2020 Oak Ridge National Laboratory

Neutron Sciences Annual Plan

OAK RIDGE National Laboratory | HIGH FLUX ISOTOPE REACTOR | SPALLATION NEUTRON SOURCE

U.S. DEPARTMENT OF ENERGY | Office of Science

Managed by UT-Battelle LLC for the US Department of Energy

2020 Oak Ridge National Laboratory
Neutron Sciences Annual Plan[1]

Vision: *The Spallation Neutron Source (SNS) and the High Flux Isotope Reactor (HFIR) are world-leading neutron scattering user facilities and centers of scientific excellence, attracting leading researchers to come and work with Oak Ridge National Laboratory (ORNL) to solve challenging problems that are important to the mission of the Department of Energy (DOE).*

Executive Summary

Leadership in materials science underpins future technologies in energy, security, and other applications that drive this nation's economy. Neutron scattering is among the crucial characterization techniques necessary to ensure a world-leading position in materials research for the United States. The uniqueness of the neutron as a probe for matter and energy makes it an essential tool for the discovery and delivery of knowledge that is complementary to other probes such as photons and electrons. The Neutron Sciences Directorate (NScD) at ORNL enables the research carried out by the scientific community by providing a powerful array of neutron scattering capabilities for researchers at the HFIR and SNS. Both facilities are operated on behalf of the DOE Office of Basic Energy Sciences (BES) as advanced neutron scattering user facilities.

In 2014, NScD published a strategic plan (referred to herein as the 2014 Plan) that outlines a series of coordinated activities for the next decade that would (1) maximize the performance and scientific impact of neutron scattering capabilities, (2) continue to provide the neutron facilities required to address existing and future major energy challenges, and (3) ensure that the United States maintains a forefront position in future materials research utilizing neutron scattering (*Neutron Sciences Directorate Strategic Plan 2014*). The central principle of the 2014 Plan was the formulation of science priorities that in turn drive the development of new and upgraded beam lines, sources, and enabling technologies. The 2014 Plan was intended as a living document to be routinely amended in response to changes in national materials research and BES scientific priorities as they are continually refined through consultation with key stakeholders. This flexibility reflects the fact that our scientific understanding of the world evolves in leaps that are not easy to predict.

This plan defines specific goals and actions for FY 2020 that advance the strategic intent of the 2014 Plan. Some of these goals reflect amendments to the original scientific priorities and execution timeline for the strategic developments described in the 2014 Plan. The FY 2020 goals are organized into three main areas of strategic activity in the body of this plan:

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[1] Note that the activities associated with the SNS Second Target Station (STS) are being executed by the STS Project, which is now organizationally separate from NScD. Nevertheless, STS plans and goals are included in this plan to reflect the partnership between the NScD and STS directorates and provide an integrated view of ORNL's Neutron Sciences program.

- Science Priorities: Excel in the execution of a science program that uses neutrons to enable breakthrough advances in key scientific areas focused through the Science Initiatives that are organized around quantum materials, soft matter and polymers, catalysis and interfacial chemistry, materials and engineering, and biological materials and systems. Additional initiatives emphasize high-pressure science and sample environments as well as high-performance computing and data analytics.
- New and Upgraded Capabilities: Execute upgrades to ORNL's existing neutron sources to deliver wholly new capabilities in neutron scattering, providing researchers with unprecedented tools for examining the structure and dynamics of a wide range of materials.
- Excellence in Safety and Operations: Optimize the operation of SNS and HFIR in support of a broad and growing user community.

The FY 2020 goals and actions also reflect the performance priorities that NScD has set for FY 2020. These performance priorities are represented by the following critical outcomes and measures of success.

