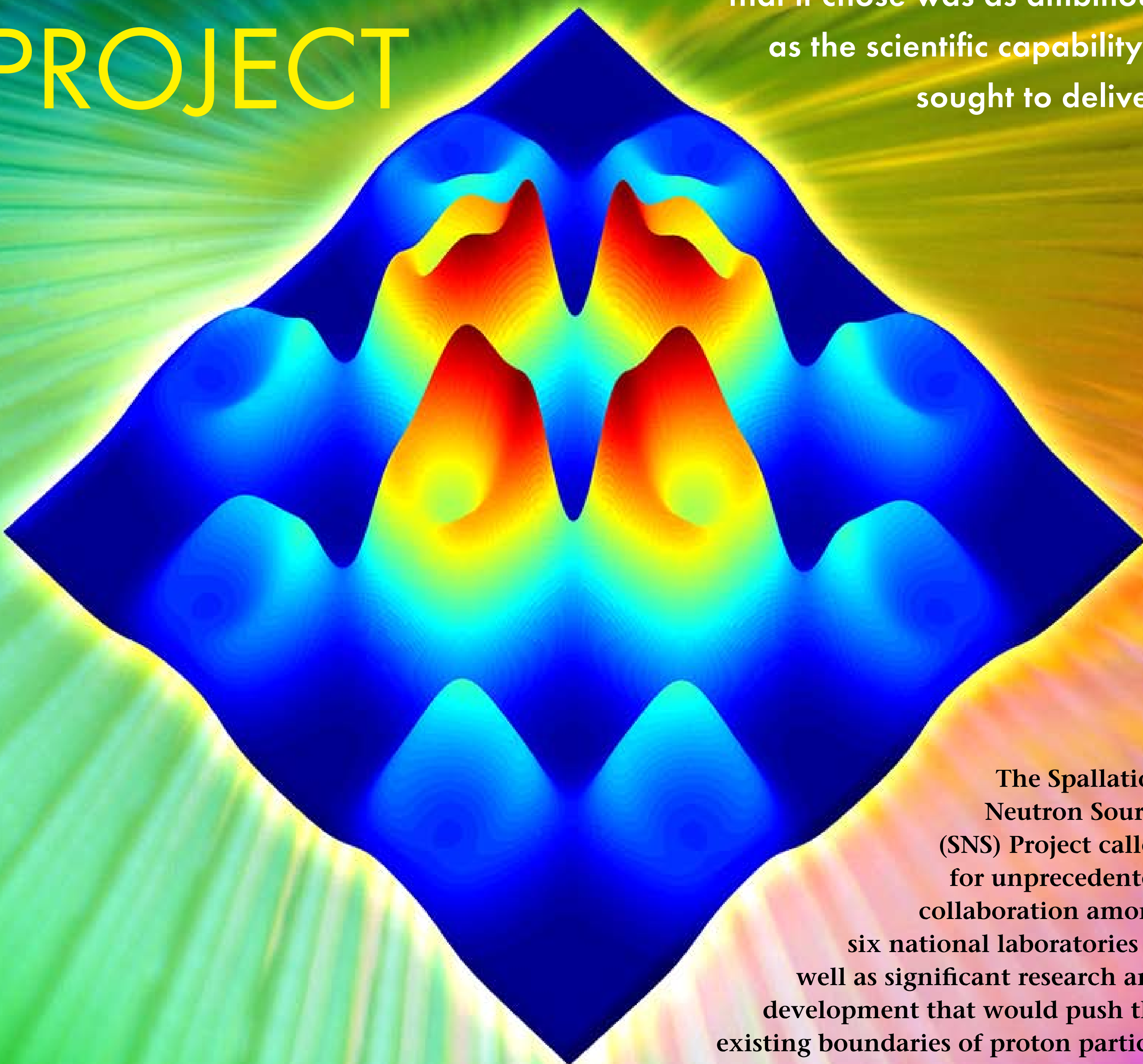
