Spallation Neutron Source
A U.S. Department of Energy Multilaboratory Project
SNS
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Conventional Facilities Construction Moves Ahead

R. Etheridge

The Spallation Neutron Source (SNS), being built in Oak Ridge, Tennessee, will be the world's most advanced accelerator-based, pulsed-neutron system. The U.S. Department of Energy (DOE) Office of Science is funding the project, which is being designed by six DOE national laboratories.

Construction at SNS began on December 16, 1999, following the previous day's official groundbreaking ceremony. Work began with construction of a new road from existing Bear Creek Road into the north side of the SNS site. The road was completed in June of this year. In February, mass excavation began and is now almost complete. The contract for construction of the Bethel Valley Access Road, on the south side of the site, was issued in early March 2000, and that work is scheduled for completion in early November. A contract for a retention pond dam and outfall line was signed in April, and work should be finished in December.

By late September, additional contracts had been awarded, bringing the total to ~$60M. Construction should be equally aggressive for 2001 through 2003, with the conventional facilities scheduled for completion in 2004. Installation of technical equipment will begin as soon as individual buildings or portions of them are complete in early 2002.

Artist's conception of the SNS overlaid on the actual construction site in Oak Ridge, Tennessee.

In This Issue

Director's Comments

David E. Moncton
SNS Executive Director

In the last *Neutron Pulse*, I described how the project and its supporters had met the many challenges facing us. We had just received what we hoped would be a positive omen for the upcoming budget process, namely Chairman Sensenbrenner's recommendation that the president's full budget of $278.5M be appropriated for FY 2001. On Oct. 27, President Clinton signed legislation making that budget a reality, while also providing significant increases for many of the other critical programs and operations within the DOE Office of Science.

As many of you close to this year's budget process know, the events of the last six months that culminated in this good news were anything but routine. At times it looked as if DOE and the SNS would be held to last year's funding level, which would have terminated the SNS. Fortunately, an outpouring of support came from the scientific community, and the results speak for themselves. I want to take this opportunity to say how thankful I am for the active support shown by the community on behalf of science generally and the SNS specifically. The community has clearly shown how much it can accomplish by working together on behalf of science as an integrated whole.

As for the project itself, it has developed great momentum, one measure of which is having committed all the funds allocated to the project through FY 2000. On the site, a massive excavation contract for 1.3 million cubic yards of earth is nearing completion. Concrete and steel for many of the major structures will follow early in the new year. At the partner labs, advanced research and development and detailed design are leading to major component procurement. About 600 people are working on SNS across the laboratory system.

The five or so years until project completion will no doubt bring further challenges. We are concerned, for example, that the robust U.S. economy is not favorable for receiving the lowest construction bids. We are also concerned about resources available for the preoperational period during commissioning. These pressures may ultimately lead to some difficult choices. But I want prospective users to know that we are committed to delivering a facility that is consistent with the vision outlined in our last newsletter and to doing so within the budget that Congress has accepted.

Superconducting Linac

D. K. Olsen

The SNS linac will be a state-of-the-art combination of normal, room-temperature conducting and superconducting (SC) technologies. The addition of a cold niobium linac provides substantial advantages over use of a warm copper linac alone. First, operating costs for the cold linac are considerably less compared with the warm linac, and expected power consumption, including the cryoplant, is about 12 MW—50% less than for a normal-conducting linac. Second, because the tunnel length is much shorter for an SC linac, construction costs are reduced. Third, the SC linac can be designed for higher availability than a warm linac because each SC cavity has substantial reserve capability and is independently phased and controlled. Consequently, if a cavity or klystron fails, the linac can be quickly retuned to operate without the failed component, eliminating downtime during the operating schedule. Moreover, accelerator activation will be less. In particular, energy stability will be better for the SC linac than for the warm linac, resulting in lower beam loss in the high-energy beam transport and ring. This stability is the result of ultrahigh vacuum in the cryogenic system, which creates less beam-gas scattering and hence less beam loss. The much larger bore of the SC cavity also reduces beam loss.

