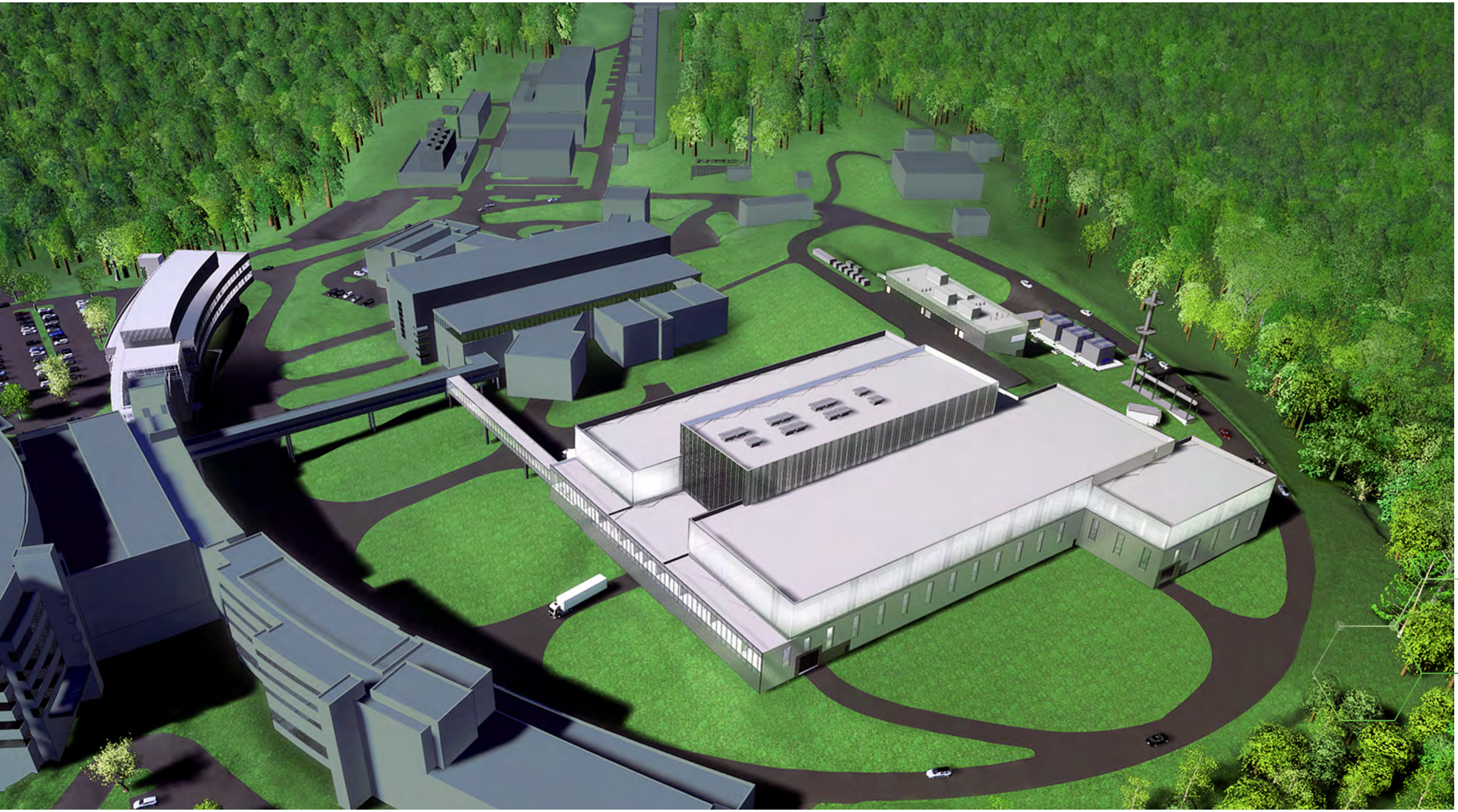
The Second Target Station
at the Spallation Neutron Source