Critical Outcomes:

- Maximize neutron production at ORNL's neutron sources
- Operate ORNL's current neutron sources at ≥ 90% availability of agreed-upon schedule
- Develop a plan for continuing to improve operational stewardship
- Ensure users have reduced data at the end of the experiment
- Develop and implement a strategic plan for data analysis software
- Upgrade existing instruments to realize their full potential
- Construct prioritized new instruments at SNS
- Design and construct an optimized, expanded HFIR Cold Guide Hall
- Develop and review a strategic vision for each of the Science Initiatives
- Achieve Critical Decision (CD) 2 and 3 approval for the Proton Power Upgrade (PPU) project

Measures of Success:

- Provide maximum neutron production hours
- Operate SNS and HFIR at ≥ 90% availability of the agreed-upon schedule
- Achieve excellence in operations
- Provide users with reduced data upon completion of their experiments
- Design and construct world-leading neutron scattering instruments
- Complete an optimized, expanded HFIR Cold Guide Hall
- Complete the PPU project within the budget and on schedule

Overview

Neutron scattering and spectroscopy were initially developed in the 1940s and 1950s, and the 1994 Nobel Prize in Physics was awarded to Clifford G. Shull and Bertram N. Brockhouse for their pioneering efforts. Over the past seven decades, neutron scattering has become a vital tool for studying materials across many scientific fields and applications, including automotive engines, batteries, data storage, geology, polymers, and biomedicine. The exceptional properties of neutrons provide unique insight into the structure and function of materials, as summarized below.

- *Materials structure and dynamics:* Neutrons have a broad range of useful wavelengths, allowing the examination of structures from the atomic level to the size of biological cells. (The achievable wavelength range is dependent on the design of the neutron source and neutron scattering instrument.) Neutron energies span a range that is ideal for studying the individual and collective atomic motions that determine the properties of materials. Differences in neutron energy can be measured to allow the dynamics of atomic and molecular processes to be followed on time scales ranging from fractions of a picosecond to microseconds—corresponding to vibrations in rigid lattices to the slow movements of large macromolecules.
- *Elemental and isotopic sensitivity:* Neutrons are scattered via interactions with atomic nuclei, making them sensitive to the identity of both the element and the specific isotope being studied. Hence, unlike other techniques that scatter from the electric charge density in atoms, neutron scattering can readily distinguish between some elements with similar atomic numbers and is sensitive to light elements such as hydrogen, even in the presence of heavy elements. Further, the neutron scattering response of some isotopes can vary, making differentiation of isotopes very distinct. This unique property of neutrons makes it possible to use isotopic substitution—for example, replacing hydrogen with deuterium—to study the role of hydrogen in catalytic processes or the association of water in protein complexes.
- *Magnetism:* Neutrons have a magnetic moment, but no charge. Thus, neutrons provide an exquisitely sensitive probe for the study of magnetic properties and dynamics in materials. This feature has been exceptionally valuable for the study of materials ranging from superconductors and quantum materials to computer storage media.
- *Penetrating power:* Neutrons readily pass through most materials, making possible the study of bulk materials and buried interfaces. Further, samples can be studied under realistic conditions, such as in situ and operando studies of catalytic processes in reactors, studies of geological processes under extremes of pressure and temperature, and observations of fuel injector performance in an operating automobile engine.

Today, more than a dozen major neutron scattering facilities exist worldwide, including both reactor-based and accelerator-based neutron sources. In the United States, DOE BES supports two major neutron scattering user facilities at ORNL—HFIR and SNS; and the US Department of Commerce supports the National Institute of Standards and Technology Center (NIST) for Neutron Research (NCNR). Each year, more than a thousand researchers from nations around the globe use the two DOE neutron sources that are made available by the Office of Science user program. A brief summary of the characteristics of HFIR and SNS, and how they compare with other leading neutron sources, follows.

Operating at 85 MW, HFIR is the highest-flux reactor-based source of neutrons for research in the United States, and it provides one of the highest steady-state neutron fluxes of any research reactor in the world. Its thermal neutron flux is similar to that of the high-flux reactor of the Institut Laue-Langevin (ILL), the premier European reactor-based neutron source, and neutron scattering instruments at HFIR and ILL address similar scientific questions.

