TEAM SCIENCE TAKES

The Laboratory's new Emergency Operations Center will consolidate Livermore's emergency response functions and facilitate better collaboration with external emergency partners.

ON INFRASTRUCTURE

Using science-based infrastructure stewardship, the Laboratory tackles 10 years of infrastructure modernization as it anticipates several major projects and a rapidly growing workforce.

THE University of California Radiation Laboratory, now Lawrence Livermore National Laboratory, was opened on September 2, 1952, on the site of a decommissioned naval air station used to train pilots during World War II. Operating under the aegis of the U.S. Atomic Energy Commission, the Laboratory was tasked with the mission to advance nuclear weapons science and technology (S&T) to defend the nation at the height of the Cold War. As a "new ideas" laboratory guided by E.O. Lawrence's "team science" approach, in its first six years, the Laboratory produced rapid, innovative breakthroughs in nuclear weapons S&T. In six years, its workforce grew from 76 employees to more than 3,000, and its budget burgeoned from $3.5 to $45 million. Over the next 70 years, Lawrence Livermore continued to make significant advances in data-driven, computationally and experimentally based S&T, and established a reputation for its multidisciplinary approach, integrity, and commitment to excellence.

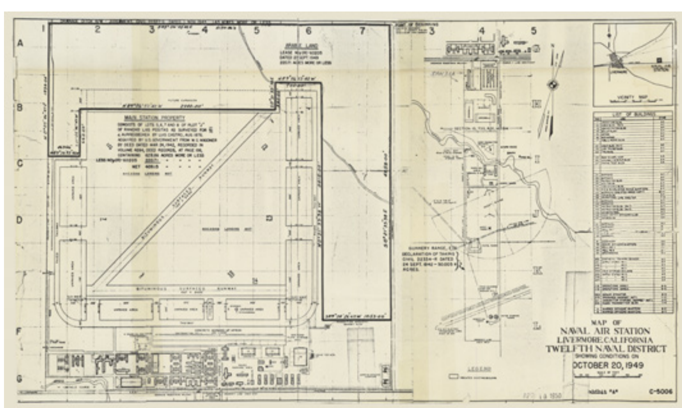
Today, with a workforce of more than 8,300 employees, contractors, postdoctoral fellows, and students, and an operating budget of $2.3 billion, the Laboratory's mission has evolved to stockpile stewardship, nuclear nonproliferation, and application of world-class S&T to strengthen the nation's security. The Laboratory's continued success draws from its ongoing commitment to its core S&T strengths and foundational values: team science and innovation. As Lawrence Livermore strives to support a growing workforce, rapid advances in information technology, and the challenge of pursuing two major National Nuclear Security Administration (NNSA) stockpile modernization programs, it is marshaling its signature strengths and a $2 billion infrastructure investment plan to guide the transformation of facilities, utilities, programmatic equipment, and workspaces over the next decade to fulfill its mission.

Mission Delivery Is Key

The Laboratory's Site Development Plan, Campus Capability Plan, and NNSA's Master Asset Plan outline the orchestration and execution of more than 500 infrastructure projects at Livermore ranging from the complete demolition and construction of entire buildings to the renovation of computing and data storage facilities, advanced manufacturing and materials labs, experimental glovebox rooms, and science enclaves that will impact and upgrade 80 percent of the Laboratory's workspace. When surveying infrastructure modernization needs, Lawrence Livermore and NNSA faced the complex question of where to begin and how to proceed. Seventy-six percent of the Laboratory's buildings are over 30 years old, and the sprawling campus has approximately 670 structural assets across 7 million gross square feet. Fortunately, the Laboratory's key mission drivers provided a good starting point.