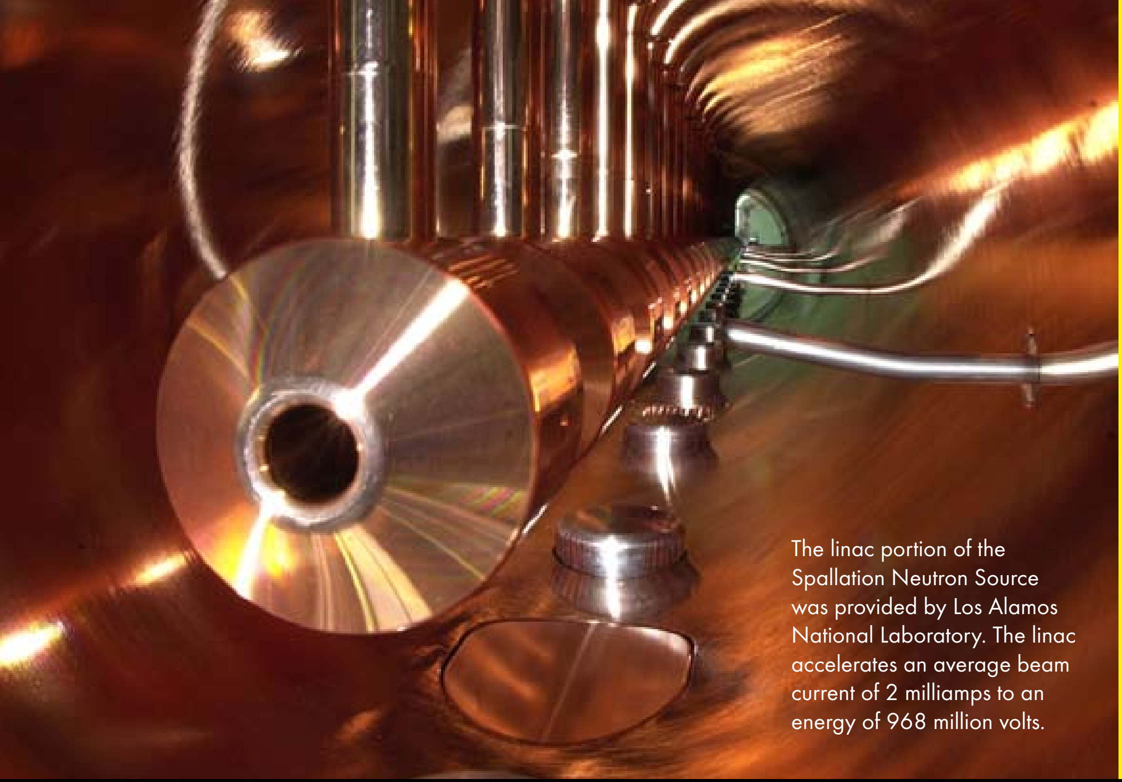
THE SPALLATION NEUTRON SOURCE PROJECT