The First Target Station (FTS) at SNS is currently the most powerful accelerator-driven neutron source in the world, operating at a power of 1.4 MW. It provides beams of neutrons in short pulses at a repetition rate of 60 Hz with the highest peak brightness in the world. When the 25 Hz pulsed neutron source at the Japan Proton Accelerator Research Complex (J-PARC) reaches its full power capability in the near future, it will exceed the peak brightness of SNS. In addition, the European Spallation Source (ESS), now under construction in Sweden, will provide similar peak brightness once it begins operating at 2 MW in the mid-2020s, with a future upgrade path to 5 MW. ESS will deliver beams of neutrons in long pulses at 14 Hz, which will provide time-averaged fluxes of both cold and thermal neutrons comparable to those of a reactor-based source. The lower repetition rates of ESS and J-PARC compared with the FTS will allow the use of broader ranges of neutron energies in each pulse. Long-pulse spallation sources, such as the ESS, are highly flexible; and their individual instruments can be optimized for experiments that require high peak brightness and a broad range of energies, or for high time-averaged flux, essentially bridging between short-pulse sources and continuous neutron sources.

HFIR and the FTS at SNS provide optimized beam characteristics that are used for specific studies of materials. Briefly, HFIR produces continuous beams of either cold or thermal neutrons that are typically monochromatic and are optimized for studies of materials over selectable but narrow ranges of length scale or energy. The FTS produces pulsed beams of neutrons with very short pulses and therefore high energy resolution. Its high (60 Hz) repetition rate allows for a medium bandwidth of neutron energies to be used, because neutrons of different energies are separated by their arrival time at the detector; a longer time between pulses therefore results in a broader energy bandwidth. The FTS is best optimized for thermal neutrons that are ideal for spatial resolutions on the atomic scale and fast dynamics studies of materials.

Even with these existing capabilities, there is a global need for improved neutron scattering capabilities to address emerging science challenges. ORNL is undertaking major improvements at the SNS to provide unprecedented capabilities, including the PPU project and the Second Target Station (STS), as well as the design of new instrumentation, such as the neutron image station VENUS, and supporting data analytics. The PPU project will double the available proton beam power at the SNS accelerator complex from 1.4 to 2.8 MW, delivering 2 MW to the existing FTS and providing the capability to drive the STS. Increasing the neutron flux and brightness at the FTS will provide new and substantially improved capabilities for studying a broad range of materials and associated chemical and physical processes with neutron scattering.[2]

The STS addresses a global need for a high-intensity cold neutron source that is able to simultaneously use a broad energy/wavelength range.[3] Such a source would provide the research community with exciting new opportunities to explore a wide range of materials, including in situ and operando studies during synthesis and processing, nonequilibrium phenomena, and dynamics. This need will be partially addressed by ESS in Europe and J-PARC in Japan, as discussed above. The STS will provide the United States with a world-leading capability in high-brightness cold neutron beams with broad energy/wavelength ranges. It will complement existing US sources to ensure future state-of-the-art capabilities for the US research community. On August 1, 2019, STS activities moved to a separate project office that reports to the ORNL director.

A series of cost-effective improvements to HFIR are planned to sustain its capabilities for neutron scattering, materials irradiation, and isotope production into the future. A Beryllium Outage Project Plan and Schedule have been developed and communicated to the affected stakeholders. Preparations are under way to replace HFIR's beryllium reflector in 2024–2025. The project plan provides the timeline for all the preparatory activities that must be completed to successfully implement the permanent reflector replacement and other necessary component replacements. It also identifies critical in-vessel components and special tooling, fixtures, and equipment required to replace the permanent beryllium reflector. The plan also includes the key infrastructure improvements needed in the beam room. The replacement reflector has been designed, the beryllium material has been procured, and fabrication of replacement components (including four beam tubes and specialized tooling and fixtures) will continue in FY 2020. The replacement provides an opportunity to upgrade the cold neutron source and to work toward improvement of the thermal beams provided to the instruments.

NScD is also assessing steps that can be taken to renew and upgrade HFIR to provide world-leading reactor-based science and technology capabilities to serve DOE missions well into the future. Considerations include pressure vessel replacement, alternative moderators, and alternative fuels, as well as projections of future mission needs in neutron scattering, isotope production, and materials irradiation. Based on feedback from the user community and its own assessment of scientific opportunities, NScD intends to propose an expansion of the HFIR Cold Guide Hall to provide sufficient space for

- A new cold neutron triple-axis spectrometer (MANTA)
- Continued operation of the existing instruments (the cold neutron imaging instrument IMAGING, which is an image-plate single crystal diffractometer; two small-angle neutron scattering [SANS] instruments, Bio-SANS and GP-SANS; and development beam lines)
- Future opportunities, such as a high-resolution neutron spin echo instrument.

