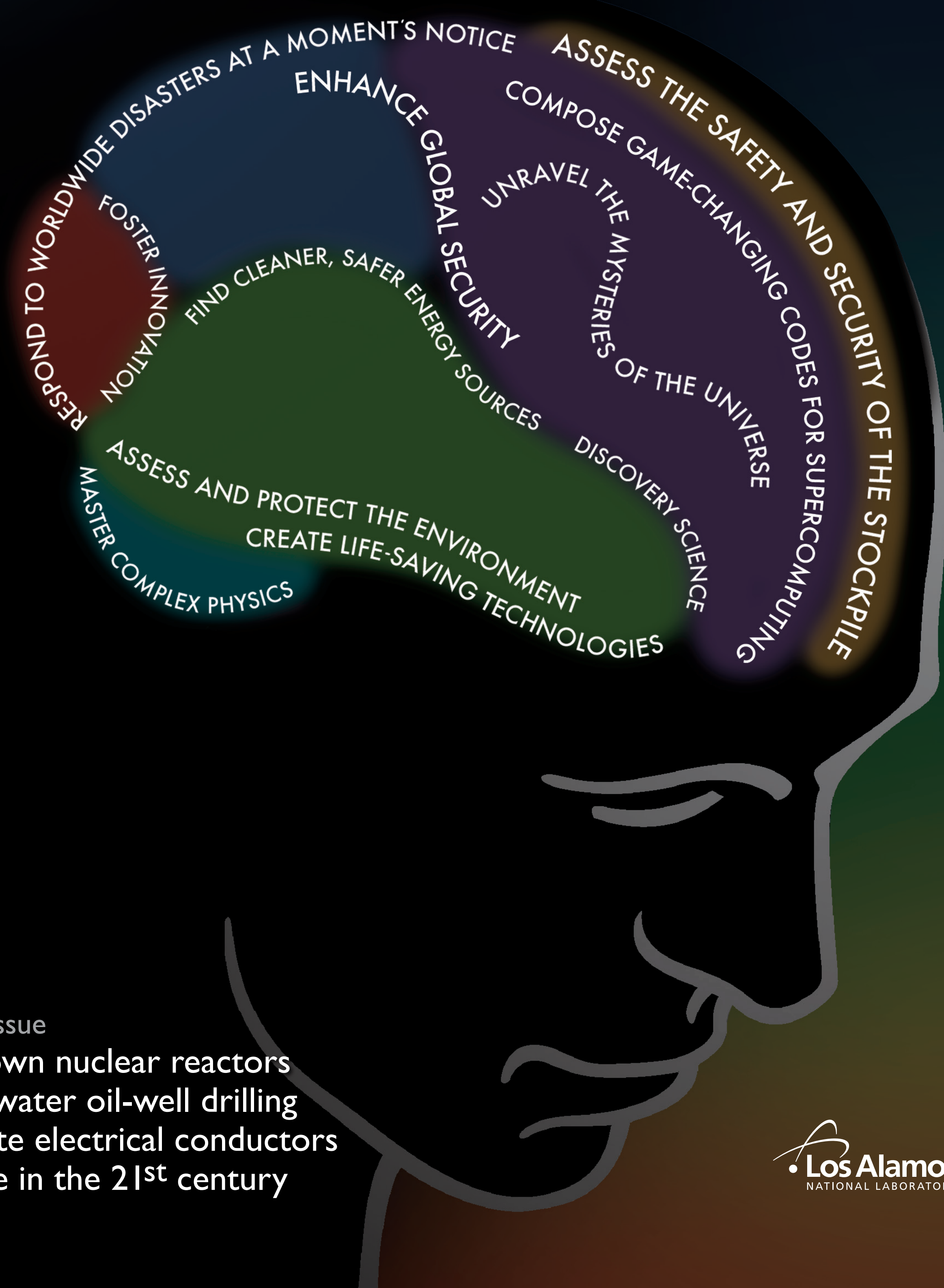
NATIONAL SECURITY
SCIENCE

TOMORROW'S QUESTIONS **ANSWERED TODAY**



Also in this issue

No-meltdown nuclear reactors

Safer deepwater oil-well drilling

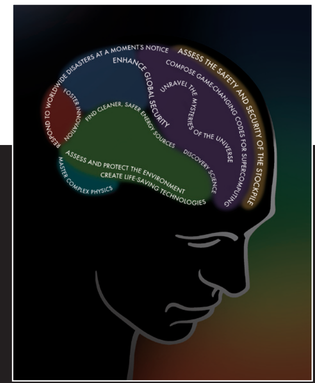
The ultimate electrical conductors

Deterrence in the 21st century

Los Alamos
NATIONAL LABORATORY

About the Cover

LANL continues to provide solutions to tomorrow's crises. From Ground Zero to the Gulf of Mexico and Japan—we respond with answers to complex international questions.



MICHAEL ANASTASIO

A few months ago, I announced my decision to retire, after five years as the director of Los Alamos National Laboratory, in June. It has been a distinct privilege to serve as your director. I am pleased with our many achievements. The Laboratory has delivered on its national security commitments, provided solutions to unanticipated challenges, and invested in new tools and technologies that are essential to the continued success of the Laboratory.

A vibrant science, technology, and engineering enterprise is the technical underpinning for all of LANL's diverse missions. LANL's expertise provides the basis for confidence in the stockpile in the absence of nuclear testing and supports development of solutions to protect the environment and human health while helping meet future energy needs.

The Laboratory, as it has for the last 68 years, remains committed to sustaining confidence in the nation's nuclear weapons stockpile through a science-based understanding of weapons safety, reliability, and performance. I have signed five annual-assessment letters to our nation's President as the Laboratory director, and I am keenly aware of the daunting technical challenges we have overcome to meet national security missions. In 2007, the Laboratory reestablished the capability to manufacture pits for the W88. In 2008, the first W76-1 life-extended warhead was assembled. Design for extending the life of the B61 bomb, vital to national deterrence, is in progress. Later this year, the Chemistry & Metallurgy Research Replacement Radiological Laboratory Utility Office Building will be dedicated—a step in providing a modern actinide research and development complex.

We have significantly advanced high-performance computing since I joined the Laboratory. Roadrunner, one of the world's fastest supercomputers, broke the petascale barrier. Cielo is up and running, supporting research at three laboratories. Exascale computing—the next great challenge that must be addressed—will truly revolutionize simulation.

Signature experimental facilities are cornerstones of the Laboratory's scientific capabilities. The Dual-Axis Radiographic Hydrodynamic Test facility has performed successful experiments that provided multiple high-resolution, time-sequenced images. The Los Alamos Neutron Science Center is one of the world's most powerful linear accelerators with multiple beamlines that contribute to medicine, stockpile performance, and genetics. MaRIE (Matter-Radiation Interactions in Extremes), the proposed signature science facility, will be built onto the LANSCE infrastructure and will incorporate a 20-billion-electron-volt electron accelerator, new x-ray beams, and three experimental halls and laboratories.