Transformative new capabilities for discovery science

Oak Ridge National Laboratory



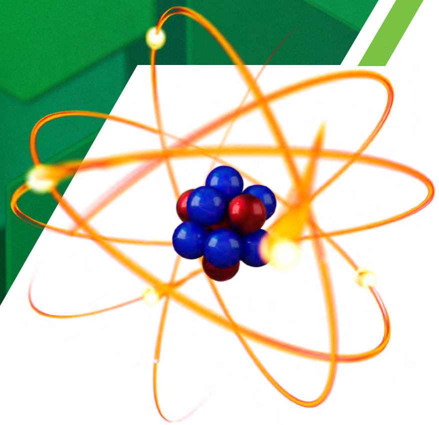
neutrons
for materials research and innovation

Oak Ridge National Laboratory (ORNL) in Tennessee is the US epicenter for neutron scattering—one of the most powerful techniques for exploring the nature of materials and energy.

Neutron scattering is essential for advancing materials research that supports the US economy and provides solutions to challenges in energy, security, and transportation. It provides information that cannot be obtained using any other research method.

ORNL hosts two of the world's most powerful sources of neutrons for research: the High Flux Isotope Reactor (HFIR) and the Spallation Neutron Source (SNS).

ORNL is moving forward with a third neutron source: the Second Target Station (STS) at SNS, to address emerging science challenges.



what are neutrons
and why do they matter?

Anything that can be touched is made of small building blocks called atoms. At the center of each atom is a nucleus containing even smaller particles called protons and neutrons. Orbiting the nucleus is a cloud of electrons that occupies most of the volume of the atom.

Neutrons are one of the particles that make up matter. Abundant in the universe, neutrons make up more than half of all visible matter. Neutrons are extremely useful to scientists because they have no electrical charge and, when released from the nucleus of an atom, they can enter materials without damaging them. In fact, they have higher penetrating power than electrons or X-rays. Neutrons also are uniquely sensitive to magnetism and lighter elements, such as hydrogen.

Neutrons enable scientists to see the internal structure of that material.

Neutron research has led to discoveries and improvements vital to our economy, national security and daily lives, including in these areas:

- Biotechnologies critical to health, such as more effective drug delivery
- More powerful computers
- Stronger glass for mobile devices
- More reliable aircraft and rocket engines
- Cars with better gas mileage
- Improved armor for the military
- Batteries that are safer, charge faster, and last longer
- Solar energy
- Engineered materials, such as strong, lightweight metal alloys
- Quantum computing, data storage and handling
- 3-D printed composite materials, such as turbine blades for aerospace engines
- Nuclear materials for next-generation reactors
- Superconducting wires and devices
- Biofuels
- Consumer products, such as detergents, paints and cosmetics
- Vehicle engine fuel injection systems and components
- Polymers
- Catalytic devices and materials
- Thermoelectrics for spacecraft, rovers and probes

what is neutron scattering?

When a beam of neutrons is aimed at a sample, many neutrons will pass through the material. But some will interact directly with atomic nuclei and “bounce” away at an angle, like colliding balls in a game of pool. This technique is called neutron scattering.

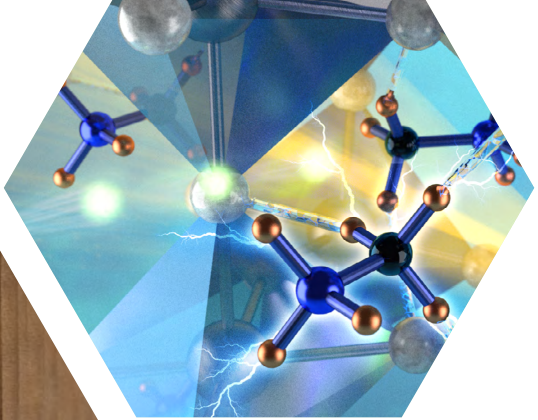
It’s employed to gain information that can’t be found with any other research method. It’s used in many industries—automotive, aerospace, steel, defense, industrial materials, energy storage, data storage, biomedicine and others—to address the 21st century’s major scientific challenges.