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[2] The Science Case for a Proton Power Upgrade of the Spallation Neutron Source, 2018.

[3] First Experiments at the Spallation Neutron Source Second Target Station, 2019.

In FY 2019, several operational events impacted the availability of HFIR and SNS. At SNS, problems with the target mercury loop that prematurely ended the previous operating cycle in January 2019 have been resolved, and neutron production resumed on June 23, 2019. There were further operational events with the cryogenic moderator system and premature failure of a mercury target. Action has been taken to improve system engineering, safety, and operational processes and procedures. Additional actions will be implemented during future planned maintenance outages to ensure continued safe and reliable operation of SNS.

At HFIR, work is in progress to resolve problems that led to the shutdown of the reactor in November 2018 in response to indications of a radiation leak, which were traced to a defective fuel element. ORNL is working closely with the fuel manufacturer and with DOE to ensure ORNL's ability to continue the safe, reliable, and predictable operation of HFIR, with a focus on expanded quality assurance assessments of the fuel assemblies. During the extended shutdown of HFIR, NScD proceeded with several activities that support improved predictability and reliability, including (1) replacement of the secondary cooling system supply line, (2) continued shipments of spent nuclear fuel to the Savanah River Site, (3) replacement of control rod components, (4) replacement of pony motor battery racks and chargers, and (5) performance of intrusive maintenance on HFIR's electrical distribution system.

A major priority for NScD in FY 2020 is developing and executing initiatives to strengthen the overall operational stewardship of the directorate, including (1) an organizational effectiveness assessment, (2) a safety culture assessment, and (3) implementation of asset management. We expect to begin improvements based on recommendations from these activities in FY 2020.

1. FY 2020 Goals and Actions

NScD annually holds a series of planning meetings to establish annual and long-term goals. Tasks and outcomes are defined to meet the agreed-upon goals. Funding to achieve the goals is allocated in subsequent meetings. Funding restrictions may require deferral of some activities and adjustment of timelines for task competition.

Recommendations from multiple stakeholders—the DOE program sponsor, the BES Advisory Committee, ORNL's Scientific Advisory Board, the Neutron Advisory Board, the Accelerator/Target Advisory Committee, and the SNS HFIR User Group—inform the goals and subsequent actions necessary to achieve these goals. The goals and actions outlined in this plan are also reflected in the FY 2020 ORNL Performance Evaluation and Measurement Plan Goals and Notable Outcomes and NScD Business Plan. Detailed actions to achieve the goals are also found in the Accelerator Management Plan;[4] Spallation Neutron Source Target Management Plan;[5] Beryllium Outage Project Plan and Schedule; Review of Data Reduction, Handling, and Analysis of the High Flux Isotope Reactor and the Spallation Neutron Source; and Science Productivity Steering Committee instrument improvement project rankings. An FY 2020 neutron production overview with planned maintenance actions during outages is provided in Table 1.

[4] Accelerator Management Plan, SNS 104000000-PN0003, R02, September 2019.

[5] Spallation Neutron Source Target Management Plan, 106010000-PN0005, R07, December 2019.

Table 1. FY 2020 neutron production overview with planned maintenance actions.

FY20 Neutron Production Overview

SNS — Neutron production hours: 4600

OCT 2019	FY20A	• RFQ RF seal inspection • CMS mitigation • RTBT water leak repair
NOV 2019	T24	MTX-019 JF 2040 hours @ **1.4 MW**
DEC 2019		
JAN 2020		
FEB 2020		
MAR 2020	FY20B	• Install T25 • RFQ RF seal inspection • CMS mitigation • HVCM oil cooling upgrade (1 unit) • Al PBW replacement • Phase 2 Hg loop recovery actions • Change target gas injection control mode > 2 SLPM • VENUS bulk shield insert
APR 2020	T25	HML-001 Orig with GI 2048 hours @ **1.4 MW**
MAY 2020		
JUN 2020		
JUL 2020	FY20C	• Install T26 • RFQ RF seal inspection • Complete phase 2 Hg loop recovery
AUG 2020		
SEP 2020	T-26	ORTE-004 Modified Blue 1544 hours @ **1.4 MW**