The Laboratory's most important mission deliverables fall under the area of stockpile stewardship—maintaining and modernizing the United States nuclear weapons stockpile without conducting nuclear tests (*S&TR,* July/August 2015, pp. 6–14). Currently, Lawrence Livermore has two major stockpile projects directly supporting this mission: the W80-4 Life Extension Program and the W87-1 Modification Program (*S&TR,* October/November 2018, pp. 4–11). Stockpile modernization programs, major efforts to extend the service life of a warhead by as long as 30 years, typically draw on most, if not all, of the Laboratory's technical and scientific resources, as they constitute Lawrence Livermore's most significant weapons development effort since the Cold War. "To determine what areas to invest in, you have to look at what assets will have the greatest impact in supporting a stockpile modernization program," says Office of Laboratory Infrastructure director Cliff Shang, "Capabilities like hydrodynamic testing, high explosives testing, computing, high-energy-density physics, advanced manufacturing, and materials research are critical."

One of the broadest-impact areas of stockpile stewardship is radiochemistry, which has had four supportive laboratories and a glovebox facility renovated as part of the infrastructure investment plan. In one of the radiochemistry laboratories, scientists analyze aged post-detonation shot debris to characterize an explosion. One challenge radiochemistry scientists face is reducing ambiguity in their test results. "High-fidelity measurements help us refine our models, reduce uncertainty, and even measure and discover new things," explains Nuclear and Radiochemistry group leader Tim



(left) Members of the Naval Air Station, Livermore, stroll down Second Street in the 1940s. (right) A map depicts the Laboratory when it was acquired by the United States government in 1942.

Rose. In addition to equipment, the team requires clean laboratory space. "Recent improvements in our laboratories have allowed us to handle the most sensitive materials and reduce the risk of cross-contamination." It has also allowed the Laboratory to take on more specialized ventures, like developing surrogate material debris for the Technical Nuclear Forensics mission. "Surrogate materials resemble the real thing, which people can process in different laboratories to compare results," says Rose. "These experiments help provide benchmarks for nuclear materials research." A modernized workspace is not only critical for the work itself, but for attracting and retaining scientific staff—updating lab space makes the Laboratory a more desirable place to work. For radiochemistry, that rings especially true. "New hires are important for sustaining our workforce. We need a modern facility for cutting-edge research and development."

Photos of the Laboratory's radiochemistry lab show recent renovations to the facility.

Advanced Modeling Tools

Modernization of the radiochemistry laboratories serves as a successful example of Lawrence Livermore's extensive use of data to drive modernization decision-making processes (*S&TR,* September 2016, pp. 16–19). With a Laboratory and NNSA evaluation and planning methodology referred to as "science-based infrastructure stewardship," Livermore's infrastructure researchers use advanced computer modeling to predict and model infrastructure trends. Science-based infrastructure stewardship has many of the hallmarks that define stockpile stewardship and the scientific method: It is computationally based, data-driven, transparent, and there is a rigorous verification and validation process. "The budgetary constraints that come with being a government institution require us to maintain existing infrastructure much longer than in private industry, which puts Lawrence Livermore and NNSA at the forefront of facility modernization and innovation," says Jill Farrell, deputy for the Office of Laboratory Infrastructure. In fact, Farrell and two retired Livermore employees hold a U.S. patent for a maintenance recapitalization model that set a precedent for similar models used across NNSA.

Infrastructure enterprise-level modeling tools, including BUILDER, a specialized NNSA software program developed by the U.S. Army Corps of Engineers, and Move Management System (MMS), analyze equipment conditions, manage and prioritize facility improvements, track existing assets and ongoing maintenance costs, and even manage office and lab space utilization. Critical amongst these tools is Equipment Data Archive and Decision Support (EDADS). EDADS is a web-based information system

The Equipment Data Archive and Decision Support (EDADS) web-based information system helps the Laboratory manage programmatic equipment investments.

that allows the Laboratory to manage programmatic equipment investments, like the those needed in radiochemistry. Within EDADS, scientists and engineers can enter equipment replacement or purchase requests, which are reviewed by group leaders in their areas. EDADS generates a score based on the equipment's benefit, risk, and complexity, which stakeholders use to create a prioritized request list as well as to approve equipment acquisition. The full capability-based portfolio is provided to NNSA to inform decision making on a yearly basis. "Before EDADS, nobody gathered equipment requirements or understood strategic planning to give people the resources they needed at a systematic, Laboratory-enterprise scale," says Weapons Infrastructure deputy program director Katy Lu. "You really need to bring an enterprise-level view into the process early on to understand the needs required to support the mission."