As my time as the Laboratory director draws to a close, I want to express my profound gratitude to all who have worked creatively and tirelessly to support the Laboratory. It has been my extreme privilege to have served as the ninth director of Los Alamos National Laboratory.

Los Alamos National Laboratory Director

Adam Manzanares, Christopher Ticknor, and David Collins (left to right) talk about the research that earned them their Metropolis Postdoctoral Fellowships.

Rolling out a NEW SUPERCOMPUTING FELLOWSHIP at Los Alamos

Postdoctoral students are the backbone of scientific institutions such as Los Alamos National Laboratory, as each new generation brings exciting ideas and fresh energy to the world of science. The Los Alamos Postdoctoral Program offers uniquely qualified early-career scientists the opportunity to perform challenging research in a scientifically rich research and development environment. Postdocs also have the opportunity to present and publish their research and advance knowledge in critical scientific areas at Los Alamos.

"I once served as part of the postdoc committee here at the Laboratory," explained Brian J. Albright, a scientist who works for the Plasma Theory and Applications Group at Los Alamos. "One of the things that was apparent to me was that this program is outstanding at bringing in fresh talent from the outside—the best scientists in the world in the areas of theoretical science or experimental science. But often, it seemed as if computational science was not served quite as effectively, so I wanted to develop a fellowship that specifically targeted computational and computer scientists to join the community here at the Laboratory. This community is very important, given that much of our weapons work today is done on computers."

In collaboration with other Los Alamos scientists and managers, as well as the Los Alamos Postdoc Office, Albright, along with Cheryl Wampler (Advanced Simulation and Computing Program) and Mary Anne With (Education and Postdoc Office), this year inaugurated the Metropolis Fellowship in Computer and Computational Science. Recipients of this fellowship can pursue advanced research in the areas of computational and computer science, physics, and engineering. Under the Advanced Simulation and Computing Program, computer simulation capabilities are developed to support the Stockpile Stewardship Program, as well as broader national security needs.

Selecting Candidates

The competition for this year's inaugural fellowship was rigorous. The Los Alamos Fellowship Prescreening Committee reviewed candidates from around the world, as this fellowship is open to citizens and noncitizens. The pre-screening committee selected and advanced 12 candidates, who underwent two additional reviews through another screening committee consisting of representatives from the Computational Physics; Theoretical Design; Computer, Computational & Statistical Sciences; and High-Performance Computing division offices, as well as from the Advanced Simulation and Computing Program Office.

"Prospective postdocs must have a mentor who sponsors them," says Albright. "So, one of the functions of the prescreening committee was to match possible postdocs with prospective mentors."

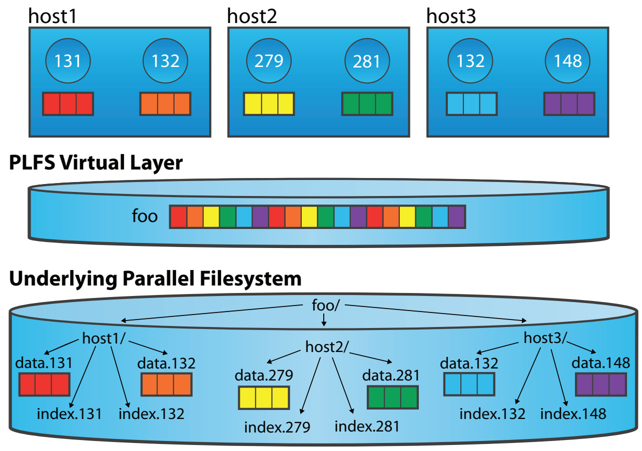
Four offers were extended to candidates, two of whom were already postdocs at the Laboratory. All four Metropolis fellows are U.S. citizens.

Adam Manzanares

Adam Manzanares works under the mentorship of Meghan Wingate and John Bent, both in the High Performance Computing Division. Manzanares grew up in northern New Mexico and attended the New Mexico Institute of Mining and Technology while working on a BS in computer science. From 2002 to 2007, Manzanares worked as a student intern at Los Alamos—he had the opportunity to work on wireless network security and integration. In the spring of 2010, he received his PhD in computer science from Auburn University, where he concentrated on energy-efficient storage systems. His research interests include high-performance and parallel computing, storage systems, and computer science education.

As a Metropolis Fellow, Manzanares is working to determine how a parallel log-structured file system (PLFS) will fit into an exascale input/output (I/O) stack and what improvements PLFS will require to operate at this extreme scale of computing.

As computer platforms move toward the exascale era, the complexity of a system will drive downward the mean time to interrupt (MTTI). As the MTTI begins to diminish, the frequency of checkpointing increases for parallel applications. Such checkpointing requires that the parallel file systems used to store checkpoint data deliver high-write bandwidths across a variety of I/O workloads. Shared file writing is one particular workload that is in heavy use, but this workload also causes performance degradation on many parallel file systems. Los Alamos computer scientists developed PLFS to map these difficult I/O workloads into manageable workloads on a parallel file system.



The Parallel Log-Structured File System (PLFS) decouples a logically shared file, This improves write bandwidth significantly and allows scientists to map the workload into parallel I/O optimized layouts. PLFS helps shield application developers from increasingly complex I/O subsystem details.

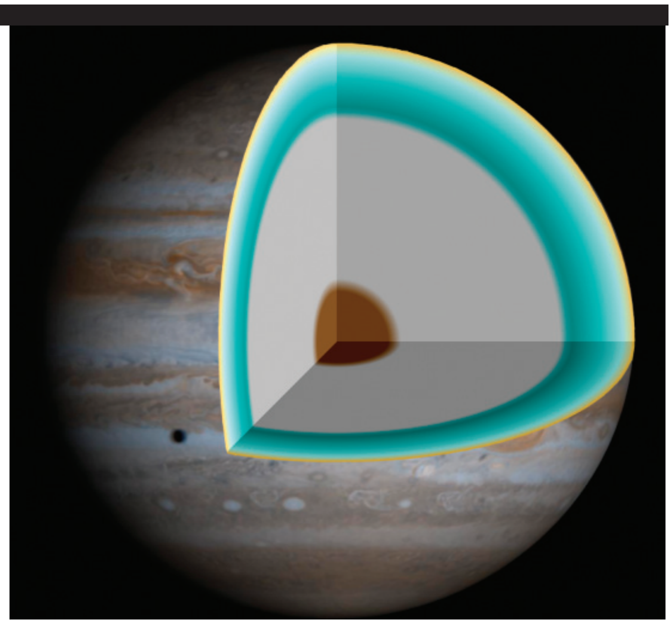
Although PLFS solves the shared-file-writing dilemma, scientists quickly realized that its performance required the improvement of read performance before it could go into production at Los Alamos. Manzanares has developed several collective I/O optimizations that have increased PLFS's read performance so that it rivals direct access to the parallel file system. Such enhanced performance in PLFS has enabled Los Alamos computer scientists to manipulate I/O metadata workloads so that it is possible to achieve high performance from a parallel file system.