HFIR — 7 Cycles

OCT 2019	EOC 483 484	
NOV 2019	EOC 484	
DEC 2019	485	
JAN 2020	EOC 485	
FEB 2020	486	
MAR 2020	EOC 486	• Control plate changeout & core inspection • Servo Ch 3 upgrade • 4 Pri Limit-torque replacement
APR 2020		
MAY 2020	487 EOC 487	
JUN 2020	488	
JUL 2020	EOC 488 489	
AUG 2020	EOC 489	
SEP 2020	490 EOC 490	

Neutron production

Rev. 02 12-05-2019

1.1. Science Priorities

Excel in the execution of a science program that uses neutrons to enable breakthrough advances in key scientific areas including quantum materials, soft matter and polymers, catalysis and interfacial chemistry, materials and engineering, and biological materials and systems.

Goals and Actions:

- Work with the research community to advance scientific discovery.
- Consult with the scientific user community to identify needed advances in neutron scattering capabilities.
- Continue to implement the seven Science Initiatives and sharpen their focus on the most relevant areas of research.
- Develop new sample environment capabilities in high pressure, soft matter, high temperature, and specialized conditions such as electric fields, and enhance the capabilities at low temperature and high magnetic fields.
- Emphasize the development of data analytic tools for the benefit of neutron scattering research.
- Advance ORNL LDRD initiatives that develop new techniques, sample environment equipment, or data analysis protocols to expand the application of neutron scattering in key scientific areas.

NScD will continue its leadership role in using neutron scattering to provide unique information about the structure and dynamics of matter, thereby accelerating the pace of scientific discoveries and addressing important technical materials problems. Directorate staff will continue to work with their colleagues across ORNL to enable advances in five key scientific areas: quantum materials, polymers and soft matter, catalysis and interfacial chemistry, materials and engineering, and biological materials and systems. They also will continue working with the scientific user community to identify needed advances in neutron scattering capabilities that can catalyze scientific discoveries and applications. NScD will engage the user community through webinars, workshops, and conferences during FY 2020.

In FY 2018, NScD established six Science Initiative areas, each led by a researcher who serves as the coordinator. NScD will continue to implement the Science Initiatives and sharpen their focus on the most relevant areas of research. The areas include quantum materials; soft matter and polymers; catalysis and interfacial chemistry; materials and engineering; biological materials and systems; and computing, modeling, and data analysis. These Science Initiatives represent areas within which neutrons will be a crucial tool for addressing compelling science questions, and they are expected to change over time as scientific priorities change.

Another Science Initiative, high-pressure science and technology, was established in FY 2019 to further ORNL's world-leading status in this research area, bringing the current number of initiatives to seven. Implementation of the following seven science initiatives will continue during FY 2020:

- Biological materials and systems
- Catalysis and interfacial chemistry
- Computing, modeling, and data analytics
- High-pressure science and technology
- Materials and engineering
- Quantum materials
- Soft matter and polymers

The Science Initiative leaders assisted with the development of the First Experiments Report in FY 2019, the selection of projects for mid-scale investments and instrument improvements, the definition of new post-doctoral positions, and the prioritization of workshops. The process for the selection of Discretionary Time was redesigned in FY 2019 to put more emphasis on the Science Initiatives, and the importance of staff members developing their research identities has been strongly communicated.

NScD will develop new sample environment capabilities in high pressure, soft matter, high temperature, and specialized conditions such as electric fields, and enhance the capabilities at low temperature and high magnetic fields. To promote science drivers and instill an innovation culture, Sample Environment Steering Committees were established in FY 2015. NScD formed four such steering committees to serve as an interface between scientific and sample environment staff. These committees focus on the following technical areas: Low Temperature and Magnetic Fields, Pressure and Gas Handling, High Temperature, and Soft Matter and Biological Materials. The committee members consist of science staff, scientific associates, sample environment staff, and external users. Committees meet periodically with the expectation that the meeting minutes will be recorded and distributed. Each steering committee has developed a plan that assesses the current state of sample environment and identifies gaps in skill sets and capabilities. The plans are periodically updated and continue to be the basis for investment. The committees have been, and continue to be, a highly effective mechanism to encourage innovation and collaboration.

