A LEGACY OF RESEARCH

Lawrence Livermore pays tribute to its legacy facilities while making room for state-of-the-art workspaces for research and collaboration.

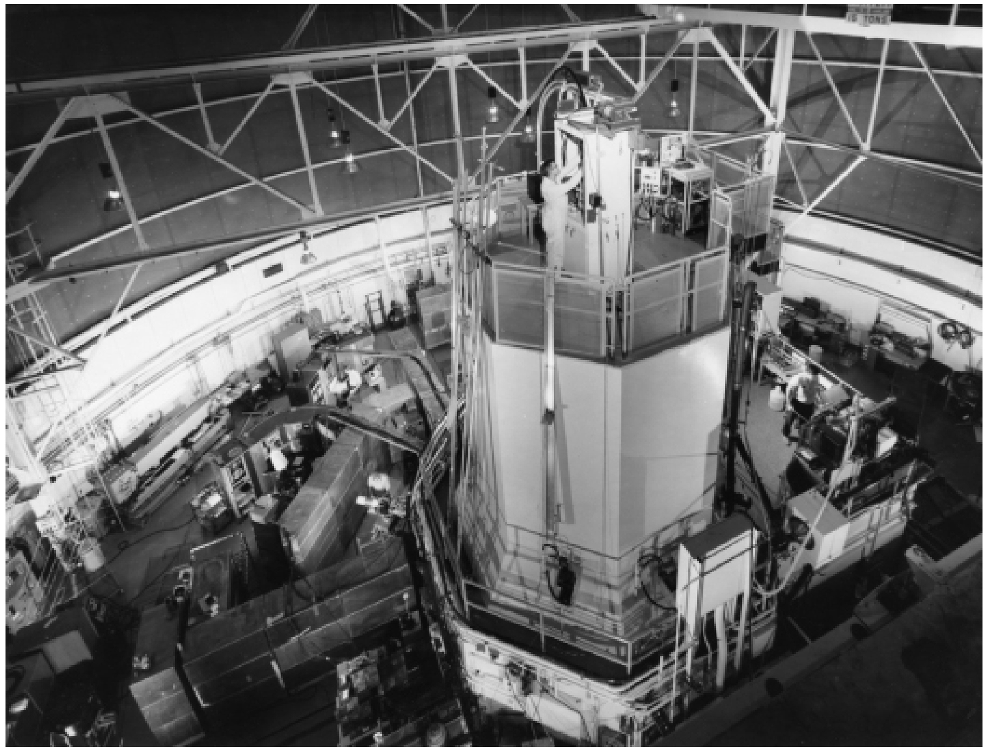
WORKING at the forefront of scientific research requires the world's most sophisticated technologies and facilities. As Lawrence Livermore National Laboratory advances the boundaries of knowledge, the Laboratory's supporting infrastructure evolves in tandem. However, upgrading and modernizing facilities is a complicated process. An underlying parameter is that the Laboratory's main site sits on a fixed 2.5 square kilometers of land, and research capabilities cannot expand beyond that perimeter even though new buildings require space. Through Livermore's Site Development Plan, the Laboratory's leadership and infrastructure team, program teams, and the National Nuclear Security Administration (NNSA) and Department of Energy (DOE) have identified which legacy buildings—those built in the Laboratory's earliest days—can be repurposed and modernized and which must be torn down to make room for new facilities.

Decontamination, disposition, and demolition of legacy facilities present challenges. Many of the Laboratory's legacy buildings housed research activities with radioactive and other high-risk materials. Lawrence Livermore takes seriously its duties toward safety for personnel, local communities, and the ecosystems within and beyond property boundaries, and the Laboratory has created a meticulous process for the safe multi-phase retirement of legacy buildings.

Three facilities at different stages in the decommissioning and demolition process—the Livermore Pool Type Reactor (LPTR), the Heavy Elements Facility, and the Rotating Target Neutron Source II (RTNS-II)—highlight the complexities of removing facilities that were key components in Livermore's

Doors weighing 41,000 kilograms at the Rotating Target Neutron Source II (RTNS-II) legacy facility at Livermore were necessary to prevent radiation escaping the building when it was in use. Despite the doors' immense weight, a single person could easily open them due to unique hinges.

scientific legacy to create space for modern research facilities and other infrastructure. A new set of facilities—the Laboratory's Applied Materials and Engineering (AME) Complex—demonstrates the result of such care and effort: an upgrade to a highly collaborative environment that will support current and future mission needs.



