license/maintenance fee	\$10,000
1 PATRAN licenses/maintenance fees	\$10,000
Total	\$150,000

Table 4. Target systems staff for ISIS and IPNS-II

Category	IPNS-II estimate[a]	ISIS[b]	SINQ[c]	SNS
Leader	1	1	1	1
Neutronics & shielding	2	0.5		2
Materials	1		2	
Lead (Mech) engineering	1	1	1	1
Process/utilities engineering	1		4	1
Designer	1	1.5	1	2
Cryoengineering	1		2	1
Remote handling	1		2	1
I&C	1	2	1	2
Engineering analyst			1	1
Target, moderator, and remote handling development			7	4
Total	10	6	22	16

[a]From Bruce Brown on March 2, 1998.
[b]From Tim Broome on March 31, 1999.
[c]From Paul Scherrer Institut Web site at cgi.web.psi.ch/ASQ/org.html.

2.4 USER COORDINATION OFFICE

2.4.1 Functions

The User Coordination Office will

- manage the proposal system;
- manage the scheduling of instruments;
- manage user agreements, badging, travel, and assignment of office space;
- provide general training of users;
- organize workshops and conferences;
- compile after-run reports and publications data;

- keep statistics and report them to DOE;
- provide general tours;
- coordinate educational and public promotional activities;
- create general interest publications; and
- provide receptionist function for CLO.

2.4.2 Effort (7 FTEs)

Based on benchmarking of similar facilities, the appropriate staff level for the User Office is ten FTEs, which needs to be reached several months before users begin to arrive in significant numbers. Currently, seven positions are budgeted, with the intention that as instruments and users increase, staff will be added.

Two facilities were benchmarked to determine appropriate staffing levels for this office. The Advanced Photon Source (APS) at Argonne National Laboratory (ANL) serves about 1000 new users annually. The seven full-time and one temporary staff perform all of the aforementioned functions except giving tours, scheduling instruments, and creating general interest publications. To perform all these functions, they would need about ten FTEs. The Los Alamos Neutron Science Center (LANSCE) at Los Alamos National Laboratory (LANL) serves about 400 users annually, half of which are new users. The current staff of level of 7 FTEs performs all of the aforementioned functions except training of users.

Database development for user support will be funded by the User Office but will be managed through central SNS Management Information System (MIS) Group.

2.4.3 Materials and Other Expenses

Based on the May 2000 conference held in Washington, D.C., user conferences are estimated to cost ~$70,000, Holding future conferences in the Oak Ridge area may reduce expenses by reducing travel-related costs. Publications costs are estimated to be $25,000 for the Neutron Pulse and an additional six publications per year at $30,000. Funding for the library is not included; ORNL overhead would pay for library staff and ongoing subscriptions, but the initial collection would require startup funding.

The user administrative support account will fund telecommunications, computer charges, and office supplies and is based on $60 per month, two months per user, with 100 users in FY 06 ($12K) and 500 users in FY 07 ($60K). Travel support will be provided to attract selected graduate students and new faculty as new users; these are estimated to include 25% of the estimated users from U.S. institutions, averaging $1000 per visit or $100,000. Security access fees for 250 new users in FY 07 will be an additional $25,000.

2.4.4 Risks

Adequate support for users will be needed as this new facility develops, as the proposed staff is at a minimal level for 50 users in FY 06 and 500 in FY 07. Establishing a good reputation with users begins with the User Office, and poor levels of service will tarnish the efforts of those who fund, design, and operate the SNS. The current plan does not include 1.5 FTE's to provide receptionist services for CLO.

2.5 OPERATIONS

2.5.1 Effort (55 FTEs)

The effort listed here includes technical support for Instrument Operations.

- Manager and deputy (2)—responsible for operating the target facility under contract to DOE.

- Secretary (1)—provides administrative support for the Operations Group.
- Waste management engineer (1)—responsible for all disposition requirements for high-level radioactive waste (handling, storage, packaging, shielding, transportation, waste site coordination, etc.).
- Moderator/Cryogenics Systems Engineer (1)—responsible to ensure reliable moderator/cryogenic system operation, system upgrades and design improvements, and maintain safety related documentation.
- I&C Engineer (1) - responsible for the operation and maintenance of instrumentation and integrated controls associated with operation of the target systems.
- Operations Team Leader (1)—supervises shift operators and is certified in operations.
- Facility Team Leader (1)—coordinates nuclear facility maintenance (normal and preventative), facility upgrades, and activities associated with outages.
- Operations shift technicians (6)—staff the control room and operate the target and support systems.
- I&C Technician (2)—supports the I&C Engineer in the operations and maintenance of the instrumentation and integrated controls associated with the target systems.
- Facility technicians (10)—change out major components, perform hot cell work, and maintain the facility.
- User Technical Support (6)—provide round-the-clock technical support for users.
- Health physics (HP) technicians (6)—provide HP support for the target building. The HP staff will report to the directorate ES&H manager and may support the entire SNS complex if necessary. Six technicians are budgeted in Target Facility Operations.
- Facility Space Manager (1)—coordinates allocation and utilization of space.
- Safety Analyst (1)—provides support for handling Unreviewed Safety Questions and other safety related analyses.
- Training Coordinator (1)—will implement the operations training program and ensure training quality meets or exceeds required standards.
- Data Base Coordinator (1)—provides support for document control, maintenance management, surveillance control and training management.
- Hourly workers (13)—provide craft support necessary for maintenance and support of the facility.

2.5.2 Materials and Equipment

- Small tools and supplies—includes the hand and small power tools and measuring gages and meters (new, replacement, and consumables) required for technical staff to do their work. Cost is estimated as part of the 20% materials budget for craft and technician labor. This does not include any major shop tools or equipment or initial inventory.
- Training—all technical staff will be target facility worker trained. Technicians will be qualified and certified. Training is budgeted at $10K/technician, which is comparable to HFIR, where the annual training cost is $875K for approximately 80 facility workers. For purposes of this budget, the SNS target facility required training for support personnel (HP techs and crafts) is budgeted through their respective organizations. The most cost-effective way to provide training for operations and support personnel may be to employ contract manpower on an as needed basis to support the dedicated training person. If this is the case, such manpower would be covered by the training costs already assumed in the budget under additional material and services.
- Waste disposal costs are for low-level waste (LLW), mixed waste, hazardous waste, and other waste generated by XFD. Costs are detailed in Table 5 from an analysis based on the current Target Systems design. This estimate will continue to be updated as the design matures and as more accurate disposal cost estimates become available.

- Consumables cover costs of bulk gases (nitrogen, helium and hydrogen) and charges for associate equipment rental and leasing.

In Appendix A-3, an additional $200K has been included to cover leasing a CS120B cask and to provide storage casks for the target inner plug assemblies. These casks are separate from and are in addition to the TN-RAM cask capital purchase discussed in Section 2.5.3.

Table 5. Waste disposal costs

Category	Name	Quantity (kg)	XFD cost ($K/year)	ERWM[a] cost ($K/year)
1	Contact-handled LLW	2,163	11	11
2	Remote-handled LLW	26,775	511	308
3	Contact-handled mixed waste debris	19,151	15	7
4	Contact-handled mixed waste nondebris	1,196	10	4
5	Remote-handled mixed waste debris	2,059	125	68
6	Remote-handled mixed waste nondebris	10,860	652	362
7	RCRA[b] hazardous waste debris	8,340	17	15
8	RCRA hazardous waste nondebris	2,582	6	5
9	Process wastewater LLLW wastewater	8,000	162	226
10	Universal wastes	0	-	-
11	Industrial solid wastes	0	-	-
12	Recyclable metal and equipment	0		
	Total		1,509	1,006

[a]Present Oak Ridge Reservation (ORR) waste system allows programs to pay for only characterization/packaging with Environmental Restoration and Waste Management (ERWM) paying the balance.
[b]Resource Conservation and Recovery Act.

2.5.3 Risks

- If component lifetimes are less than expected, or if some of the systems perform poorly, additional staffing and materials will be required for component replacements, system enhancements, and operations monitoring.
- The mercury target system is a first-of-a-kind system. Therefore, although we believe that the staff level assumed in this budget is adequate to operate and maintain the target system, only operating experience will demonstrate the actual requirements.
- Purchase and certification of a TN-RAM waste cask is a long lead activity (12 to 24 months). Beginning this activity sufficiently early will ensure continued operation and minimize lease costs. For this planning exercise, the $2M capital cost to certify and purchase a TN-RAM cask has been placed in the startup spares costs (costs incurred before FY 07). If for some reason this cask is not available when needed to ship operational wastes, the alternative is to lease a cask. Lease costs for an operational target facility will be $500K per year (these costs are not included in the present operating budget). Moreover, leasing introduces the operational risk of not being able to obtain the cask when required.

2.6 PERSONNEL PROTECTION

2.6.1 Effort (2 FTEs)

- An engineer will improve and enhance design and help maintain the Personnel Protection System (PPS). This person will also assist in writing operating procedures and appropriate safety documentation.
- A technician will maintain the PPS system.

2.6.2 Materials and Equipment

- Supplies and support include administrative support as well as tools and technical support. This does not include any major shop tools or equipment, nor does it include initial inventory.
- PPS personnel will be nuclear facility worker trained.
- Travel is assumed at three trips per year per monthly employee.

2.6.3 Risks

- PPSs are critical to safe operation of the facility. Reductions in this budget should be considered carefully.

3. ACCELERATOR SYSTEMS DIVISION

This section provides backup and details for the Accelerator Systems Division (ASD) budget request for FY 07. After the end of commissioning and the start of operations, the completion of CD-4, the function of ASD is to increase the accelerator system operation from the CD-4 level to the baseline 1.4 MW of beam power, 95% reliability, and 5000 user operating hours per year. This ramp up from FY 06 to FY 11 is described with more detail in the white paper "The Spallation Neutron Source: Operational Aspects and Reliability in the Transition from Commissioning to Fully Committed User Operation," SNS 102000000-TR0004-R00, February 2002 (see Appendix C).

In addition, it has been proposed that during this ramp-up the SNS facility will complete a project to increase the beam energy from 1.0 GeV to 1.3 GeV and increase the beam power from 1.4 MW to 3.0 MW. This upgrade project is based on nine additional linac cryomodules, and is described in detail in "A Beam Power Upgrade for the SNS Complex," SNS 104000000-AC00001-R00, February 2003 (see Appendix D). It is believed that a fully developed SNS facility will have an ultimate beam power capability of 5 MW. This program to both operate as a highly reliable user facility from the CD-4 power level to the 1.4 MW level and then simultaneously enhance the inherent capability of the facility to substantially higher beam power requires total funding as show in Table 8. This budget covers: (1) direct ASD staff; (2) matrixed staff working for ASD; (3) materials, supplies, and shop supplies; (4) major equipment operating costs; and (5) major equipment upgrade costs. These operating costs do not include the proposed funding of $120M described in the "Beam Power Upgrade for the SNS Complex."

3.1 DIRECT ASD STAFF

The direct ASD staff is divided into groups and consists of 178 FTEs. Short descriptions of the direct ASD positions and their responsibilities are listed in Sections 3.1.1–3.1.13.

3.1.1 Division Management (10 FTEs)

The division management directs and coordinates the overall activities and planning for ASD and consists of the following eight positions.

- Division director
- Secretary (2)
- Associate division director—coordinates the overall physics, hardware, beam diagnostics, and controls design of the accelerator system. Provides high-level planning for accelerator system development and upgrades. Provides oversight of the ASD R&D and prototyping effort.
- Associate division director—leads, coordinates, and integrates the administrative activities of ASD, including maintaining and planning high-level budgets, staffing plans, field work proposal (FWP) development, and coordination of preparations, presentations, and responses to external review and advisory committees.
- ES&H specialist—coordinates the overall ASD ES&H effort and interfaces with the SNS ES&H effort and ES&H director.
- Quality Assurance (QA) specialist—coordinates the overall ASD QA effort and interfaces with the SNS QA effort and QA director.
- Finance officer—provides detailed budget, cost, and schedule support and information, including maintaining the ASD list of accounts, providing costs projections, and interfacing with the SNS business office on ASD accounts.

- Procurement Specialist—provides procurement support for ASD technical procurements
- HR Specialist—provides human resource support for ASD division staff and management

3.1.2 Accelerator Physics Group (14 FTEs)

The Accelerator Physics Group is responsible for providing physics and software support for ASD and consists of 1 group leader, 12 accelerator physics and software staff, and 1 secretary. This group will provide the intellectual leadership to bring the accelerator system to the beam power design level of 1.4 MW and then develop upgrades to higher beam power. Group responsibilities are as follows.

- Group leader
- Secretary
- Subsystem physicists (4)—The accelerator system is divided up into four major subsystems: front end, normal conducting linac, superconducting linac, ring and beam transfer lines. For each subsystem, a subsystems manager is required to make sure that the operating parameters are met or exceeded. This person will define the upgrade goals and the accelerator-study time goals and will interface directly with the Operations Group.
- Linear effects ring physicist—maintains and develops high-energy beam transfer (HEBT), ring, and ring-to-target beam transport (RTBT) system machine optics and simulation codes; develops magnetic field error corrections and beam dynamics; develops applications for ring tune settings, radio frequency (RF) ramp, and closed-orbit correction.
- Collective effects ring physicist—analyzes machine collective effects, including space charge compensation, vacuum effects, impedance and instability limits and compensation; develops schemes and applications for tune measurement and compensation.
- Linac physicist for superconducting radio frequency (SRF) performance and codes—responsible for SRF linac operations and performance optimization; maintains and develops linac simulation and modeling codes; develops applications for setting the RF, closed orbit, and failed cavity operation.
- Linac physicist for cavity physics and RF—analyzes and optimizes linac cavity physics and performance, provides support in cavity tuning and RF control, maximizes SRF cavity gradient and usable power.
- Senior applications team leader and deputy group leader—coordinates the effort in accelerator applications and environment in full support of accelerator operation and improvement.
- Application physicist 1—responsible for maintaining and developing the infrastructure used in the application-programming environment.
- Application physicist 2—responsible for maintaining the application programming environment and interface to the global database. Assists interfacing to other scripting and commercial programming environments.
- Application physicist 3—responsible for maintaining general-purpose application programs such as orbit difference, bump algorithms, etc. Assists in the maintenance of the programming infrastructure.

3.1.3 Operations Group (23 FTEs)

The Operations Group performs all typical control duties for accelerator operation and interfaces with conventional facility operation and ES&H. The group operates the accelerator complex during standard operation and supports accelerator physics during maintenance and accelerator improvement periods.

- Operations manager
- Secretary
- Deputy operations manager—assists the operations manager with oversight of safe and efficient accelerator operation and operations team. Provides technical and administrative expertise during accelerator operations and coordinates future operations R&D activities. Assumes the position of

acting operations manager and operability coordinator or training and certification specialist as required.

- Operations coordinator for operations staff—manages the staffing of rotating shifts for chief operators and operators.
- Training, certification, records, and operability coordinator—manages the training and certification of all operations staff. Logs and archives data from rotating shift operation, fault reporting, and resolution, etc. Acquires and analyzes data from accelerator operations to improve the overall reliability and availability of accelerator systems.
- Operators (18)—One chief operator and two operators are planned for each shift during around-the-clock, seven-day-per-week normal operation. A minimum of 18 operators are needed to provide coverage for the projected schedule of 5000 hours of beam to the neutron production targets plus development and repair time. The intent is not to include mandatory overtime in the rotating shift schedule, so staffing coverage must be included for vacation and holiday time, sick time, training time, and other staff vacancies.

3.1.4 Ion Source Group (4 FTEs)

The Ion Source Group performs routine maintenance work as well as further development of the state of the art of high-duty-cycle negative hydrogen (H-) sources. The group operates a hot spare test stand and a developmental test stand in the ion source laboratory. The reliability of the ion source plays a major role in the overall availability of the facility. Ion source positions are as follows.

- Group leader
- Ion source physicist—guides the SNS ion source R&D activities in the ion source laboratory.
- Senior ion source technicians (2)—coordinate and perform maintenance, testing, and conditioning of all SNS ion sources. When time permits, assist SNS developmental ion source lab activities.

3.1.5 Linac RF Group (20.5 FTEs)

The Linac RF Group is responsible for the complete linac RF system, including high-voltage power supplies (HVPSs) and low-level radio frequency (LLRF) controls. The group will support standard operation, maintenance, and development of the linac RF system. The group will contribute to the development of upgrade scenarios and install future hot spare RF stations as well as RF stations for additional cryomodules. Group positions are as follows.