Neutron scattering provides information about the positions, motions, and magnetic properties of materials. Using special detectors, scientists count scattered neutrons, measure their energies and the angles at which they scatter, and map their final position. This makes it possible to glean details about the nature of materials ranging from liquid crystals to superconducting ceramics, from proteins to plastics, and from metals to metallic glass magnets.

ORNL’s neutron facilities, the Spallation Neutron Source (SNS) and the High Flux Isotope Reactor (HFIR), attract the world’s top materials researchers to conduct experiments they can’t perform elsewhere, to better understand the materials important in physics, biology, chemistry, materials science and engineering. Few neutron facilities around the world can match the power and scientific capabilities they offer, and the Second Target Station (STS) will provide a third neutron source with new, transformative capabilities that will complement the existing facilities and fill the gaps in materials research.

Representing 500-plus academic institutions, 70-plus companies, and 90-plus scientific institutions, thousands of researchers from around the world apply each year to pursue their research at HFIR and SNS. More are expected to come to ORNL once the STS is built.

The most promising proposals are selected by a scientific panel through peer review. Scientists whose proposals are chosen use the facilities and instruments at SNS and HFIR free of charge in return for making their data and findings public.



"Neutron facilities are one of those key elements to fundamental science, to really understanding materials from the bottom up, and that's something that you need, essentially, in the country where the development happens."

–Adrian Brugger, Director, Robert A. Carleton Strength of Materials Laboratory, Columbia University


STS


SNS


HFIR

what is the Second Target Station

and what is the three-source strategy?

The Spallation Neutron Source (SNS) at ORNL provides the most intense, pulsed accelerator-based neutron beams in the world, while the High Flux Isotope Reactor (HFIR) is the most powerful reactor-based source of neutrons for research in the United States.

The Second Target Station (STS) Project, now in progress at ORNL, includes design, construction, installation, and commissioning of the facilities and equipment needed to create a world-leading third neutron source at SNS. The STS will complement capabilities at the SNS First Target Station (FTS) and HFIR by providing new capabilities for materials research.

Together, these three facilities will form an unbeatable combination that will maintain US global leadership in neutron science capabilities.

why is the Second Target Station so important?

The STS will be a transformative new tool for addressing big challenges in fundamental science and for developing materials for next-generation energy technologies, national security and other needs, including cars with better gas mileage, more powerful computers, and biotechnologies critical to health, such as more effective drug delivery.

Other countries are designing and building more advanced neutron research facilities that soon will eclipse existing US capabilities.

The STS is needed to maintain US leadership in neutron scattering research.