In device testing, that early input has proved critical for meeting experimental test schedules supporting weapons engineering and research and development. "In the weapons program facilities, we fabricate, assemble, and test components and assemblies. Some parts are classified, some are radiological, but all of them require high-precision tools to fabricate," says Chris Adams, Livermore's associate program leader for NNSA's Capabilities-Based Investment Program. Computerized coordinate-measuring machines and transmission electron microscopes are examples of the unique equipment needed to facilitate the team's work. "Recently, we implemented a new hydraulic skid to control the doors of the firing tanks. That simple improvement reduces the firing tanks' risk," says Adams.

New equipment investments have also supported high explosives field tests at Site 300, the Laboratory's remote testing site (*S&TR,* July/August 2017, pp. 12–15). "When the Laboratory is ready to test explosives at scale, they go to Site 300. There, we have diagnostic equipment like cameras, oscilloscopes, and specialized recording devices to measure the characteristics of the explosives. Capability-based investments have allowed us to efficiently acquire and upgrade these critical equipment systems," says Adams. The EDADS tool has worked so effectively that it has been shared with sister laboratory Los Alamos, and other institutions have expressed interest in the program. "Our ultimate goal is an enterprise system for programmatic equipment. EDADs has helped us better understand and communicate our resource needs," says Lu.

Another critical piece in the Laboratory's infrastructure toolbox is CostLab—a facility maintenance and operations modeling tool that is the result of a decades-long collaboration between the Laboratory and commercial real estate services company, Coldwell Banker Richard Ellis (CBRE). CostLab helps the Laboratory predict budget requirements needed to sustain the Laboratory's current facility and utility asset portfolio, also known as "real property." The risk-based model can predict maintenance needs up to 10 years, allowing the Laboratory to plan for real property equipment and system replacement expenditures earlier in the budget planning cycle. Similarly, for the Laboratory's buildings, Lawrence Livermore has utilized an NNSA implementation of BUILDER to track facility condition and functionality. BUILDER aggregates data from other infrastructure tools like the Laboratory's Computerized Maintenance Management System (CMMS) to track overall building and trailer conditions.

Lawrence Livermore even has a tool for moving people's offices and tracking utilization of office space within the Laboratory. "On a one-square-mile campus with hundreds of buildings and trailers, it's important to be aware of what office spaces are available," says Farrell. The

The Contained Firing Facility at Site 300 supports the Laboratory's design and certification capabilities.

Laboratory's MMS solves that problem by cataloging each office space in real time, ensuring efficient, high-asset utilization of the nation's investments. As the Laboratory experiences unprecedented growth coupled with changes in how and where employees work, especially with new work controls established during the COVID-19 pandemic, the MMS is critical to office space planning. The tool includes features like floor plan maps, room reservations for new employees, and documentation of secondary offices, eliminating the need for yearly labor-intensive building walkarounds to survey the Laboratory's working spaces. The MMS has even been applied to other, more unique purposes—such as modeling a post-COVID-19 office repopulation scenario and locating people onsite for emergency planning purposes.

Innovation in Construction

"The last piece of infrastructure planning, and probably the most important, is execution. That's the Project Management Office," says Shang. The Project Management Office (PMO), an in-house construction management team, handles everything from design and budget estimation to engineering and construction. Under a "one team" approach that takes the Laboratory's model of team science and adapts it to construction, PMO collaborates with other programs and entities around the Laboratory to complete projects. Organizations like Environment, Safety, and Health; the Laboratory's financial office; and the Supply Chain Management organization all work with PMO to ensure federal regulations are followed and to procure the equipment, materials, and subcontractors needed to execute a facility construction project.