NScD will continue to emphasize the development of data analytic tools for the benefit of neutron scattering research.

ORNL has a Neutron Science and Technology LDRD Initiative that is focused on using ORNL discretionary resources to extend NScD leadership in the international neutron scattering community by focusing on research and development in critical areas that underpin neutron scattering research. The overall goal of the LDRD initiative is the development of new techniques, sample environment equipment, or data analysis protocols to expand the application of neutron scattering in key scientific areas. Projects funded through the FY 2019 call that will be executed in FY 2020 are focused on using polarized neutrons and Wollaston prisms to quantitatively understand quantum entanglement in materials; combining rheology with small-angle neutron scattering, neutron spin echo, and simulations to understand the flow response of soft materials; and developing new equipment to allow neutron scattering to reveal the fundamental nature of catalytic reactions.

1.2. New and Upgraded Capabilities

Execute upgrades to our existing neutron sources to deliver wholly new capabilities in neutron scattering, providing researchers with unprecedented tools for examining the structure and dynamics of a wide range of materials.

Goals and Actions:

- Effectively manage and execute the PPU project in accordance with the Project Execution Plan and deliver the project scope in compliance with the technical performance specifications and within the established DOE performance goals for cost and schedule. Performance will be assessed based on the work planned and accomplished during FY 2020, not on the cumulative performance of the project.
  - Receive CD 2 and/or CD 2/3 approval for the PPU project.
  - Complete FY 2020 PPU project milestones.
- Prepare for accelerator power ramp-up for post-PPU operations.
  - Execute system improvements as outlined in the SNS Accelerator Management Plan and Target Management Plan.
  - Plan outages to support system improvements and execution of PPU plan.
- Continue construction of SNS BL-10, VENUS.
  - Complete all beam line chopper designs.
  - Accomplish delivery and acceptance of core vessel and shutter inserts.
  - Install bulk shield insert.
- Continue investments in instrument upgrades, sample environments, and ancillary equipment to support world-class neutron scattering.
- Depending on final funding decisions, execute the instrument projects approved by the NScD Science Productivity Steering Committee:
  - HFIR HB-1A, FIE-TAX, backend
  - SNS BL-7, VULCAN-X phase II
  - HFIR HB-1, P-TAX, polarization
  - SNS BL-1B, NOMAD detectors and collimators
  - SNS BL-5, CNCS detectors
- Receive CD 1 approval for STS.
- Execute the STS project scope in compliance with DOE Order 413.3B. Advance toward CD-1: *Approve Alternative Selection and Cost Range* during this performance period.
- Continue implementation of the HFIR beryllium outage plans.
- Continue design of the HFIR Cold Guide Hall expansion and initiate procurement of neutron guide system.

During FY 2020, NScD will effectively manage and execute the PPU project in accordance with the Project Execution Plan and deliver the project scope in compliance with the technical performance specifications and within the established DOE performance goals for cost and schedule.[6] NScD staff will work to receive CD-2 and/or CD-2/3 approval for the PPU project in FY 2020.

NScD is actively preparing for the accelerator power ramp-up. Activities to prepare for the power increase have begun and will continue through FY 2024. Actions over the next few years include upgrading the Cryogenic Moderator System refrigerator to increase cryogenic capacity and increasing the number of spares. A comprehensive list of actions and deadlines to prepare for the accelerator power ramp-up can be found in the Accelerator Management Plan.[7] NScD will plan outages to support system improvements and execution of the PPU project plan.

NScD will continue implementation of the HFIR Beryllium Outage Plan. It will begin cutting/drilling of the permanent beryllium reflector, initiate fabrication of HB-2, and award a design/build contract for the replacement of the Cold Source Cryogenic Plant. During FY 2020, NScD will complete the design of the HFIR Cold Guide Hall expansion and initiate procurement of the neutron guide system.