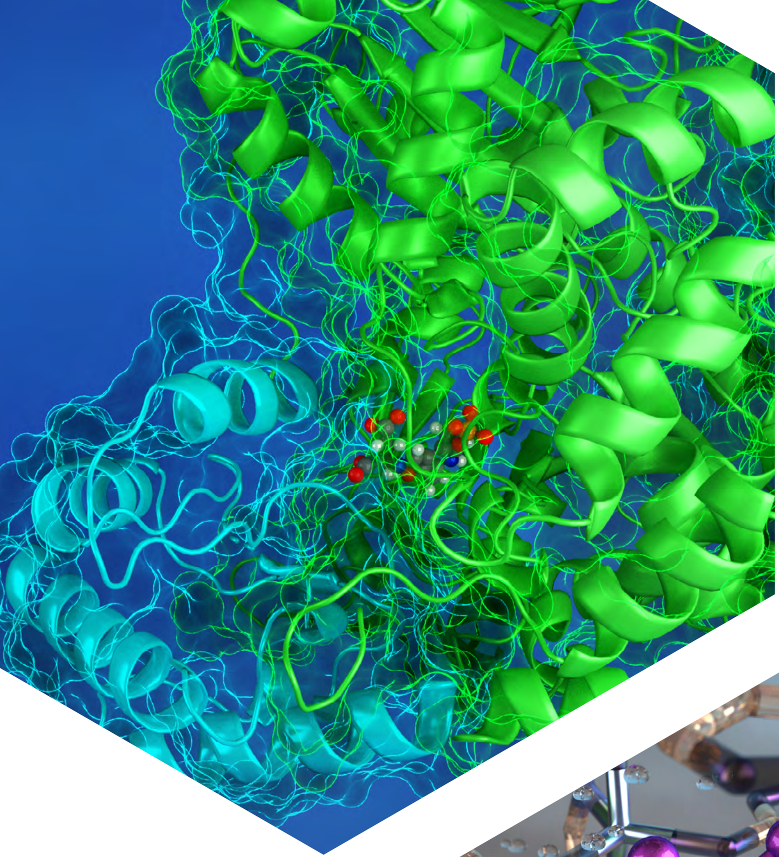
If the STS does not move ahead now, the US will lose its lead in neutron sciences and groundbreaking science will be done outside the country. US scientists from academia, industry, and the federal government will have, at best, limited access to superior facilities abroad, jeopardizing America's ability to test and develop materials vital to the economy, public health, and national security.

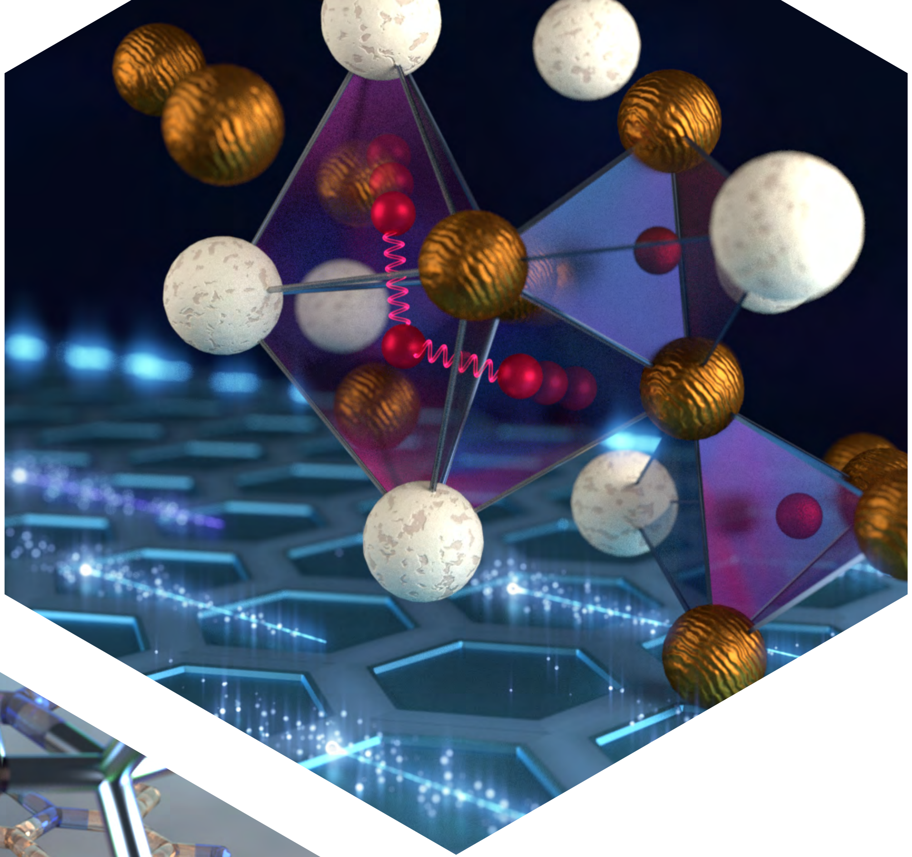
The new STS facility will:

