Enterprise Modeling Leads to Smarter Decisions

THE nation's strategic deterrent, embodied in its arsenal of nuclear warheads, is supported and maintained by a sophisticated enterprise of laboratories, facilities, and people. Lawrence Livermore is a part of this enterprise and supplies key technologies and skills across the National Nuclear Security Administration (NNSA) complex. One particular Livermore product plays an integral role in supporting decision making: the Nuclear Weapons Enterprise Model. This model provides NNSA with a comprehensive view of the entire complex and enables better strategic decision making at the highest levels of management.

Designed by a team headed by Cliff Shang, a physicist in Livermore's Weapons and Complex Integration Directorate, the Nuclear Weapons Enterprise Model comprises a comprehensive database coupled to dynamic stockpile, infrastructure, and workforce models. The enterprise data include information about NNSA's assets, including its buildings, personnel, and the weapons themselves.

NNSA looks to enterprise modeling to project the effects of proposed reductions to the U.S. stockpile, the impacts of facility construction schedules, and the number of scientists and engineers needed to execute life-extension programs (LEPs) for nuclear weapons over the next decade. Shang says, "Enterprise models are ideal for testing implementation strategies, discovering inconsistencies, and identifying possible unanticipated consequences to policy options."

The complex has many aging facilities, including critical buildings built in the 1940s and 1950s, that are acutely in need of either modernization or replacement. (See the figure on p. 20.) Many highly specialized employees with critical skills that can take 10 years to acquire are nearing retirement. In addition, existing weapons have been in the stockpile for many years longer than originally intended.

By streamlining and consolidating operations, NNSA has closed 40 percent of all nuclear testing and production sites. Also, staff within the complex has been reduced by more than 60 percent over the last few decades. However, reduction decisions are becoming more difficult. If NNSA decides to eliminate another facility, unintended consequences on the nation's ability to conduct LEPs may occur, and the number of people who possess the critical skills to conduct a particular kind of work may be affected.

Collecting and Mining the Data

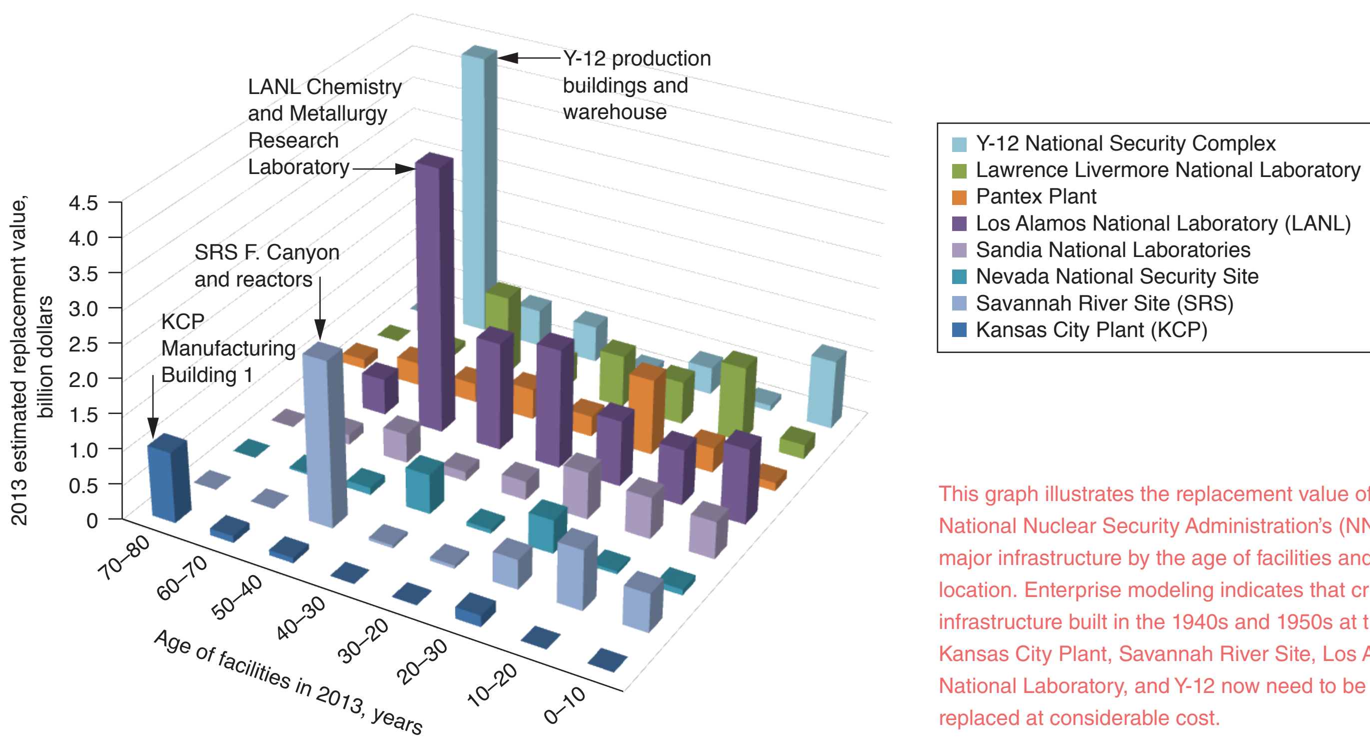
Since 2004, Livermore has worked closely with NNSA and its nuclear weapons laboratories and production plants to collect enterprise data, ensuring that the most current information is available for modeling calculations. A major challenge for code developers and analysts is to ensure the consistency of and to validate the detailed data gathered on NNSA's infrastructure, people, and stockpiled weapons. "The team conducts extensive verification and validation of modeling tools and data to ensure a comprehensive understanding of the range of applicability, sensitivity, and uncertainty in modeling results," says Shang.