Construction of the SNS BL-10 instrument VENUS, a time-of-flight neutron imaging station, began in FY 2019. Construction of VENUS will continue in FY 2020 with installation of the instrument's core vessel and shutter inserts. VENUS chopper design will be completed in FY 2020. Development of new instrument concepts to fill open beam ports will also be pursued, including a new diffraction instrument concept, DISCOVER. DISCOVER represents the world's highest-resolution dedicated total scattering instrument at SNS. Its construction will present the same challenges as the construction and operation of VENUS. Over the next few years, the number of neutron production hours will be less than optimal because longer maintenance outages will be required to accommodate VENUS construction and the PPU project.

The Instrument Improvement Program will continue in FY 2020. Activities include continuing the SNS BL-5 (SNAP) optics upgrade project and beginning several new instrument improvement projects. New projects in FY 2020 will include the SNS BL-7 (VULCAN) detector upgrade project; SNS BL-5 (CNCS) detectors; SNS BL-1B (NOMAD) detector and collimator upgrade; HFIR HB-1 (FIE-TAX) polarization capability; and HFIR HB-1A (PTAX) backend replacement. System-wide improvements for data acquisition and instrument controls will be executed, including the completion of the migration of SNS and HFIR instruments to Experimental Physics and Industrial Control Systems (EPICS).

A series of instrument suite reviews will be conducted in FY 2020 to evaluate the productivity of the suite and determine actions to improve beam line output. In FY 2020, ownership and operation of SNS BL-15 (Neutron Spin Echo) will transfer to DOE from Juelich. NScD will work with Juelich to ensure a seamless transition that does not impact the User Program.

1.3. Excellence in Safety and Operations

Optimize the operation of SNS and HFIR in support of a broad and growing user community

Goals and Actions:

- Restart HFIR before November 13, 2019.
- Reestablish safe and reliable operations at HFIR.

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[6] FY 2020 PEMP Goal 2.1.

[7] Accelerator Management Plan, SNS 104000000-PN0003, R02, September 2019.

- Provide effective UT-Battelle leadership to execute short- and long-term initiatives to restart and sustain fuel manufacturing activities.
- Maintain reliable 1.4 MW operations at SNS.
- Conduct Phase 2 of target mercury loop repair.
- Create and maintain an inventory of at least two SNS reliable spare target modules.
- Manage procurement and fabrication of inner reflector plug (IRP) 3, scheduled for FY 2022 delivery.
- Continue execution of system-wide improvements for data acquisition and instrument controls, including the completion of the migration of SNS and HFIR instruments to EPICS.
- Implement the data reduction and analysis software remediation plans identified in the July 2019 peer-reviewed assessment of the "Data Reduction, Handling and Analysis at the Instruments Suites at HFIR and SNS." By the end of CY 2019, complete the actions for the SANS instruments and develop and submit to BES timelines for the remaining instruments. Provide updates in regular NScD operation calls and submit a summary progress report to BES by September 30, 2020
- Develop and execute new initiatives to improve operational performance and reliability, management of operational events, and drive the Safe Conduct of Research (SCoR) principles into the organizational culture and operations

During FY 2020, NScD is committed to reestablishing safe and reliable operation of HFIR and maintaining reliable 1.4 MW operation of SNS.[8] HFIR was successfully restarted in October 2019. NScD will operate HFIR safely and reliably for seven operating cycles at ≥ 90% predictability and is committed to providing 4600 hours for users at 1.4 MW at 90% availability at SNS.

NScD will provide effective leadership to execute short- and long-term initiatives to restart and sustain HFIR fuel manufacturing activities.[9] The directorate is working closely with the fuel manufacturer and DOE to ensure ORNL's ability to continue the safe, reliable, and predictable operation of HFIR, including expanded quality assurance assessments of the fuel assemblies. The failed fuel element event that led to the shutdown of HFIR in November 2018 and the subsequent investigation have led to a commitment to install new nondestructive testing equipment in the fuel manufacturing process. NScD has put into place a robust Corrective Action Plan that will rectify the conditions that produced fuel element 0-488. Corrective actions include the hiring of two engineers who will provide additional oversight at fuel manufacturer BWX Technologies (BWXT). This oversight will include the witnessing of critical manufacturing steps, by HFIR personnel, to ensure all future fuel elements are properly fabricated. A new inspection technique, computed tomography (CT), is also being developed to examine the roots of the welds of finished elements. NScD staff will begin installation and qualification of the CT scanning machine at BWXT.