- Group Leader
- Secretary (.5)
- Pulsed power engineer—responsible for operations, reliability, and corrective and preventive maintenance of pulsed power systems, including modulators and low-energy beam transport (LEBT) and medium-energy beam transport (MEBT) choppers.
- Pulsed power engineer—responsible for functionality and reliability upgrades and improvements, and operations including modulators and LEBT and MEBT choppers.
- High-power RF engineer—responsible for normal conducting RF systems operations, reliability, and corrective and preventive maintenance including transmitters, klystrons, RF transport, structures, and instrumentation.
- High-power RF engineer—responsible for superconducting RF systems operations, reliability, and corrective and preventive maintenance including transmitters, klystrons, RF transport, cavities, and instrumentation.
- LLRF engineer—responsible for normal conducting RF systems operations, reliability, and corrective and preventive maintenance of low-level hardware and software systems.

- LLRF engineer—responsible for superconducting RF systems operations, reliability, and corrective and preventive maintenance of low-level hardware and software systems.
- RF engineer—responsible for operations, reliability, and corrective and preventive maintenance and upgrades of linac RF control systems and database software.
- Pulsed power technicians (4)—support operations, maintenance, and development.
- High-power RF technicians (4)—support operations, maintenance, and development.
- LLRF technicians (4)—support operations, maintenance, and development.

3.1.6 Cryomodule and Cryogenics Group (19 FTEs)

The Cryomodule and Cryogenics Group is responsible for two main tasks. The Cryomodule Task will maintain the linac cryomodule as well as take the leading role in the construction of new cryomodule and design improvements. The Cryogenics Task is responsible for the operation of the central helium liquefier as well as the overall cryogenic system, including transfer lines. Group positions are as follows.

- Senior Physicist
- Senior Engineer
- Secretary
- Cryomodule engineer—analyzes, optimizes, and improves cryomodule performance to meet overall operations goals and schedules; contributes to cavity and cryomodule repair, improvement, and development efforts.
- Cryomodule engineer—coordinates cryomodule operations, scheduling, and installation of modifications to the cryomodules and related systems.
- Lead cryomodule technician—performs operations and maintenance support, coordinates and participates in writing operations and maintenance procedures, scheduling, purchasing, and work documentation.
- Cryomodule instrument technician—performs operations and maintenance support for the cryomodules and related cryogenic instrumentation, interlocks, and controls hardware.
- Cryomodule technicians (4)—perform operations and maintenance support for the cryomodules including cryogenic, cavity, and vacuum systems. Test, repair, and reassemble cryomodules, cavities, and components as needed. Participate in or perform electrical and mechanical measurements, cavity chemistry, and particle-free assembly in a clean room.
- Cryogenic engineer—coordinates central helium liquefier (CHL) operations, scheduling, and installation of modifications to the CHL and its related systems.
- Cryogenic engineer—analyzes, optimizes, and maintains CHL performance to meet overall operations goals and schedules. Contributes to improvement and development efforts.
- Cryogenic technician—performs operations and maintenance support, coordinates and participates in writing operations and maintenance procedures, scheduling, purchasing, and work documentation.
- Cryogenic instrument technician—performs operations and maintenance support for the CHL and related cryogenic instrumentation and controls hardware.
- Cryogenic technicians (2)—perform operations and maintenance support for the CHL cryogenic and vacuum systems.
- Cryogenic technicians (2)—perform operations and maintenance support for the CHL cryogenic and compressor systems.

3.1.7 Power Supply Group (15.5 FTEs)

The Power Supply Group services, maintains, and improves all the AC and DC power supplies of the facility. This group also supports the low-frequency RF system for bunching in the accumulator ring.

Operation of switchgears and breakers and the power distribution in the accelerator enclosures is also part of this group's responsibility. Group positions are as follows.

- Group leader
- Secretary (.5)
- Pulsed power engineer—operates, maintains, and develops the 14 fast extraction kickers and the 8 injection kickers plus the beam in gap kickers.
- Pulsed power technicians/field engineer (2)—operate, maintain, and develop the 14 fast extraction kickers and the 8 injection kickers plus the beam in gap kickers.
- Power supply engineers (2)—operate, maintain, and develop more than 400 DC power supplies.
- Power supply technicians/field engineer (3)—operate, maintain, and develop more than 400 DC power supplies.
- Ring RF power engineers (2)—operate, maintain, and develop the ring buncher RF cavities, both high power and low-level control.
- Ring RF power technicians/field engineer (2)—operate, maintain, and develop the ring buncher RF cavities, both high-power and low-level control.
- AC power engineer—operates, maintains, and develops the AC power, switchgear, breakers, and power distribution.
- AC power technician/field engineer—operates, maintains, and develops the AC power, switchgear, breakers, and power distribution.

3.1.8 Mechanical Group (29 FTEs)

The Mechanical Group combines the design and drafting capability of the ASD (engineers and designers) with the ability to maintain and install technical components. The mechanical Group also is responsible for all the vacuum systems within the accelerator facility, including the superconducting part of the linac. Group positions are as follows.

- Group leader
- Secretary
- Water system engineer—operates, maintains, and develops the water-cooling systems for all accelerator components.
- Water system technicians (2)—operate, maintain, and develop the water-cooling systems for all accelerator components.
- Magnet engineer (2)—operates, maintains, and develops the accelerator magnet system and magnet measurement equipment.
- Magnet technicians (2)—operate, maintain, and develop the accelerator magnet system and magnet measurement equipment. Assist with magnet prototyping.
- Front-end (FE) mechanical engineer—operates, maintains, and develops the FE mechanical equipment.
- Warm linac mechanical engineer—operates, maintains, and develops the warm linac mechanical equipment.
- Ring and transport mechanical engineer—operates, maintains and develops the ring and transport mechanical equipment.
- Subsystems technicians/field engineers (3)—operate, maintain, and develop the accelerator system mechanical equipment.
- Analytical mechanical engineer—performs mechanical, stress, thermal, and finite-element analysis on mechanical components as required.
- Mechanical engineer—provides mechanical engineering support for upgrades, RF, diagnostics, power supplies, and other ASD groups as required.

- Designers (4)—perform drafting and design of accelerator components and support equipment including cooling and cabling. Prepare design documents and drawings as required. Perform basic engineering calculations. Work with engineers and vendors to help ensure optimal designs.
- Vacuum engineer (2)—provides technical engineering oversight of design, operation, vacuum system performance upgrades, testing, and direction of vacuum technicians, crafts, vendors, and subcontract support.
- Vacuum technician team leader—provides vacuum operations technician resource management, maintenance scheduling, inventory control, training, safety and compliance issues, material safety data sheet (MSDS) tracking, and purchasing issues.
- Vacuum technician—provides high-voltage power supply expertise, diagnosis, and repair of all vacuum pumps and power supplies. Maintains spare parts inventory and safety issues concerning working on HV equipment.
- Vacuum technician—provides leak detection expertise, diagnosis, and leak repair of detectors; repairs and rebuilds turbo, mechanical, and cryogenic pumps; defines and documents leak detection criteria/records for the vacuum group.
- Vacuum technician—provides instrumentation expertise, diagnosis, and repair of all vacuum gauges including residual gas analyzers (RGAs) and their controllers. Maintains network communication, including the Experimental Physics and Industrial Control System (EPICS), to all vacuum system components.
- Vacuum technician—provides cryogenic and RF vacuum-related expertise, diagnosis, repair, and maintenance of tuners, couplers, waveguides, and window installations.
- Vacuum technician—provides ultrahigh voltage (UHV) process-related expertise in the operation and maintenance of cleaning, bake-out, outgassing, and surface treatment vacuum equipment, maintains clean room and associated consumables.

3.1.9 Survey and Alignment Group (8 FTEs)

The Survey and Alignment Group is responsible for maintaining the survey and alignment network used during construction on the site. The group has to realign the components of the facility on a regular basis, especially in the first couple of years when settlement will play a major role. The group also provides survey and alignment services for the other SNS divisions. Group positions are as follows.

- Group leader
- Alignment engineer—geodetic engineer responsible for maintaining the global survey network as well as site settlement issues.
- Alignment engineer—responsible for alignment of the target and instruments and cryosections. In addition, serves as an optical tooling specialist.
- Alignment engineer—responsible for alignment of the FE, most linac components, and the ring. Also provides laser tracking expertise.
- Technicians (2)—support the network. Provide support for elevation and settlement-related issues.
- Technician—supports FE, linac, and ring alignment and maintenance.
- Technician—supports target and instrument alignment and maintenance.

3.1.10 Diagnostics Group (10 FTEs)

Diagnostics Group is responsible for maintaining and developing the beam diagnostics system from the Front-End to the Target interface. Group positions are as follows.

- Group leader

- Diagnostic physicist—serves as group liaison to the Accelerator Physics Group. Responsible for loss monitor system, laser wire, carbon wire, and emittance-measurement diagnostics. Responsible for unique diagnostics such as fast data acquisition.
- Engineer 1—responsible for the EPICS diagnostics needs and the database, serves as group web master, web designer, electronic documentation organizer, and PC and workstation specialist. Oversees the smart systems and data acquisition during operation.
- Engineer 2—responsible for electromagnetic modeling of the diagnostics. Also responsible for the ultrafast Faraday cups, beam position monitor (BPM) and beam current monitor (BCM). Serves as liaison to the LLRF group and the high-level RF group and handles the diagnostics required for LLRF feedback needs.
- Engineer 3—digital circuit design engineer. Maintains and upgrades the circuit boards used in BPMs, BCMs, etc., and designs digital feedback systems to damp beam instabilities and beam in gap cleanup.
- Engineer 4—low-level application program engineer. Responsible for writing digital signal processing (DSP) codes and for maintaining and upgrading diagnostic drivers such as Labview codes, and dlls. Improves digital signal processing algorithms for the installed diagnostics.
- Software technician—maintains the installed software in all smart devices and upgrades the developed codes to all devices. Also tests and calibrates instruments.
- Digital circuit technician—repairs, maintains, tests, and calibrates the digital boards for all diagnostics.
- Analog electronics field engineer—maintains, repairs, and calibrates the analog circuitries. In charge of maintaining diagnostic input signal to systems such as machine protection.
- Diagnostic RF and timing field engineer—maintains, repairs, and calibrates devices. Performs time-domain reflectometer (TDR) characteristics, and transfer function measurements of equipment.

3.1.11 Controls/Personnel Protection Group (25 FTEs)

The Controls Group is responsible for the control systems of the accelerator, part of the conventional facilities controls, the cable plant, the safety systems, and the PPS. These diverse responsibilities require a large group with very different skill sets. Group positions are as follows.

- Group leader
- Secretary
- Lead engineer—working-level engineer who ensures that engineering interfaces and standards are maintained. Responsible for some subsystems such as the Network. Acts as deputy group leader when required.
- Safety lead engineer—responsible for Personnel Safety System operation and maintenance, reviews, and interfacing with ES&H.
- Controls engineer—responsible for system maintenance, drawing packages, configuration management, and programmable logic controller (PLC) program maintenance.
- Safety technicians (2)—perform maintenance and testing of PPS equipment. Provide shift presence for access.
- Lead software engineer—sets directions and leads software team. Serves as primary interface with physics and applications software teams. Serves as primary interface with international EPICS community.
- EPICS programmers (2)—maintain EPICS core. Develop drivers and tools.
- Applications engineers (4)—maintain EPICS distributed subsystems. Assigned to FE, linac, ring, target, conventional, etc. Includes all subsystems, vacuum, power, cooling, RF, and diagnostics. Provide control room support.

- Applications programmers (2)—provide and support tools for high-level physics applications. Work with applications programmers in the Accelerator Physics and Diagnostics groups. Incorporate ad hoc applications under concurrent version system (CVS).
- System administrator—provides system administration of control system network and all control system servers and input/output controllers (IOCs) and the CVS.
- Database administrator—serves as database administrator for the SNS technical database. Provides views and services as required.
- Hardware lead—leads hardware team. Responsible for controls lab and maintenance of all hardware equipment. Designs new electronics as required. Responsible for electronic CAD systems, electrical safety, and the machine protection system (MPS).
- Engineers (2)—provide subsystem design, maintenance of SNS timing system, and PLC integration.
- Technicians (4)—provide hardware maintenance, maintenance of cable plant, and equipment testing.

3.2 MATRIXED STAFF WORKING FOR ASD

The ASD budget will support on a continuing basis an additional 23 matrixed workers consisting of 4 HP technicians, 1.0 IH technicians, 12 FTEs of craft labor, which includes Research Mechanics, both electrical and mechanical, and 2 postdoctoral fellows and 4 Ph.D. graduate students. The HP staff will report to the directorate ES&H manager and may support the entire SNS complex if necessary. In addition, $769K has been allocated for additional purchased services such as procurement expediting and shipping and receiving, contract technicians, and ES&H contract personnel.

3.3 MATERIALS, SUPPLIES, AND SHOP SUPPLIES

Materials and supplies for the professional staff were calculated at 10% of the salary cost and sums. Travel was calculated at 3% of salary cost. Materials and supplies for the technicians and crafts were calculated at 20%. A preliminary distribution of additional funds for shop s materials and supplies is listed in Table 7.

3.4 OPERATING MAJOR EQUIPMENT COSTS

This section lists the major materials, spares, consumables and capital equipment needs to operate and develop the accelerator system from the CD-4 power level to 1.4 MW of beam power and higher, with high operating hours and reliability.

Table 7. FY 07 Operating ASD annual shop and lab supplies budget

Area	Supplies
Operations staff lab (CCR,[a] communications, safety, LOTO[b])	75
Controls staff lab	125
Personnel protection lab	25
Beam diagnostics lab	125
Survey and alignment lab or shop	50
Power supply lab	225
Ring RF cavity shop	50
Vacuum lab or shop	75
Mechanical engineering lab	100
Magnet measurement shop	125
Drafting shop	50
IS repair and development test stand	200
IS hot-spare test stand	
Ion source lab	
High-power RF lab	200
LLRF lab	75
RF shop with test stands	
Foil lab	50
Craft tools	25
Machine shop supplies	50
Cryomodule support	175
CHL	147
Total	$1947K

[a]Central control room
[b]Lockout/tagout

3.4.1 Replacement Spares and Consumables

The SNS Spares Plan lists in detail the initial and annual spare parts and consumables required to operate the facility. This list has been developed and reviewed several times with ASD/ORNL staff and the partner laboratories and sums to $8,596K ($9,980K burdened). The largest cost is for the linac RF system, in particular the one-on-one configuration for each SRF cavity. The largest uncertainty is the "infant mortality" of these klystrons. The attached spares list assumes a klystron lifetime of approximately 25,000 hours, which might be optimistic for the first one or two years of operation and ultimately pessimistic if compared with other facilities such as the Sanford Linear Accelerator Center (SLAC), LANSCE, and Fermilab. The ultimate lifetime certainly has the potential to be very high given the operating parameters for the majority of the klystrons. Nevertheless, in the first year or two the project takes a significant risk with the high-lifetime number used for the spares calculation.

3.4.2 Cryogens

The annual cryogen replacement cost is based on experience at Thomas Jefferson National Accelerator Facility (JLab) and is estimated to be about $800K ($929K burdened) annually. The cost is split somewhat equally between nitrogen and helium.

3.4.3 Waste Disposal

Radioactive and mixed waste disposal cost for the ASD is estimated at $400K annually. Of particular concern are activated beamline components and activated oils and coolants. $400K is a compromise between the results of a detailed SAIC study and the experience of ASD personnel.

3.4.4 Laboratory Capital Equipment

The estimated annual capital cost for laboratory and shop equipment is estimated to be $1500K ($1741K burdened). These funds are for equipping, upgrading and eventually replacing obsolete test stands, shop equipment, laboratory equipment, magnet measurement equipment, calibration equipment, radiation handling equipment, repair fixtures, etc. Well-equipped state-of-the-art shops and laboratories will be required to develop the SNS accelerator system to very high beam power, operating hours and reliability.