Perhaps the most important advantage of SC linac technology is its flexibility and upgrade potential. The reserve and upgrade capability of the SC cavities can be used later to increase the linac energy to about 1.3 GeV by increasing klystron power. This energy increase would allow more beam power to be accumulated in the ring. The design peak surface electric field for the cavities is 27.5 MV/m. With experience and improvements in technology, it is expected that higher fields will be obtained, allowing for additional capabilities even at the baseline beam power of 2 MW.

Figure 1 shows the layout of the linac. The warm copper drift-tube linac will extend up to 86.6 MeV, with six tanks and a total length of 37 m. Each tank will be powered by one 2.5-MW, 402.5-MHz klystron. The warm copper coupled-cavity linac will end at 187 MeV, with 48 segments of 8 cells, each cell with a total length of 55 m. Four 5-MW, 805-MHz klystrons will supply the power.

Los Alamos National Laboratory (LANL) is responsible for the overall

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linac, and Thomas Jefferson National Accelerator Facility (JLab) is responsible for the cold accelerator cavities and cryomodules, refrigerators, and the distribution system of the SC linac. JLab has successfully built and operated the continuous beam electron accelerator, which employs 338 SC cavities, similar to the SNS design. A cavity processing and cryomodule manufacturing facility will be built on the SNS site to service and upgrade the cold linac components.

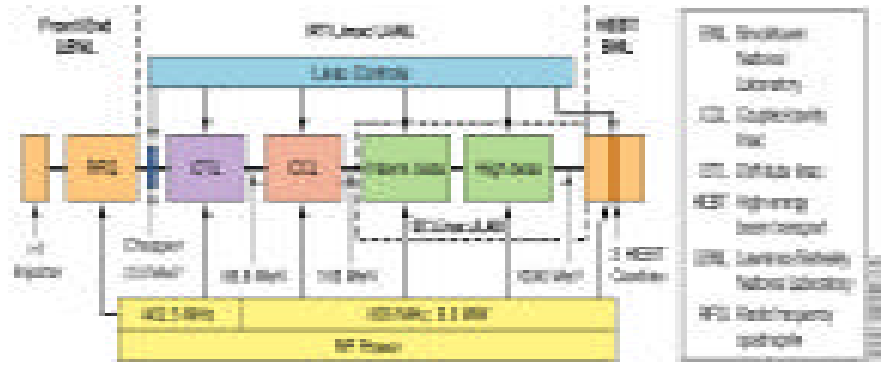

Fig. 1. SNS linac configuration.

The decision to incorporate a cold linac in the SNS design resulted from significant developments in SC technology during the last three years. First, the Deutches Elektronen SYnchrotron (DESY) laboratory in Hamburg, Germany, has demonstrated more than adequate control of pulsed operation of the TESLA Test Facility (TTF) SC linac. This success is important because most existing SC linacs are continuous beam, whereas the SNS linac will be highly pulsed. Second, the TTF has demonstrated reliably high gradients in nine-cell cavities, similar to those of the SNS, delivered by four industrial vendors. Third, a high-power SC coaxial input power coupler that meets SNS requirements has been demonstrated at the KEK-B, High Energy Research Accelerator Organization in Tsukuba, Japan. For the SNS, full niobium cavities are being fabricated for testing and plans are under way to prototype one complete medium-beta cryomodule. All of these demonstrations are allowing the SNS to incorporate SC technology with minimal risk, while providing a much more flexible and upgradeable linac for neutron scattering in the decades ahead.