When the Department of Energy (DOE) set out in the 1990s to develop a neutron scattering research facility that was ten times more powerful than the state of the art, the concept for the project that it chose was as ambitious as the scientific capability it sought to deliver.



The Spallation Neutron Source (SNS) Project called for unprecedented collaboration among six national laboratories as well as significant research and development that would push the existing boundaries of proton particle accelerator technology.

A simulation of the nature of the spin excitations in a superconducting material's structure.



The linac portion of the Spallation Neutron Source was provided by Los Alamos National Laboratory. The linac accelerates an average beam current of 2 milliamps to an energy of 968 million volts.

HOW IT WORKS

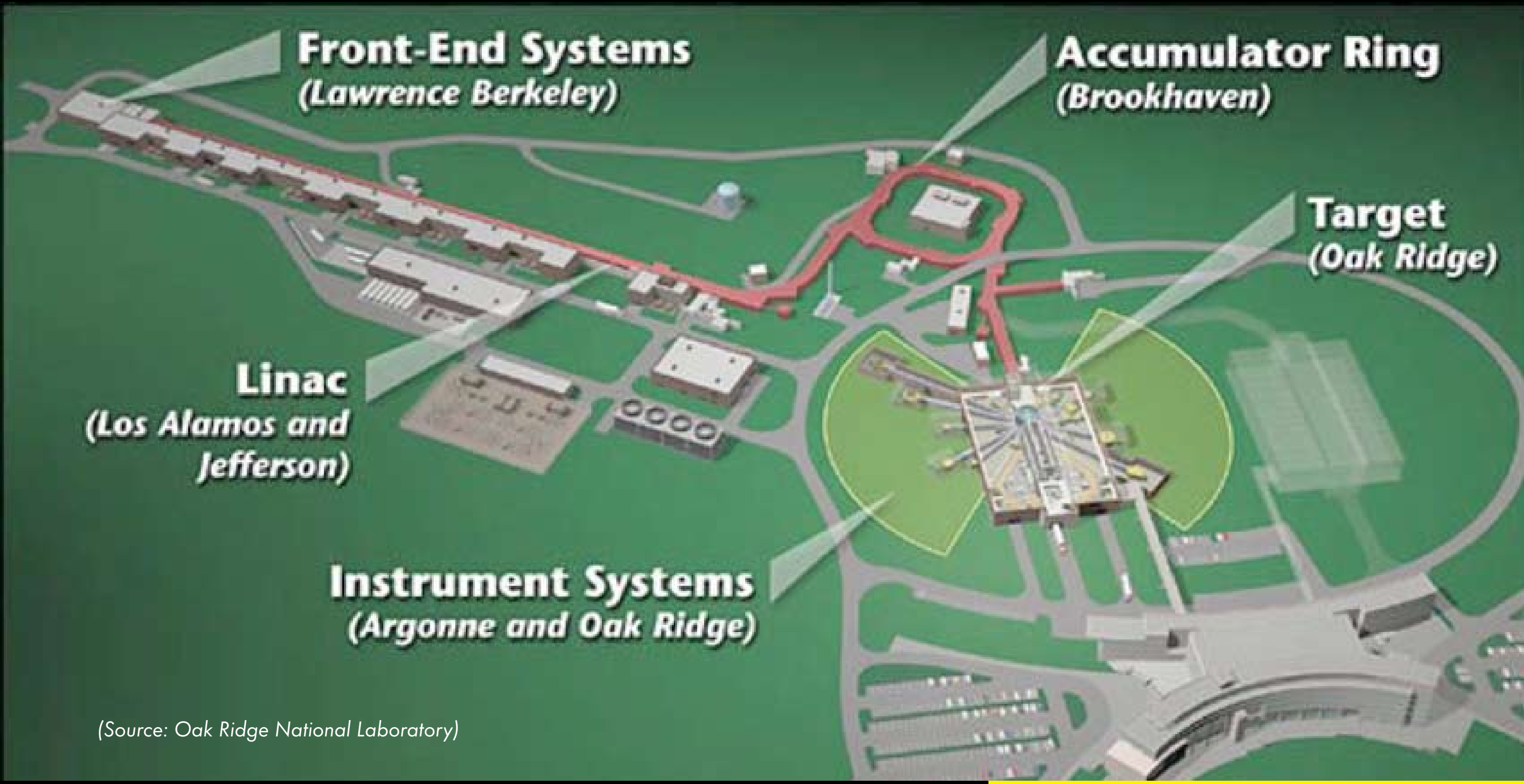
SNS is a neutron source that employs an accelerator system consisting of an ion source, a full-energy linear accelerator (linac), and an accumulator ring, which combine to produce short, powerful pulses of protons. These proton pulses converge on a liquid mercury target to produce neutrons through a process called spallation, which occurs when a material ejects fragments (in this case neutrons) as a result of stress from an impact. Corresponding pulses of neutrons freed by the spallation process are then slowed down and guided to areas containing special instruments such as neutron detectors. Once there, neutrons can be used in a variety of experiments.