The Livermore Pool Type Reactor's (LPTR's) core was housed in the center of the building. Researchers used specialized tools to insert samples into the core for their experiments. Afterward, the samples would travel via pneumatic tubes to the laboratory spaces behind the reactor for analysis.

Livermore Pool Type Reactor

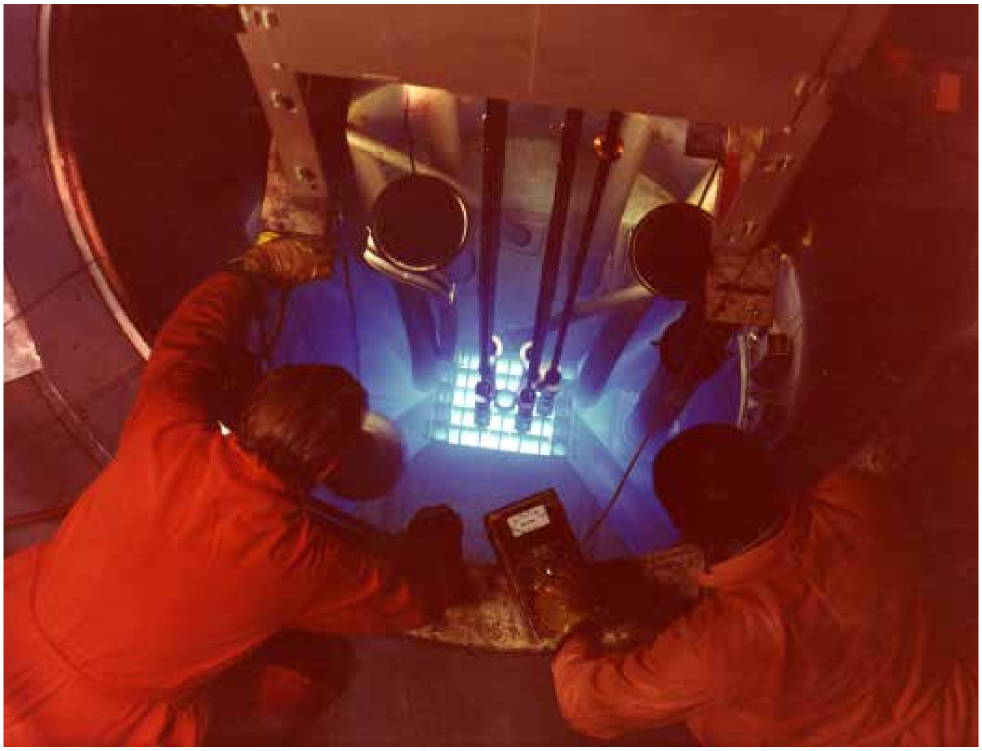
Constructed in 1955, the cylindrical, domed LPTR went into operation in 1957 with the purpose of making neutrons and laying the foundation for the research that supports Livermore's Stockpile Stewardship Program. A key purpose of the facility was to study the damage that radioactive nuclides cause in fission reactors, thereby improving safety calculations and methods to prevent core meltdowns for nuclear power plants. The LPTR core sat in a water tank and neutrons radiated outward through pneumatic tubes. In the LPTR's fast neutron irradiation facility, slabs of uranium-235 were exposed to thermal neutron flux, which then generated the fast neutron spectrum found in uranium fission. LPTR acted as a trace-element analyzer to uranium concentrations, such as in stream sediment samples. The facility was essential to studies of the atomic and magnetic structure of materials, nuclear fission, and the safety and security risks from radioactive materials. LPTR was also used for calibration work related to nuclear explosion tests, trace-elements measurements, and radiation damage studies.

Advancing technologies and changing mission objectives eventually superseded LPTR efforts, and in 1980, facility decommissioning began. The nuclear fuel rods from LPTR were sent to Idaho National Laboratory for reprocessing. Then, a team led by Mark Costella, Livermore legacy facilities manager, "mothballed" the reactor. The process involved documenting contamination in the facility and the surrounding area, shutting off the pneumatic tubes outside the reactor, and moving the entire facility into a stabilization mode for monitoring and surveillance. Costella and his team determined the locations and boundaries of the beryllium and radiological contamination and implemented controls to ensure the materials did not migrate.