Experimental Facilities Update

T. E. Mason

Since the last issue of the *Neutron Pulse,* work has continued on the design of the SNS experimental facilities, and we have begun some of the major purchases for the target systems. The initial design phase (Title I design) for the target was completed in the spring of this year, and work on the final design (Title II) is well under way. Our research and development program continues to provide important information on the performance of the mercury target system; recently, a final campaign of tests with pulsed proton beams was completed at the Los Alamos Neutron Science Center. These measurements will provide the final test of our assumptions about transient effects associated with the 34 kJ/per pulse deposited in the target in less than a microsecond. Measurements using the mercury thermal hydraulic loop have verified that the mercury will provide adequate cooling for the stainless steel target vessel. As the design is being finalized, procurement activities have begun with some of the important components already on order, such as the variable speed circulators for the cryogenic moderators and the manipulators for servicing the target module.

Significant progress with the instruments has also been made. We are continuing to build up the staff who will design, build, and eventually operate the neutron-scattering instruments. The first three instruments selected in consultation with the user community and our Instrument Oversight Committee (IOC), the backscattering spectrometer and two reflectometers (described in the last issue of the *Pulse*), are now formally included in the project. This means we have completed preliminary engineering design, cost estimates, and schedules and are ready to build them! In addition, a June 2000 meeting of the IOC led to a recommendation to move forward with another three instruments: a chopper spectrometer, engineering diffractometer, and an extended Q-range small-angle neutron-scattering instrument. These instruments are described later by the responsible instrument scientists. As with the first three instruments, these

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meet the test of "best-in-class" and will offer outstanding capabilities to the scientific community. Instrument selection will be an ongoing process, and we encourage anyone who has an interest to join one of the instrument advisory teams already assembled or initiate a new one for areas not covered. Further details can be obtained at the SNS user info web site (www.sns.gov/users/users.htm) or the SNS instrument web site (www.sns.anl.gov).

In addition to the instrumentation activities within the SNS project, there is growing interest from external groups in putting together instrument development teams (IDTs), which will build and operate instruments at SNS. These externally funded instruments will receive dedicated beam time for their own scientific programs but will also be made available to the user community. We have had expressions of interest from several potential IDTs and expect to see the first letters of intent in the coming months. Anyone interested in forming an IDT should inquire to snsusers@sns.gov.

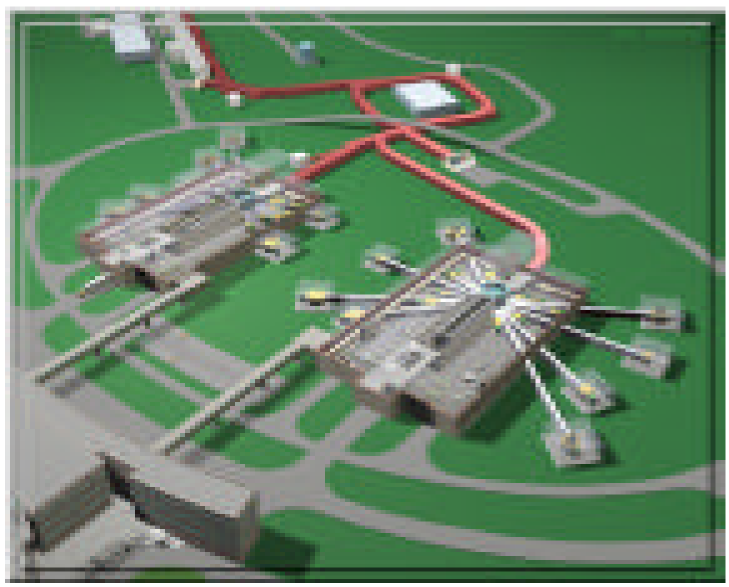
Long-Wavelength Target Station

J. Carpenter and J. Richardson

From the outset, SNS has incorporated the capacity for two target stations, even though the funded construction project includes only the first, "high-power" target station (HPTS). To extend SNS capabilities to include the large field of long-wavelength neutron applications, as of May 1, 2000, the National Science Foundation has agreed to fund development of a conceptual design for a second, long-wavelength target station (LWTS). The next step in what is expected to be a three-year activity is development of a full-blown proposal in March 2001, followed by continued refinement of the facility and instrument design.