3.4.5 Accelerator Capital Equipment

Approximately $6.0M ($7.771 M burdened) of capital equipment will be required per year during the first years of operation to develop, replace and rebuild accelerator subsystems that do not perform as originally planned and need replacement or upgrading to reach the baseline beam power level of 1.4 MW and beyond. This section describes the ASD need for funds to upgrade and add equipment over approximately the first decade of operations starting in FY 07. The main goals over this period are to provide reliable operation while achieving and then surpassing the baseline beam power in order to develop the facility to its full capability. The design baseline is for 1.4 MW of beam power on target with 95% reliability and 5000 user operating hours per year. Ultimately, the facility has the capability to deliver about 5 MW of proton beam power. A proposal has been made for a 1.3-GeV 3.0-MW upgrade, which is based on filling the SNS linac's nine empty high-beta cryomodule slots. The tunnel geometry and basic magnet system are capable of operation at over 1300 MeV.

Specifically, the equipment upgrade costs described in this section are to: (1) provide for equipment upgrades to meet the simultaneous design goals of 1.4 MW, 95% reliability, and 5000 hours; (2) provide equipment support for additional increases in beam power, reliability and operating hours, and (3) provide for the hardware development, understanding and bases for eventual operation at 5 MW.

Specific equipment upgrades are listed and discussed below. The order and priority of these upgrades will be largely determined from operational experience gained through commissioning and initial operation. The completed Front-End commissioning has already demonstrated Front-End systems that will require re-work and additional hardware equipment to meet the power, reliability and operating-hour goals of the facility. The estimated cost for the equipment upgrade program will be $6.0M per year ($7.771M per year burdened).

3.4.5.1 Ion Source and Front-End Upgrades

During the first decade of operation, the ion source may be the weakest link in achieving high-intensity reliable operation over long periods of time. The ion source itself will need a constant level-of-effort in R&D to improve the individual source; for example, a high-reliability microwave source will be

developed. A hot-spare ion-source test stand is included in the baseline. A second independent test stand for ion source development will be built. In addition, a first year's project will include the construction and installation of a second injection beamline to provide a hot-spare ion-source for the Front-End. Moreover, the present LEBT contains no diagnostics and one that contains diagnostics will be developed.

A study for halo mitigation has been completed and the desired hardware will be designed and implemented. Additional MEBT power supplies will allow independent focusing quadrupole control. An upgrade of the MEBT rebuncher RF power sources seems to be required to increase reliability. In the long term, a laser chopping system will perhaps be developed to replace the MEBT chopper and much of the MEBT, which will be a great simplification and increase reliability.

3.4.5.2 Linac RF System Upgrades

Similar to computer controls, the rapid pace of development in low-level RF, LLRF, and control will require constant attention, development, and implementation. Improved LLRF control will directly benefit the operation of the accelerator because RF power, which is not required to control the cavities, can be directly used to generate higher beam currents and therefore more beam power with the existing RF plant. In addition, halo and beam loss is decreased with increasing quality and control of longitudinal phase space. The LLRF control system has been designed and built to provide amplitude and phase stability at 1.0% and 1.0 degree, respectively. This control tolerance is sufficient to meet CD-4 and early operational requirements. Low-loss operation at high power will require a LLRF system upgrade providing a consistent phase and amplitude control of 0.5 degrees and 0.5%, respectively.

Additional RF systems, so-called hot spares, need to be built and installed in the klystron gallery. Waveguide connections to all the klystrons, with motorized switches, will allow continued operation immediately after klystron failure.

3.4.5.3 Cryomodule Maintenance and Upgrades

The piezo tuner R&D has been successful in showing a substantial capability to compensate Lorentz force detuning from the cavity RF filling. The hardware for these piezo tuners will be installed inside all cryomodules as part of the construction project. Implementing tuning as part of normal operations will improve beam control allow use of available RF power more efficiently. This will be important as the facility moves to higher power. Additional equipment needed consists of 81 HV power supplies, waveform generators, control IOCs, fibers, cables, EPICS controls, etc. The estimated cost for this hardware is about $1.6M.

Exchanging cryomodules during maintenance periods of the accelerator to improve and repair existing cryomodules is a fundamental capability the ASD must have in-house in order to avoid the time delays inherent in depending on the infrastructure of other laboratories. The development of low-beta pi/2 mode cavities to replace the CCL is a long-term goal to increase reliability and reduce operating costs. An even longer-term possibility will be to replace the DTL with spoke cavities presently being developed at ANL.

Cryogenics system reliability will be improved by the addition of a separate 4 KW, 4.5K refrigerator in an existing area of the CHL building. The new refrigerator will maintain the SRF linac temperature at 4.5K during maintenance of the CHL, avoiding potentially harmful thermal cycling. Cost of the installed refrigerator is about $12M.

3.4.5.4 Ring Upgrades

TiN vacuum chamber coating has been added to the technical baseline to reduce the secondary electron yield and the probability of electron cloud instabilities. However, the TiN coating also increases the pumping load. The ring vacuum system contains twice as many pump ports as baseline pumps.

Consequently, the number of vacuum pumps in the ring will be doubled, reducing the pressure and associated beam loss. These additional pumps will also increase reliability.

As the average current in the ring increases, more sophisticated beam feedback systems will be required to counteract beam instabilities. Wideband fast feedback systems will be developed as needed to reduce activation and allow increased beam power.

Ring injection and hence SNS intensity is limited by the foil performance to strip H- ions to H+ ions at the point of injection. Foil research and development and production will be developed as necessary to support higher beam power. The ultimate injection system will be laser stripping and laser injection stripping R&D will be performed in order to first prove the principle and then perhaps develop a working system.

Higher Ring RF voltage is desirable for higher-power lower-loss operation and will be installed as needed. R&D on a barrier bucket RF system will be performed and perhaps hardware will be implemented.

Other potential Ring upgrades include: (1) ring ramping magnets for the correction of intensity dependent effects during the 1.0-ms ring injection period; (2) RF quadrupoles for active compensation of space-charge tune shifts along the longitudinal bunch length; and (3) fast magnet elements in the HEBT to allow more flexible injection painting schemes and beam stacking.

3.4.5.5 Power Supply Upgrades

The SNS linac RF system is the first large-scale installation of IGBT technology in klystron power supplies, the HVCMs. Significantly improved reliability will be achieved with improved HVCM diagnostics that will indicate needed repairs prior to failure. In addition, more flexibility for operations will be achieved by increasing the HVCM pulse length to 1.5 ms. Hot-spare DC power supplies for both the linac and ring magnets will substantially increase reliability. Hot spare pulsed power supplies for both ring injection and extraction will also increase reliability. A gradual power supply upgrade will be supported.

3.4.5.6 Beam Diagnostics Improvements

Beam diagnostics beyond the initial complement required to bring the machine into operations will improve beam control and reduce losses. In order to minimize worker exposure we plan to enhance the diagnostics suite as more is learned about accelerator operations. . Initial accelerator operation is guaranteed, but beam power levels of 1.4 MW with simultaneous low losses, high reliability, and long running times will require additional diagnostics to be developed and installed. Some specific areas that will need improvement are listed below:

- High-bandwidth Ring beam-position-monitor hardware and software will be needed.
- Some wire scanners will be replaced with harps, particularly in the RTBT and probably also in the beam dumps.
- The present ring ionization profile monitors may not work well at high power and may require replacement with gas fluorescence profile monitors.
- A laser system will be developed for Front-End longitudinal-phase-space beam measurements.
- A fast software feedback system from beam diagnostics to hardware controls will be developed. The first application will be an improved beam-loss-monitoring system with a fast feedback system to hardware controls.
- More sensitive halo measurements will be made in the RTBT and Target with a conducting plate system.
- Laser-based bunch shape monitors will substantially improve longitudinal-phase-space control.

- A minimal laser-wire system has been built and this system will be upgraded for improved linac halo and beam-in-gap measurements.
- Better instrumented beam dumps will increase reliability.

3.4.5.7 Control System Upgrades

With the lifecycle of computer and controls equipment today, constant upgrades of the control system will be necessary. Upgrades in the accelerator controls, particularly for fast feedback systems will require continuing support.

3.4.5.8 Shielding and Remote Handling Upgrades

The number of moveable shields, that may be require for hands-on maintenance, is limited in the Project baseline. The need for additional moveable shielding and also permanent shielding will probably increase during the ramp-up to full operations and may perhaps become an ALARA issue. In addition, the SNS accelerator system has very limited capability for remote handling of highly activated components. At very high beam power and operating hours remote handling capability may be necessary. Shielding and remote maintenance will be developed as needed.

3.4.5.9 Accelerator Utility Systems Upgrades

Of particular concern are upgrades of the accelerator utility systems. For example, resonant control of the copper linac cavities is achieved by feedback control of the cavity cooling water systems. High beam power, reliability and running time will probably require substantial upgrading and rework of these systems.

4. MANAGEMENT

The SNS Associate laboratory Director's Office will be responsible for overall management of the SNS facility. The office will also provide support for the SNS divisions in the areas of ESH&Q, Business, Communications, and Human Resources. The staff consists of the Associate Laboratory Director, a technical assistant, a business manager, a technical editor, an ESH &Q manager and ESH specialist, and a human resource generalist, as well as two support staff members.

A detailed list of ESH&Q functions is shown in Appendix B-2.

5. SNS COMPLEX FACILITIES AND SUPPORT ORGANIZATION

Additional support services will be provided to the SNS technical divisions through the SNS Complex Facilities and Support Organization (CFSO). This group includes the support services of Technical Information Systems (TIS), and the central services of Maintenance and Site Support, and Facilities Engineering (CF). Figure 1 depicts the CFSO organization structure. SNS document control and records management services will be procured through ORNL; however, the point of contact for these services for SNS will be the CFSO manager.

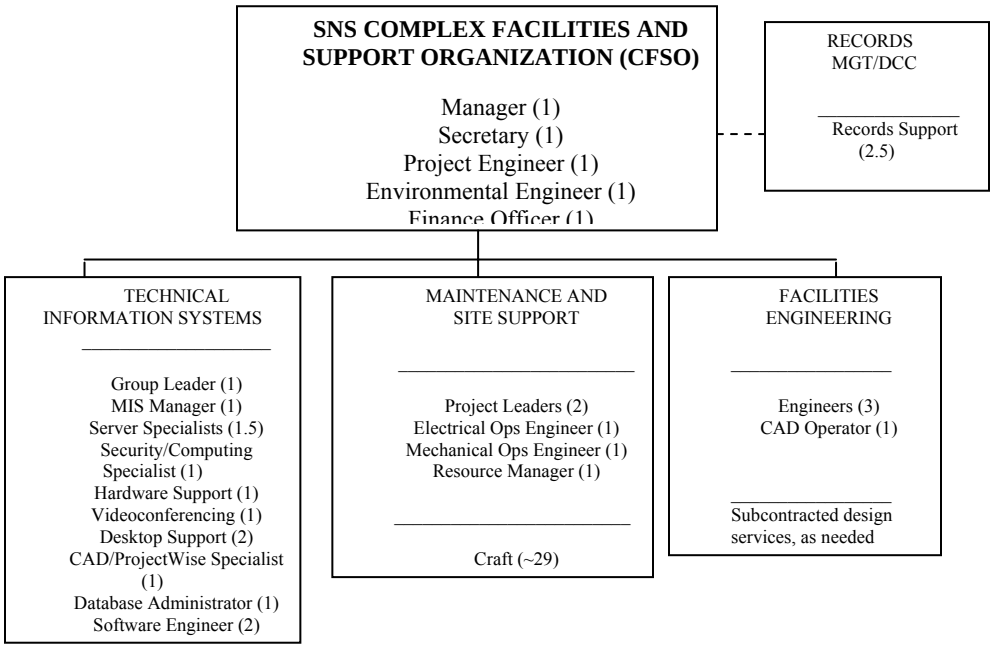


Fig. 1.

5.1 MANAGEMENT (4 FTES)

The administrative support of CFSO will consist of the CFSO manager, a secretary, a project engineer, an environmental engineer and a finance officer. This small group will provide personnel oversight and management for CFSO.

Position	No. of Staff	Responsibilities
Manager, SNS CFSO	1	Integrates CF efforts in support of ASD, XFD, and CNMS
Secretary	1	Supports CF organization
Project Engineer	1	Prepares FUAs, monitors progress and provides resource planning
Environmental Engineer	1	Provides environmental engineering support for waste management systems, among others
Finance Officer	1	Provides detailed budget, cost and schedule support as well as accounting for power operations

5.2 TECHNICAL INFORMATION SYSTEMS (TIS)

The Technical Information group will consist of 12.5 FTEs and will be responsible for software application development support, software maintenance, scientific data management for computer (cyber) security, computer user support, file storage, output capability, application support, data-communications, telecommunications, and video-conferences. An additional 4 FTEs for software development are anticipated to be supported through ORNL and SNS divisions. A detailed list of functions is shown in Appendix B-1.

5.3 COMPLEX FACILITY (CF) MANAGEMENT

The CF staff will provide daily operation and maintenance of the SNS facilities, systems and equipment assigned to CF. The group will be composed of administrative and engineering staff, and full time craft necessary for routine maintenance and facilities services. The principal role of CF is to ensure that facility support and utilities are available and operate safely within the specifications required for reliable SNS operation.

SNS facilities managed and maintained by CF consist of 85 acres of building and grounds, 591,000 square feet of building space, and approximately 3 miles of roadway. CF will manage operation of the utilities systems that serve the entire SNS site, which will initially include the SNS and the Center for Nanophase Materials Sciences (CNMS), but may include other buildings as the site is developed further.

5.3.1 CF Model for Fiscal Year 2007

The organization of CF will be patterned after the ORNL Facility and Operation (F&O) Directorate and will be organized to take maximum advantage of the resources available at ORNL. SNS has negotiated a Memorandum of Agreement (MOA) with F&O to provide dedicated crafts that are managed by CF personnel. In addition, other MOAs will be established prior to 2007 for services where ORNL has established programs for performing the work or where it's more cost effective for SNS to buy the service. Also, some specialized services will be subcontracted.

At the beginning of FY 07 all enclosures, buildings, and utility systems will have been constructed and in use for at least a year. The CF staff will have been hired and facilities provided for their work and shops.

5.3.2 CF Organization

The CF organization will support two primary functions: Maintenance and Site Support and Facilities Engineering. The first group will maintain the buildings, physical plant, and operate the site utilities. The second group will plan and supervise upgrades to the facilities, services, and site in conjunction with personnel from the technical divisions of the Laboratory. Figure 1 depicts the Organizational Structure of CF. Other support will be provided from within the CFSO or from SNS management.

5.3.3 CF Staffing

Table 8

Position	No. of Staff	Responsibilities
Facilities Engineering		
Mechanical Engineer (Lead Engineer)	1	Mechanical engineering support to facilities and maintenance and oversight of design. "Design Authority" for CF
Electrical Engineer	1	Electrical engineering support to facilities and maintenance and oversight of design
Controls Engineer	1	Instrument and controls support to facilities and maintenance and oversight of design
CAD Operator (Draftsman)	1	CAD support for new designs and "As Builts"
Maintenance and Site Support		
Project Leaders	2	Responsible for coordinating maintenance projects and upgrades of assigned facilities
Electrical Operations Engineer	1	Manages CF electrical systems and telephone system
Mechanical Operations Engineer	1	Manages CUB and CF mechanical and utility systems
Resource Manager	1	Manage craft resources
Craft (Bargaining Unit)		
Skills Work	~17	Approximately 17 skills workers to perform electrical and mechanical maintenance on HVAC units, electrical systems, pumps, mechanical instruments, and mechanical utilities.
Service Work	~12	Approximately 12 service workers to provide janitorial support, equipment operations support, routine painting, transportation services, and general site-wide laborer support.

5.3.4 Facilities Engineering (4 FTEs) (additional funded from projects)

The Facilities Engineering section has the following areas of responsibility:

- Engineering support for maintenance work
- Design support for and oversight of projects
- Construction oversight for projects
- CF support to XFD and ASD on specific technical projects
- SNS CF Engineering drawing management
- Maintain "As Builts" of facilities and utilities

The staff will consist of three discipline engineers, with one of those being the lead, and a CAD operator. The discipline engineers consist of a mechanical engineer, an electrical engineer and a controls engineer, who monitor site support and facility operations and provide SNS complex-specific engineering support. At this staff level, all major design work will be accomplished by non-SNS design organizations, either by ORNL Engineering or by subcontract. This organization structure lends itself to expansion to support any new scientific effort through engineering subcontracts.