In 2015 and 2016, however, Costella identified another potential risk from LPTR when the Government Accountability Office (GAO) and Inspector General began to investigate high-risk buildings in the NNSA complex. "Although the containment was controlled and secured, the cracks in LPTR's shielding represented risk to public perception if the reactor tower were to collapse in an earthquake," says Costella. "We had to be proactive about ensuring that this risk never became a reality." Costella reached out to the office of then U.S. Senator Diane Feinstein via Livermore's Congressional liaison office regarding the situation. Livermore's prompt communication and efforts to determine the full range of potential risks led GAO to accelerate LPTR's demolition date ahead of other legacy facilities at the Laboratory. The demolition process began in 2020, and the mothballed reactor was removed in 2022. Throughout 2024 and 2025, the U.S. Army Corps of Engineers and external contractors will carefully tear down the building, safely remove process-contaminated equipment, and repurpose equipment fit for continued use to other facilities.

Heavy Elements Facility

Some of Livermore's biggest scientific discoveries to date were made at the



Livermore scientists in the 1970s insert experimental test samples into the LPTR's core.

Laboratory's Heavy Elements Facility. Built in 1956, the Heavy Elements Facility focused on three key tasks: nuclear tracer fabrication, radiochemical analysis of recovered nuclear-test debris, and heavy elements research. Research in this facility contributed to the discovery of seaborgium (element 106) and three other new elements in the periodic table: moscovium (115), tennessine (117), and oganesson (118). (See *S&TR,* September 2019, pp. 16–19.) In addition, the facility's use of gamma spectroscopy to measure concentrations of fissile isotopes aided in the development of safeguard systems for nuclear materials accountability.

Unlike LPTR, the Heavy Elements Facility decommissioning process was abrupt. In the 1990s, it became increasingly clear to the Laboratory that even with preventative maintenance, the building's safety and experimental systems were deteriorating faster than they could be fixed. Costs to renovate the facility to meet seismic requirements of updated post-construction codes were prohibitive. In 1995, Lawrence Livermore put the building into standby mode and created a process to mitigate the risk of radioactive contamination spreading from the gloveboxes, blue caves (large, shielded glove boxes with manipulator arms), and hot cells that researchers used to work with radioactive material.

The Laboratory addressed the risk of exposure and the migration of radioactive materials by implementing a building stabilization strategy with continued monitoring and surveillance. The facility was considered high risk due to its history of research involving heavy elements and highly radioactive materials, so the Laboratory ultimately decided to decommission the building.

A risk reduction program (RRP) team responsible for the building's decontamination process moved the Heavy Elements Facility out of standby, restarting power and other utilities and providing restricted access to the building. Following this step, the RRP team transferred rare and useful radioactive materials to other sites; decontaminated, decommissioned, and removed the gloveboxes and ventilation systems; and packaged and shipped the radioactive waste offsite. Such hazardous work could not be performed without extensive training, and the Laboratory recruited highly skilled personnel with experience safely working with alpha-emitting isotopes. To ensure safety, an in-house health physicist and hazard control technicians were integrated into the RRP while the facility's inventory was characterized and removed.

By 2006, the Heavy Elements Facility was successfully downgraded from a Category II Nuclear Facility (meaning the facility possessed nuclear materials of moderate strategic significance) to a Radiological Facility (a facility that handles nuclear materials below the threshold of strategic significance), posing lower security risks. Costella says, "We invested significant resources to remove process-contaminated equipment from the building to achieve this downgrade in radioactive facility category. Inside, the facility is completely different from its research heyday: the rooms are empty, and the gloveboxes and equipment are gone." Contamination embedded in the building and ductwork that require demolition, scheduled for completion in 2025, must be done with the utmost care and caution for personnel and environmental safety.

Rotating Target Neutron Source II

Lawrence Livermore built the RTNS-II in 1976 as part of the U.S. government's program to understand how and to what extent 14-megaelectronvolt (MeV) neutrons, characterizing a fusion environment, could damage reactor materials. A decade earlier, Livermore had begun to focus on intense 14-MeV sources with the installation of the Insulating Core Transformer accelerator, which bombarded a tritium target absorbed in titanium to produce 2 x 10^{12} 14 MeV neutrons per second. The RTNS-I, RTNS-II's predecessor, could produce 6 x 10^{12} neutrons per second, while RTNS-II could produce 4 x 10^{13} neutrons per second.