Throughout development of the LWTS, facility and instrument design groups will maintain close collaboration with the scientific community and those formulating the science case, with the intent of providing a highly optimized installation.

The guiding theme for this venture is to provide a facility distinctly different from the HPTS. Emphasizing the production of long-wavelength neutrons means using the coldest possible moderators, low target power, and low pulsing frequency, all of which are complementary requirements. Tentatively, and to give scale to the development of the concept, we assume the LWTS will operate at 10 Hz and 333 kW (1/6 of the nominal SNS beam power). To help prepare the science case, we have engaged leading members of the university community, as well as a core of experienced neutron-scattering instrument and target system designers from Argonne National Laboratory.



SNS site plan showing the second target station on the right.

For reasons of economy, work thus far has led to preliminary configuration of a target, experimental hall, and instruments similar to those of the HPTS but that are distinct in the following ways:

- The target will be a vertically extended, water-cooled solid (e.g., tungsten), although we will continue to evaluate the mercury target alternative, which would provide operational advantages.
- All moderators will be cryogenic (20 and 100 K), with extensive use of guides in two configurations: (1) large-aperture, gently curved guides and (2) compact benders, including, however, some beams with a line-of-sight view of at least one moderator.
- Considerations to date lead to an asymmetric experimental hall that includes heavy crane coverage with

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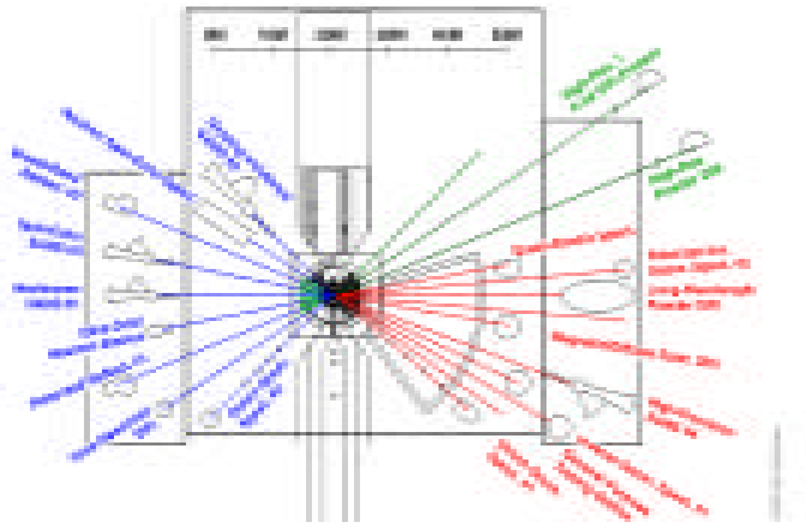
attached sheds, or porticos, with lighter-duty crane coverage.

We are pursuing extensive neutronic and engineering evaluations of alternatives and optimizations of these interim assumptions.

From a preliminary selection of 20 instruments, we have chosen 3 to concentrate on in the short term. In the longer term, we will develop specifications for up to six more instruments. To ensure a broad input into the specification of instruments and the overall design of the LWTS, a series of small workshops focused in specific areas (i.e., soft matter, disordered materials, magnetism, and crystallography) were held in spring 2000, followed by the Users Meeting and Instrumentation Workshop in May. These activities next converged in an instrumentation and science review, held November 21-22, 2000, at Argonne. Furthermore, we have input from separately sponsored discussions of applications of SNS in fundamental neutron physics. These diverse contributions should enable us to design a target station of tremendous benefit to many different scientific disciplines.

One important function of SNS is the education of young researchers at the graduate and postgraduate levels. The large increase in scientific capability created by the LWTS will allow the SNS facility to better serve U.S. academic institutions in this regard. In addition, the LWTS will provide a further means for academic departments and industrial partners to use a well-equipped, interdisciplinary environment that integrates research with education.



Preliminary layout of the proposed target, guides, and instruments, which matches moderator types, flight path, and guide systems with conceptual instruments.