A COMPLEX ORGANIZATION

DOE decided to build SNS on the Oak Ridge Reservation in Tennessee, and selected the Oak Ridge National Laboratory (ORNL) and its Management & Operating (M&O) contractor to lead this effort. ORNL had deep expertise in nuclear science, but it had never built an accelerator of this size and scope. To ensure that the necessary expertise was available for the project, SNS was initially set up as a partnership among ORNL and four other national laboratories. (A sixth partner lab was added later.) The partner labs were responsible for the research and development, design, and procurement of all technical equipment, as well as its transportation and transition to ORNL. ORNL played the lead role in managing and integrating the work done by the partner labs as well as the Architect-Engineer/Construction Manager tasked with constructing the conventional facilities that would house the scientific equipment.

"One of the major challenges of this kind of project was [for the partner laboratories] to turn the reins over," said Les Price, who served as the top federal official in the field at Oak Ridge. (His title became Federal Project Director after DOE issued new policy guidance on project management roles and responsibilities in 2003.) "We have this phrase coined by Don Rej from Los Alamos: 'Lead, mentor, and consult.' In the early part of a transition, the partner lab was in the leadership position, making decisions on getting it installed and solving problems. Then they were mentoring the ORNL people who were taking it over. After ORNL had taken it over, they were in the position of consulting as needed. That actually worked out quite well."

The Spallation Neutron Source, an extraordinarily complex facility, contains more than 100,000 control points.



(Source: Oak Ridge National Laboratory)

Price led a very small onsite federal team of just two engineers, an office manager, and a part-time health and safety officer. "From an accountability standpoint, I was the first tier of accountability on the federal side for the project. "I had the authority to issue all federal technical direction regarding project matters in the field." Price noted that this small number of federal staff is consistent with the strong partnership approach that the Office of Science has with its with its laboratory M&O contractors.

Price kept up with the work going on across the country through a contact person at each of the DOE site offices at the different laboratories. "It was what I call a 'soft glove' approach. We wanted to make sure it was clear that the partner lab was working under the direction of ORNL. They were not working under the direction of the DOE site office. That was kind of tricky, but we all understood it. The guy at the site office was very careful not to direct them in any way that would conflict with the direction they were getting from ORNL, but the site rep and I would talk frequently, and he would give me his perspective and what the issues were."

Price took direction from the program sponsor, Dr. Pat Dehmer, who at the time was the head of the Office of Basic Energy Sciences, and program manager Jeff Hoy. "Jeff and I were in day-to-day contact, and Pat was involved in all major project issues. She was the funding sponsor for the project, and if you look at it from a PMBOK standpoint, she met all the criteria you would want from a project sponsor," Price said.

SIX PARTNER LABORATORIES

Argonne National Laboratory was primarily responsible for developing the initial suite of neutron-scattering instrumentation for SNS and for working closely with ORNL to develop the experimental facilities.

Brookhaven National Laboratory was responsible for the accumulator ring structure, which bunches and intensifies the ion beam for delivery to the mercury target to produce pulsed neutron beams.

Lawrence Berkeley National Laboratory was responsible for designing and building the SNS front-end system, which includes an ion source, beam formation and control hardware, and low-energy beam transport and acceleration systems.

Los Alamos National Laboratory was responsible for the overall design of the linear accelerator, or linac, which accelerates the negatively charged hydrogen ion (H^-) beam from 2.5 to 1000 million electron volts, as well as the low energy structures and power supplies.

Oak Ridge National Laboratory was responsible for the design and construction of the liquid mercury target.

Thomas Jefferson National Accelerator Facility was responsible for the superconducting structures used in the high energy portion of the linac and the associated cryogenic systems.