In their experiments, Livermore researchers exposed metals and alloys to RTNS-II's high-intensity 14 MeV neutrons to measure disordering of the atomic structures and changes in the microstructures and tensile properties of materials. They studied high-energy neutron damage to insulators, specifically how neutrons could damage reactor materials and how different types of damage could interact with each other. Researchers examined the extent of damage in fusion reactors, how superconductors might fail, and how damage could affect structural and radiation-safety components.

In the 1980s, Livermore and the Japanese government collaborated at RTNS-II, focusing on changing and broadening techniques for analyzing irradiated specimens. Carrying out some types of experiments in a fission reactor required extensive modifications and high-vacuum irradiations under precisely controlled temperatures for liquid nitrogen and liquid helium. Instead, they were relatively inexpensive to conduct at RTNS-II. Researchers also achieved several technical firsts, including irradiating metals and alloys at the highest fluence (the number of radiant-energy particles emitted from a surface divided by the surface area) at the time (10^{19} neutrons per square centimeter). They also were able to irradiate metals and alloys at cryogenic temperatures and transfer them to an electron microscope for examination without raising their temperatures.

Through these experiments, scientists could see the structure of cascade damage (damage to the interconnected units containing centrifuges to enrich uranium), the cascade damage's relaxation at high temperatures, and defects that evolve when cascades overlap. Researchers also compared the effects of neutron bombardment on metals, alloys, superconductors, and semiconductors at high and low temperatures. These early experiments informed subsequent fusion experiments at Livermore and elsewhere. Techniques developed at RTNS-II have been applied by other programs within the Laboratory for miniaturizing specimens; cryogenic transfer; high-temperature, vacuum-insulated furnace irradiation; in situ measurements of microscopic changes; and imaging through transmission electron microscopy.

After the RTNS-II programs ended, the building had a variety of other uses, including molten salt operations to vitrify waste. After the facility was completely shut down, Livermore sealed the vacuum systems to prevent residual tritium from escaping and conducted a broader clean-up of contaminated areas to ensure environmental, health, and safety. Research conducted with RTNS-II served to inform recent fusion experiments at the National Ignition Facility, including insights on how irradiation effects from fission and fusion might differ. The RTNS-II facility is one of Lawrence Livermore's lower risk process-contaminated buildings with demolition not scheduled to begin until 2026.

When the Heavy Elements Facility was operational, scientists used glove boxes, ventilator hoods, and hot cells to protect themselves from radiation exposure. The pneumatic arms on the hot cell (left) allowed precise movements with irradiated samples while shielding scientists from radiation.

Taking Ownership

As Costella and his team develop and fine-tune the decommissioning and demolition process, the Laboratory has led the way in establishing and formalizing best practices for the entire National Security Enterprise and received an Annual Excellence Award from NNSA in 2024 for their work. "Historically, mission delivery has been the main priority rather than the end state of facilities," says Costella.

Costella leads the decommissioning and demolition program for Livermore

and activities for the National Security Enterprise. He describes himself as Lawrence Livermore's "real estate agent." Once he takes ownership from program teams that previously maintained the facilities, Costella safeguards personnel and the local community by ensuring that no one can use the building or equipment inside for any other purpose. Costella's leadership extends to his role as chair of Transition and Disposition Continuity of Practice under NNSA, where he provides guidance to the National Security Enterprise on how to smooth the shut-down transition or "soft land" an operational facility and bring it to a state of stewardship while negotiating funding pathways for its demolition. Costella is also the DOE Joint Working Group on Decommissioning and Demolition liaison to the Atomic Weapons Establishment in the United Kingdom, one of Livermore's key international research partners.

Emerging Facilities

In addition to stewarding legacy facilities, the infrastructure team has worked with Lawrence Livermore's leadership, NNSA, program teams, subject matter experts, and other stakeholders to plan and build new facilities, such as the AME Complex, which replaces the Engineering Development and Assembly Facility built in the 1950s. The legacy facility housed a range of materials science and engineering infrastructure that supports Livermore's stockpile stewardship mission, but the Laboratory ceased investments in the facility in 2005 due to beryllium contamination and seismic-safety deficiencies.