VULCAN: The Roman God of Fire and Metalworking

X. Wang

At the recommendation of the SNS IOC, conceptual design work has begun for an engineering materials diffractometer. The instrument is tentatively named VULCAN, after the Roman god of fire and metalworking. Although the primary use of VULCAN is intended for deformation and residual stress-related studies, other uses include spatial mapping of chemistry, microstructure, and texture. The desired performance parameters for VULCAN are as follows:

- Rapid volumetric (three-dimensional) mapping with a sampling volume of 1 mm^3 and a measurement time of minutes.
- High spatial resolution (0.1 mm) in one direction with a measurement time of minutes.
- About 20 simultaneously defined reflections for in situ loading studies.
- Capability for studying kinetic behaviors in subseconds.
- Simultaneous characterization capabilities, including dilatometry, weight, and microstructure.
- Integration of ancillary equipment such as furnace and load frame.

Together, these requirements call for a "compound" engineering diffractometer with a large degree of flexibility for intensity-resolution optimization. Fig. 1 shows the 44-m-long baseline design for VULCAN. Neutrons are delivered to the sample position via a series of straight and curved supermirror neutron guides. An interchangeable guide-collimator system is planned for the incident beam path. To achieve the maximum data rate and large d-spacing coverage, detectors will be employed continuously from 60 to 150° in the horizontal scattering plane and from -30 to 30° in the vertical plane.

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Thus designed, VULCAN can be operated flexibly for experiments with highly different intensity-resolution requirements. In high-intensity mode, the super-mirror channel will be employed in all segments of the guide-collimator system, effectively extending the supermirror guide all the way to 1 m from the sample. In high-resolution mode, which is appropriate for in situ loading studies where the response of individual reflections needs to be examined, the collimator channel is employed in all segments of the guide-collimator system. This mode produces a resolution of 0.10-0.22%, which is sufficient to resolve ~20 peaks for most engineering materials. To enable simultaneous characterization of microstructure, a SANS detector will be mounted at 4 m downstream from the sample. With a small specimen (e.g., <5 mm wide), the estimated Q-range for SANS measurements is 0.01 D^{-1}-0.18 D^{-1}.

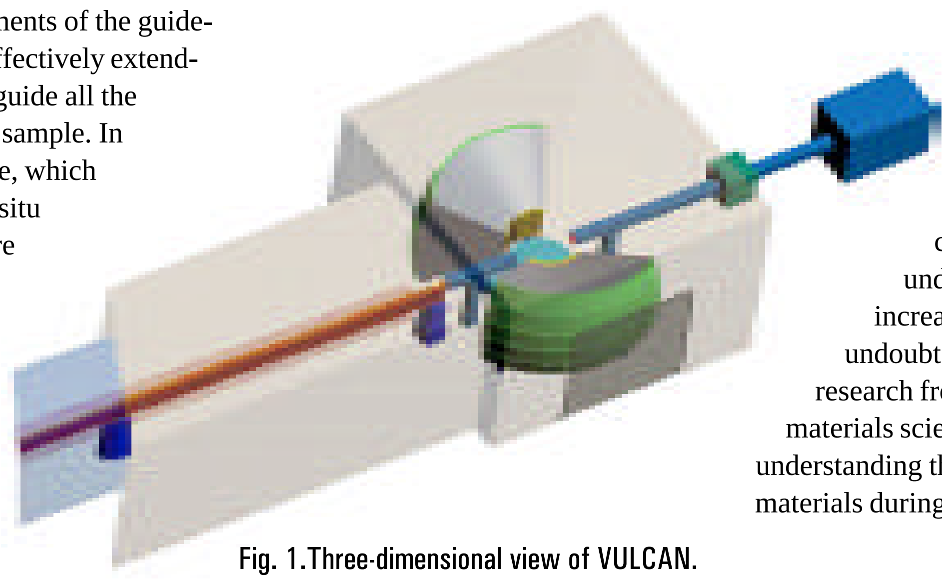


Fig. 1.Three-dimensional view of VULCAN.