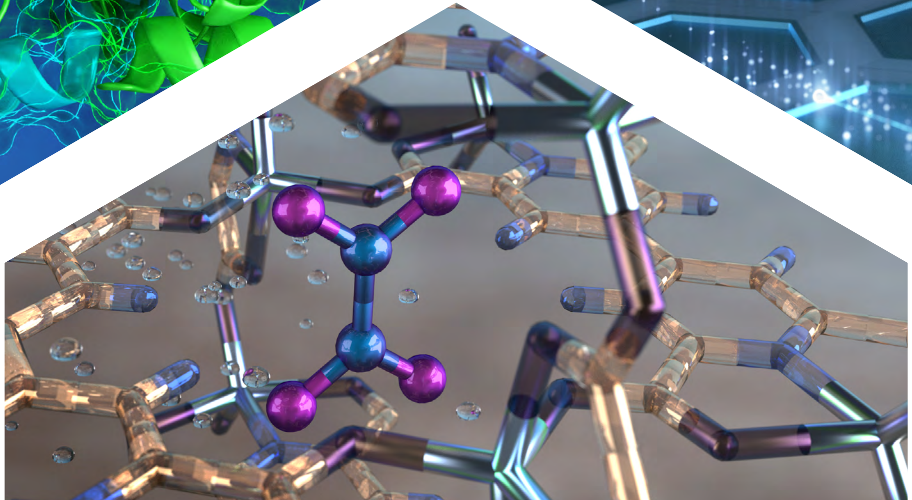
- Enable new scientific capabilities demanded by the user community
- Accelerate discovery in quantum matter, polymers and soft materials, biology and life sciences, energy materials, structural materials and other scientific fields
- Maintain US leadership in the neutron sciences
- Allow faster data collection
- Enable innovative neutron experiments under more extreme conditions, using smaller samples
- Respond to the Basic Energy Sciences Advisory Committee report that states the STS is *"absolutely central to contribute to world-leading science."*

"One of the major reasons for my coming back to work for Oak Ridge National Lab is the Second Target Station project. I want to be involved in the development of and, eventually, commissioning of the STS, which will be instrumental in addressing the major scientific challenges of the future with its unique capabilities."

–Neelam Pradhan, Lead Engineer, STS Target Systems







the STS will help drive the nation's economy and transform neutron research

The research that can be done at the STS is essential to the development of future technologies that will drive the nation's economy—new batteries and structural materials for transportation, new catalysts for efficient production of fuels and chemicals, next-generation polymers that make it possible to upcycle waste into new consumer products, and quantum materials to enable advances in computing and sensors.

Construction of the STS will provide transformative capabilities that allow thousands of users from national laboratories, universities, and industry to address these challenges and accelerate industrial innovations.

key STS scientific capabilities

The STS will provide new capabilities for many fields of research—materials science, physics, chemistry, geology, biology, and engineering, among others.

The STS will incorporate major advances in instrumentation and technologies to make optimal use of the neutrons it produces. Projected to conduct its first experiments in the early years of the next decade, the STS will have transformative capabilities that will be available to the broad research community, including academic, industrial, and government laboratories, as part of the Department of Energy (DOE) Office of Science User Facility program.

These capabilities can be applied to challenges in five key areas of science:

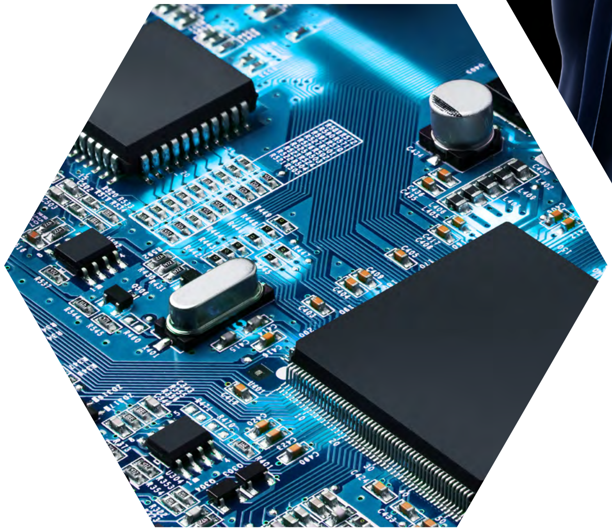
- polymers and soft materials,
- quantum matter,
- biology and life sciences,
- materials synthesis and energy materials, and
- structural materials.

Polymers and Soft Materials

The capabilities provided by the STS promise to revolutionize our understanding of polymers and other soft materials, which are the foundation for many industrial and consumer products such as detergents, pharmaceuticals, cosmetics, membrane filters, and batteries. The STS's next-generation instruments will lead to breakthroughs in the development of new technologies such as next-generation polymers, making it possible to upcycle waste into new consumer products.

Quantum Matter

Research into quantum materials with novel properties holds exceptional promise for the development of next-generation computers, high-density storage devices, high-precision sensors, new energy technologies and secure communications using unbreakable encryption. The STS will accelerate the transformation of quantum materials into new technologies with the potential to strengthen national security, create unparalleled computing power and enhance economic competitiveness.



Biology and Life Sciences

The STS will provide insights into molecular and cellular processes that will enhance human health and quality of life, such as developing more effective drug treatments for disease. Neutrons are sensitive to light elements such as hydrogen, so they are essential for studying biological systems, from viruses to cancer to healthy cells. Plant studies are improving biomass conversion to biofuels and increasing drought resistance in crops.

Materials Synthesis and Energy Materials

Research done at the STS will have a broad impact on development of new materials and chemical processes for applications in energy efficiency, production and storage including safer, longer-lasting batteries, and for securing access to clean water in an increasingly water-stressed world.

Structural Materials

Structural materials can be found everywhere in modern society, as key components in automobiles, airplanes, buildings and bridges. However, a big challenge is how to increase their strength without sacrificing toughness and flexibility. The capabilities of the STS are critical for the design of a new generation of more reliable, better-performing structural materials for transportation, construction and other applications.