The AME Complex built in its place will advance science, technology, and engineering capabilities critical to Livermore's mission, including the design, testing, and certification of nuclear explosive package components. These capabilities include characterization, coating, joining, vapor deposition, electronics, brazing, and mechanical testing of polymers, radiological materials, and electronics.

The AME Area Plan involves facility recapitalization, repurposing, new construction, and demolition to efficiently consolidate and reduce the overall materials engineering footprint by 650 square meters. Given the scope of the work, it is no surprise that Livermore's infrastructure team was heavily involved in the planning for the AME Complex early on. "The traditional way to deal with

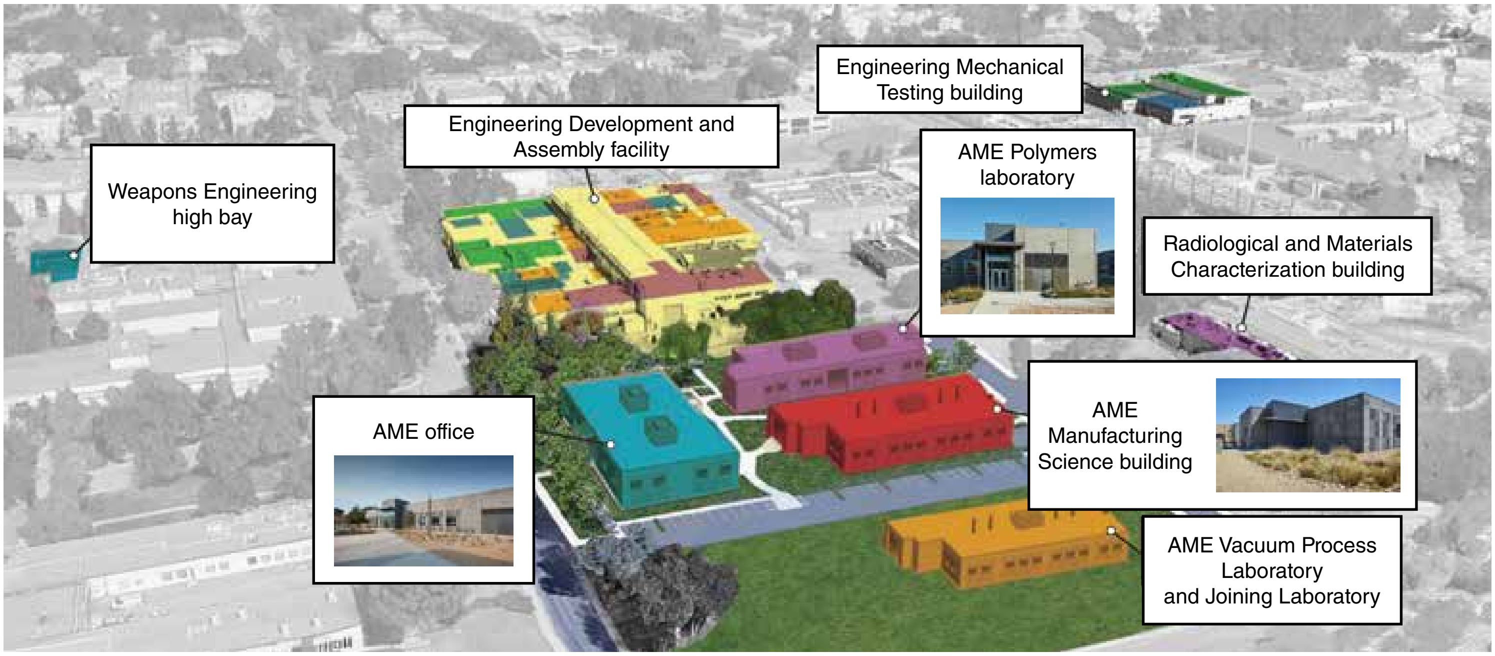
Following the decommissioning of the Heavy Elements Facility, Livermore's risk reduction program team removed process-contaminated hot cells. These hot cells, such as the one pictured here, were shielded spaces in which researchers worked with radioactive materials.

legacy buildings is to build a replacement facility, which is defined as a 'line-item' project," says Katy Lu, the principal deputy for Laboratory Infrastructure. "Given the funding pressures from the National Security Enterprise for line items, we expected to finish as far out as 2040. Instead, with the AME concept, we're 15 years ahead of schedule."