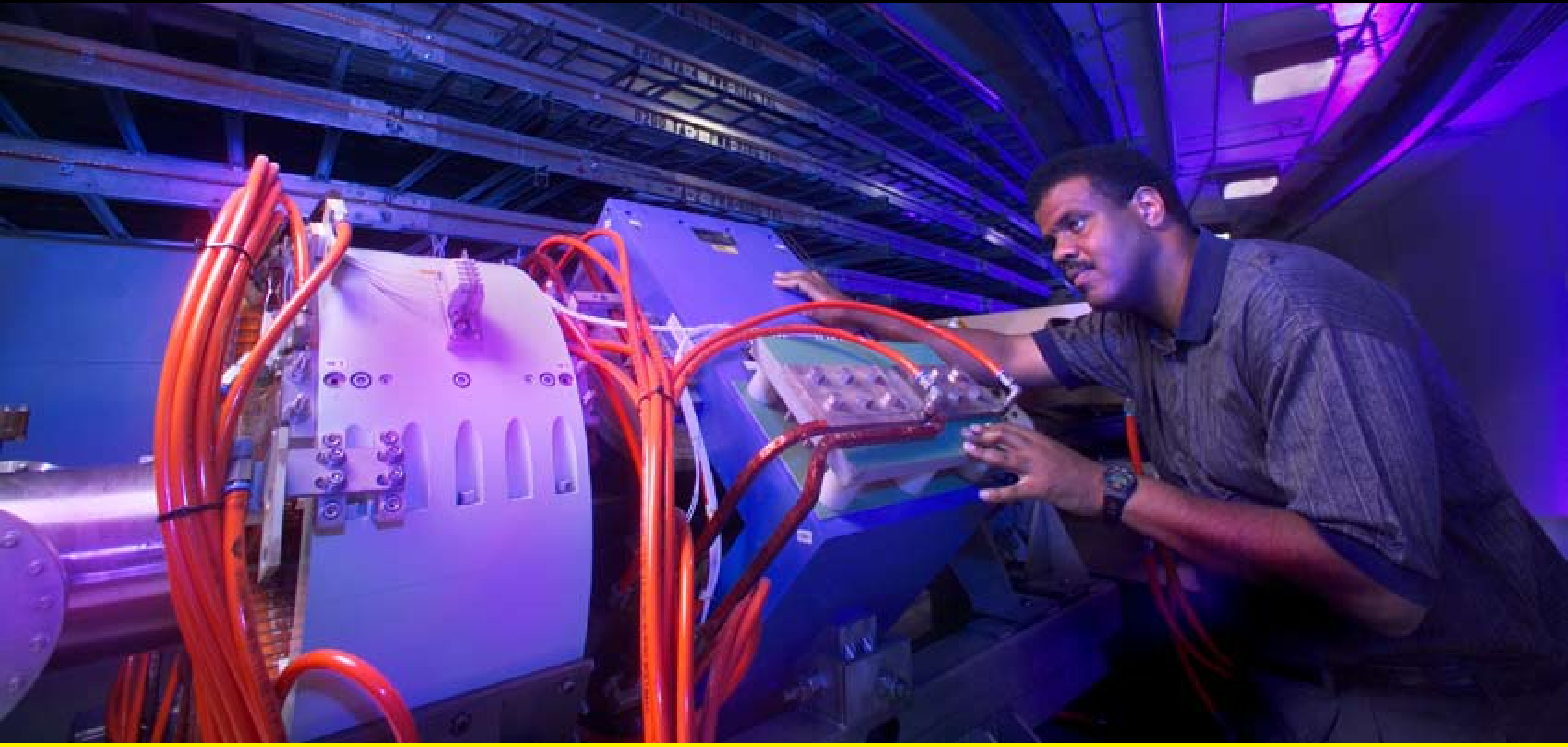
As the project team came together, they laid out several alternatives for the White House Office of Management and Budget (OMB), which would have to request funding from Congress over the course of the project's life cycle. OMB agreed on a budget profile for the project in December 1999, and that profile remained the project baseline until its completion in 2006. "The Department supported, OMB requested, and Congress appropriated the money that SNS needed according to the plan that was laid out in 1999. That's very rare," said Price.