Christopher Ticknor

With Laboratory Fellow Lee Collins as his mentor, Chris Ticknor works at the Laboratory's Physics and Chemistry of Materials Group. Ticknor is studying quantum correlations computationally in two systems. The first involves warm dense matter, in which electrons are treated quantum mechanically and the ions are treated classically. The second involves a multielectronic molecule interaction with an attosecond pulse. Both projects require the use of supercomputers.

Scientists postulate that warm dense matter is at the core of some large planets. It is also possibly within the solid-to-plasma phase transition driven by laser pulses during inertial confinement fusion and in other systems that start as solids but are heated to become plasmas. The latter two examples are relevant to nuclear explosions.

Ticknor was a Director's Postdoctoral Fellow at Los Alamos National Laboratory and previously was a postdoctoral fellow at Swinburne University of Technology in Melbourne, Australia. Ticknor holds a BS from Bucknell University and a PhD from JILA/University of Colorado at Boulder. Both degrees are in physics.



Scientists are studying warm dense matter, in part, to better understand planetary interiors (such as Jupiter's, shown here) in terms of equation of state and other material properties. Such understanding will enable scientists to one day understand and perhaps even predict planetary formation and evolution.

David Collins

Co-sponsored out of the Theoretical Design and Theoretical divisions at Los Alamos, David Collins is working under the guidance of principal investigators James Cooley, Hui Li, and Shengtai Li. Collins' focus area is on determining the role of magnetic fields in star formation. His work will involve developing models and implementing them into large-scale multiphysics computer codes.

David Collins began his studies at the Eastman School of Music in Rochester, New York. He then transferred to the University of Cincinnati to study engineering and ultimately graduated with degrees in mathematics and physics. While in Cincinnati, Collins discovered a deep interest in programming and experiment modeling while working with particle physics experiments. Collins worked with Professor Michael L. Norman on numerical magnetohydrodynamic methods for adaptive mesh refinement codes, as well as with Professor Paolo Padoan on studies of star formation and supersonic turbulence. Collins graduated in 2009 but remained at the university for two years as a postdoc.

The Orion Nebula (shown here), is an archetypical example of star formation. New research suggests that cosmic magnetic fields, which can channel condensing interstellar gas, may play an important role in the birth of stars.

At Los Alamos, Collins has begun working on extending the numerical models of star formation he developed in graduate school. He intends to include a broader and more realistic description of physics in these models. The turbulent fragmentation model Collins is using possesses well-described statistical properties of isothermal supersonic turbulence used to predict the formation rate and mass distribution of stars in the galaxy. He will follow collapsing protostars beyond the isothermal regime to include several changes of state in the magnetized hydrogen. He will also model the formation of isothermal molecular clouds from their larger atomic progenitors. Collins will use a combination of two codes: Enzo (developed at the University of California, San Diego) and RAGE (developed at Los Alamos).

Brian Haines

Scheduled to begin his fellowship in the summer of 2011, Brian Haines will work for the Los Alamos Computational Physics Division under the mentorship of principal investigator Fernando Grinstein. Haines' work will address fundamental turbulence-physics-modeling issues of advanced programmatic interest, such as the mixing of materials in shock-driven turbulence.

The Advanced Simulation and Computing Program

The Metropolis Fellowship in Computer and Computational Science was created under the auspices of the Los Alamos component of the Advanced Simulation and Computing Program.

The Advanced Simulation and Computing Program is a National Nuclear Security Administration tri-lab program (Los Alamos, Lawrence Livermore, and Sandia) tasked with ensuring the safety, security, and effectiveness of the nation's nuclear weapons stockpile.

The program was established in 1995 to shift its approach from test-based confidence to simulation-based confidence. Its mission is to analyze and predict the performance, safety, and reliability of nuclear weapons and certify their functionality. The tri-lab collaborators also work in partnership with computer manufacturers and in alliance with leading universities.

–Octavio Ramos Jr.

The Metropolis Fellowship: Who Was Nick Metropolis?

Nicholas Constantine Metropolis was born June 11, 1915, in Chicago, Illinois. He received his BS in 1936 and PhD in 1941 from the University of Chicago. Both degrees were in chemical physics.

In 1942 and 1943, Metropolis accepted an appointment as a research instructor at the University of Chicago, where he worked with James Franck. Franck was a Nobel Laureate in physics, having received the award with Gustav Hertz in 1925 for discovering the laws that governed the impact of an electron upon an atom.

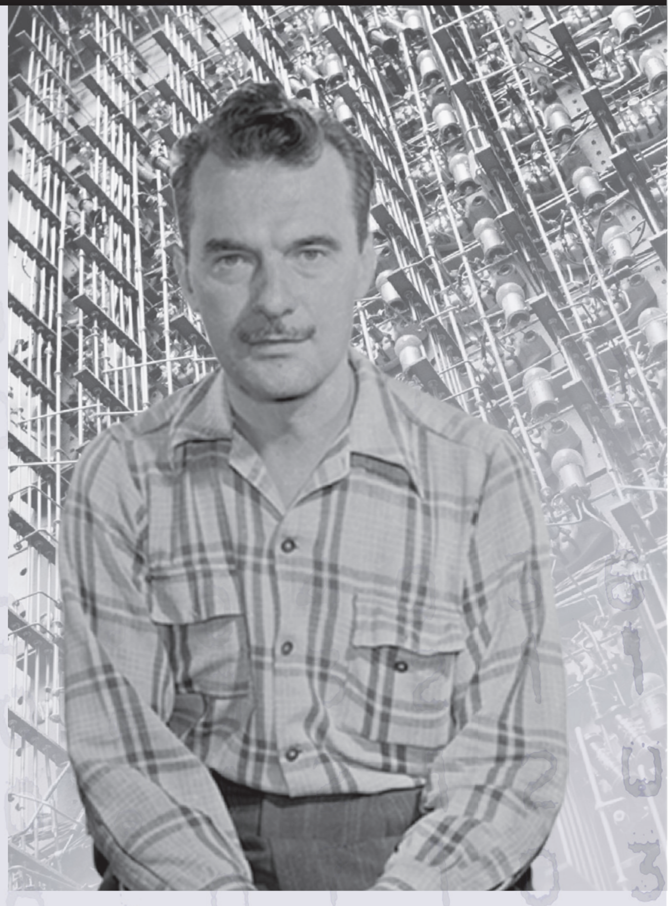
In early 1943, Robert Oppenheimer convinced Metropolis to come to Los Alamos. His first assignment was to develop equations of state for materials at high temperatures, pressures, and densities.