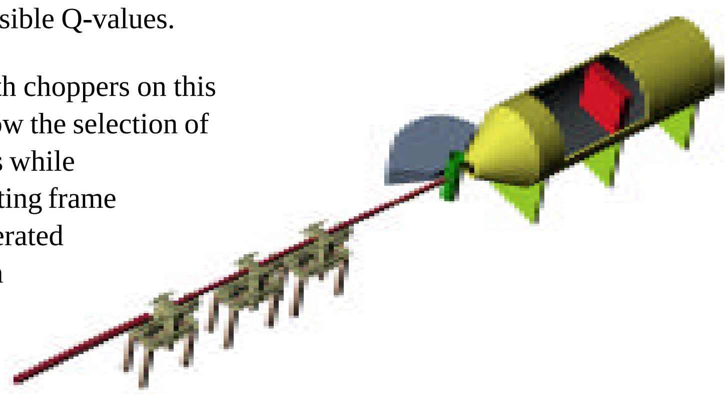
When completed, VULCAN will provide a 30 to 50 times increase in data rate over that of the best instruments currently operating or under construction. This increase in performance will undoubtedly open up new research frontiers in engineering materials sciences, notably in understanding the dynamic behavior of materials during fabrication or use.

Extended Q-Range, High-Intensity, High-Precision, Small-Angle Diffractometer

J. K. Zhao

With a covered Q-range from Q=0.001 to 10 Å^{-1}, the dynamic Q-range on this small-angle neutron scattering (SANS) instrument being planned for SNS will be unparalleled. This machine will have a 14-m primary flight path and a variable, 1- to 4-m secondary flight path. Depending on collimation length, flux at the sample position will be in the range of 10^8 to 10^9 (n cm^{-2}s^{-1}Å^{-1}), which will be the highest among existing SANS machines. A high-angle detector bank provides access to the high Q-region, covering an angle range of 35 to 150°. On the low-Q end, Soller collimators are used. The large, low-angle detector is located in a 4-m-long scattering chamber. The instrument will have a 3-m-long, true-curved, supermirror bender to avoid the direct line of sight from the moderator, thus reducing the background. The bender allows neutrons with wavelengths $1Å to pass, ensuring the high available flux and high accessible Q-values.

The three bandwidth choppers on this instrument will allow the selection of the different frames while completely eliminating frame overlaps. When operated at higher revolution rates, the chopper system will allow the SANS machine to function as a chopper spectrometer with no additional modification of the instrument. In this chopper mode, the machine will have 0.5 to 1.5% elastic resolution and 5 H 10^5 to 5 H 10^6 (n cm^{-2}s^{-1}Å^{-1}) neutron flux, and very low accessible Q-values, allowing the study of large-scale dynamics.

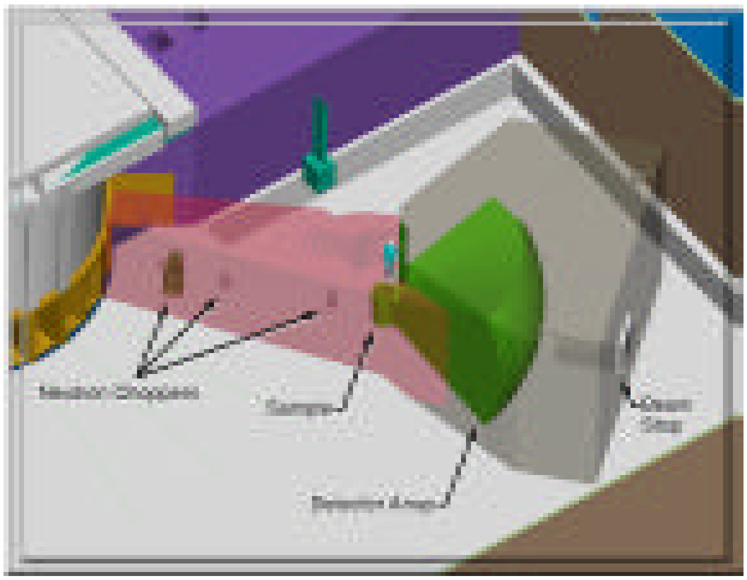


Extended Q-range, high-intensity, high-precision, small-angle diffractometer.