The data come in many forms, and Livermore computer scientists Jeene Villanueva and Lisa Clowdus have written the code to structure the disparate information so that it can be correlated and connected with defined relationships. They have also built a user interface, which allows for rapid access to the validated, up-to-date enterprise data. Users can access information that ranges from a high-level view of the overall nuclear weapons complex to a specific detail about, for example, a ventilation or electrical system within a particular building. Villanueva says, "We collect enterprise-wide data and provide NNSA with the capability to access that data to perform stockpile life-cycle calculations, make infrastructure transformation choices, project the need for critical skills, evaluate data trends, and generate budget projections."

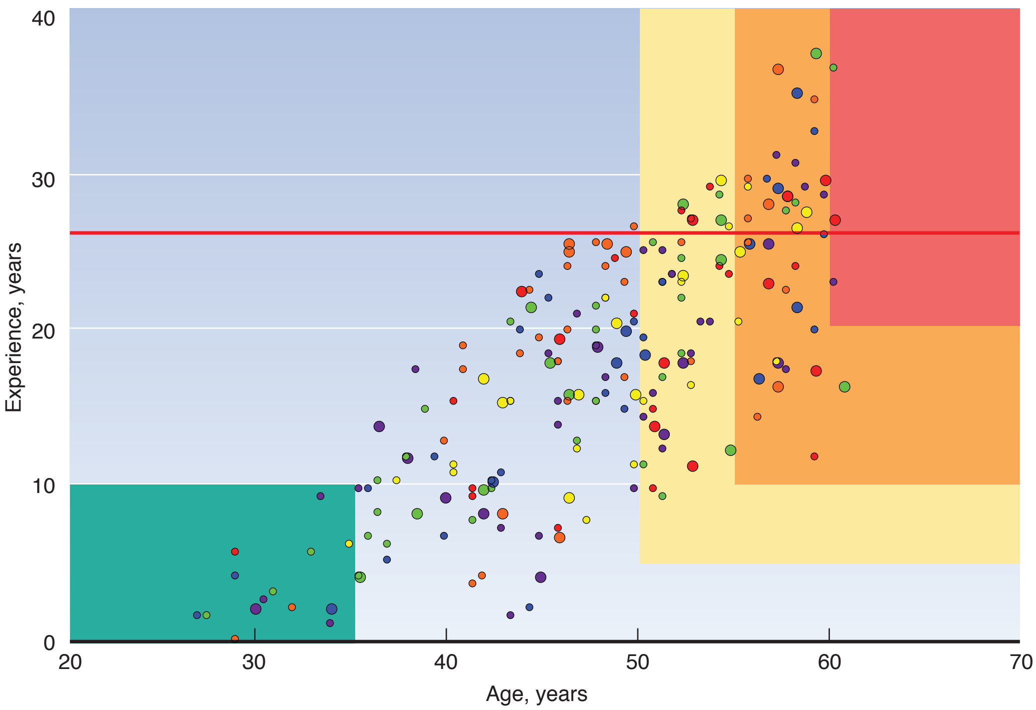
An Evolving Model

In its earliest incarnation, the model focused on NNSA's infrastructure and its employees with critical skills. (See *S&TR,* December 2005, pp. 4–10.) Using a systems dynamics approach, the model allowed NNSA to simulate proposed enterprise consolidation and streamlining. However, to make the nuclear weapons complex even smaller and less costly, NNSA needed even more information and model improvements. The enterprise model can now be used to evaluate the skills of the complex's entire workforce, all buildings and their components, and the stockpiled weapons. The model can also be used to evaluate plans to make the nuclear weapons complex safer and more secure.