5.3.5 Facilities Maintenance and Site Support

5.3.5.1 Facilities Maintenance

The Facilities Maintenance staff consists of two project leaders, one resource manager, two operators and twenty nine craft.

Project Leaders (2): The project leaders will coordinate the CF craft resources on the site. Specific responsibilities will include:

- Ensuring that the facility supports the planned SNS operations schedule by coordinating preventive maintenance and engineering support to eliminate schedule conflicts and ensure reliable SNS operation
- Organizing and scheduling critical maintenance during accelerator downtime
- Acting as the focal point and controlling all work within a particular building(s)
- Integrating and scheduling all work based on scope of work, priorities, staffing, work restrictions, and other factors that impact completion of construction maintenance tasks
- Monitoring work to verify that tasks are completed in a timely manner in accordance with work instructions and obtaining additional resources as required
- Obtaining necessary work permits

Resource Manager (1): The resource manager will be responsible for scheduling the proper craft resources for each task, assuring that materials and other resources are available, and attaining necessary permits.

Maintenance/Craft Support (29 FTEs): CF will be responsible for maintaining buildings and building-related systems throughout the site. This proposed staffing will support the routine maintenance of the following systems and equipment where not specifically assigned to other SNS Divisions:

- Hot off-gas system;
- Hot water heating system;
- Cooling tower and tower water systems;
- Compressed air systems;
- Electrical substations;
- Switchgear and medium voltage (MV) distribution system;
- Building low voltage (LV) electrical system;
- HVAC systems;
- Building structural systems;
- Waste collection, treatment, storage, and transfer systems;
- Central lab and office building systems;
- Water tower systems;
- Potable water systems
- Central Utilities Building (CUB) and systems;
- Deionized water systems;
- Chilled water systems; and
- Other related systems and facilities.

The quantity of craft resources identified will maintain SNS facility systems. The proposed staff level is sufficient for normal day shift plus some second shift coverage. A system or component failure during an off-shift will require ORNL response. A determination will be made at that time whether to call in resources for an immediate repair or to wait until the next day shift. Organizationally there will be a core

of SNS craft personnel permanently assigned to SNS. Resources for tasks that exceed CF staff availability will be temporarily assigned from other divisions or from ORNL until the task is complete. Specific craft training for tasks unique to SNS and refresher training will be born by SNS/CF on an as-needed basis, and is included in current budget estimates.

5.3.5.2 Facility Operations

Operations Engineers (2): Mechanical, Electrical: Two engineers will direct SNS facility maintenance, and coordinate the effort of engineers, and ORNL support.

5.3.6 Plant Maintenance and Operations

5.3.6.1 Space Charge for CLO

The estimate for space charge is based on the assumption that only the CLO will be subject to space charge beginning in FY 07. It also assumes that the portions of the CLO that are shelled out at the end of the FY 04 will not be built-out by FY 07. Although the gross square footage of the built-out space is 193,849 ft^2, only the net square footage of 116,309 ft^2 is non-public space, approximately 60% of the total, and is subject to an ORNL space charge. All the net square footage is conditioned space; i.e., has heat and air conditioning. The current FY 04 ORNL space charge for conditioned space is $21.60/sf without overhead.

5.3.6.2 Operating Spares

An initial complement of spare parts and the procurement of replacement spares is a budgeted item. FY 07 is the last year for purchasing an initial complement of spares and accounts for roughly 65% of the total spares budget. The remaining 35% is funding for replacement of spares consumed in the ongoing maintenance of the facilities.

5.3.6.3 Materials, Supplies, Consumables and Travel

Material and related consumables will be required in FY 07 to support routine maintenance, incidental craftwork, spares, and to provision an initial bench stock and SNS stores facility. Additional materials and consumables have been budgeted to ensure that SNS maintains a high reliability rate. Bench stock and stores material will be coordinated with "just-in-time" delivery of materials for rapid problem repair. Material and consumables for maintenance and facility operation are estimated at 20% of the burdened craft labor cost based on a study relating labor cost and associated materials. Items in this category include conduit, pipe, cable, treatment chemicals, nuts, bolts, screws, filters, paper, janitorial supplies and other routine items necessary to support the assigned craft.

The estimate for material and supplies is based on 10% of the fully burdened professional and support staff labor cost. These items would likely include office supplies such as paper, copier support, janitorial supplies, etc.

An estimate of the cost of travel is based on 3% of the fully burdened professional staff labor cost.

5.3.6.4 Capital Equipment

Capital equipment funding will be required to procure various items of equipment that are needed to support the CF craft assigned to the SNS facilities. For the purposes of funding there are several groups of equipment based on portability and frequency of need. Large, infrequently used equipment, such as large presses, fixed electric welders, lathes, milling machines, etc., exist at ORNL and are not included in this

budget. There is also a group, such as forklifts, dollies, mobile platforms and scaffolds, mobile manlifts, etc., that will be used frequently at the job site but are not practical to transport to the site. There is still another group, such as table saws, grinders, special mechanical equipment, etc., that will be needed to minimally equip a general purpose shop that will be located on the SNS. The capital equipment budget for this and future years will be used to procure equipment in the latter two groups.

5.3.6.5 Grounds and Equipment Subcontracts

Service contracts will be used to maintain specialized equipment and for warrantee support including servicing the cooling tower, providing and servicing the deionized water resin tanks, providing chiller maintenance, providing air compressor maintenance, landscape maintenance and the like.

5.3.6.6 Electric Power

The estimate for the electric utilities and maintenance cost is based on an agreement between the Tennessee Valley Authority (TVA) and the Department of Energy (DOE) which covers the cost of power, a TVA special facilities charge which is a reimbursement for TVA provided equipment and maintenance of the primary substation. The total site load is composed of the accelerator; approximately 60% of the total load; general site and plant loads, comprising 30% of the total load; and the liquid helium (LHe) refrigerator. The cost estimate for electrical power is based on the accelerator operational goal of 5000 hours per year, a 60% diversity factor for the site connected loads and the LHe refrigerator operating essentially full time. Negotiations are in progress for future TVA rates. In addition to the cost of power, the special facility charge and TVA maintenance, this item also includes the cost of ORNL maintenance of the distribution system on site and the Tennessee use tax on purchased power.

5.3.6.7 Utilities

CF has budgeted for the following utility cost: natural gas, water and the distributed cost of other miscellaneous utilities used at the site. The estimates of consumption are based on the current SNS configuration; unit prices are based on current ORNL FY 04 average rates.

5.3.6.8 Wastes

The waste stream consists of various liquid and solid wastes originating from CF. Wastes originating from other divisions are budgeted in those divisions. The CF estimate is based on information from the Waste Management Plan.

APPENDIX A.

LABOR COST	**A-1**
OVERHEAD RATES	**A-1**
CRAFT LABOR SUMMARY	**A-2**
XFD BUDGET TABLE	**A-3**
ASD BUDGET TABLE	**A-4**
CSFO BUDGET TABLE	**A-5**
MANAGEMENT BUDGET TABLE	**A-6**
SUMMARY BUDGET TABLE	**A-7**

SNS FY 07 Operations Budget

Using FY 04 rates with full lab overhead

Division	FTE	Labor Cost	M&S	Additional Matls, Services, Etc.	Travel	Total Direct Costs	Overhead Costs	Overhead Funding	Total Cost
Experimental Facilities	179	20,147	3,587	16,077	768	40,579	10,651		51,230
Accelerator Systems	201	21,589	4,245	19,685	559	46,077	13,112		59,189
Site Operations	58	6,850	1,444	25,862	154	34,309	3,473		37,781
ALD Office	9	1,407	199	0	107	1,713	613	-969	1,358
Total SNS	447	49,993	9,474	61,623	1,588	122,678	27,849	-969	149,558
Escalate Direct Costs to FY 07						10,428			10,428
Total SNS									159,986

Note: Escalation is 2.9% per year (8.5%)

APPENDIX A. RATES FOR FIRST YEAR OPERATIONS BUDGET PLANNING

Labor Cost

COR Category	FY 04 Wage Pool Planning Rates	FY 02 SNS Org Burden Planning Rate	FY 04 Labor Cost per Hour	Average SNS Hours/Yr	Labor Cost	Rounded $ K
Admin 1	$33.83	$5.00	$38.83	1,831	71,098	71
Admin 2	$44.19	$5.00	$49.19	1,831	90,067	90
Admin 3	$57.66	$5.00	$62.66	1,831	114,730	115
Admin 4	$76.67	$5.00	$81.67	1,831	149,538	150
Clerical / Secr 1	$27.07	$5.00	$32.07	1,831	58,720	59
Clerical / Secr 2	$35.49	$5.00	$40.49	1,831	74,137	74
Crafts 1-SNS	$28.78	$5.00	$33.78	1,831	61,851	62
Crafts 2-SNS	$34.23	$5.00	$39.23	1,831	71,830	72
Crafts 3-SNS	$40.55	$5.00	$45.55	1,831	83,402	83
Crafts 4-SNS	$14.76	$5.00	$19.76	1,831	36,181	36
Crafts 1-F&O*	$28.78	$23.38	$52.16	1,831	95,505	93
Crafts 2-F&O*	$34.23	$23.38	$57.61	1,831	105,484	103
Crafts 3-F&O*	$40.55	$23.38	$63.93	1,831	117,056	115
Crafts 4-F&O*	$14.76	$23.38	$38.14	1,831	69,834	67
Mgmt 1	$47.47	$5.00	$52.47	1,831	96,073	96
Mgmt 2	$67.66	$5.00	$72.66	1,831	133,040	133
Mgmt 3	$86.57	$5.00	$91.57	1,831	167,665	168
Mgmt 4	$104.61	$5.00	$109.61	1,831	200,696	201
Mgmt 5	$122.42	$5.00	$127.42	1,831	233,306	233
Mgmt 6	$142.84	$5.00	$147.84	1,831	270,695	271
S&T 1	$44.88	$5.00	$49.88	1,831	91,330	91
S&T 2	$57.49	$5.00	$62.49	1,831	114,419	114
S&T 3	$71.58	$5.00	$76.58	1,831	140,218	140
S&T 4	$85.08	$5.00	$90.08	1,831	164,936	165
S&T 5	$100.01	$5.00	$105.01	1,831	192,273	192
S&T 6	$123.41	$5.00	$128.41	1,831	235,119	235
Student	$26.69	$5.00	$31.69	1,831	58,024	58
Support Engr 1	$61.66	$5.00	$66.66	1,831	122,054	122
Tech Exempt A	$46.70	$5.00	$51.70	1,831	94,663	95
Tech Exempt B	$56.15	$5.00	$61.15	1,831	111,966	112
Tech Exempt C	$64.96	$5.00	$69.96	1,831	128,097	128
Tech Exempt D	$78.78	$5.00	$83.78	1,831	153,401	153
Technician	$36.96	$5.00	$41.96	1,831	76,829	77

Assumptions:
Uses ORNL projected wage pool rates revised June, 2003.
Assumes SNS Org Burden rate for FY 2002
Assumes F&O Org Burden rate for FY 2003*
Uses ORNL FY 03 Overhead Rates for routine lab work

Other Overhead Rates
Using FY 04 ORNL Rates for Routine Lab Work

Effort	43.60%
Materials	16.60%
Travel	9.10%
Onsite Subcontracts	43.60%
Offsite Subcontracts	3.20%

Assume Power is exempt from overhead
Assume utilities receive full lab overhead of 43.6%

Space Charge

Conditioned	$21.60/sq ft
Unconditioned	$7.20/sq ft

Table 10. Management and Support FY 07 Ops

Using FY 04 rates with full lab overhead

Function	Wage Pool	FTE	Annual Cost / FTE	Labor Cost	M&S	Additional M&S	Travel	Overhead	Total Cost
Management	Management 6	2	271	542	78		70	236	926
Publications	Admin 2	1	90	90	13		4	39	146
Business	Management 3	1	168	168	24		7	73	273
ESH&Q	Management 4	1	201	201	29		9	88	326
	S&T 3	1	140	140	20		6	61	227
Human Resources	Management 2	1	133	133	19		6	58	216
Clerical	Clerical 1	1	59	59	8		3	26	96
	Clerical 2	1	74	74	11		3	32	120
Total		**9**		**1,407**	**199**	**0**	**107**	**613**	**2,329**
Available from ALD Overhead Sources									969
Ops Funded									1,360

M&S = 10% of professional staff burdened labor and 20% of craft and technicians burdened labor

Travel = 3% of professional staff burdened labor

Additional M&S

IT

Hardware	$894K
Software	213K
Training	49K
Total	$1,156K

Additional M&S

MIS

Software	$ 182K
Training	36K
Total	$ 218K

Additional M&S

DCC

Software	$ 38K

Table 8. Accelerator Systems Division FY 07 Ops

Using FY 04 rates with full lab overhead

Function	Wage Pool	FTE	Annual Cost / FTE	Labor Cost	M&S	Additional Matls, Services, Etc.	Travel	Overhead	Total Cost
Division Management									
Division Manager	Management 5	1	233	233	33		10	102	378
Managers	S&T 5	1	192	192	28		8	84	312
Managers	S&T 6	1	235	235	34		10	102	381
ES&H	S&T 2	1	114	114	16		5	50	185
Finance Officer	Admin 2	1	90	90	13		4	39	146
QA	Admin 3	1	115	115	17		5	50	187
Clerical	Clerical 1	2	59	118	17			51	186
Procurement Specialist	Admin 2	1	90	90	13		4	39	146
HR Specialist	Admin 3	1	115	115	17		5	50	187
Accelerator Physics									
Group Leader	S&T 5	1	192	192	28		8	84	312
Physicists	S&T 2	9	114	1,026	147		44	447	1,665
Physicists	S&T 4	2	165	330	47		14	144	535
Physicists	S&T 5	1	192	192	28		8	84	312
Clerical	Clerical 1	1	59	59	8			26	93
Operations*									
Ops Manager	S&T 5	1	192	192	28		8	84	312
Ops Coordinators	S&T 3	2	140	280	40		12	122	454
Chief Operators	Management 1	6	96	576	165			251	993
Operators	Technician	12	77	924	265			403	1,592
Clerical	Clerical 1	1	59	59	8			26	93
Deputy Ops Manager	S&T3	1	140	140	20		6	61	227
Ion Source									
Physicists	S&T 3	1	140	140	20		6	61	227
Physicists	S&T 4	1	165	165	24		7	72	268
Technicians	Technician	2	77	154	44			67	265
Linac RF Group									
Section Head	S&T 5	1	192	192	28		8	84	312
Engineers	S&T 3	5	140	700	101		30	305	1,136
Engineers	S&T 4	2	165	330	47		14	144	535
Technicians	Technician	12	77	924	265			403	1,592

Table 8. Accelerator Systems Division FY 07 Ops

Using FY 04 rates with full lab overhead

Function	Wage Pool	FTE	Annual Cost / FTE	Labor Cost	M&S	Additional Matls, Services, Etc.	Travel	Overhead	Total Cost
Clerical	Clerical 1	0.5	59	30	4			13	47
Cryo-module									
Physicists	S&T 3	1	140	140	20		6	61	227
Engineers	S&T 2	1	114	114	16		5	50	185
Engineers	S&T 3	1	140	140	20		6	61	227
Technicians	Technician	6	77	462	133			201	796
Clerical	Clerical 1	0.5	59	30	4			13	47
Cryogenics									
Engineers	S&T 3	2	140	280	40		12	122	454
Engineers	S&T 4	1	165	165	24		7	72	268
Technicians	Technician	6	77	462	133			201	796
Clerical	Clerical 1	0.5	59	30	4			13	47
Power Supply									
Physicists	S&T 4	1	165	165	24		7	72	268
Physicists	S&T 5	1	192	192	28		8	84	312
Engineers	S&T 2	1	114	114	16		5	50	185
Engineers	S&T 3	4	140	560	80		24	244	909
Technicians	Technician	6	77	462	133			201	796
Clerical	Clerical 1	0.5	59	30	4			13	47
Field Engineers	Tech Exempt A	2	95	190	55			83	327
Mechanical									
Group Leader	S&T 5	1	192	192	28		8	84	312
Engineers	S&T 2	2	114	228	33		10	99	370
Engineers	S&T 3	2	140	280	40		12	122	454
Engineers	S&T 4	4	165	660	95		28	288	1,071
Designers	S&T 1	2	91	182	26		8	79	295
Designers	Tech Exempt B	2	112	224	32		10	98	363
Technicians	Tech Exempt B	3	112	336	96			146	579
Technicians	Technician	4	77	308	88			134	531
Clerical	Clerical 1	1	59	59	8			26	93
Vacuum									
Engineers	S&T 2	1	114	114	16		5	50	185
Engineers	S&T 3	1	140	140	20		6	61	227