During World War II, scientists at Los Alamos used slow, clanking, electromechanical calculators when designing the first atomic weapons. These calculators proved fragile, and soon Metropolis and Richard Feynman were spending some of their time repairing these calculators.

At the end of World War II, mathematician John von Neumann brought together the developers of the first electronic computer, known as ENIAC, and several Los Alamos scientists, Metropolis among them. It then fell upon Stanley Frankel and Metropolis to develop a problem for ENIAC to solve: in 1945, the two men had the computer run complex calculations involving the design of the first hydrogen bomb.

Metropolis returned to Chicago, where he continued to work with ENIAC. Using the germ of an idea conceived by Enrico Fermi some 15 years earlier, Metropolis in 1948 led a team that carried out a series of statistical calculations on ENIAC. These statistical calculations would become collectively known as the Monte Carlo method of calculation, which since then has helped address issues such as traffic flow, economic problems, and the development of nuclear weapons.

Fascinated by the power of computation, Metropolis attempted to establish a major computing facility at the University of Chicago. When this facility did not materialize as he had hoped, Metropolis began to think about other possibilities. As he was weighing options, he received a call from Carson Mark, head of the Theoretical Division at Los Alamos. Mark suggested that Metropolis set up a computing facility at Los Alamos—he accepted the offer and in 1948 began to build a computer that would implement the rapidly developing concepts of digital computation.



The Mathematical Numerical Integrator and Computer—MANIAC for short—became operational on March 15, 1952. From 1953 to 1959, Metropolis and his team used MANIAC and the Monte Carlo technique to address complex problems in physics, biology, chemistry, and mathematics.

In 1957, Metropolis returned to Chicago, where he became the founding director of the Institute for Computer Research. In Chicago, he invented online data processing for scientific instrumentation. He designed and built a computer that was coupled to the Navy's cyclotron. This computer received and analyzed data while an experiment was running.

Metropolis returned to New Mexico in 1965, where he remained the rest of his life. He continued to develop computational techniques and encouraged others to become interested in parallel computing. He was the Laboratory's first Senior Fellow Emeritus. Metropolis died in 1999 at the age of 84.

THE NATION'S DETERRENT IN THE 21st Century

B61 Life Extension Program

Following a period of reduced attention and funding during the 1990s, the nuclear security enterprise that provided nuclear deterrence from the end of WWII to the end of the Cold War has seen a reemergence in both national policy focus and funding. Large, meaningful projects, such as the B61 Life Extension Program (LEP), are being used to provide the nation with an updated, 21st century deterrent force as well as a new generation of trained scientists and engineers that contribute to the credibility and reliability of this force.

The Cold War ended nearly two decades ago. In response to the ensuing expectations of a peaceful world, our nation has since halted all underground nuclear testing, canceled development of new nuclear systems, and retired or eliminated 13 different stockpile nuclear weapons.

As the focus of the nation's nuclear laboratories shifted to stockpile stewardship and broader support of nonproliferation and nuclear material protection, the United States, as the only remaining superpower, became heavily engaged in conventional warfare and in humanitarian and policing activities around the world. At this point, the concept of nuclear weapons and nuclear deterrence as tools of war became viewed by some as being as anachronistic as the Cold War itself.

To maintain a worldwide U.S. presence through active military campaigns and associated humanitarian activities, our nation's senior civilian and military leaders have been forced to make hard choices about expenditures and national priorities. After all, the American people expected a peace dividend, and budget cuts within the nuclear enterprise seemed like a good place to start.

In short, until 2007 the nation's leadership no longer perceived a "great need" for robust nuclear enterprise funding. Faced with decreased attention and, more important, diminishing annual budgets, the nuclear security enterprise, including Los Alamos National Laboratory, was left hard-pressed to continue to attract the best technical personnel, to justify infrastructure upgrades and sustainment, and to accomplish the hands-on science and engineering necessary to support the current aging nuclear weapon stockpile in a nonnuclear testing environment.

Late in the last decade, several U.S. Air Force incidents involving nuclear warheads or components brought to light the compounding effects of inattention to the role of nuclear weapons in deterrence.

In 2006, the Air Force shipped forward-section parts of a sensitive intercontinental ballistic missile reentry vehicle from F. E. Warren Air Force Base (AFB) to Taiwan. In 2007, members of then Air Combat Command's Eighth Air Force transported, without authorization or intent, nuclear-armed cruise missiles from Minot AFB to Barksdale AFB on a B52 bomber normally used for nonnuclear transport. In a review carried out by former Secretary of Defense Schlesinger at the request of Secretary of Defense Gates, Schlesinger's task force found that "there has been an unambiguous, dramatic, and unacceptable decline in the Air Force's commitment to perform the nuclear mission," and the task-force's report reminded decision makers that, "the nuclear deterrent is 'used' every day by assuring friends and allies, dissuading opponents from seeking peer capabilities to the United States, deterring attacks on the United States and its allies from potential adversaries, and providing the potential to defeat adversaries if deterrence fails."

While the incidents were unrelated in specifics, a review by Admiral Kirkland H. Donald in 2008 found commonalities in them and attributed both events to a gradual erosion of nuclear standards and a lack of effective oversight. Defense Secretary Robert Gates then highlighted the "degradation of the authority, standards of excellence, and technical competence" being observed in some nuclear weapons operations.

In an historic speech in April 2009 at Hradcany Square, Prague, President Barack Obama outlined his vision of a world someday without nuclear weapons and reiterated a long-standing U.S. commitment to "a safe, secure, and effective arsenal".

Redefining Deterrence

A question then arose: Is nuclear deterrence really a relic of the Cold War, no longer necessary in a 21st century world in which globalization and overall economic development and competition tend to dominate as tools of engagement?

An answer might be found in a definition of deterrence by General Kevin P. Chilton: "The purpose of a deterrence force is to create a set of conditions that would cause any potential adversary to conclude that the cost of a particular act against the United States or one of her allies is far higher than the potential benefit from that act." General Chilton, recently retired commander of the U.S. Strategic Command, is one of the main advisors for the recent New Strategic Arms Reduction Treaty and the *Nuclear Posture Review* (NPR) report.

As we have learned during the last two decades, the end of the Cold War did not mean the end of conflict for the United States. Instead of having one major peer adversary, we are now looking at multiple adversaries (some that are nation states and some that are not) looking to position themselves against our country and our allies, with different goals, different approaches, and different stakes in the game.

Under President Barack Obama's administration, the world waited to see what role nuclear weapons would have. In April 2009, President Obama challenged world leaders to create a world free of nuclear weapons. However this challenge did not mean the United States would unilaterally disarm. While some factors, such as the geopolitical environment, cannot be controlled, the fact remains that nuclear weapons ready for immediate deployment need to maintain their long-term status as a strategic existential deterrent for our nation.

