

## Creating Life, Saving Lives

Miniature machines repair technology and heal our bodies from within

### Quick read

Protocells could completely change technology as we know it. Infinite possibilities, from saving the environment to saving lives.

A computer chip that heals itself, microbe-sized machines that removes greenhouse gases from our skies, nanoscale devices that extract radioactive materials from the environment, or, even more fabulous, a miniscule molecule that heals our bodies from within. Science fiction fantasies? Maybe not. Researchers at Los Alamos are creating life from nonliving materials and life-saving technology is on the horizon.

The ability to self-replicate, metabolize, and evolve into new forms is considered the defining characteristic of living cells, but Los Alamos is creating tiny machines that possess these abilities. Government and science institutes worldwide predict that convergent, or living, technologies will impact our technology and economy within the next 25 years and become key to our technological leadership and national security.

Now, collaborating teams of scientists from Los Alamos National Laboratory (LANL) and across Europe are close to developing the "protocell," a system of molecules that exhibit living cell-like behavior. The microscopic protocell would be the first step toward making lifelike devices that perform specific, useful functions.

"Our goal is not to modify existing living cells and turn them into little machines," says Steen Rasmussen, leader of the Los Alamos Protocell Assembly project. "Our goal is to take those features that make living cells so successful and apply them to something new. Because we're starting from scratch, we can design our protocell to do things that living cells cannot. In theory, we can make it so different that it can operate in any environment-toxic, radioactive, or otherwise. Protocells can also be designed so they don't interact directly with the biosphere."

### The Protocell Different

The simple protocell has just three components that interact strongly with each other: a metabolism, an information system, and a container.

The Los Alamos team has already built a pared-down version of a protocell; it has achieved the team's major milestone: it used its information system to control a metabolic pathway that converted external resources into container material. This machine built its own container!

"In a living cell, the DNA creates proteins that control the metabolism's chemical reactions," says Los Alamos physicist and team member Hans Ziock. "In our protocell, the information molecule participates directly in the metabolic pathway, so no protein synthesis is necessary. It's a great simplification."

"Our simplistic information molecule nonetheless captures the essential features of an information system. It makes the reaction work and, in that sense, controls or instructs the metabolism. Though it's a modified DNA base, it can still pair with another base and, in principle, copy itself the way DNA does," Ziock adds. "Lastly, it can join with other bases and become more complex. That might allow for more-efficient metabolic pathways, thereby opening up a way for the protocell to evolve."

Unlike a living cell, the Los Alamos protocell conducts all of its business within the oily part of the bi-layer or at its surface, allowing the protocell to exchange nutrients and wastes with

the environment and eliminating the complex cellular resource transportation process. Although this simplified protocell has the features of a complete system, the team still must demonstrate experimentally that the protocell's information molecule can replicate-the critical missing link for completing the first human-made, fully functional protocell.

#### Multiscale Modeling

To help understand and build a more complex system, the team developed a computational version of all key protocell processes, combining different simulation methods to provide various details. Because of the complexity of the system, it has been surprisingly difficult to simulate the protocell's full life cycle-but Los Alamos researchers are close.

The Laboratory's researchers' greater understanding of how to make self-replicating materials is the big first step toward creating living technology that will benefit society in fundamental ways.

## Pushing Frontiers

In the second half of 2008, Los Alamos National Laboratory made significant advances in its primary mission: safeguarding the U.S. nuclear deterrent and pushing the frontiers of science on multiple fronts.

The national stockpile stewardship program achieved a major milestone in September with the production of the first life-extended W76-1 ballistic missile warhead for Trident submarines. The achievement culminated more than a decade of work by scientists and engineers at Los Alamos and across the nuclear weapons complex-including two crucial experiments conducted by the Laboratory's Hydrodynamic Experiments Division.

Another highlight: Roadrunner reached a new performance record of 1.105 petaflops, keeping it atop the list of the world's fastest supercomputers. Built by IBM for the Lab, Roadrunner was the first computer to crack the petaflop barrier: one thousand TRILLION operations per second. Initial applications will range widely: studying in great detail the evolution of HIV... exploring deeply the formation&mdash;as well as deformation&mdash;of metallic nanowires...and-toward producing biofuels more efficiently-unraveling the processes by which bacteria break down cellulose.

Safety and environmental stewardship were again a major theme for our work in the latter half of 2008. In November, the last group of unvented high-activity drums left Los Alamos for the Waste Isolation Pilot Plant near Carlsbad. That shipment fulfilled a commitment to the Defense Nuclear Facilities Safety Board to prioritize disposal of the highest-activity transuranic wastes stored at the Lab.

Los Alamos also strengthened security, ensuring that nearly six dozen classified and unclassified computing systems are managed and operated securely. The Lab has now complied with all 14 security actions mandated two years ago by the Department of Energy. And, through our program to recruit cognizant systems engineers, we met the crucial need for sufficient numbers of engineers to keep vital mechanical and electrical safety systems functioning properly in our nuclear facilities.