Table 8. Accelerator Systems Division FY 07 Ops

Using FY 04 rates with full lab overhead

Function	Wage Pool	FTE	Annual Cost / FTE	Labor Cost	M&S	Additional Matls, Services, Etc.	Travel	Overhead	Total Cost
Technicians	Technician	6	77	462	133			201	796
Survey and Alignment									
Engineers	S&T 2	3	114	342	49		15	149	555
Engineers	S&T 4	1	165	165	24		7	72	268
Technicians	Technician	4	77	308	88			134	531
Diagnostics									
Physicists	S&T 3	1	140	140	20		6	61	227
Physicists	S&T 4	1	165	165	24		7	72	268
Engineers	S&T 2	1	114	114	16		5	50	185
Engineers	S&T 3	3	140	420	60		18	183	682
Technicians	Technician	2	77	154	44			67	265
Field Engineers	Tech Exempt B	2	112	224	64			98	386
Controls									
Group Leader	S&T 5	1	192	192	28		8	84	312
Engineers	S&T 3	9	140	1,260	181		54	549	2,045
Engineers	S&T 4	4	165	660	95		28	288	1,071
Technician	Technician	6	77	462	133			201	796
Clerical	Clerical 1	1	59	59	8			26	93
Personnel Protection									
Engineers	S&T 3	2	140	280	40		12	122	454
Technicians	Technican	2	77	154	44			67	265
Subtotal ASD Division		**178**		**19,727**	**3,778**	**0**	**553**	**8,607**	**32,657**
Health Physics	Technicians	4	77	308	88			134	531
Industrial Hygienist	Technician	1	77	77	22			34	133
Post Docs & Students									
Post Doc	S&T 2	1	114	114	16		5	50	185
Post Doc	Subcontractor	1	75	75	11			0	86
Student	Student	4	73	292	42			0	334
Additional Purchased						660		109	769

Table 8. Accelerator Systems Division FY 07 Ops

Using FY 04 rates with full lab overhead

Function	Wage Pool	FTE	Annual Cost / FTE	Labor Cost	M&S	Additional Matls, Services, Etc.	Travel	Overhead	Total Cost
Services									
Craft Labor	Craft 3	12	83	996	286			434	1,716
Total ASD and Support		**201**		**21,589**	**4,245**	**660**	**559**	**9,369**	**36,411**
Replacement spares and consumables						**8,596**		1,384	**9,980**
Lab Capital Equipment						**1,500**		241	**1,741**
Lab and Shop Supplies						**1,786**		161	**1,947**
Cryogens						**800**		129	**929**
Waste Disposal						**343**		57	**400**
Accelerator Cap Equip						**6,000**		1,771	**7,771**
Grand Total ASD		**201**		**21,589**	**4,245**	**19,685**	**559**	**13,112**	**59,189**

M&S = 10% of professional staff burdened labor and 20% of craft and technicians burdened labor
Travel = 3% of professional staff burdened labor

Table 11. Complex Facility and Support Organization FY 07 Ops

Using FY 04 rates with full lab overhead

Function	Wage Pool	FTE	Annual Cost / FTE	Labor Cost	M&S	Additional Matls, Services, Etc.	Travel	Overhead	Total Cost
CFSO									
CF Manager	S&T 5	1	192	192	28		8	84	312
Secretary	Clerical 1	1	59	59	8			26	93
Project Engineer	S&T 3	1	140	140	20		6	61	227
Environmental Engineer	S&T 3	1	140	140	20		6	61	227
Finance Officer	Admin 2	1	90	90	13		4	39	146
Records Mgt/DCC									
DCC	Management 2	1	133	133	19	38	5	64	259
DCC	Clerical 1	1.5	59	89	13		4	39	144
Technical Information Systems									
Tech Info Systems	Management 4	1	201	201	29	1,156	9	105	1,500
Tech Info Systems	S&T 2	4.5	114	513	74		22	224	832
Tech Info Systems	S&T 3	7	140	980	141		42	427	1,590
Plant Engineering									
CAD Operator	S&T 2	1	114	114	16		5	50	185
Plant Engineers	S&T 3	3	140	420	60		18	183	682
Maintenance & Site Support									
Project Leaders	S&T 1	2	91	182	26		8	79	295
Elect. Operations Engineer	S&T 3	1	140	140	20		6	61	227
Mech. Operations Engineer	S&T 3	1	140	140	20		6	61	227
Resource Manager	S&T2	1	114	114	16		5	50	185
Crafts	Craft 1 F&O	6	93	558	160			243	962
Crafts	Craft 3 F&O	23	115	2,645	760			1,153	4,558
Space Charge for CLO						3,779		0	3,779
Operating Spares						459		41	500
Materials/Consumables						1,065		95	1,160
Capital Equipment/Tools						494		6	500
Grounds Subcontract						97		3	100
Equipment Subcontracts						500		0	500
Power						13,976		0	13,976
TVA Special Fac. Charge						820		0	820
TVA Maintenance						280		0	280
ORNL Maint of Primary System						223		37	260
Use tax on power						1,258		0	1,258
Natural Gas						1,166		191	1,357
Water						255		42	297
Other Utilities						17		3	20
Solid and Sanitary Waste						279		46	325
Total		**58**		**6,850**	**1,444**	**25,862**	**154**	**3,473**	**37,781**

M&S = 10% of professional staff burdened labor and 20% of craft and technicians burdened labor
Travel = 3% of professional staff burdened labor

Table 6. Experimental Facilities Division FY 07 Operations

Using FY 04 rates with full lab overhead

Function	Wage Pool	FTE	Annual Cost / FTE	Labor Cost	M&S	Additional Matls, Services, Etc.	Travel	Overhead	Total Cost
Division Management									
Division Manager	Management 5	1	233	233	33		60	102	428
Finance Officer	Admin 2	1	90	90	13		4	39	146
ES&H Specialist	S&T 2	1	114	114	16		5	50	185
QA Specialist	Admin 3	1	115	115	17		5	50	187
Clerical	Clerical 1	1	59	59	8			26	93
ProcurementSpecialist	Admin 2	1	89	89	13		4	39	144
HR Specialist	Admin 3	1	115	115	17		5	50	187
Instrument Systems									
Manager	S&T 5	1	192	192	28		8	84	312
Project Admin	Management 2	1	133	133	19		6	58	216
Group Admin	S&T 3	2	140	280	40		12	122	454
Mechanical Engineer	S&T 4	4	165	660	95		28	288	1,071
Electrical Engineer	S&T 4	4	165	660	95		28	288	1,071
Scientist	S&T 4	23	165	3,795	545		163	1,655	6,158
Software	S&T 3	9	140	1,260	181		54	549	2,045
Scientific Assoc	Tech Exempt A	23	95	2,185	314		94	953	3,546
Designer	S&T 2	4	114	456	65		20	199	740
Technician	Technician	19	77	1,463	420			638	2,521
Clerical	Clerical 1	2	59	118	17			51	186
Replacement Spares						917		74	991
Consumables						459		42	501
Instrument Upgrades						1,668		332	2,000
Instrument Development						4,002		498	4,500
Target Systems									
Manager	S&T 5	1	192	192	28		8	84	312
Engineer/Scientist	S&T 4	5	165	825	118		36	360	1,339
Draft/Designer	S&T 2	1	114	114	16		5	50	185
Clerical	Clerical 1	1	59	59	8			26	93
Spares						4,768		415	5,183
Consumables						183		17	200

Table 6. Experimental Facilities Division FY 07 Operations

Using FY 04 rates with full lab overhead

Function	Wage Pool	FTE	Annual Cost / FTE	Labor Cost	M&S	Additional Matls, Services, Etc.	Travel	Overhead	Total Cost
Target Systems Development									
Engineer/Scientist	S&T4	7	165	1,155	166		50	504	1,874
Draft/Designer	S&T2	1	114	114	16		5	50	185
Software licenses						129		21	150
Target Development						1,834		166	2,000
User Coordination									
Manager	Mgmt 2	1	133	133	19		6	58	216
Assistant	Mgmt 1	1	96	96	14		4	42	156
Data Base Controller	S&T 1	1	91	91	13		4	40	148
Training Coordinator	S&T 1	1	91	91	13		4	40	148
Proposal Admin	S&T 1	1	91	91	13		4	40	148
User Admin	S&T 1	1						Funded by CNMS	
Clerical	Clerical 1	1	59	59	8			26	93
Conf. & Publications						107		18	125
User Admin Supt						52		9	60
Travel Support							97	3	100
Security Access Fees						21		4	25
Exp. Fac. Ops									
Manager	S&T 5	1	192	192	28		8	84	312
Deputy	S&T 4	1	165	165	24		7	72	268
Waste Mgt Engr	S&T 3	1	140	140	20		6	61	227
Mod/Cryo Engineer	S&T 3	1	140	140	20		6	61	227
I&C Engineer	S&T 3	1	140	140	20		6	61	227
Lead Techs	S&T 2	2	114	228	33		10	99	370
Ops Techs	Technician	6	77	462	133			201	796
I&C Techs	Technician	2	77	154	44			67	265
Nuc. Fac. Techs	Technician	10	77	770	221			336	1,327
User Tech Support	Technician	6	77	462	133			201	796
Health Phys. Techs	Technician	6	77	462	133			201	796
Facility Space Mgr	S&T 3	1	140	140	20			61	221
Safety Analyst	S&T 3	1	140	140	20			61	221
Training Coordinator	Admin 2	1	90	90	13			39	142
Data Base Controller	S&T 1	1	91	91	13			40	144

Table 6. Experimental Facilities Division FY 07 Operations

Using FY 04 rates with full lab overhead

Function	Wage Pool	FTE	Annual Cost / FTE	Labor Cost	M&S	Additional Matls, Services, Etc.	Travel	Overhead	Total Cost
Crafts	Craft 3	12	83	996	286			434	1,716
Crafts	Craft 1	1	62	62	18			27	107
Clerical	Clerical 1	1	59	59	8			26	93
Training						349		11	360
Waste Disposal						1,569		257	1,826
Personnel Protection									
Engineers	S&T 3	1	140	140	20		6	61	227
Technicians	Technician	1	77	77	11			34	122
Training						19		1	20
Grand Total XFD		**179.0**		**20,147**	**3,587**	**16,077**	**768**	**10,651**	**51,230**

M&S = 10% of professional staff burdened labor and 20% of craft and technicians burdened labor

Travel = 3% of professional staff burdened labor

APPENDIX B.

TECHNICAL INFORMATION SYSTEMS **B-1**
ENVIRONMENT, SAFETY, HEALTH AND QUALITY **B-2**

APPENDIX B-1
TECHNICAL INFORMATION SYSTEMS

SOFTWARE RESPONSIBILITIES

- System Requirements Definition
- Data Model Development
- Software Development
- Software Test, Acceptance, and Implementation
- Software Documentation
  - Requirements Document
  - User Procedures/Training Guides
  - Application Flow Charts
  - Software QA
- Software Maintenance/Upgrades
- System Software Administration
- Web pages development/maintenance
- Software licensing programs
- Interface with ORNL on computing initiatives

CURRENTLY SUPPORTED TASKS THAT WILL CONTINUE IN FUTURE

- Enterprise Database Model (Single Source for all SNS Data)
- ProjectWise (Document/Drawing Management System)
- IntraLink (Drawing release system)
- Equipment Receiving/Tracking/Bar Coding
- Data Stream—Maintenance Management System
- EPICs
- Procurement systems
- Corrective Actions Tracking system
- Electronic Log book

FUTURE PROJECTS AND PRODUCTS

- Change control system for maintaining drawings configuration control
- WEB based procedures
- Stockroom system for lab
- Safety inspections action tracking
- Conference support (Web application for reservations, abstract submittal)
- Circuit breaker panels labeling system
- User Support
  - Entry/Scheduling of experiments
  - Scientific Data Management
- Integrated Ops System (waste generation, location of hazardous materials, training, etc.)

COMPUTER HARDWARE RESPONSIBILITIES

Security

- Monitor network
  - Intrusion detection
  - Scanning of computer systems for vulnerabilities
- Monitor servers
  - Reviewing logs
  - Monitoring usage
- User security training
- User security threats (internal hackers)
- Virus
  - Monitor new virus warnings
  - Deal with viruses introduced at SNS
  - Keep virus scanners installed and up-to-date

Users Support

- Education of users
- Computer Specification
- Personal Digital Assistants and other type devices
- Cell phones
- Pagers
- Computer installations
  - Implementation of system management software to speed up computer installations
- Ongoing desktop support
- Computer relocation
- Computer decommissioning
  - Removal of computers
  - Security cleaning of computers
  - Salvage usable parts for other users
- Co-ordination of ORNL/UCAMS account creation and management for SNS staff
- Visitor support
- Mail systems
  - Exchange/Outlook support
- Mailing lists—Creation and partial maintenance of many SNS mailing lists (some maintenance is shared with proper SNS admin. staff.)
- Maintain a working knowledge of all project supported software. Including, but not limited to:
  - Operating Systems
    - Microsoft Windows server and desktop operating systems
    - Linux
    - Unix (Solaris for Sun Microsystems)
  - Microsoft Office Suite products
  - ProjectWise
  - Data Stream
  - Adobe Acrobat
  - Collaboration tools (Sharepoint, Netmeeting, Placeware)
  - Compression tools (Winzip)

- Photoshop
- etc.

File Storage

- Servers
  - Windows file servers for user files
  - Windows Internet Information Server (MIS support)
  - Linux file server and web server (1)
    - IT
  - Oracle servers (2 UNIX servers—1 Oracle, 1 OraWeb)
  - CAD servers
  - Media servers
  - Terminal servers
- Storage area network to support file servers
  - 5 Terabyte storage minimum
    - Assuming today's drives we will have a drive failure every 6 days. So, redundancy and fail safe capability is needed. (Assumed MTBF = 20,000 and 36 GB/drive)
- Backup Systems
  - Backup of all servers
  - Storage of backup tapes
  - Restoration of deleted files
  - Periodic checking of backup integrity
  - Tape backup barcode management

Communications

- Data Communications
  - Cable plant >1100 network Enterprise network connections at SNS
  - Switches >20 network switches
  - Routers
    - 701 Scarboro—1 for SNS
  - Wireless network
    - 802.11 b/g network throughout SNS facility
  - Virtual Private Network
  - Firewall
- Telecommunications
  - Design of SNS site systems
- Videoconferencing
  - Scheduling
  - Setup of VCs
  - Attending requested VCs
  - Software updates
  - Hardware upgrades

Output Capability

- Printers
  - Maintain printer servers

  - Maintain printers
  - Specify printers
  - Add printers to user machines
- Projection equipment and smartboards

Application Support

- Data Stream
- Projectwise
- Lynx—image database
- CAD systems
  - ProE/ProIntralink
  - AutoCAD
  - Microstation
- Review support
  - Audio/visual support for conference rooms
  - Computer support for Review setup
  - Maintain laptop support for reviewers
  - Support for reviewers and visitors during the review on their own personal computers.
- Point of contact and support for enabling IT infrastructure for subcontractors
- Integrate SNS systems with laboratory and DOE systems

Special Systems

- Computer room
  - Maintain computer room racks and hardware.
  - Monitor computer room temperature
  - Manage access to the computer room and network closets

FUTURE

- Keep abreast of latest technologies for all of the above systems. This includes learning new systems others provide and new systems we are designing and implementing.
  - Servers
  - Desktop machines
  - PDAs
  - Monitors
  - Home systems
  - Laptops
  - Printers
  - Virtual private networks
  - Videoconferencing
  - Communication systems

APPENDIX B-2

ENVIRONMENT, SAFETY, HEALTH, AND QUALITY

The SNS Environment, Safety, Health and Quality (ESH&Q) organization will consist of an ESH&Q Manager, a Safety Documentation leader, and a shared administrative staff. The ESH&Q organization will establish ESH&Q policy for the SNS, verify compliance with regulatory compliance, interface with the DOE and external regulators, maintain all required permits and documentation, and determine the ESH&Q implications of changes in SNS operations. ESH&Q support services provided to and funded by other SNS organizations will be directed by the SNS ESH&Q manager.