In the President's strategy, our nation would set the example by reducing the numbers of weapons in its arsenal and, while not developing new nuclear weapons, maintaining and improving a safe, secure, and effective active stockpile. As a nation, the United States can achieve this goal by (1) modernizing facilities, (2) recruiting a new generation of "the best and the brightest" nuclear scientists and engineers capable of backing up the credibility of the deterrence function, and (3) investing in component modernizations and upgrades to extend the life of current aging weapon systems and to certify their reliability without underground nuclear testing.

To achieve the first of these ends, within DOE's nuclear weapons operations, the NNSA's Complex Transformation plan is turning the current aging nuclear weapons

Production technicians prepare a B61 for a surveillance test.

complex into a 21st century national security enterprise that is smaller, safer, more secure, more cost effective, and environmentally compliant.

Extending the Life of Aging Weapons

Given that fielding a new nuclear weapon is not part of the current national strategy, the second and third ends can be achieved through a multi-laboratory process within the enterprise called an LEP.

While extending the functional lifetime of current nuclear weapon systems has obvious benefits, maintaining the stockpile through such an approach has some level of risk. Consider the following analogy offered by former Los Alamos Fellow Stephen Younger. Imagine buying a car (nuclear weapon) and promising your neighbors that you will not drive it except in an absolute emergency. Over the years, you have to perform periodic maintenance, e.g., replace the spark plugs, change the oil, etc., to ensure the car will be drivable if needed. As the car ages, the car industry stops making specific parts for it, forcing the "owner" to find suitable replacement parts. Finally, an emergency arises and the owner has to drive the car. Will it really start? If it starts, will it operate as required?

In an LEP, hundreds of scientists, engineers, and technical personnel from across the complex contribute to a combined development, testing, and manufacturing project designed to best improve the safety, security, efficiency, and lifetime of a current nuclear weapon system. This process allows an entire generation at several laboratories and production plants to acquire the skills, knowledge, and expertise required to provide the nuclear deterrent of the future without creating a new nuclear weapon. To date, the LEP approach has been successfully applied to the W87 and W76 warheads.

In August 2010, guided by the administration's NPR, LANL and Sandia National Laboratories' scientists and engineers began the daunting task of ensuring that the nation's nuclear automobile, i.e., the B61, would not only be ready to start, but would run at a moment's notice upon presidential direction for several decades to come. Additionally, they took to heart the President's instruction to ensure that the B61 is as safe, secure, and effective as possible.

The B61 bomb is an integral part of our nation's strategic defense; a considerable segment of the stockpile's nuclear weapons are B61s, many designed and produced in the late 1960s and early 1970s. These weapons were not intended

Gen. Roger Brady, then–Commander of the U.S. Air Forces in Europe, being shown B61 nuclear weapon operation procedures on a "dummy" in an underground Weapons Security and Storage System in June 2008.

to last indefinitely—nuclear and nonnuclear components deteriorate over time, even in storage, making maintenance increasingly difficult.

Therefore, to extend the "life" of a weapon so that it remains safe and reliable in the stockpile, a generation of mostly new scientists, engineers, and technicians must use science-based R&D to find specific solutions to the need for extending or certifying the lifetime of each component, as well as the functionality of the system as a whole.

During the program, each nuclear and nonnuclear component is assessed individually and within its functional subsystem, and a decision is made whether to reuse, rebuild, or redesign the part. For example, if the component is too old and cannot be recertified for another 30-year life period, then it can be rebuilt as designed or completely redesigned within the constraints of the system and program. A component rebuild or redesign does not mean a new weapon design; it addresses only those components that cannot be reused and must be replaced. When an opportunity arises to upgrade a critical component to improve safety or security of the weapon, this program taps the new technology and experience from the past 30 years.

Several major components, including detonators, control systems, and gas transfer system components, are being redesigned for safety, security, reliability, or efficiency improvements. Here, new component technology intermingles with years of stockpile surveillance and R&D experience (see the Innovative Component Technology sidebar).

An Evolving Workforce

During the LEP process, regardless of how much change the component undergoes, if any, the steps include product development and engineering; component-, subsystem-, and system-level testing; certification and qualification; system integration; and Weapons Reserve manufacturing.

As the LEP evolves, the benefit in terms of education for the workforce evolves with it, involving personnel from quality, reliability, project development, purchasing and acquisition, facilities, safety, manufacturing, and management and leadership, as well as multiple cross-discipline technical teams. The ensuing collaborations needed to develop, integrate, manufacture, and test components increase the probability that the weapon will operate reliably.

Overall, as Laboratory Director Michael R. Anastasio stated before the U.S. Senate Committee on Armed Services in late March, "The recommitment to the nuclear weapons enterprise embodied in the NPR has … engendered a sense of stability and dedication in our workforce" that helps replenish an essential workforce into the future.

–Dan L. Borovina and Michael Port

Innovative Component Technology

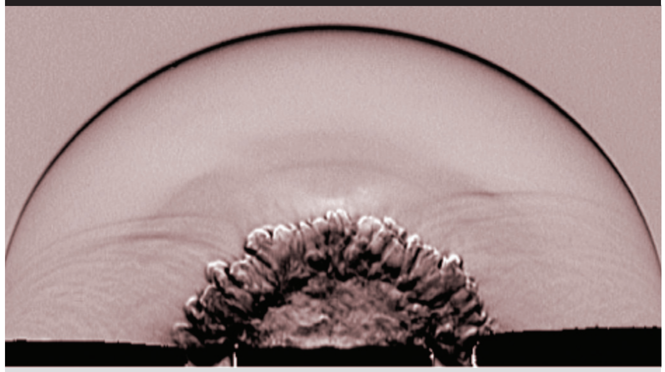


Image courtesy of Mike Murphy

Replacing the aged components of nuclear weapons requires a fundamental understanding of how a current component performs and how the new component impacts the performance of the full assembly. Novel diagnostics based on 21st century technology are actively being developed at LANL to characterize performance aspects of explosive detonation systems.

To understand and establish a baseline performance of explosive components and systems, the Laboratory has developed an innovative diagnostic technique that simultaneously employs specialized ultra high speed imaging with surface velocimetry. This method takes advantage of scientific advancements made in the last decade in the form of ultra high speed camera technology and gigahertz digitizers coupled with infrared detector technology.

LANL scientists, such as Steven Clarke and Mike Murphy of the Detonator Technology Group, use these diagnostics to quantify explosive system output in terms of kinematic quantities like position and velocity or thermodynamic quantities like shock pressure and specific internal energy. In turn, these abilities provide B61 team engineers with a useful means of performing equivalence tests for comparing explosive components, allowing the team to make changes to existing components while maintaining the assurance of safety, security, and reliability.

