Twenty years of discovery science at the Spallation Neutron Source

On a clear April day in 2006, a team of engineers and scientists erupted with excitement from the control room of the Spallation Neutron Source (SNS), a newly built user facility at Oak Ridge National Laboratory. A pulse of protons — racing at nearly the speed of light — shot from the accelerator and struck liquid mercury at the facility's first target station, freeing tens of millions of neutrons.

That moment launched a new era of discovery science that continues to shape technologies we use every day, from spacecraft to smartphones. The technique used to reveal the atomic-scale insights needed for these technological advancements emerged from science brought to life during the Manhattan Project, foremost at ORNL's famed X-10 Graphite Reactor, the world's first nuclear reactor to operate continuously, produce electricity from nuclear energy, produce grams of plutonium, and generate studies on the nature of matter and health hazards associated with radioactivity. Two scientists working at X-10 pioneered the technique known as neutron scattering. Researchers from all over the world compete each year for beam time at SNS and ORNL's High Flux Isotope Reactor to explore and discover fundamental science.

Contributing to the nation's tradition of leadership in science and technology, on that spring day, SNS became the world's first high-power facility to use superconducting technology to accelerate protons, as well as the first to use a liquid mercury target, setting a new standard for particle accelerators.

Accelerating science

Today, particle accelerators exist in many different sizes and forms. However, in the 1940s, these accelerators were rare and used mainly for fundamental research for particle physics. As science and technology evolved, by the 1980s accelerators drove discoveries in materials science. Today, tens of thousands of accelerators worldwide sit in doctor's offices, research labs and industrial settings. Likewise, neutron scattering evolved alongside accelerators, eventually leading to DOE's decision to build the SNS.

Accelerator beam power at SNS grew from 160 kilowatts at its 2006 inception to 2 megawatts in 2026, a progression of power critical to scientific progression. More power means more neutrons, and more neutrons means more science.

Since user experiments began in 2008, tens of thousands of researchers from all over the world have used the scientific instruments at the SNS First Target Station to make important discoveries in fields, such as quantum materials, soft matter, biomaterials and chemistry. As a user facility, beam time is granted through the SNS User Program and is completely free of charge as long as researchers publish their results in open literature available to the scientific community.

The Proton Power Upgrade project paves the way for an increase in power from the accelerator's original design of 1.4 megawatts to the potential to reach 2.8 megawatts. The Proton Power Upgrade project also has established the infrastructure to support the Second Target Station project, which will expand scientific capabilities and help maintain U.S. leadership in discovery science for decades to come. The Second Target Station will extend scientific reach in a range of fields and grow SNS's already vibrant user community just as the First Target Station continues to demonstrate.

Today, SNS stands at the edge of another scientific revolution: the Genesis Mission, a national initiative led by the Department of Energy and its 17 National Laboratories to build the world's most powerful scientific platform to accelerate discovery, strengthen national security and drive energy innovation.

"Years ago, people would hold up a mobile phone and say, 'The materials inside this went through the discovery pipeline 30 years ago,'" said Jon Taylor, associate laboratory director for ORNL's Neutron Sciences Directorate. "The Genesis Mission is about accelerating that process, shortening the time from a great idea to a usable material."

SNS by the numbers (2008 – 2026)

- 2-megawatt accelerator
- 11,300+ experiments
- 3,900+ instrument peer-reviewed publications
- 19 SNS User Program instruments for experiments

With great power comes great science

Building upon SNS's record of operational reliability, the Second Target Station will provide a new foundation for achievements in basic science based on the major power increase enabled by the Proton Power Upgrade project. However, the story of SNS began at its initial operating power level of 160 kilowatts.

300 kilowatts: A world record
SNS earns a Guinness World Record

SNS's story of power progression began when the accelerator reached 300 kilowatts, earning a Guinness World Record in 2008 as the planet's most powerful pulsed spallation neutron source, a title SNS still holds. Over the next two decades, with every increase in beam power, scientific capabilities advanced. Similar to increases in power for a magnifying glass, each leap in beam power, or brightness, allows researchers to study smaller samples in sharper detail. Brighter beams mean more neutrons. More neutrons means faster, better science.

1 megawatt: A quantum leap
Scientists unlock molecular secrets

A mere year later, the facility reached 1 megawatt. This operational milestone symbolized a jump forward in analytical capability for the international neutron scattering community and reinforced SNS's role as an unmatched resource for unlocking molecular secrets of advanced materials. Publications from the first experiments grew as researchers from all over the world sought neutrons at SNS to better understand fundamental concepts for quantum science, batteries, drug delivery and tissue regeneration.

1.4 megawatts: Design power achieved
Publications triple as SNS powers new discoveries

By 2010, experiments at SNS and its sister facility, the High Flux Isotope Reactor, also a DOE Office of Science User Facility at ORNL, were recognized with the Gordon Battelle Award for Scientific Discovery for insights into the physics of iron-based superconductors. Over the next decade, the facility reached two major milestones: annual peer-reviewed publications rose from 29 in 2010 to 336 in 2020, and SNS achieved its original design power goal of 1.4 megawatts in 2014. Throughout this period, discovery science at SNS advanced across a wide range of fields, including developing deeper insights into the behavior of quantum magnets and designing drugs with fewer side effects to understanding the secrets of superconductivity, testing engine performance, and studying why experimental methods measure different lifetimes for free neutrons.