ESH&Q SUPPORT SERVICES

The SNS will operate as a Health Physics (HP) Complex. The SNS HP complex will be staffed to provide 24/7 service to ensure compliance with 10 CFR 835. Certified HP staff will be assigned to the SNS by the ORNL Office of Radiation Protection, with concurrence by the SNS ESH&Q Manager. Staff will be assigned to portions of the SNS, but resources will be shared between activities for efficiency. HP staff will evaluate the radiation hazards associated with specific activities, perform surveys of areas and materials, certify wastes, evaluate the potential doses related to changes in operations or facilities, maintain and review exposure records, and recommend changes in activities, personnel assignments, shielding, or equipment.

Certified Industrial Hygiene and Industrial Safety (IH/IS) staff will be provided to each SNS organization. The individuals will be responsible for providing safety and health support and guidance to staff, evaluating and documenting workplace hazards, and supporting ES&H training. Staff will have expertise in hazards associated with specific SNS operations, but will provide general support across all functions as required.

Environmental compliance staff will develop and maintain SNS air and water permits, evaluate monitoring data, assist in certification of wastes, and ensure compliance with National Environmental Policy Act (NEPA) requirements.

Quality Assurance staff will be provided to the SNS divisions. The individuals will be responsible for providing quality support to staff and management, evaluating documentation and programs, and quality services. Staff will be involved in program reviews, procurement activities, vendor evaluations, and software support.

Staffing:

ES&H Manager	1 FTE
Safety documentation lead	1 FTE
Administrative staff (shared)	0.5 FTE
IH/IS	2 FTE
Environmental	1 FTE
Quality	2 FTE
Complex leader	1 FTE
HP staff	1 FTE
HP Technicians	7 FTE

APPENDIX C.

THE SPALLATION NEUTRON SOURCE: OPERATIONAL ASPECTS AND RELIABILITY IN THE TRANSITION FROM COMMISSIONING TO FULLY COMMITTED USER OPERATION

SNS 102000000-TR0004 - R00

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

SPALLATION NEUTRON SOURCE

A U.S. Department of Energy Multilaboratory Project

Argonne National Laboratory • Brookhaven National Laboratory • Thomas Jefferson National Accelerator Facility • Lawrence Berkeley National Laboratory • Los Alamos National Laboratory • Oak Ridge National Laboratory

SNS

Discussion Paper

February 6, 2002

Thom Mason/Norbert Holtkamp

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

Introduction

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

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

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

Operation Mode for the SNS

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

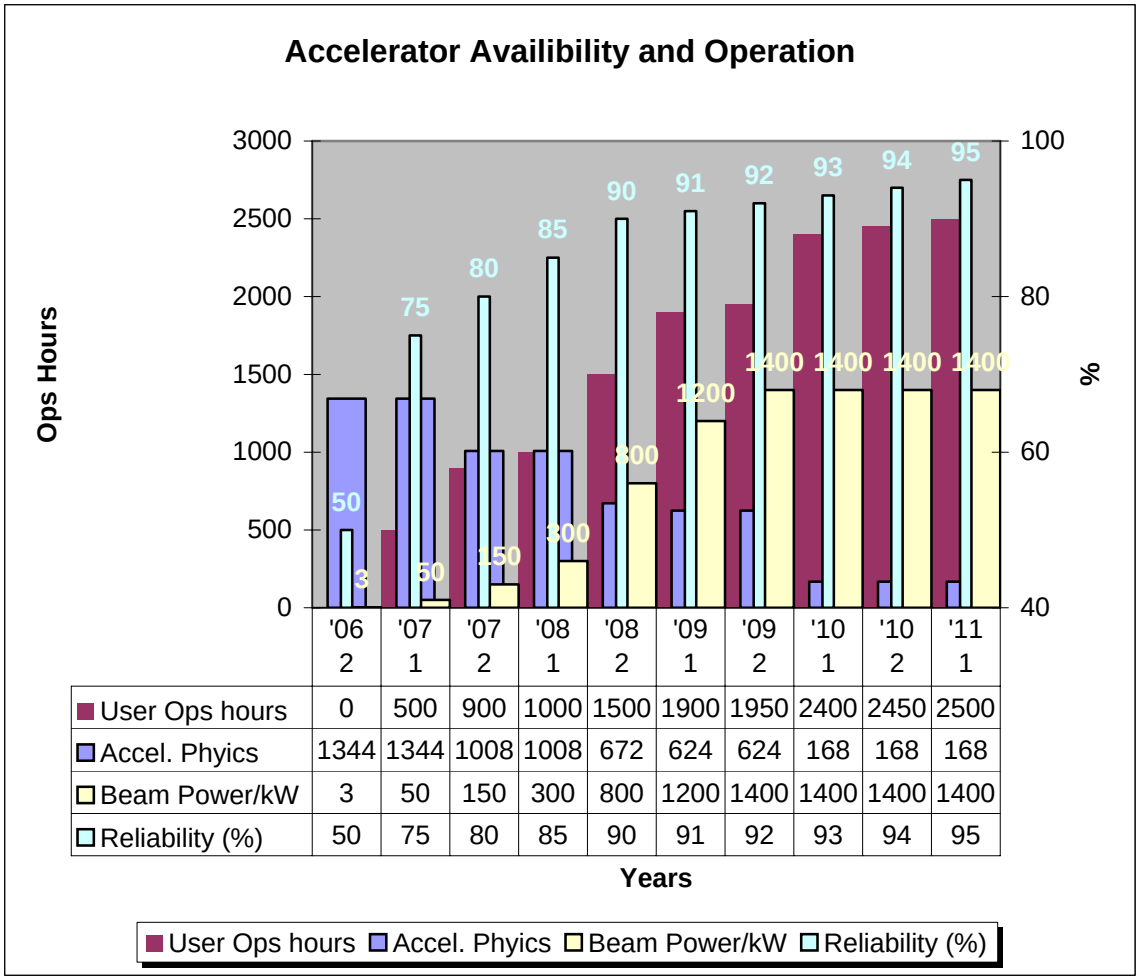
In addition, driven by the lifetime of the target, additional downtime is planned to exchange the liquid mercury vessel of the target.

Activity		Hours	%Up	%Down
One week run cycle	168			
One shift of PM per week		8	4.7%	
Two Recovery/AP Shifts	16	9.5%		

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

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

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



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

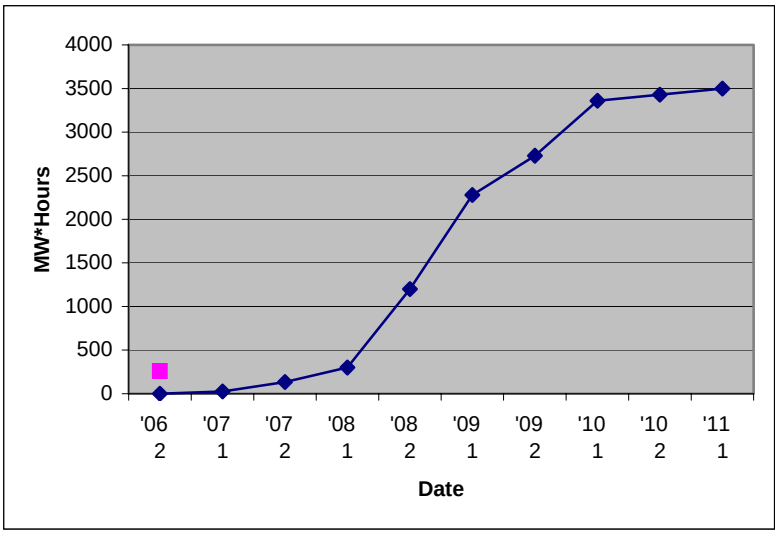
The gradual increase for the three user parameters is based on the presently foreseen program in which the commissioning of the instruments, as well as the continuous development, construction and installation of instruments, will require significant time especially in the first two years of operation.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

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

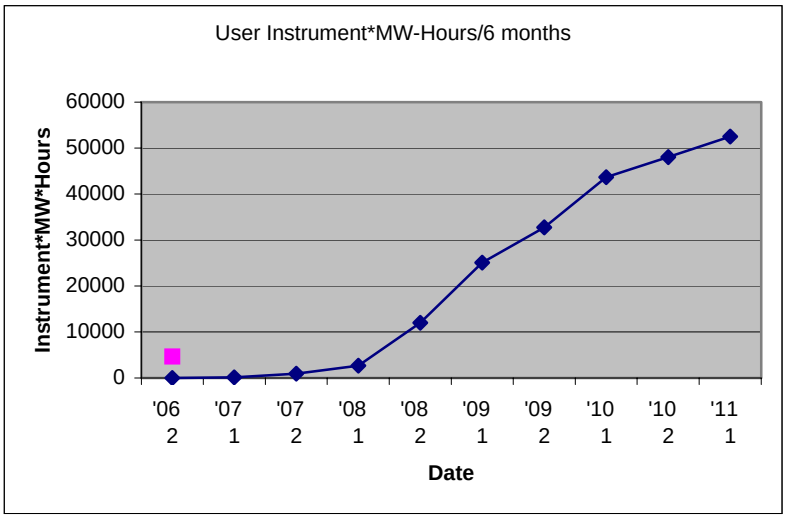
Once the ORR is complete, the facility will be able to initiate high power operation. The first six months of high power operation will also be used by facility staff for test experiments and debugging instrument control and data analysis software. The beam power should be sufficient to permit testing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

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

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



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



Summary

A multiyear plan for the Spallation Neutron Source has been described in which the ultimate goals of the facility (beam power, availability, and reliability) can gradually be achieved over a time period of approximately two and a half years. The plan allows for installation, testing, and commissioning of instruments as well as for careful commissioning for the ultimate power on a one of a kind liquid mercury

target. It should provide the basis for a successful initiation of research at SNS and the basis for planning to achieve this.

APPENDIX D.

A BEAM POWER UPGRADE TO 3 MW AND BEYOND FOR THE SNS COMPLEX

SNS 104000000-AC0001 - R00

A Beam Power Upgrade to 3 MW and Beyond for the SNS Complex

SPALLATION NEUTRON SOURCE

A U.S. Department of Energy Multilaboratory Project

Argonne National Laboratory • Brookhaven National Laboratory • Thomas Jefferson National Accelerator Facility • Lawrence Berkeley National Laboratory • Los Alamos National Laboratory • Oak Ridge National Laboratory

SNS

1. EXECUTIVE SUMMARY

The Spallation Neutron Source (SNS) employs a linear accelerator (linac) to produce a 1-ms-long negative-hydrogen ion (H^-) beam 60 times per second and accelerate it to 1 GeV, resulting in a total beam power of 1.4 MW. The H^- beam is converted to protons and is then compressed to 700 ns in a 248-m-circumference proton accumulator ring. The SNS baseline accelerator delivers its 1.4-MW of proton beam power to a mercury target, where neutrons are generated by the spallation process. The baseline design allows for increased beam power following the recommendations of the BESAC subpanel (Russell panel) that provided the input to the initial Level 0 baseline for SNS. This document summarizes a 3-MW upgrade program that makes use of existing margins designed into the facility to create an ultimate capability of up to 5 MW. This plan builds upon recent progress in SNS development programs to improve superconducting cavity performance in the linac and design changes to reduce intensity thresholds in the accumulator ring. Because key elements of the upgrade rely on replicating existing designs, the upgrade is positioned for aggressive deployment, with construction starting in FY 06 and finishing early in FY 09. The total cost of the upgrade program is 110 $M (i.e., current year dollars with contingency but no escalation). The increased beam power can also be extracted to a potential second target station, thereby widening the suite of SNS instruments and the scope of science that can be studied.

2. SCIENCE JUSTIFICATION

Because the vast majority of neutron-scattering experiments are limited, even modest improvements in source intensity can lead to scientific measurements that were previously out of reach. A factor of 2 or 3 increase in power will enable practical study of smaller samples and real-time studies at shorter time scales. It will also allow a modest increase in resolution on most instruments and will allow more experiments to take advantage of the highest resolution available on each instrument. Since many such experiments are at the scientific frontier, such a power increase would immediately make a significant increase in the scientific productivity of SNS. Another benefit would be an increased volume of research supported because of faster throughput of already feasible experiments. Further increases in scientific capabilities can be expected in the longer term, as instruments optimized to exploit these higher powers come on line. In addition, by providing beam power to support a second target station, a Long-Wavelength Target Station (LWTS), the power upgrade facilitates a significant expansion of capacity and substantial performance gains for long wavelength applications of neutron-scattering techniques. Although the LWTS can be implemented without the power upgrade, its power level, and hence scientific performance, would be significantly curtailed if its operation were to come at the expense of the High Power Target Station (HPTS). Consequently, the science case contained in a separate LWTS proposal should be viewed as an important element of the scientific justification for the power upgrade. This report contains a description of the impacts of higher power at HPTS, which is the second element of the power upgrade justification.

The SNS instrument designs being developed have been quantitatively benchmarked at the 1.4-MW performance level. In many instances, with the new performance level offered by a megawatt-class spallation source the instrumentation approaches count rates that will support single-pulse experiments. At 1.4 MW however, single-pulse measurements will still be limited to a subset of possible materials, that is, those with simple structures or favorable cross sections. By increasing the power level by a factor of 2, the range of materials that can be measured increases dramatically. Some examples of new areas of science that could be addressed include the following:

- *Engineering Materials*—The increase in power would make feasible dynamic experiments at the engineering diffractometer that can only be dreamt of today. Single-pulse diffraction would become possible for engineering materials such as steel, aluminum, and nickel-based superalloys. Because neutrons of different wavelengths are scattered by the sample at different times, continuous monitoring of the dynamics of a process would be possible. Examples of studies where information on this time scale is important include change of stress state during cyclic fatigue, development of recrystallization texture, decomposition kinetics in bulk metallic glass, and phase stability of metallic clusters. Another area that will benefit from the increase of target power is spatial mapping experiments. Spatial resolutions of 0.1 mm are required for studies of surface engineered materials and coatings; such measurements are difficult to achieve at a 1-MW flux.
- *Powder Diffraction*—Higher power would greatly increase the performance of the powder diffractometer in stroboscopic (crystal structure as a function of applied alternating stimulus, e.g., ferroelectrics under high-frequency AC voltages) and nuclear density distribution (e.g., determination of hydrogen conduction pathways in fuel cell materials) measurements. Similarly, in a high-flux scenario, maximum entropy methods could be used to deconvolute the instrument and pulse shape functions from the measured diffraction data, possibly doubling the resolution of the powder diffractometer. This higher resolution is important in the study of subtle structural phase transitions and in separating Bragg peaks in complex, low-symmetry structures, which is a requirement for ab initio powder methods when single crystals are not obtainable. Flux increases will also allow phase diagram determinations to be made extensively and rapidly.
- *Reflectometry*—Higher flux will also allow time-dependent reflectometry studies on thin films at high temporal resolution. Examples include diffusion experiments; parametric studies in which temperature, magnetic/electric fields, chemical environment, and/or pressure are changed; chemical kinetics; solid state reactions; phase transitions; and chemical reactions in general. In many cases, useful data sets could be produced on a pulse-by-pulse basis. We are close enough in flux at 1.4 MW to almost bridge the gap between reflectivity and Bragg diffraction along the specular diffraction rod. A factor of 2 increase in intensity would enable continuous measurement of layered structures from 3 to 10,000 Å in one scan on one instrument. This becomes important for in situ studies of the layer-by-layer growth of multilayers or the study of dynamic processes at surfaces and interfaces. Furthermore, an increase in intensity would break the threshold required for performing inelastic scattering experiments on thin films and surfaces. Such a capability, which does not exist at current neutron sources because of flux limitations, would open up a completely new domain of measurements with applications in membrane function, catalysis, and relaxation processes in magnetic films, for example.
- *Dynamics*—Inelastic experiments are generally flux limited. Two examples where current flux levels make experiments marginal at best are studies of protein dynamics and of thin layers of adsorbed polymers. To study the dynamics (side chain motions as well as global diffusion) of proteins in solutions that mimic biological environments, sample concentrations must be kept low because of protein clustering at higher concentrations, which makes the scattering particularly weak. A factor of 3 would extend the range of proteins that can be studied in this way. Another area of study that would benefit is the dynamics of thin films of adsorbed polymers (1 to several radii of gyration thick). Current study is limited to either intense sample preparation efforts (many iterations of coating individual silicon wafers) or study of relatively thick films. An additional factor of 3 in performance for the inelastic instruments will increase the viability of taking such measurements because less sample would be required.
- Biomaterials—Neutrons have a key role to play in the post-genomic era where the structure-function relationship of biological molecules has shifted more and more to the center stage. Even with SNS (which represents a significant improvement over the current state of the art) or the High Flux Isotope Reactor, many neutron-scattering experiments with biological systems are not practical because of flux limitation. Most potential biological samples are available only in small amounts, behave well only in low concentrations, and have low contrast. Higher flux will enable a number of biological

neutron-scattering experiments that are not possible at current flux levels. Moreover, the applicability of neutrons to structural problems where the role of hydrogen and loosely bound water is important is expected to expand considerably

3. ACCELERATOR UPGRADES

Table 1 lists three sets of key baseline parameters for SNS: the current parameters (baseline), parameters with an upgrade to 3 MW (upgrade), and parameters with a later upgrade to 5 MW (ultimate). The final-stage upgrade would use most of the hardware now being installed in the linac, ring, and transport lines and would achieve what is foreseen as the ultimate capability of the facility. Achieving power levels beyond 3 MW would involve more of a learning curve on accelerator and target operations than significant capital expense. Increasing the operating energy or beam power beyond 5 MW would require substantial design changes.