The supersonic shock waveform created by an exploding bridgewire detonator is captured in this image in a five-nanosecond snapshot. LANL component and system engineers and scientists have been working for several years to develop new technology, such as this, in preparation for potential future LEPs.

Drill ships performing deepwater oil drilling use moon pools through which to pass drill pipe and fluids during the drilling phase of the well—without contaminating the water. It is within the annuli of the well below the sea floor that drilling fluids can expand so much that they collapse or rupture the pipes, leading to lost production or environmentally catastrophic oil leaks.

PHOTO COURTESY
ROBERT HERMES, LANL

Revolutionizing Deepwater Oil-Well Drilling

During the drilling of an oil well, crews set and cement in place a series of concentric pipes, or casings. These casings prevent the collapse of the geological formation into a well and also prevent potential leaks either in or out of a well. This structure results in a series of annuli (an annulus is the space between two concentric objects, such as between casing and tubing, where fluid can flow) generally filled with a heavy spacer fluid and/or packer or drilling fluid used to balance the pressure from the geological formation.

In the upper reaches of a deepwater oil well, casings are typically in a relatively cold portion of the geological formation (near freezing). The lower portions, where the oil is located, are as much as 25,000 feet below the ocean floor. These portions are extremely hot as a result of the natural geothermal gradient.

When crews first produce the oil well, the hot oil comes up from below, warming the whole casing string assembly (a long series of connected casings). Such heat causes the formerly cold drilling fluid in the annuli to undergo thermal expansion. In the industry, this phenomenon is known as trapped annular pressure or annular pressure buildup. The resultant pressure can lead to the collapse (or bursting) of the casing(s).

On land-based wells, crews can use a relief valve to manually alleviate pressure buildup. In deepwater locations, such valves are impractical, given that the actual wellhead at the sea floor can be as deep as 10,000 feet underwater. Moreover, there is no access to individual annuli, so it is not possible to relieve pressure simply through relief valves or through the use of a remotely operated vehicle.

Rather than rely on relief valves or other similar technologies that address pressure once it becomes critical, scientists at Los Alamos National Laboratory have developed a technology that avoids the problem altogether. The trapped annular pressure shrinking spacer, known as TAPSS, is a type of specialized fluid that shrinks—rather than expands—when heated. Such shrinkage eliminates the problem of thermal expansion, thus eliminating the issue of pressure in annuli.

To develop TAPSS, Los Alamos scientists worked with scientists from Chevron Energy Technology Company, Baker Hughes Incorporated, and Lucite International Ltd.

Preparing TAPSS for Drilling

TAPSS uses methyl methacrylate, the same commodity monomer (a molecule capable of combining with other molecules to form a polymer) that makes the plastic used in latex paint, hot tubs, taillights, and giant aquariums. When emulsified into a water-based drilling fluid and placed into the appropriate annulus of an oil well, the microscopic monomer droplets polymerize into solid microscopic particles. This process reduces the volume of the methyl methacrylate droplets by 20%. When a drilling engineer determines the pressure requirements of a particular annulus, it is possible to calculate the amount of methyl methacrylate needed for the appropriate amount of shrinkage to compensate for any potential pressure problem.

TAPSS is mixed offsite and transported by an offshore supply vessel in large tanks. On the deepwater oil rig, crews will pump TAPSS from the tanks as a spacer into each annulus of the casing string that is being treated.

First the spacer is thoroughly mixed with an initiator; the completed mixture is passed to a high-pressure pumping unit, and the fluid is pumped so that it is placed in the desired part of the annulus when the cement portion of the process is complete.

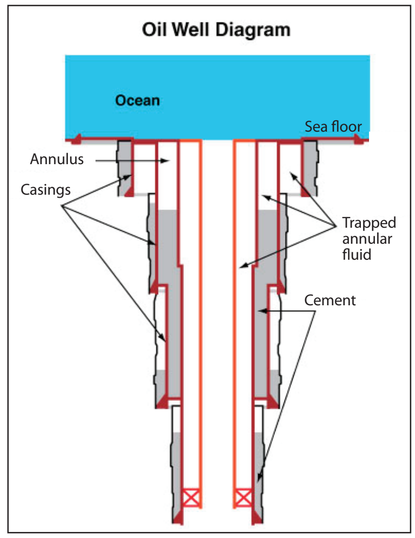
When exposed to heat inside the annuli, deep in the well, the initiator triggers the TAPSS monomer's polymerization—and shrinking—process. The spacer is formulated with enough methyl methacrylate to ensure adequate shrinkage to offset the thermal expansion of all the fluid in the annuli.

Then, when the desired quantity of water-based TAPSS has been pumped, crews clear the line to the rig floor with water and close the valves on the manifold, thus isolating the high-pressure TAPSS pump skid. Crews then pump the cement down the drill pipe to seal the annulus and set the casing.

Revolutionizing the Oil Industry

Although seemingly simple, TAPSS stands to revolutionize the way worldwide oil industry drills and completes deepwater oil wells. By using TAPSS, oil companies might avoid pressure-caused oil spills, thus saving them the time and effort of repairing or shutting down such wells. Moreover, companies will avoid lost revenue as a result of unproductive wells.

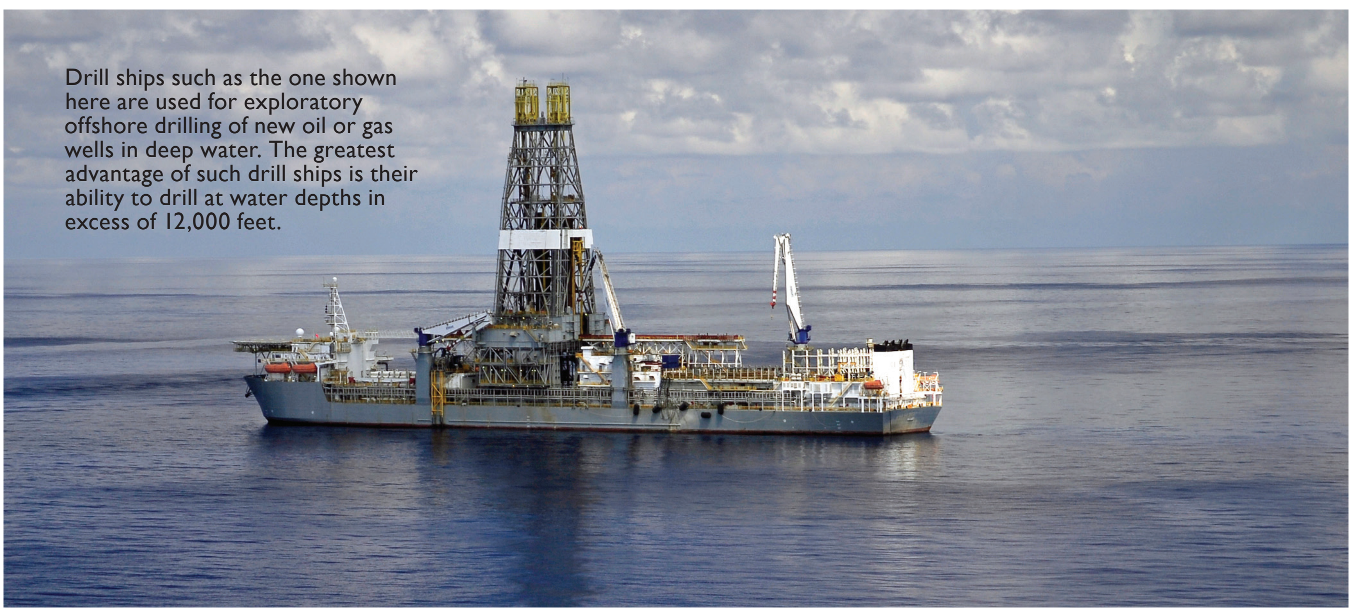
TAPSS can also help eliminate the disastrous environmental consequences related to oil spills. Such spills cause both immediate and long-term environmental damage—some damage can last for decades after an oil spill. Oil spills damage beaches, marshlands, and fragile marine ecosystems. Spills destroy plants and kill marine life, birds, and even mammals. Moreover, the oil contaminates many fish and smaller organisms that are essential to the global food chain.