GETTING THE RIGHT PEOPLE IN PLACE

In January 1999, nearly a year before SNS held its formal groundbreaking ceremony, a peer review team (conducting a "Lehman" review that followed the guidance of the Office of Science) concluded that ORNL did not have a team with the necessary experience to get the project off the ground. The Lehman review team was not alone in this judgment. Two months later, a report by the General Accounting Office (GAO) warned that the project might face trouble because, "DOE has not assembled a complete team with the technical skills and experience needed to properly manage the project." ORNL brought in Ed Temple and David Moncton, two experienced veterans from Argonne National Laboratory who had worked on the Advanced Photon System, and secured two-year commitments from them to get the project on solid footing and recruit a staff that could steer it to successful completion. When that two-year period ended, the transition to Thom Mason as the ORNL project lead was seamless.

By the time Les Price joined SNS in October 1999, much of the hiring had already taken place. "If you asked me what the biggest project management challenge was, it was getting the right project team in place at ORNL," he said.

DOE assisted with the personnel challenge by putting in place rules that allowed individuals to transfer from other facilities to Oak Ridge without giving up benefits that they would have otherwise lost (e.g., vacation days). "The government helped give ORNL a more flexible set of rules that enabled them to recruit from other laboratories more effectively than it could before that time. That gave ORNL more flexibility to attract some of the staff they needed to build up an accelerator lab at Oak Ridge."



A ring half cell quadrupole magnet received from Brookhaven National Laboratory undergoes an inspection by Samuel McKenzie of Oak Ridge National Laboratory's Neutron Sciences Directorate.

This spring 2009 photo shows the Spallation Neutron Source complex as it appears flying over from the southeast.

By 2000, it was clear that the original team at ORNL had not fully understood the personnel challenges involved with staffing an accelerator laboratory. "The people on the project before Moncton came in didn't really have a good feel for the size of the team and skill mix that they needed to run a big accelerator facility like this," said Price. "When we got the more experienced team in place, we realized that in addition to building the facility, we had to build up the operational capability to run that facility, and it was going to cost more than was in the original planning."

The solution that the ORNL management team and Price agreed on was to speed up the technical transitions from the partner labs to ORNL. "We basically moved the transition from the partner labs to ORNL earlier so that we could move budget to ORNL and they could hire operational staff to run that equipment earlier than planned. That required the cooperation of the partner labs, which we got. That's something in the original planning that we just missed. We collectively didn't realize the size of the staff we were going to need to run the facility."

NEW TECHNOLOGY AND A NEW PARTNER

After Moncton and Temple came aboard at ORNL, they reviewed the technical plan for SNS. The original concept called for using a copper-based accelerating structure technology developed in the 1970s that was rugged but not very efficient. By 1999, a great deal of research had been done on superconducting technology, both in the U.S. at the Jefferson Laboratory as well as in Europe. The technology had advanced significantly since SNS had made its first series of technical decisions, and the ORNL team concluded that building the machine with superconducting technology would provide significant advantages in reliability and flexibility. "That was one of the tough project management decisions we made early on," said Price. "We knew it would cost a little more money, but we thought that in the long run it would be worthwhile."

The project team committed approximately $20 million of its contingency (reserve) funding to cover the expense of the technology upgrade. "Since we hadn't started building, we concluded that we could still meet the schedule," said Price. "We increased the baseline by $20 million and reduced the contingency by that amount." SNS also brought Jefferson Lab into the project because of its experience building niobium-based superconducting cavities and the associated cryogenic systems.

Another big technology challenge was the use of a liquid metal target in the accelerator's target chamber. Most accelerator-based neutron sources before SNS used a solid metal target, typically made of tungsten, but the tenfold increase in performance required from SNS demanded improved technology. The technical team decided to employ a liquid mercury target. This presented significant technical challenges in materials engineering and heat transfer. The ORNL contractor also had to design the target to be replaceable, because the containers would become radiation-brittled (damaged) over time. This called for using remote handling technology (robotics) to take one target out and replace it with a new one. The use of a liquid metal target also meant addressing safety concerns about the possibility of a release of radiation in the event of an accident. "We had to do a lot of work on the safety side to make sure that there would not be any kind of public health or safety risk." said Price.