Evolving to answer evermore difficult questions, the second-generation Livermore enterprise model incorporates mathematical techniques to provide simulation, optimization, economic-analysis, and decision-analysis tools. Shang explains, "In earlier versions of the model, as we were considering 'the big knobs' in the system, we developed codes in which a user entered input parameters to project an outcome. As we better understood the important variables in the enterprise model, we focused on implementing optimization models from the field of operations research."



This graph illustrates the replacement value of the National Nuclear Security Administration's (NNSA's) major infrastructure by the age of facilities and location. Enterprise modeling indicates that critical infrastructure built in the 1940s and 1950s at the Kansas City Plant, Savannah River Site, Los Alamos National Laboratory, and Y-12 now need to be replaced at considerable cost.



This chart depicts a projection of the critically skilled workforce in a specific NNSA program area in 2018. Each colored symbol represents a critical skill, which takes about 10 years to fully acquire. The bottom left shows employees entering the workforce as apprentices (green box), while the upper right shows experienced employees as they approach retirement age (yellow to orange to red). The red line indicates when nuclear tests were discontinued (1992). By 2018, essentially all of the workers who have had experience with conducting nuclear tests will be at or past retirement age.

With these tools, the enterprise model can simulate NNSA operations in detail and help assess how decisions would affect workflow. NNSA is able to evaluate different scenarios and examine how the enterprise model adjusts workflow to optimize results. Economic-analysis tools allow NNSA to estimate cost trajectories of stockpile, infrastructure, and science programs or campaigns. Finally, decision-analysis tools can be used to compare alternatives based on the preferences of decision makers.

In addition to merely projecting the effects of a proposed policy or the consequences of different budget scenarios, the enterprise model can now run through tens of thousands of decision variables to find the optimum solution and plot the best course of action. The model considers all the discrete entities that interact with each other. Probabilistic equations then provide potential best solutions and help eliminate poor decisions.

People as Enterprise Assets

Because the enterprise model includes detailed data about the entire workforce of the nuclear weapons complex, users can study statistics and trends such as how many people are employed; whether they work full or part time or as subcontractors; and what skills they possess. Users can also determine worker age distribution and years of experience, how much it costs to train personnel, and attrition rates. The model considers redundancy and is designed to optimize the workforce among the national laboratories and across the enterprise. It also allows NNSA to optimize workload to preserve and maintain critical skills.

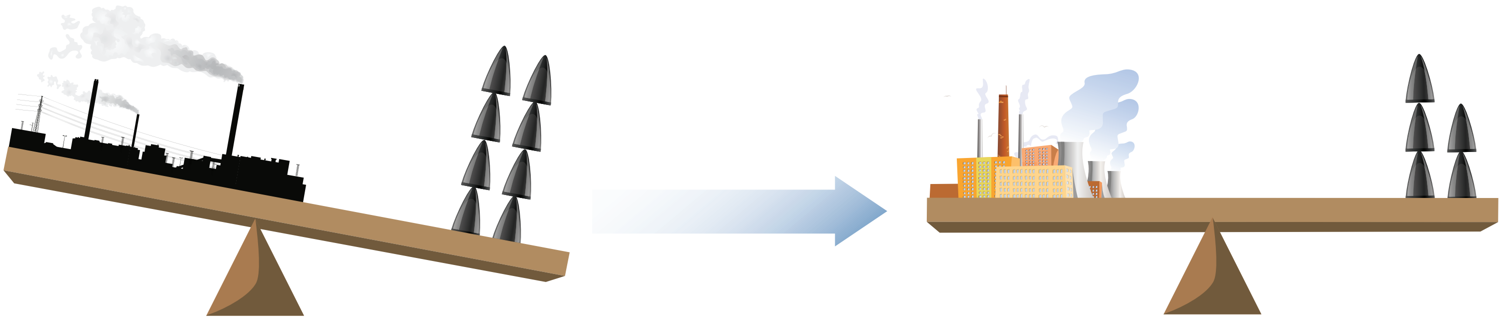
NNSA has long been concerned about recruiting and retaining personnel with critical skills for a modernized nuclear weapons complex. Over the last two decades, as NNSA has consolidated and closed facilities, the workforce has shrunk. In addition, employees with critical skills necessary for performing stockpile activities are retiring, and NNSA faces many challenges in replacing them. By 2018, essentially all of the workers who have had experience with conducting nuclear tests will be at or past retirement age.