Chopper Spectrometer

D. L. Abernathy

Another instrument being designed for the SNS is a high-resolution, direct-geometry spectrometer. A fast 600-Hz magnetic-bearing chopper with neutron-absorbing slats and a large sample-to-detector distance of 6 m will provide an elastic resolution $\Delta E/E$ of approximately 1% (FWHM). By combining this resolution with the high flux from the bottom upstream moderator, new regimes in the study of the dynamics of condensed matter systems can be explored. This instrument will be useful in studies of magnetic systems, molecular and lattice dynamics, and superconductivity and quantum fluids, just to name a few.



Three-dimentional representation of the chopper spectrometer.

The instrument will operate with incident energies from 10 meV to more than 1 eV, employing background-suppressing neutron choppers and a Fermi chopper to select the desired energy. Preliminary calculations show that tapered neutron guides in the primary flight path from moderator to sample (15.5 m) will increase the flux on the sample by up to a factor of 10 for the lowest energies. Sample rotation and tilt stages will enhance capabilities for single-crystal research, and an oscillating radial collimator will decrease background from complex sample environment equipment.

The detector array will cover approximately 1 steradian of solid angle, almost twice that of any existing chopper spectrometer. Composed of linear position-sensitive ^{3}He detectors, the array ranges in scattering angle from 2 to 30° at all azimuthal angles, with additional detectors continuing to 60° horizontally with reduced vertical coverage. A pit will be incorporated in the building design to allow for the large vertical detector coverage and for access to maintain the instrument.

SNS and HFIR User Group

P. Butler

The SNS and High Flux Isotope Reactor (HFIR) User Group (SHUG) was formed for all persons interested in using the new neutron-scattering facilities being built or upgraded at Oak Ridge. SHUG provides input to management on user concerns, provides a forum for keeping the entire community informed of issues and progress at these facilities, and serves as an advocacy group for neutron-scattering science at these facilities. The initial bylaws for SHUG were adopted at the first SNS user meeting held in the fall of 1998. The Executive Committee for SHUG was formed in the summer of 1999 and had its first meeting, by conference call, in January 2000. Officers were elected in April 2000, and the committee moved quickly to prepare for the May 2000 User's Meeting in Washington, D.C. At the end of that meeting, the second general SHUG business meeting, and the first to be conducted by the Executive Committee, was held. The meeting began with the Executive Committee presenting a number of changes to the bylaws for approval. These changes included the creation of a secretary position for the committee and specific provisions for the length of terms of the initial Executive Committee members, items that were overlooked in the original bylaws. The most important change in the bylaws was the provision for forming special committees, consisting of members of the Executive Committee, to better address serious user issues whenever such concerns arise. The proposed changes were passed unanimously by the membership. The Executive Committee then introduced two special committees, one to serve as an advisory group to SNS management during construction of SNS and the other to serve in a similar role for HFIR during its upgrade. Robert McQueeney and Costas Stassis will serve as chairs of

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the SNS Special Committee and HFIR Special Committee, respectively. In addition, a constructive discussion took place regarding the role that the SHUG Executive Committee should play in serving the membership and in building a sense of community among its members. Among the items discussed were creation of a web site that includes a membership enrollment page and neutron-scattering reference list.

The Executive Committee has started working on the web site and membership list. The committee has also begun planning the next users' meeting, which will likely take place in summer 2002. Conference call meetings are taking place regularly (every month or two), during which issues are discussed and actions taken or tasks assigned as appropriate. Anyone who is interested in expressing concerns or ideas is encouraged to contact any of the members of the Executive Committee or special committees as appropriate.

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