The SNS accelerator complex is based on a 1-GeV linear accelerator with superconducting cavities and an accumulator ring capable of providing up to 2 MW of beam power at the nominal energy of 1 GeV. The linac tunnel includes space for the nine additional cryomodules that would be needed to upgrade to 1.3 GeV. Additional construction outside the tunnel would be required for the radio-frequency (RF) power systems. The missing section of the klystron gallery, including all necessary infrastructure and technical systems (RF, water, etc.) required to support the last six cryomodules, would have to be completed (see Fig. 1). The current cryogenic capability is adequate to supply all nine additional cryomodules. The assumed “in-house” construction of the additional nine cryomodules (36 cavities) is predicated on the availability a fully functional superconducting RF (SRF) facility in order to complete the construction within three years. How much of the SRF facility will be furnished during SNS construction is not yet known. If the facility is not completed, additional time (up to two years) and money (up to $15M) would be required before starting the upgrade. Alternatively, production of cryomodules by Thomas Jefferson National Accelerator Facility (JLab) could be extended. Of the 36 required high-β cavities, 24 have been purchased and are to be used as spares in the ongoing cryomodule production at JLab. These spares would likely be available for the upgrade.

Table 1. SNS baseline, upgrade, and ultimate parameters

	Baseline	Upgrade	Ultimate
Kinetic energy, E_k [MeV]	**1000**	**1300**	**1400**
Beam power on target, P_{max} [MW]	**1.4**	**3.0**	**5.0**
Chopper beam-on duty factor [%]	**68**	**70**	**70**
Linac beam macro pulse duty factor [%]	**6.0**	**6.0**	**6.0**
Average macropulse H- current [mA]	**26**	**42**	**65**
Peak current from front-end system	**38**	**59**	**92**
Linac average beam current [mA]	**1.6**	**2.5**	**3.9**
SRF cryomodule number (med-beta)	**11**	**11**	**11**
SRF cryomodule number (high-beta)	**12**	**12 + 8 (+1 reserve)**	**12 + 8 (+1 reserve)**
Number of SRF cavities	**33+48**	**33+80 (+4 reserve)**	**33+80 (+4 reserve)**
Peak gradient, E_p (β=0.61 cavity) [MV/m]	**27.5 (+/- 2.5)**	**27.5 (+/- 2.5)**	**27.5 (+/- 2.5)**
Peak gradient, E_p (β=0.81 cavity) [MV/m]	**35 (+2.5/-7.5)**	**31**	**34**
Ring injection time [ms]/turns	**1.0 / 1060**	**1.0 / 1100**	**1.0 / 1110**
Ring rf frequency [MHz]	**1.058**	**1.098**	**1.107**
Ring bunch intensity [10^{14}]	**1.6**	**2.5**	**3.8**
Ring space-charge tune spread, ΔQ_{sc}	**0.15**	**0.15**	**0.2**
Pulse length on target [ns]	**695**	**691**	**683**

(Assuming 4% injection loss to dump, 4% target window loss, and linac maximum of 20° phase.)

From an accelerator physics point of view, all three scenarios listed in Table 1 are viable for the SNS facility as a result of the strong dependence of space charge tune shift on kinetic energy of the nonrelativistic protons. Space charge tune shift is the dominant beam loss mechanism in the ring and will therefore ultimately limit the beam power because of residual activation of the beam line components. Because the ring is designed for 2-MW operation at 1 GeV, scaling particle energy and velocity ($\sim\beta^2\cdot\gamma^3$) to 1.3 GeV (1.4 GeV) allows for 3-MW (5-MW) operation, as shown in the table. Currently, almost all ring components are designed and constructed to support 1.3-GeV operation, with a substantial safety margin that allows for eventual 1.4-GeV operation.

Other support systems on the site, such as for deionized (DI) water distribution and cooling, cabling for the linac and most of the ring, main power distribution, and the heating, ventilation, and air conditioning (HVAC) systems for the accelerator enclosures, have sufficient margin to support the 3-MW upgrade.

The following sections describe in more detail the necessary technical upgrades, including all major systems that would be affected. These upgrades would require about three years and would optimally start immediately following the current construction project (CD 4 for the SNS project is in the summer of 2006) to make best use of the still-existing construction and installation work force. With that start date, the upgrade program would be finished in December 2009, with minimal interruption to the ongoing user program that would still be ramping up.

Most of the installation could be accomplished during SNS operation and routine maintenance periods. Final installation would be from FY 08 to 09 during a six-month shutdown. For some of the upgrades, an earlier start of the development phase would be extremely advantageous. Table 2 contains a high-level cost estimate that summarizes the cost of the upgrades by technical system and installation and includes a 25% contingency on the total project cost. Escalation is not included because it depends on the eventual start date.

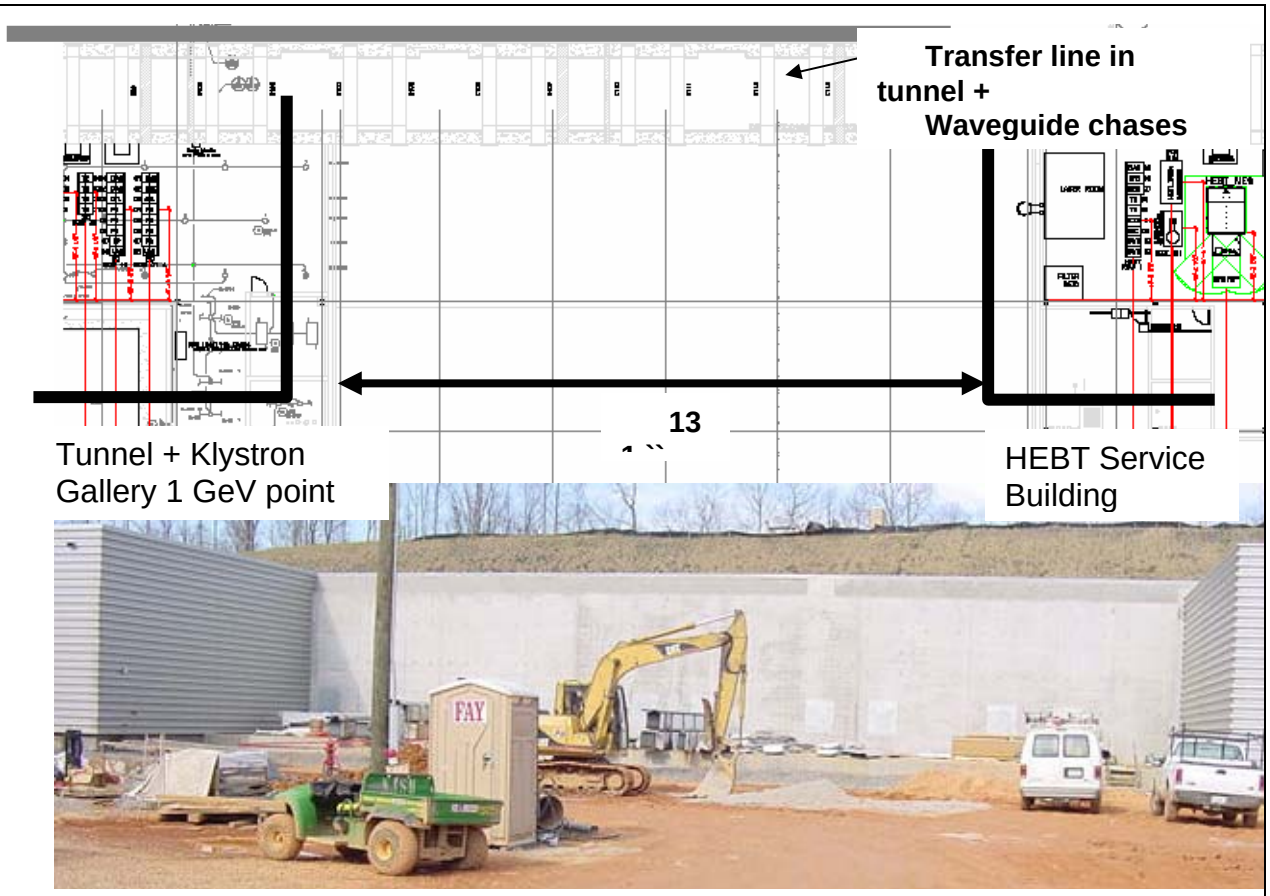


Figure 1. This January photo shows the gap in the klystron gallery between the linac and the high-energy beam transport (HEBT) Service Building. The existing gallery wall (left) and the HEBT service-building wall (right) are visible. The concrete slab and waveguide chases in the klystron gallery, as well as the complete helium distribution line in the tunnel, are already in place.

4. TECHNICAL PROGRAMS

This upgrade proposal focuses on increasing the energy and ion source current and on performing the required technical subsystem upgrades to support higher power operations. Although increasing the pulse length is a technically viable option for upgrading to 5 MW, it is less cost effective and less desirable overall for accelerator operation than the aforementioned methods. Longer pulse length is a backup option at this time. If the peak ion source currents listed in Table 1 cannot be achieved, the pulse length can be extended to 1.5 or even 2 ms. In addition to the upgrades to the accelerator and target, a detector research and development (R&D) program is outlined that provides detector technologies fully capable of making use of higher power. This program would develop high-count-rate detectors, deployment cost for which would be borne as part of the ongoing instrument development program. However, without sustained investment in R&D, the technical capability of deployed detectors would lag.

4.1 ION SOURCE PROGRAM

Operation at the 3-MW level requires an ion source pulse current in excess of 60 mA, which is only 10 mA above the 50 mA demonstrated at Lawrence Berkeley National Laboratory when operated at 40 kW RF power with a duty cycle of 0.05%. The required 20% increase can be expected from coupling more RF power into the plasma and enhancing the H^- surface production by separating the cesium collar from a temperature-controlled outlet aperture. However, operations at the increased power level with a full 8% ion source duty cycle can be expected to significantly shorten the life cycle of the source. We propose designing, building, and implementing a new low-energy beam transport (LEBT) system that features two ion sources that allow switching from one source to the other within a minute or less. The fast switchover would require a complete duplicate set of control electronics for the second source. The new LEBT would be designed around a symmetric, reversible dipole switching magnet with two entry ports (~±15°), each holding a magnetic solenoid lens and an ion source. A third magnetic solenoid lens would be installed at the exit to provide the telescopic focusing power desired for the RF quadrupole injection. The machine safety compromised by the increased beam power would be improved with a fast, sequentially fired, multiplate low-energy chopper, with a beam rise time below 15 ns. In addition to the reduced rise time, multiplate choppers maintain significant chopper strength when a chopper element fails, minimizing any damage that could occur before the machine is be switched off. Before the start of the project, it would be necessary to design and assemble a prototype mostly from existing components, including the hot spare stand, for a proof-of-principle experiment.

Table 2. High-level cost estimate ($M) for the 3-MW power upgrade

	Prior CD 1	Year 1	Year 2	Year 3	Year 4	Total
Conceptual Design	$2.0					$2.0
Ion Source		$2.6	$3.5	$3.2	$1.8	$11.1
RF Systems		$3.4	$8.6	$6.8	$2.7	$21.5
Cryomodules		$3.5	$3.5	$3.0	$0.5	$10.5
Ring		$1.4	$3.6	$1.1	$0.3	$6.4
Target Modification			$2.0	$2.0	$2.0	$6.0
Detector R&D	$4.0	$2.0	$2.0	$2.0	$2.0	$12.0
Civil Engineering		$1.7				$1.7
Installation (DB+M&S)		$0.9	$1.8	$2.7	$1.4	$6.8
Labor Cost (FTY)	$0.8	$1.0	$1.0	$1.4	$1.4	$5.6
Project Management		$1.5	$3.0	$3.0	$1.5	$9.0
Cost (no contingency)	**6.8**	**18.0**	**29.0**	**25.2**	**13.6**	**92.6**
contingency	$1.7	$4.5	$7.3	$6.3	$3.4	$23.2
Total FY	**$8.5**	**$22.5**	**$36.3**	**$31.5**	**$17.0**	**$115.8**

4.2 WARM LINAC AND HIGH-POWER RF

An increase in linac beam current would not significantly affect operation of the drift-tube linac (DTL) or coupled-cavity linac (CCL). The accelerating fields would remain the same, as in the current baseline, although additional rf power would have to be supplied to accelerate the additional beam current. If the beam pulse length were extended instead of, or in addition to, an increase in current, the

warm linac would experience a higher thermal load because of the higher duty cycle. Preliminary calculations show that both the DTL and the CCL could handle an increase in duty cycle from ~7 to 10%, without stressing the copper or exceeding temperature limits because of increased rf dissipation. The resonance control and cooling systems are adequate to handle the additional load. The high-power rf systems are composed of high-voltage converter modulators (HVCMs) and RF power sources (klystrons). Most of the klystrons have a substantial margin designed into them compared with the present baseline and therefore do not need upgrades for 3-MW facility operation. This is definitely the case for the warm linac. The first superconducting linac klystrons have been tested up to 700 kW, far beyond the 550 kW required in the current baseline. Because the baseline design incorporates more than a 25% margin, further upgrades would be unnecessary. An additional 36 klystrons are required to power the 36 additional cavities for the 3-MW upgrade, together with the HVCMs and appropriate infrastructure. The HVCM would have to be upgraded to allow increased average power performance with high reliability because the current design supports the 3-MW upgrade with no margin left. For the additional acceleration, three complete additional HVCM installations would be required.

4.3 SUPERCONDUCTING LINAC OPERATION AT HIGH BEAM CURRENT

The increased beam energy would be achieved by the addition of nine high-β cryomodules consisting of four cavities each. These cryomodules would be identical to those already under construction. Because 24 of the 36 high-β cavities required for this effort will already be on hand, cryomodule production could begin without delay, provided an SRF facility is available at Oak Ridge National Laboratory or JLab.

Operation of the superconducting linac at higher peak beam currents would require delivery of more power to the cavity via the fundamental power coupler (FPC). The existing FPCs are compatible with beam currents of 42 mA (700 kW) and 65 mA (1.1 MW) and were tested to 2.2 MW, or four times the baseline requirement. External Qs (Q_{ext}) and the additional RF power that would be required in the most heavily beam-loaded cavities were estimated. With present matching, medium-β $Q_{ext} = 7.3 \times 10^5$ and high-β $Q_{ext} = 7.0 \times 10^5$, the additional required power is less than 1% above optimum for the medium-β and about 1% above optimum for the high-β cavities at 42 mA of beam current. At 65 mA, using the same external Qs, the additional power is only 8% for medium-β and 3% for the high-β cavities. Rematching the FPCs is thus unnecessary. Increased heat dissipation caused by the increased power (~× 2) would be easily handled by increased cooling to the FPC, the end groups, and the higher order mode couplers. The central helium liquefier is capable of providing the additional cooling.

The linac physics design was reinvestigated to see if a new cavity design could lead to significantly better efficiency. The existing β = 0.81 cavity was designed for the linac when it was optimized at 1.3 GeV and would still be adequate for the upgrade. The energy gain could only be increased by 2 MeV per cavity with a new design.