Preparation is required for the transition of uranium oxide processing from its current location to the new Uranium Processing Facility at the Y-12 National Security Complex. The transition, scheduled to begin in 2025, is estimated to take 2 to 3 years. Before the transition, the uranium

[8] FY 2020 Performance Evaluation and Measurement Plan Goals 2.3.

[9] FY 2020 Performance Evaluation and Measurement Plan Goal 3.2.

oxide inventory must be increased to ensure that fuel fabrication can be continued during the transition. We will continue to increase uranium oxide levels processed at Y-12 for HFIR fuel. It is projected that 125 Kg of uranium oxide will be processed.

Executing a robust maintenance program, maintaining a supply of critical spares, and addressing system obsolescence is critical to safe and reliable operation of HFIR and SNS. During FY 2020, NScD will execute the actions set forth in the Spallation Neutron Source Target Management Plan. These actions include creating and maintaining an inventory of two SNS spare target modules. NScD will continue to manage the procurement and fabrication of Inner Reflector Plug IRP-3 scheduled for delivery in FY 2022.

At SNS, Phase 2 of the target mercury loop repair will be conducted in FY 2020. The repairs will include the engineering design and procurement of mercury loop components to support loop modifications. NScD will execute the actions outlined in the Accelerator Management Plan,[10] created by the Research Accelerator Division (RAD), to improve the SNS accelerator system in the critical areas of beam power, performance, reliability, and ultimately planning for 5,000 hours of neutron production. The plan includes the schedule to achieve this objective, taking into account the impacts on scheduled beam time resulting from the PPU and STS projects and the installation of planned new instruments.

Accelerator Improvement Projects (AIPs) are essential to maintain the cutting-edge capability of the SNS accelerator complex. In FY 2020, an AIP for the heavy water recombiner will begin. Significant investments will be made in FY 2020 to replace the two manipulators used in SNS operation. This activity will occur over several years.

System obsolescence is another factor that requires investment and mitigation. SNS was commissioned in 2005, so the systems and subsystems are approaching 20 years of use and experiencing the onset of end-of-life. These issues include systems in which components are failing at a higher rate and systems for which components, particularly electronics, are no longer available. A RAD Obsolescence Plan will be developed and implemented during FY 2020.

At HFIR, improvements to the reactor infrastructure will continue. NScD will install a new steam line, connect one emergency diesel generator to the electrical system, replace two of four control rod drives, and replace the removable beryllium reflector. Plans are also to continue shipments of spent nuclear fuel to the Savanah River Site.

NScD will continue to implement a robust accelerator research and development program. The program will demonstrate laser stripping, experimentally verify self-consistent beam distribution, develop foils for 2 MW operation, conduct beam dynamics and halo studies at the Beam Test Facility, and pursue plasma processing and laser research and development.

NScD will implement the data reduction and analysis software remediation plans identified in the July 2019 peer-reviewed assessment of "Data Reduction, Handling and Analysis at the Instrument Suites at HFIR and SNS."[11] NScD will provide regular updates to DOE in progress reports and

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[10] Accelerator Management Plan, SNS 104000000-PN0003, R02, September 2019.

[11] FY 2020 PEMP Goal 3.2.

monthly conference calls. A progress report will be provided to DOE by September 30, 2020. As new software is developed, webinars will be held to introduce the user community to the new software.

In FY 2020, NScD will develop and execute new initiatives to improve operational performance and reliability, manage operational events, and drive the Safe Conduct of Research principles into the organizational culture and operations.

2. Summary

The actions outlined and the related plans will be monitored throughout FY 2020 to ensure they are completed. Additional actions that may be needed to ensure NScD meets its goals will be added as they are identified. NScD leadership believe the actions they will take in FY 2020 will move ORNL toward achieving the vision to lead the world in neutron science and technology by delivering and leveraging world-leading neutron sources to enable scientific discoveries and solve critical technical challenges.