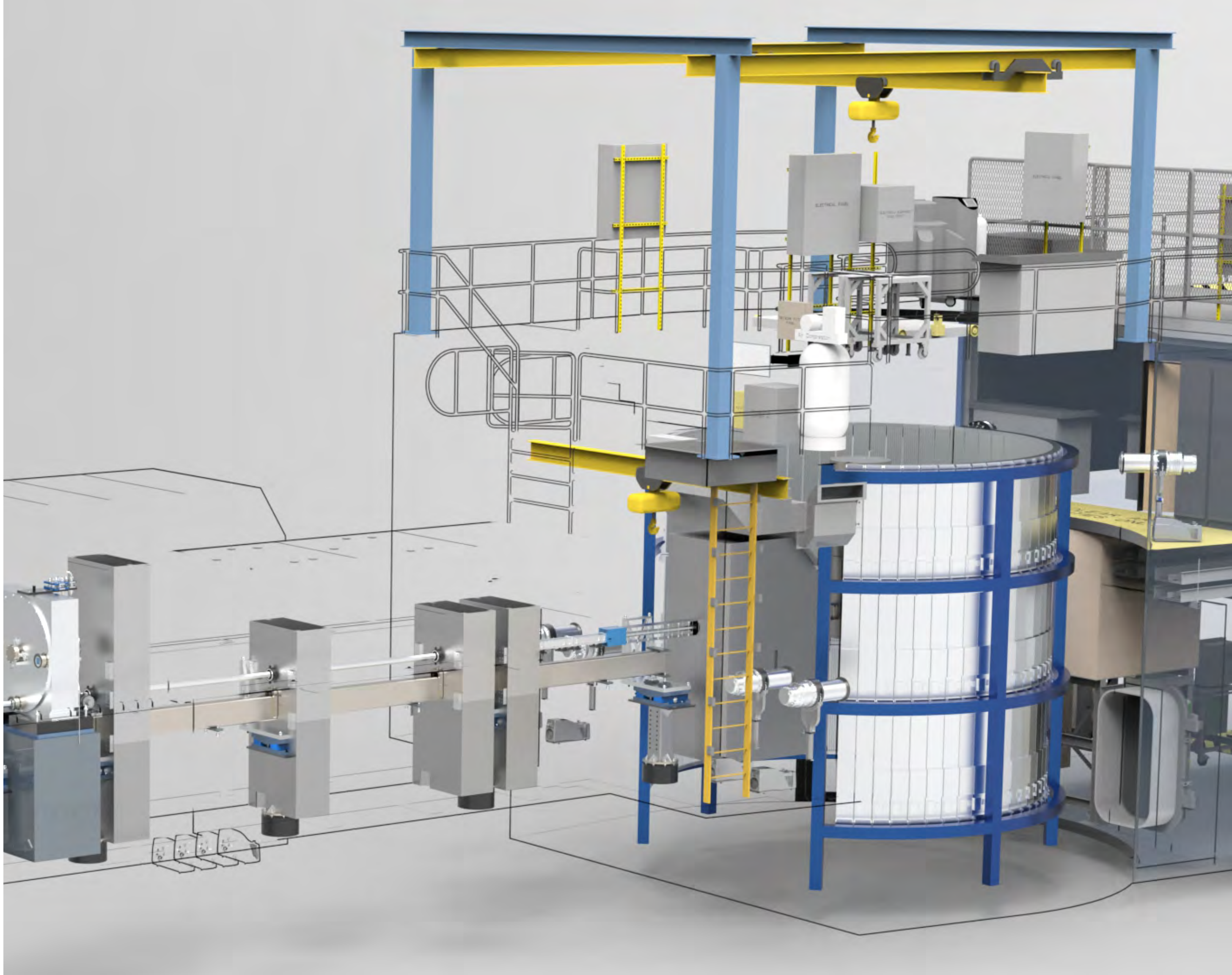
world-leading instruments *for world-leading science*

With its unique combination of neutron beam characteristics and a new suite of instruments boasting the latest advances in high-resolution optics, detector technologies, sample environments, new computational methods and instrument design, the STS will deliver performance gains 100 to 1,000 times better than the best existing instruments. This will make it possible to conduct a wide range of experiments now not possible anywhere in the world.

An upgrade under way at the Spallation Neutron Source (SNS)—the Proton Power Upgrade (PPU)—will double the power capability of its accelerator to 2.8 megawatts by 2025. The increased power will improve the performance of the existing SNS instrument suite and provide a platform for powering the STS.

The capabilities offered by the STS instruments will complement those of the FTS and the High Flux Isotope Reactor (HFIR), providing the US with unparalleled resources for neutron scattering and unparalleled opportunities to meet the big science challenges of the future.

CHESS is one of several concepts developed for possible inclusion in the initial suite of Second Target Station instruments. It has been designed to explore the fundamental nature of novel materials, including candidates for quantum computing.

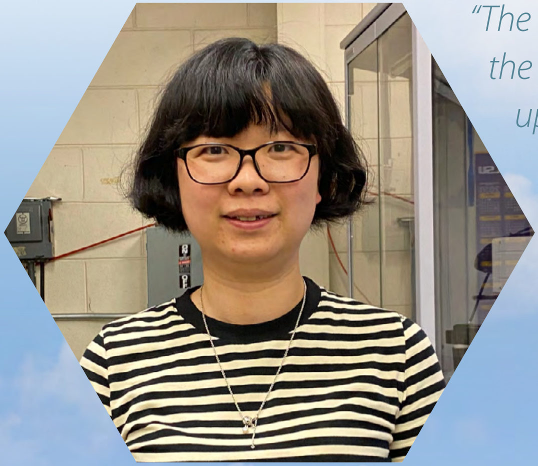


the STS will support DOE's Office of Science mission

UT-Battelle LLC manages ORNL for the DOE Office of Science. The Office of Science is the single largest supporter of basic research in the physical sciences in the United States and is working to address some of the most pressing challenges of our time.