Researchers also use SNS to study fundamental physics. Neutrino Alley is an underground corridor where the COHERENT collaboration uses intensely pulsed beams to explore some of the universe's most elusive particles. Physicists use the Fundamental Neutron Physics Beamline to answer questions about the nature and existence of matter in the universe.

1.55 megawatts: Major upgrades completed
Major upgrade clears the way for the Second Target Station

In 2023, SNS once again pushed the limits of accelerator performance, reaching an operating power of 1.55 megawatts and setting a new world record for accelerator-driven neutron sources.

Meanwhile, SNS reached another turning point: the Proton Power Upgrade project finished installation and commissioning of the new equipment ahead of schedule and under budget, adding seven additional superconducting cryogenic modules and supporting power systems to the accelerator. These major upgrades paved the way to double the accelerator's original design for neutron beam brightness from 1.4 megawatts to 2.8 megawatts, clearing the way for the Second Target Station and expanding SNS's scientific potential.

1.7 megawatts: Greater precision
Tackling tougher scientific challenges

The momentum continued in July 2023 when the accelerator's beam power reached 1.7 megawatts — enabling scientists to probe materials faster with greater precision and tackle increasingly complex challenges. Users published research based on experiments at SNS for high-performance glass (for everything from mobile phones to jet aircraft), better drug design for aggressive cancers, manufacturing for space and longer-lasting batteries.

1.9 megawatts: VENUS arrives
SNS welcomes its 19th instrument, expanding research horizons

As SNS approached its 20th anniversary, its pace of achievement showed no signs of slowing. In 2025, the accelerator reached a new power record of 1.9 megawatts while opening its 19th instrument, VENUS, to SNS's User Program for the first time. Built with AI in mind, VENUS's instrument scientists and users will use AI to produce 3D models of samples from time-of-flight raw data in significantly fewer measurements.

2 megawatts: A new operating frontier
Milestone reflects decades of investment in performance, reliability and capability

On April 23, 2026, just days before the 20th anniversary of safe operations, the Spallation Neutron Source reached 2 megawatts of beam power, marking the latest step in a progression that has steadily expanded the facility's scientific reach since operations began in 2006. The achievement also comes as neutron science becomes more closely integrated with advanced computing as well as AI to interpret large datasets and guide experiments in real time, reducing the time between measurement and insight.

AI and quantum

As the challenges we currently face require a historic national effort, comparable in urgency and ambition to the Manhattan Project, ORNL once again stands at the ready to answer the nation's need for AI-accelerated innovation and discovery.

Experiments at SNS generate massive amounts of data — far more than scientists can analyze in a day's time. However, AI can sift through neutron scattering data at lightning speed, spotting patterns to help steer experiments. Instead of running one experiment and waiting weeks for analysis, researchers could extract five times the insights in a single session. The convergence of AI and neutron science promises to supercharge discovery at SNS and accelerate critical breakthroughs in materials, energy and quantum computing.

Neutrons give scientists a unique window into quantum states — the way atoms spin and interact inside complex materials. Traditional computing runs on ones and zeros, but quantum computing operates across a spectrum of probabilities. Neutrons help scientists probe these quantum states.

“Neutrons reveal the fundamental nature of unusual quantum states, which can underpin next-generation technologies in computing, sensing and communications,” said Mark Lumsden, interim director of ORNL’s Neutron Scattering Division.

The arc of a promise

Nearly 20 years after the first pulse of protons struck liquid mercury, the beams at SNS are brighter than ever — and the mission that began in 2006 is still accelerating. From the first pulse to today’s record-breaking beams, SNS’s story is one of relentless innovation and teamwork. Each leap in power sharpened our view of the atomic world and widened the circle of impact, from resilient materials to quantum foundations. The promise of discovery continues: brighter pulses, deeper insights and faster science for tomorrow’s technologies.

“It takes a remarkable, mission-driven team, from operators to engineers to scientists, to deliver world-leading capabilities,” said Brian Weston, chief operating officer of ORNL’s Neutron Sciences Directorate. “Their dedication makes this science possible.”

As SNS celebrates two decades of discovery, its story is far from complete. Building on the foundation of reliability, power and innovation established by the First Target Station, the Second Target Station will open new frontiers in quantum science and energy and will ensure the arc set in motion in 2006 continues to bend toward discovery.

SNS is a DOE Office of Science user facility.

UT-Battelle manages ORNL for DOE’s Office of Science, the single largest supporter of basic research in the physical sciences in the United States. The Office of Science is working to address some of the most pressing challenges of our time. For more information, visit energy.gov/science. — *Sumner Brown Gibbs*