A key innovation developed by Lawrence Livermore and NNSA for construction is the use of "area plans." Many capital construction projects—projects costing more than $20 million—are expensive and can take years to complete, which does not always align with the delivery of major scientific research. The area plan essentially creates a time-phased approach to infrastructure investment, so programs can obtain the facilities and equipment they need more quickly at a more affordable price. A key example of an area plan applied to scientific research is in materials engineering. One of the most important aspects of stockpile stewardship is understanding the behavior of the materials placed in nuclear weapons. "Over the lifetime of a weapon there may be material incompatibility issues. Before putting nuclear material into a package, you need to exhaustively test and understand how it behaves over time," says Shang. The time and resources necessary to update the materials engineering facilities as a single capital project would take over a decade to complete, so Livermore and NNSA developed the Applied Materials Engineering (AME) area plan. "Rather than allocating a large amount of time and money into a single building, we will construct a limited set of smaller buildings and repurpose existing ones. There's a little bit of innovation on how you do that, and there's a lot of modeling and analysis by subject matter experts," says Shang. Not only is the AME facility getting renovated 15 years earlier, it is also consolidating and better utilizing available space, decreasing its environmental footprint, and improving sustainability. The materials engineering facility footprint will shrink from 150,000 to 80,000 square feet while maximizing the available workspace and equipment.

Lawrence Livermore's infrastructure team is applying area plans in other locations across the Laboratory such as the 3200 building block, where engineers and expert machinists manufacture experimental assemblies and parts. As demands for complex hardware not found commercially increase, the need grows for a modernized infrastructure to support the Laboratory's manufacturing capabilities. A revitalized infrastructure will allow the 3200 block to introduce new manufacturing techniques, augment capacity for increased demand for precision parts, and sustain activities on critical building systems' utilities and specialized equipment.