4.4 RING PHYSICS AND SYSTEMS IMPLICATIONS

Although the energy and intensity upgrade in the linac is straightforward, the ring will ultimately limit the beam power available because of beam loss driven by space-charge tune shift and other instabilities. The transverse impedance in the ring is dominated by the extraction kicker magnets. Measurements indicate a peak transverse impedance of about 45 kOhm/m for the 14 kicker modules required for 1-GeV extraction. Multiparticle simulations show that this impedance has an instability threshold of about 3×10^{14} protons at the natural chromaticity. There are three factors that describe the scaling to higher energy operation. First, the beam rigidity is increased, whereas the wakefields, which give rise to the instability, are independent of beam energy. Secondly, two additional kicker modules are required to extract a 1.3-GeV beam from the ring; the transverse impedance is increased by approximately

14%. Finally, the chromatic contribution to the tune spread is decreased at higher energy. The tune spread, $\Delta\omega$, is given by

$$\Delta\omega/\omega_0 = (\xi - m\eta)\delta \ ,$$

where ω_0 is the revolution frequency, ξ is the chromaticity, n is the mode number, $\delta = \Delta p/p$ is the fractional momentum deviation, and η is the slip-factor. The slip factor is reduced from –0.198 to –0.139 at 1.3 GeV. At the natural chromaticity, the tune-spread reduction for lower mode numbers is approximately 20% smaller than at 1.0 GeV. Taking these three factors into account, one expects the threshold for instability caused by the extraction kicker impedance to be somewhat reduced relative to that at 1.0 GeV. Multiparticle simulations, including space charge and transverse impedance, show that the beam is near the instability threshold at 2.5×10^{14} protons/pulse for 1.3-GeV operation, nearly independent of the accumulation time (1.0 ↔ 1.5 ms).

Electron cloud ("e-p") instability is not expected to occur in the ring when operating at 1 GeV up to 2×10^{14} protons/pulse after sufficient vacuum chamber processing has occurred. The RF system provides more than a factor of 3 safety margin in voltage overhead. As a result, encountering the e-p instability at the 1.3-GeV design intensity of 2.5×10^{14} protons/pulse is not expected. Given the difficulties inherent in predicting electron effects, and the present incomplete understanding of those effects, an active damper system was considered as a way to mitigate the e-p instability in the SNS ring should it arise.

A wideband transverse damper system, which provides transverse damping in three frequency ranges, would probably be used. First, depending on the ring's operating point, the resistive wall impedance could excite the lowest betatron sideband with growth rates of ~5 ms^{-1}. The extraction kicker impedance could drive a transverse instability in the frequency range of 5 to 30 MHz, with growth rates up to 10 ms^{-1}. Finally, the e-p instability observed in the proton storage ring at Los Alamos National Laboratory (LANL) results in coherent motion in the 100–200-MHz band, with growth rates in the range of 30 to 100 ms^{-1}. To address these instabilities, a broadband resistive feedback system operating in the range of 0.2 to 200 MHz is foreseen. The system would consist of a set of 50-cm stripline kickers (with 50-Ohm characteristic impedance) to achieve the required high-frequency response. Two pickup electrodes would be sampled with a 4 GS/s processor to provide position and angular information along the bunch on a turn-by-turn basis. A digital processing system would be employed using a two-turn filter for closed-orbit rejection. The feedback system requires 2 kW of RF power driving three 0.5-m-long striplines that provide sufficient damping time. If necessary, additional space would be reserved in the ring for additional active dampers.

The baseline design for the collimators is for 2 MW, with a safety margin of five on top of the hadronic calculations. The upgrade would decrease that safety margin. Since the energy increases, less energy deposition per unit length occurs and therefore the effect of higher current should wash out to first order. This argument holds for the collimators and for the windows. The only collimator elements that would most likely have to change are the movable scrapers, which would need to be thicker because of the altered scattering.

4.5 OPERATIONAL REQUIREMENTS, BEAM DUMPS, RADIATION, AND SHIELDING

SNS radiation shielding was evaluated in detail for accelerator operation at 1.0 and 1.3 GeV, up to 2 MW of beam power. Radiation levels were calculated for areas outside the accelerator enclosure. Calculations for the 1-GeV, 2-W case are documented in the SNS Final Safety Assessment Document Preliminary Safety Analysis Report. The difference between the 1-eV and 1.3-GeV cases, assuming the same beam loss rate per unit length (e.g., 1 W/m to allow hands-on maintenance), is less than the calculational uncertainty. Radiation levels outside the accelerator enclosure scale linearly with this loss rate, and no difference is expected for operation at 3 MW.

SNS beam dump operation was also evaluated at 1.0 and 1.3 GeV, and there is no significant effect of the increased energy on the operation of either the passive or active dumps. The heat-handling capability of the dump structures is the same at either energy. Increased scattering length contributes only marginally. The heat-handling capability of the injection dump was verified to be 200 kW with a minimum of 10% engineering margin in the dump and 14% margin in the cooling system. Injection simulations show 4% loss at 3 MW, or 120 kW well below the 200-kW limit.

4.6 TARGET SYSTEMS

With the exception of the mercury target container itself and the inner neutron reflector plug, the remainder of the SNS target systems, including the mercury pump, mercury-to-water heat exchanger, moderator, supercritical hydrogen refrigerator for the moderators, shielding, and utility systems, is designed to operate at the upgrade power level of 2 MW (target station one), while 1 MW is reserved for the second target station. The inner reflector plug that will be installed initially is designed for operation at 1.4 MW. Fabricating and installing an inner reflector plug capable of 2-MW operation could require design modifications to the moderator vessel/reflector interface region that are judged to be relatively straightforward in nature; therefore, this item is not further addressed in this report. Because the inner reflector plug will be replaced every 3 to 5 years during normal operation, provision would be made for higher power in a replacement deployed before operation of the upgraded facility.

The mechanism that may limit the mercury target container to 1 MW is the cavitation damage caused by the intense pressure pulse induced in the mercury during each sub-microsecond beam pulse. The two primary pathways that need to be investigated for upgrading the target container to the 2-MW level are (1) improving the materials/surface treatments to reduce the erosion rate from cavitation and (2) mitigating the pressure pulse by injection of a fine dispersion of small gas bubbles in the mercury. Both of these paths are briefly described as follows.

Initial tests designed to study various materials and treatments have shown that large improvements in cavitation damage resistance are possible with surface treatments. For example, treating the reference target container material (316 type stainless steel) with one carburizing treatment, called Kolsterising, completely eliminated pitting from a 100-pulse test conducted at LANL's WNR facility. Off-line tests with a large number of mechanical pulses have shown that although this surface will eventually succumb to cavitation erosion, its incubation time before bulk erosion occurs is greatly extended and its steady-state erosion rate is about a factor of ten less than untreated material. Examining whether this treatment holds up under irradiation, identifying alternative treatments, and establishing the lifetime limits on erosion are identified as important tasks in this pathway to achieving the desired upgrade.

Introducing a fine dispersion of small gas bubbles is the other possible upgrade pathway. Theory holds that a bubble fraction of only about 0.5 % or greater by volume with diameters of about 50 μm will provide sufficient compressibility to the mercury-bubble mixture to virtually eliminate the pressure buildup. Various bubble-injection schemes should be explored in off-line experiments on small mercury loops such as that available in the SNS mercury thermal hydraulic loop. Following these tests, a demonstration of the most promising scheme(s) should be attempted at the SNS Target Test Facility (TTF). The TTF tests are intended to show that a fine dispersion of bubbles can be achieved in the mercury-beam interaction region and that the bubble-production and gas-removal systems can operate on a steady-state basis. After successfully demonstrating these capabilities in the TTF, a series of in-beam tests must be conducted at an existing pulsed proton beam facility to demonstrate that the bubbles eliminate or greatly reduce the erosion and the strain on the mercury container walls.

In anticipation of the need to incorporate upgrade capabilities, some easily incorporated features are being added to the SNS mercury target subsystem. A collaborative effort between the European Spallation Source and SNS design teams has recently identified bubble-injection feed line sizes and locations in the mercury loop. Fittings are being added to the mercury loop piping to accommodate these gas injection lines if they are needed later. The bubble-injection system hardware that proves to

successfully mitigate the pressure pulse would have to be procured and installed as part of the power upgrade program.

Furthermore, since the cavitation damage appears to be most severe in the small coolant passages that are provided to cool the target container walls, a set of water inlet and outlet coolant pipes were added to the target cart in case they were needed later. These pipes were added because it would be difficult to add them after the target becomes radioactive and because replacement of the entire cart is considered difficult. Design, fabrication, and installation of a water-cooling loop, including additional piping, pumps, heat exchangers, etc, could be required as part of the power upgrade program.

Detector Upgrades

To take full advantage of the benefits from the increased source flux, it will be important to upgrade the performance of the neutron detectors on many of the instruments. This will require extension of the current state of the art and will only be possible with a significant program of targeted detector developments. Including such a program as part of the plan for power upgrades will be important.

Detector development would also be needed. For the reflectometers and SANS instruments, where high rates and gamma sensitivity are the primary issues, multiwire proportional chambers become less suitable as the data rate increases. Gas detectors have highly desirable background rejection capabilities, but to achieve the full potential of these instruments, gas detectors are needed that have parallel pixel readout and that operate in ionization mode. Such new detector technology would provide enhanced rate capabilities because each pixel is read out individually and is not affected by the dead time of its neighbor. In addition, operating in ionization mode will minimize the effects of positive ion drift in the gas, which is the limiting rate factor in proportional counters. Finally, ionization mode will significantly improve the lifetime of the detector by eliminating the use of wires and minimizing gain-dependant aging effects. To take full advantage of the opportunities offered by the increased flux, detectors that operate in time-of-flight mode and that are capable of higher spatial resolution (down to 0.1 mm) will also be needed on some of the instruments.

Additionally, many instruments will need detectors with the ability to detect weak signals in the presence of strong ones (e.g., weak features close to strong Bragg peaks). Individual pixel readout will be necessary to prevent the very high intensity from the Bragg peaks or other strong features from saturating the entire detector. For optimum performance, each pixel will still need to have a high counting rate capability. For some instruments, these capabilities would need to be provided over large area arrays; hence, cost becomes a significant issue as well. Scintillation detectors would be attractive for some of these applications because of the cost issues, but improved scintillator materials are needed to provide the detection efficiency, light production, and speed needed for optimal performance.

It should be mentioned that, with the exception of the high-resolution detector, each of the aforementioned developments is incremental. These efforts are based on solid technical foundations, and the proposed tasks represent logical next steps in development. Nevertheless, this represents a significant development program extending over several years, and this program should be considered as an integral part of the power upgrade.

4.7 CIVIL CONSTRUCTION AND INFRASTRUCTURE

The civil construction to the support the 3-MW beam power upgrade is minimal and is best described in Fig. 1. The klystron gallery area that would have to support the installation of the additional klystrons and HVCMs, as well as the support systems, is not built out and has a footprint of 130 ft long × 30.5 ft wide × 24 ft high. This area includes the architectural and structural buildout of the existing space, which connects the klystron gallery with the HEBT service building. The concrete slab, retaining wall to the linac tunnel berm, and empty chases for the waveguide and utility connections into the tunnel (foreseen for such an upgrade) are in place. The buildout would include extension of the mechanical utilities such

as fire protection, chilled water, DI water, hot water, tower water, compressed air, potable water, and HVAC systems from the existing Klystron Building. Additional slabs for the substations and two more transformers would also be necessary.

5. COST AND SCHEDULE INFORMATION

A summary of the overall project cost is shown in Table 2. A detailed bottoms-up cost estimate is a task for the conceptual design required prior to CD-1. At this stage, a contingency of 25% has been assigned to the power upgrade. The dollar values are not escalated and are based on recent market experience during SNS construction, which is directly comparable to the proposed scope.

The upgrade schedule was prepared on the basis of construction and installation experience with the same equipment, which is ongoing at this point (FY 02–04). Most of the construction and installation for the upgrade could be done without affecting SNS operation. At the end of the upgrade (FY 09 if CD-1 is in FY 06), a six-month shutdown period would be required to finalize installation in the tunnel and target systems.

6. CONCLUSION

SNS is in an excellent position to start an immediate upgrade of the technical infrastructure to support higher power. Higher beam power provides for both increased scientific capacity and performance. Measurements that are marginally possible at 1.4 MW become feasible at higher power, for example, time-resolved studies employing single-pulse diffraction. Higher throughput allows for a broader user program and facilitates the addition of an LWTS that can be powered without degrading the rating on the HPTS. Many of the components for a near-term upgrade that would allow for operation up to 3 MW have already been built into the facility and carry minimal risk. The 5-MW parameter list outlines the asymptotic capability of the SNS in its present geometric configuration and illustrates the margin that exists even in a 3-MW complex. Because the 3-MW upgrade program is based on deployment of proven technology and designs and offers quantifiable scientific benefit, we believe there is already a firm basis for CD-0.

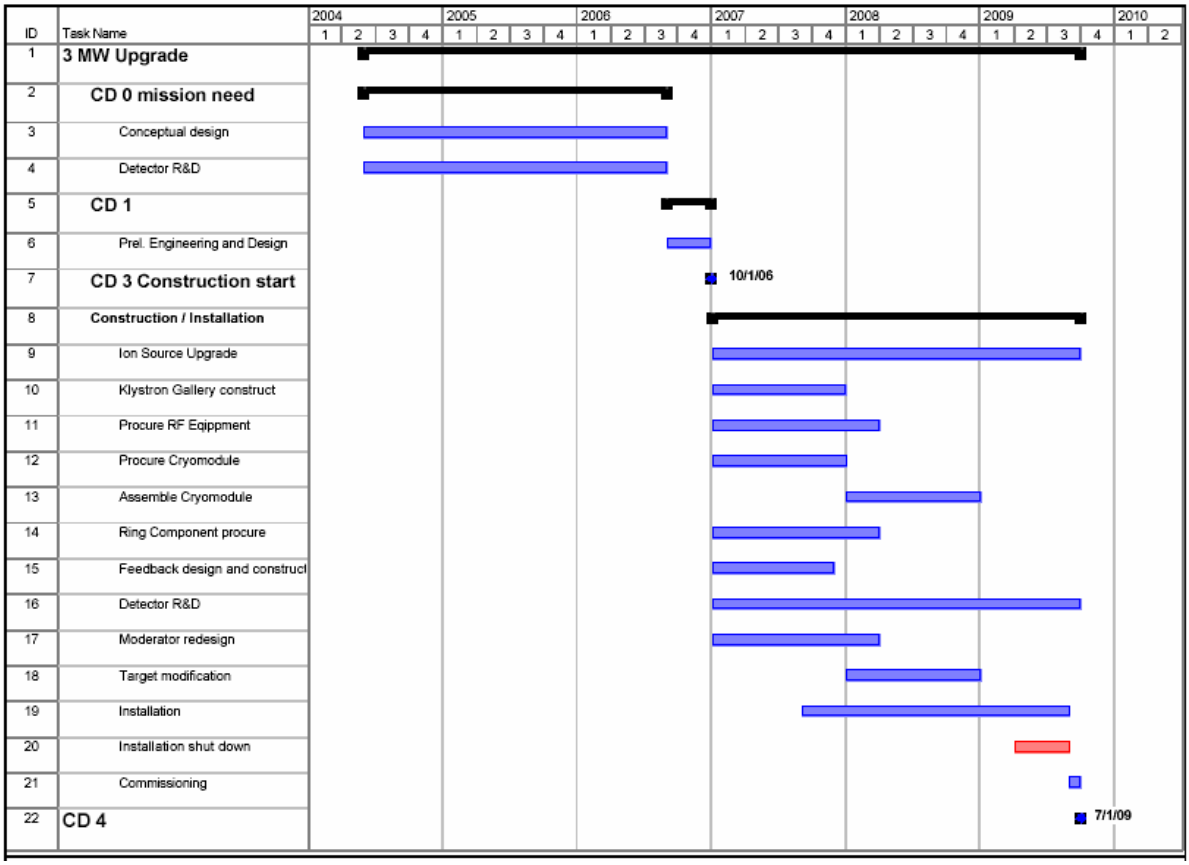


Figure 2. Schedule for the 3-MW upgrade with a completion date of July 1, 2009, assuming CD-1 in FY 06 and a two-year conceptual phase.

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