SOLVING PROBLEMS

With such a widely distributed organization of partner laboratories, problems inevitably surfaced that had to be solved before they became serious. One instance involved a contractor installing massive concrete foundation structures in the SNS target building. The contractor began falling behind schedule and not meeting the quality standards for the project. The project team decided to terminate the contractor early, and brought in the contractor who was scheduled to take over the next phase of the construction. Another contractor working for Los Alamos was building parts for some of the accelerator structures for the linac that weren't meeting quality standards—tight tolerances and high cleanliness requirements. "Los Alamos had to pull a bunch of engineers off other work and basically babysit that manufacturing contractor day and night until they got their processes straightened out," Price said. "They weren't paying attention like they needed to, and Los Alamos jumped on it. We wound up having to pay more for it because of all the management attention, but we got it solved."

Another challenge included a decision to pull some work from a partner laboratory that was failing to meet critical milestones and reassign it. It was a difficult issue that required sensitive handling, but ultimately the lab that lost the work cooperated fully with the transition. "You have a steady stream of these kinds of issues on high-tech projects where you run into something that you don't expect, and you deal with it," said Price. "Having a competent staff is really all what it boils down to, because when we ran into these problems, we had people who knew how to solve them."

The Spallation Neutron Source chamber was designed with such precision that workers had to scrape the paint from some components to make them fit.

A CULTURE OF SAFETY

On a project as complex as SNS, with 600 to 800 workers onsite at the peak of construction, safety was at a premium. Price and the ORNL team sought to create a culture that placed primary value on safety. "In terms of safety and health, one of the things I'm most proud of is that we had over 4 million construction hours without a lost workday," he said. "That didn't come easy. It took a great deal of effort, and the unions were with us in lockstep about how we were running the job, but up and down the line everybody was clear that safety was top priority."

The management team promoted safety in all kinds of ways, from all-staff barbecue luncheons for every one million safe hours to safety awards ranging from gift certificates to Home Depot to TVs to even a pickup truck giveaway. "We had a lot of safety awareness and rally cries and promotion to make everybody know that management wants safety." The project team also employed a full-time nurse at the job site who was even available on weekends, regardless of whether an illness or injury was work-related or personal. "We had a work site culture where people knew the nurse, and if they had an on-the-job injury, they weren't afraid to report it right away. We think it helped build the safety consciousness of the workforce," said Price.

ROLE OF THE FEDERAL PROJECT DIRECTOR

As the Federal Project Director (FPD), Price saw himself as the first line of accountability on the federal side of the project. "We tried to make all the federal interfaces go through the FPD. Sometimes that's hard, but I was fortunate to have very supportive managers who recognized the high priority of the project," he said. "A very important federal role in a bureaucracy like DOE is that the FPD is a gatekeeper in terms of applying federal rules. One of our big jobs was making sure people didn't put more bureaucracy on ORNL than they actually had to."

The same held true in reverse. "Where the project team had to do something because of DOE rules, we took a very strong role in making sure they met those requirements. For example, we had some design approaches in the SNS target building where we needed to have the fire protection part of the federal government sign off. Due to one thing or another, the lab got behind schedule, and we needed to crank things up. So I asked my manager for some fire protection engineering assistance, they made a fire protection engineer available, and he jumped in and helped us resolve those issues. We worked very closely with the lab's fire protection people, we all agreed on how they were going to solve these issues, and we got through that without a hitch. But it needed to have a federal stamp of approval on those systems, and I could coordinate that."

UNDER BUDGET AND AHEAD OF SCHEDULE

The SNS Project wrapped up in May 2006, slightly under budget and ahead of schedule. Price attributed the project's success to a mix of skill, luck, open communication, and a shared sense of mission. "We were all pulling for the same goal, and we all worked together."