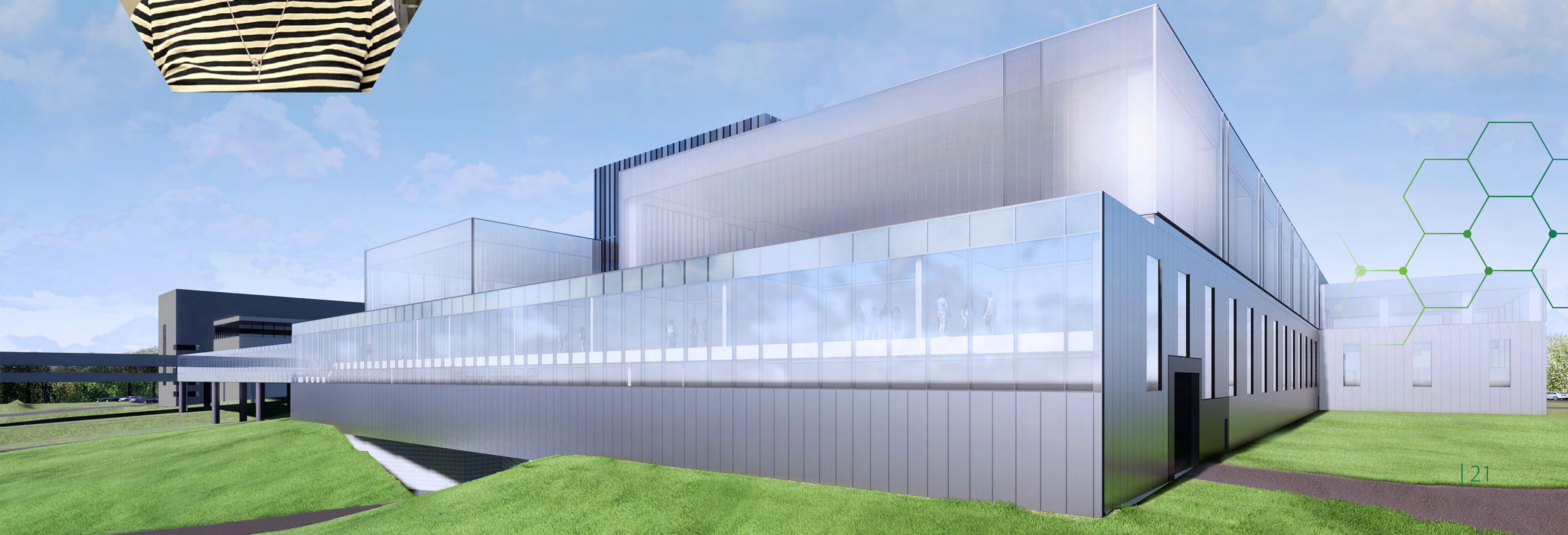
The mission of the Office of Science is to deliver scientific discoveries and major scientific tools to transform our understanding of nature and advance the energy, economic, and national security of the United States.

To that end, the Office of Science develops and operates a remarkable set of scientific user facilities, with ORNL's SNS and HFIR among them. These tools for scientific discovery and innovation, used by thousands of scientists annually, include some of the world's best resources for understanding and characterizing materials at the level of atoms and molecules.



"The Second Target Station will make it possible to observe the subtle interactions between particles, which will open up a new chapter of the materials world."

–Weiwei Xie, Assistant Professor, Department of Chemistry and Chemical Biology, Rutgers University-New Brunswick



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