The latter half of 2008 proved once again why Los Alamos is the nation's premier institution for scientific research. Capping the list of accomplishments was a new technology called MagViz that could eventually provide increased security at major airports. Based on medical MRI technology, MagViz can identify contents of bottles and other containers, distinguishing potentially hazardous liquids from the harmless shampoos and perfumes a traveler might carry onboard a jet. MagViz was demonstrated successfully in December at Albuquerque's airport.

We continued a long tradition of supporting U.S. space exploration. A NASA mission, launched in October to probe the far edge of the solar system from a high Earth orbit, carried a Los Alamos device called the High Energy Neutral Atom Imager. Its goal: to detect atoms emitted from a region where the outermost reaches of our solar system meet the vast interstellar space-giving us a panoramic view of this gateway to the galaxy.

Closer to home, Los Alamos continues to explore solutions to the energy needs of tomorrow. For example, scientists at the Lab hope to use tiny semiconductors called quantum dots to convert sunlight to electricity more efficiently than is possible with current solar panels-and to create new, efficient solid-state lighting.

Equally electrifying, Los Alamos materials scientists are helping unravel the mysteries of superconductivity. During the latter half of the year, LANL researchers identified entirely new mechanisms for superconductivity that could form the basis for new superconducting materials.

Underscoring the wealth of scientific talent at the Lab, Bob Albers, Paul Johnson, and Kurt

Sickafus were named Laboratory Fellows in December. These three Fellows represent diverse disciplines, including theoretical physics, energy science, and geophysics. Los Alamos may be one of the world's great technology incubators, yet we also strive to help others develop new ideas and products. In January, the Lab selected four young local companies as the newest recipients of awards from the LANS Venture Acceleration Fund. LANS, which manages and operates the Lab, supports the fund through donations from its earnings.

The Lab and LANS also teamed last September with a venture capital firm and a local venture capital fund to spin off technology developed by Lab scientists, with an emphasis on creating companies in Northern New Mexico. The Lab could contribute up to one million dollars to the initiative over the first three years.

We also are pushing to build top-flight research facilities for the future. In July 2008, workers hoisted the final steel beam atop the skeleton of what will be the Radiological Laboratory Utility Office Building, part of the Lab's Chemistry and Metallurgy Research Replacement Project. Once completed, the CMRR nuclear facility will house several of the Lab's mission-critical projects, including analytical chemistry, materials characterization, and actinide research and development capabilities. They'll be relocated from their current location in the historic—yet antiquated—Chemical and Metallurgy Research building at Technical Area 3.

In December, Los Alamos welcomed hundreds of employees who transferred from KSL, the subcontractor whose work the Lab brought in-house. The move was geared to improve efficiency and reduce costs associated with site-support services, including maintenance, waste removal, and custodial work.

Throughout the Lab's history, Los Alamos has helped play a vital role in the surrounding communities, and in 2008, that tradition continued. Lab employees pledged a million dollars, and LANS matched one hundred percent: a record Los Alamos contribution to United Way of TWO MILLION dollars. Contributions from the Lab and LANS also helped fund dozens of nonprofit organizations and scholarship programs, including a LANS donation of \$500,000 to a LANL Foundation scholarship named for former long-time New Mexico Senator Pete Domenici.

These accomplishments and many more added up to a strong year. Our customer, the National Nuclear Security Administration, reached the same conclusion in its very favorable assessment of the Lab's performance for fiscal year 2008. It's unmistakable: the extraordinary talent, commitment, and creativity that Los Alamos employees dedicate every day to national security science and the betterment of their communities.

## About Our Capabilities, Facilities, and Staff

"Los Alamos National Laboratory plays an indispensable role in building America as a science and technology powerhouse, and our staff are an incredible resource to the nation and the world." Michael Anastasio, Dir.

Solving Complex R&D Problems with Special Blend of Staff, Capabilities and Facilities  
Now in its seventh decade, LANL is one of the few laboratories that can bring great breadth of fundamental and discovery science, technology, and engineering rapidly together to create tangible solutions for national security needs.

Our staff, working with partners throughout science and industry, must be able to deliver today's solutions while maintaining the depth of capabilities to deliver the next generation of discoveries.

Los Alamos has demonstrated a cycle of innovation where we have developed world-leading capabilities and facilities in response to urgent, unique missions. Our new discoveries continue to respond to emerging missions.

Being able to integrate and apply our capabilities rapidly to new challenges will be a key advantage in an increasingly competitive landscape.

Our Science, Technology and Engineering Priorities  
Science that Matters

Information science and technology enabling integrative and predictive science  
Experimental science focused on materials for the future  
Fundamental forensic science for nuclear, biological, and chemical threats

### How We Work

Collaborate, partner and team to make decisive contributions to our sponsors  
Outstanding operational excellence for safety, security, and efficient pursuit of ST&E  
for our missions

### Transform Our Scientific Campus

Campus for 2020 (consistent with complex transformation)  
Modern science facilities: LANSCE refurbishment, CMR replacement, Science Complex  
Signature facilities