As NNSA assesses staffing requirements for the coming years, it must determine what skills are needed and how those skills differ from historic needs. The challenge will be to fill positions for which there is a chronic shortage of qualified candidates who also have the training and capabilities in demand by high-technology firms in the private sector. Carol Meyers, a Livermore mathematician, says, “A major challenge for NNSA is ensuring that the new generation of weapons designers, code developers, experimentalists, stewards, and engineers are capable of developing a fundamental understanding of nuclear weapons in an environment where computer-aided design has taken the place of hands-on testing.”

By factoring in various scenarios, the model helps NNSA anticipate and cultivate the skills that will be needed for different projects, such as LEPs or increased dismantling of weapons. The model projects the optimal size staff for each location.

To Replace or Refurbish

Even though NNSA has closed 40 percent of its nuclear testing and production sites since the 1980s, future goals include reducing



Currently, the infrastructure of the nuclear weapons complex (which includes approximately 6,500 facilities with a capitalized value of about $40 billion) is outdated and has more than $900 million in deferred maintenance. If the nation prudently plans for a reduced future stockpile, old infrastructure can be replaced or modernized. Doing so would result in a U.S. nuclear weapons enterprise that is smaller, more balanced, safer, more secure, and less costly.

the total footprint of the complex even more, from 35 million to 26 million square feet. As the nuclear weapons complex continues to be consolidated, NNSA is placing greater emphasis on certain key facilities. Some of these facilities can be modernized and revitalized, while others will need to be replaced.

The model's optimization tools allow NNSA to illustrate how it can adroitly allocate a limited budget under a variety of scenarios. Users with access to detailed information about every building on the complex's eight sites can study a range of scenarios. For example, a major facility project may affect the flow of work throughout the entire complex, whereas a utility upgrade at a specific site may only interrupt operations temporarily but perhaps could impact an LEP schedule permanently.

The model can provide insight into the consequences of deferring maintenance, delaying the construction of a new facility, or even implementing a policy change. As expected, the model allows cost–benefit analysis of alternatives such as, for example, the trade-off between constructing a new facility versus sustaining and modernizing an existing facility. The entire life cycle of facilities from acquisition through mission use to demolition and decontamination are represented. Equally important, the model shows how infrastructure investments are tied to stockpile deliverables.

How Many Weapons Systems Are Optimal?

The Strategic Arms Reduction Treaty (START) and New START, which went into effect in 1994 and 2011, respectively, have limited the number of the nation's deployed strategic nuclear weapons. Meyers has developed a classified version of the enterprise model, called STORM (Stockpile Transformation Optimization Requirements Model), to help NNSA make stockpile decisions. Using STORM's simulation, optimization, economic-analysis, and decision-analysis tools, NNSA analysts can address questions about building, maintaining, and dismantling weapons systems based on the number of weapons, the length of their life cycle, their delivery system, the difficulty of maintaining them, and the complexity of an LEP. The model considers weapon dismantlement, which will be driven by stockpile reductions, as well as reuse and remanufacturing options.

For example, STORM is used in studies to minimize the number of years that warheads spend in the stockpile beyond their nominal service lifetimes. This objective is constrained by cost, the availability of people and facilities for work on the warheads, and the supporting infrastructure. The data and analyses support decisions about which weapons to maintain and which ones to dismantle. By evaluating different scenarios, NNSA can consider options to reduce the number of different types of weapons in the stockpile. For example, with fewer types of weapons, NNSA may be able to consolidate or eliminate some facilities.

The people, infrastructure, and weapons are the three major components of the nuclear weapons complex and are interdependent and linked by budget. Livermore's enterprise model helps NNSA to make fully informed decisions, with the knowledge that these decisions are soundly based on data. Because the model can evaluate options and look for optimal solutions, it helps ensure that NNSA understands the consequences when policies, budget, or other circumstances change. Shang and his team are working on a more complete model that combines both Department of Defense and NNSA assets, data, and plans, so that any decisions about the weapons can be closely coordinated with delivery systems.

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Key Words: decision analysis, economic analysis, enterprise optimization, Nuclear Weapons Enterprise Model, simulation, Stockpile Transformation Optimization Requirements Model (STORM).

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