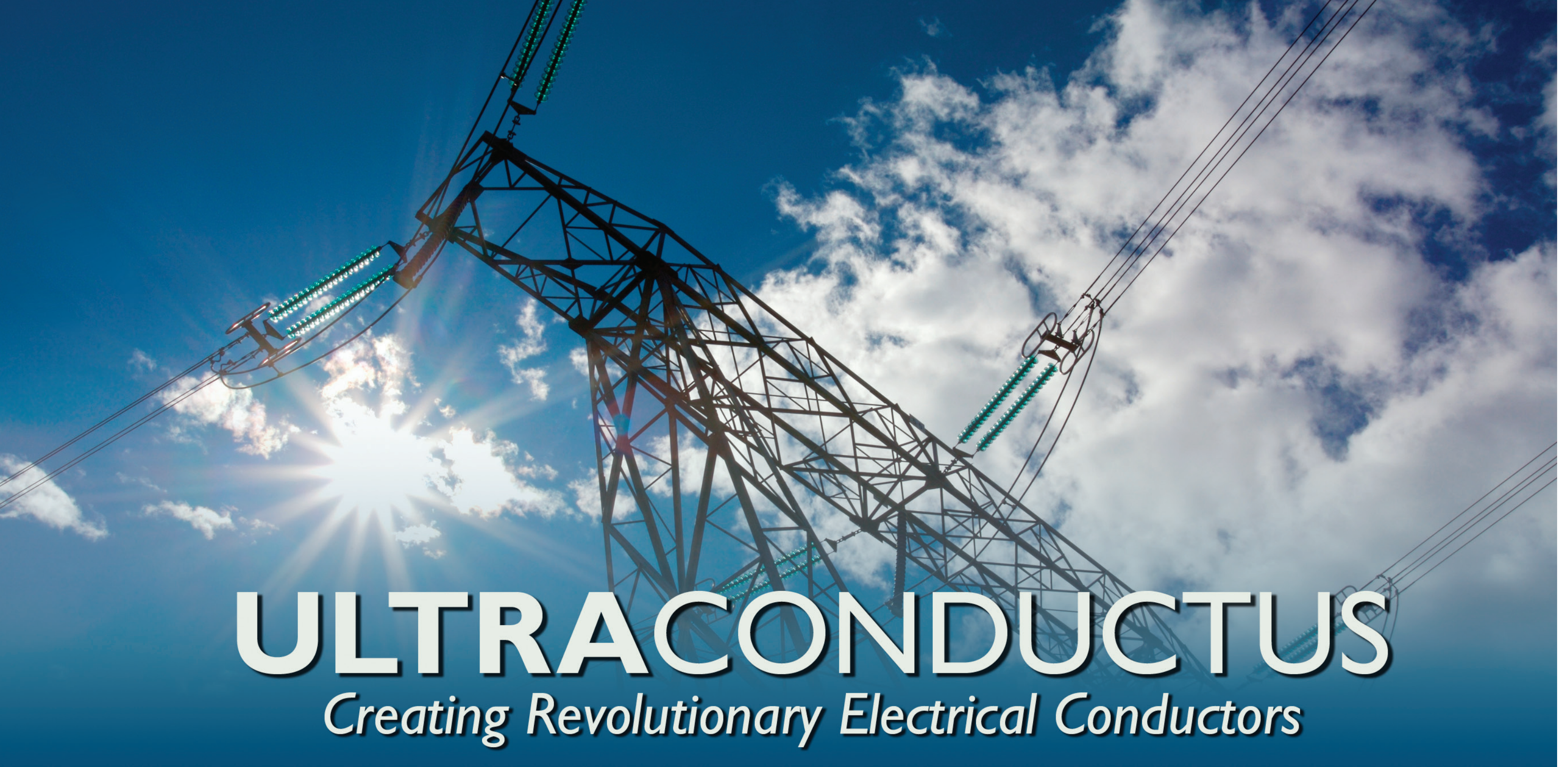
By making deepwater oil wells safer and less likely to produce an oil spill, TAPSS may serve as a catalyst in ultimately reducing the United States' dependence on foreign oil because it will be much safer to drill for oil off America's own shores.

As the world's reliance on oil as an energy source continues to grow, it is our responsibility to develop technologies that keep the oil-drilling process as safe and profitable as ever. With TAPSS, companies such as Chevron will be able to drill deepwater locations safely and cost effectively without having to worry about thermal expansion, which to this day has been the bane of the world oil-drilling industry because of its potential to cause casing failure that leads to catastrophic oil spills.

–Robert E. Hermes and Octavio Ramos Jr.



Drill ships such as the one shown here are used for exploratory offshore drilling of new oil or gas wells in deep water. The greatest advantage of such drill ships is their ability to drill at water depths in excess of 12,000 feet.



ULTRACONDUCTUS

Creating Revolutionary Electrical Conductors

If technology were music, then electricity would be one of its greatest symphonies. From 1950 to 2008, annual worldwide electrical power production and consumption increased more than 14-fold, from slightly less than 1,000 billion kilowatt-hours to 14,028 billion kilowatt-hours.