Lu and her team accelerated the project by engaging closely with stakeholders, including NNSA, the Livermore Field Office, Livermore's senior management teams, capability subject matter experts, and the Laboratory's Strategic Deterrence Principal Directorate. Lu and her team worked with the stakeholders, including the former associate director of Livermore's then Engineering Directorate, Anantha Krishnan, to map the legacy engineering facility and identify every capability and piece of equipment needed to create detailed layouts for the AME Complex. Lu says, "The legacy building felt like the Winchester Mystery House, with equipment in every available space of the facility. We had to know how close the capabilities associated with each piece of equipment needed to be to other capabilities and equipment to facilitate ease of work for different programs, what were the different safety and operating requirements for each piece of equipment, whether and how we could fit the existing equipment into a new laboratory space, what stays, and what goes."

From 2015 through 2017, Lu and her team conducted an Analysis of Alternatives (a process that identifies multiple different pathways for action), which involved relocating equipment, modernizing existing facilities, and planning new buildings. The team's process integrated and engaged stakeholders, who provided expertise and feedback throughout planning and construction. While the plans for the AME Complex evolved over the years as the infrastructure project thresholds from NNSA changed based on shifts in political and security priorities, Livermore's infrastructure team has successfully relocated equipment, tools, and furniture used in more than 13,000 square meters of space into approximately 4,600 square

Mark Costella, legacy facilities manager at Livermore, stands inside the LPTR doorway that leads from the former core back to the laboratory space where scientists analyzed neutron-irradiated samples.



The Applied Materials and Engineering (AME) Complex involves recapitalization of older buildings and the addition of new structures to relocate, expand, and update functions that, to a great extent, were originally in the old Engineering Development and Assembly Facility. Colors associated with new individual buildings represent capabilities that correspond to laboratory space in the Engineering Development and Assembly Facility.

meters of new construction and 3,500 square meters of enduring facility space.

The new complex includes the AME Office, conference rooms and collaboration spaces, the AME Vacuum Process Lab and Joining Lab, the AME Polymer Enclave, and the AME Polymers Lab. Recapitalized laboratories inside existing buildings include the Weapons Engineering high bay, the Radiological and Materials Characterization laboratory, and the Engineering Mechanical Testing building. The project broke ground in June 2019, and to date, three of the new buildings have been completed, while the fourth is currently under construction.

The planning, construction, and execution for the complex has been challenging, but the process has been effective and efficient and offers a new way to meet large infrastructure gaps in a timely manner. In advancing the legacy engineering facility capability replacement plan by 15 years, the infrastructure team has helped the Laboratory take a huge step toward fulfilling the mission while also ensuring that no gaps in research occur during construction. “Through excellent partnership with our stakeholders, we will realize capabilities for the AME Complex sooner than expected,” says Lu. “Our progress sets up an excellent model for future efforts.”

The Past Meets the Future

Without a doubt, the Laboratory needs to modernize to meet its national security mission, but the process is bittersweet when so many once-fundamental facilities must be demolished. Costella understands this dichotomy all too well, having started at the Laboratory in 1981 doing research as a Livermore High School student. Even then, he realized the importance of the Laboratory’s work and its contribution to the national mission. “I was awestruck to walk through some of these buildings and to understand the history of what had happened there,” says Costella. “I have grown on a career path that has taken me into the space where now I manage these buildings, and I steward them to the end of their life. It’s like the relationship with parents from when they took care of their child to when their child is taking care of them as they make their final journey.”

Along with his multifaceted work managing legacy facilities, Costella is racing to protect the history of the buildings the Laboratory is losing. He and his team are compiling historical documentation describing how the buildings supported the research conducted at Livermore, and how they transitioned from operations to demolition. While no museum is devoted to the Laboratory’s history, Costella hopes that pieces and items from demolished buildings can be incorporated into the Laboratory’s Discovery Center to preserve the memory of Lawrence Livermore National Laboratory’s achievements and contributions to national security. Costella says, “We are definitely beholden to what these buildings have done for us.”

—Sheridan Hyland

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