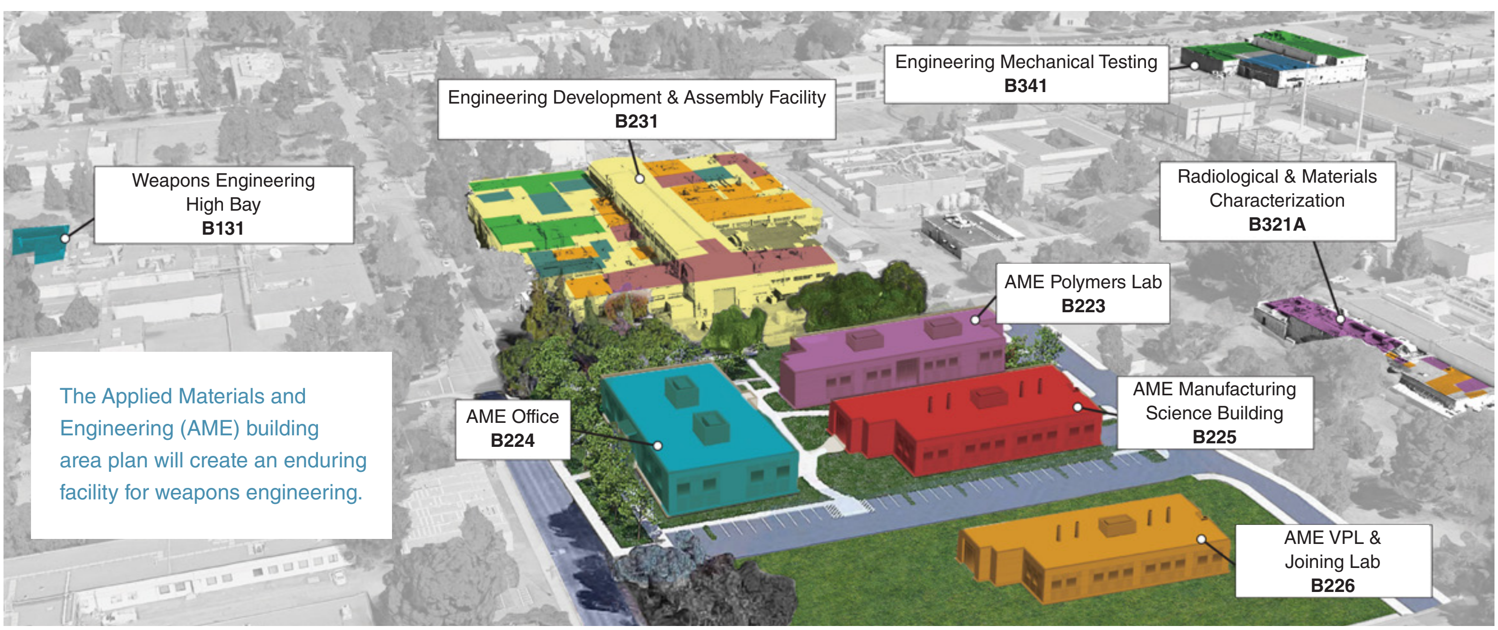
Out with the Old, In with the New

In tandem with new construction and renovation, the Laboratory decommissions and demolishes buildings too old to modernize or seismically retrofit without incurring exorbitant costs. The Laboratory's history as a naval air station has contributed to some of its contaminated and obsolete facilities. Lawrence Livermore's Transition and Disposition (T&D) program monitors these facilities and works to remove them to reduce risks and environmental impacts as well as lessen the Laboratory's footprint and make space for new, modern facilities.

"There's usually an economic breakpoint when deciding to demolish or refurbish a building," says Farrell, "For example, a roof might get replaced every 20 or 30 years. On a 70-year-old building you're probably replacing the roof for at least the second time, and now other parts of the infrastructure are failing. It becomes so expensive to maintain the facility that it makes more sense financially to demolish it and build a brand-new building."

This pool-type reactor at the Laboratory was contaminated by multiple elements, including beryllium and cobalt 60. The Laboratory has been authorized to receive funding for its demolition.

The Laboratory is currently completing several major T&D efforts, including demolishing its excessed Mars E-Beam facility and a long-vacant pool-type reactor with funding and support from the DOE. "This funding allows Livermore to remove some of the highest risk buildings from the site and clear the way for new construction. T&D efforts contribute in a significant way to site renewal," says T&D program manager Mark Costella.



The Applied Materials and Engineering (AME) building area plan will create an enduring facility for weapons engineering.

(from left) Laboratory director Bill Goldstein, Weapons and Complex Integration principal associate director Kim Budil, former National Nuclear Security Administration administrator Lisa E. Gordon-Hagerty, and Livermore Field Office manager Pete Rodrik dedicated the new AME campus in September 2020, which will include a new polymer production development enclave.

The Next 10 Years and Beyond

The integration of the Laboratory's infrastructure planning efforts are represented in its Site Development Plan, Campus Capability Plan, and NNSA's Master Asset Plan—essentially blueprints for how each capability will be supported by infrastructure and equipment investments, so the Laboratory can continue to support its national security mission and its people. A modernized infrastructure enables scientists to not only support stockpile stewardship, but also conduct groundbreaking research in areas such cancer, traumatic brain injury, drug synthesis, and more. "We're essentially upgrading the entire Laboratory," says Lu.

The Laboratory recently completed construction of an advanced manufacturing laboratory, a new office building, and a materials laboratory. It is updating its computing complex to host a new exascale computer and recently broke ground on a state-of-the-art emergency operations center. A new polymer production development enclave is being built in partnership with Kansas City National Security Campus and NNSA, which will allow scientists and engineers an opportunity to reinvent how the Laboratory produces parts for the stockpile. All of these buildings will require specially dedicated utilities, power, and cooling, among other things, which all factor into infrastructure planning. "Our new slogan is 'Pardon Our Dust' because of all the construction going on," quips Farrell.

As the Laboratory launches into the 21st century, Laboratory veterans like Shang fondly remember its history. "I can say when I walked into the Laboratory as a new graduate, I was pretty amazed by this place. The infrastructure has degraded in the last 10 years, but that's what is really energizing about this. Right now, our staff in collaboration with NNSA have a direct hand at turning things around." Shang boils down infrastructure investments to its most important benefactors: "When you invest in infrastructure, it's actually an investment in our people."

—Lauren Casonhua

Key Words: advanced computer modeling, applied materials engineering, area plan, BUILDER, campus capability plan, CostLab, Equipment Data Archive and Decision Support (EDADS), high explosives, infrastructure planning, Move Management System (MMS), radiochemistry, science-based infrastructure stewardship, Site Development Plan, stockpile stewardship.

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