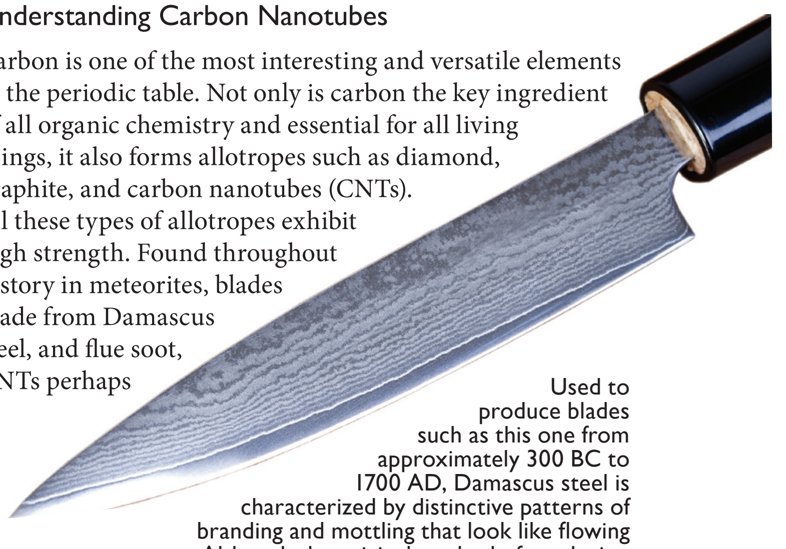
The world relies on conductors made primarily of copper and aluminum for transmitting and carrying electrical power, fabricating motors and generators, and myriad other applications. Such conductors, because they have nonzero (small but not exactly zero) electrical resistance, dissipate or lose a small portion of the power they transport. As global energy consumption increases, power transmission and subsequently losses increase, costing consumers more and more money each year.

What type of material would be ideal as an electrical conductor? The obvious answer is something with zero electrical resistance—a superconductor. But superconductors are not without limitations, in particular, their need for cryogenic operating temperatures and quench effects related to magnetic field and current capacity. What if there were a material that had electrical conductivity better than that of common metals and approaching that of superconductors, but without their operating constraints? On a normalized cost basis, it would be more cost effective to use this new type of material than to use either metals or superconductors. It also would have a tensile strength greater than steel or graphite fibers yet be easily formed and cost much less than superconducting materials. It would not be subject to current density, magnetic field, or temperature quench. Sounds like science fiction? It was—until recently.

James Maxwell and his team at Los Alamos National Laboratory have developed a process known as Ultraconductus, which produces these revolutionary electrical conductors. These new types of conductors can be easily formed into required shapes, such as wires or cables, allowing for greatly enhanced conductivity over existing metallic conductors. But perhaps most important, these "ultraconductors" are more cost effective than copper-alloy conductors and simultaneously minimize the use of expensive or rare materials.

Understanding Carbon Nanotubes

Carbon is one of the most interesting and versatile elements in the periodic table. Not only is carbon the key ingredient of all organic chemistry and essential for all living things, it also forms allotropes such as diamond, graphite, and carbon nanotubes (CNTs). All these types of allotropes exhibit high strength. Found throughout history in meteorites, blades made from Damascus steel, and flue soot, CNTs perhaps



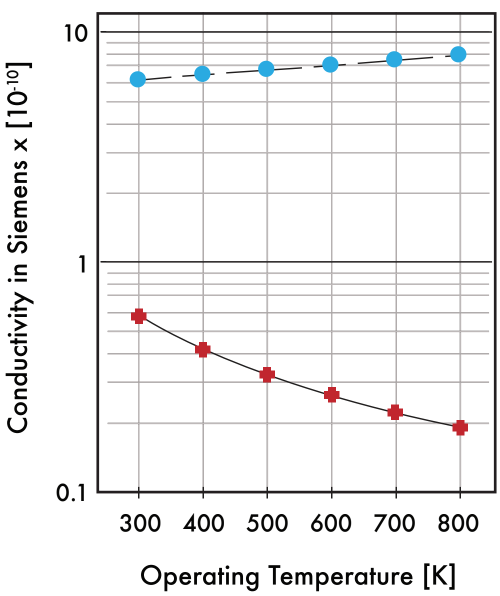
Used to produce blades such as this one from approximately 300 BC to 1700 AD, Damascus steel is characterized by distinctive patterns of branding and mottling that look like flowing water. Although the original method of producing Damascus steel is not known, *National Geographic* and others have reported that nanowires and carbon nanotubes played a role in the making of such steel.

were the first form of carbon on a growing Earth three to five billion years ago.

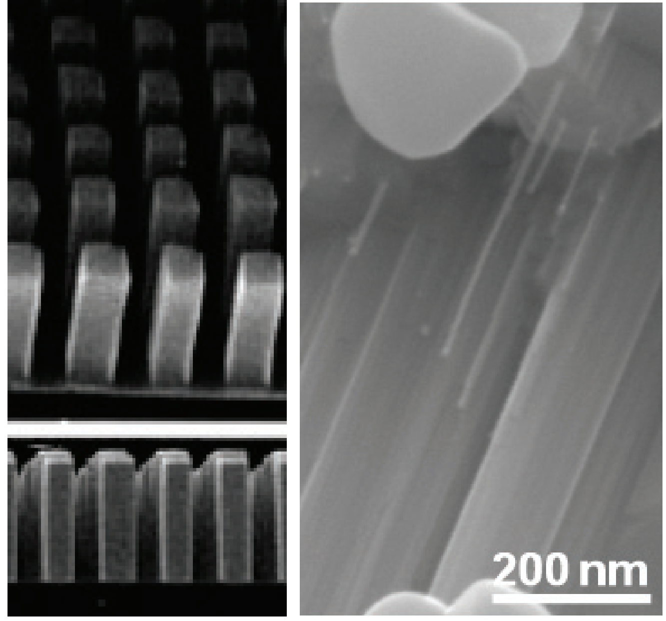
CNTs consist of cylindrical sheets of graphene (another carbon allotrope) or extended hexagonal arrays of sp2-hybridized carbon with a conjugated π-system. A CNT's side walls are arranged in a helical fashion around the tube axis and are considered single-dimensional objects because of their small outer diameters (in the nanometer range) and high length-to-width aspect ratio, which is typically greater than 100.

Because carbon-carbon covalent bonds are among the strongest in nature, it follows that structures based on such bonds form very strong materials. In theoretical and experimental studies, scientists have discovered that CNTs with a tensile strength that ranges from 100 to 600 GPa are approximately two orders of magnitude stronger than high-strength carbon fibers. Moreover, a CNT's density of 1.3 g/cm_3 is lower than that of commercial carbon fibers (1.8–1.9 g/cm_3). The significant reduction of density and volume brought about by replacing carbon fibers with CNTs has important implications in aerospace and other high-performance composite applications. CNTs also have a high stiffness-to-weight ratio, with a Young's modulus of 1,000+ GPa, which is higher than that of carbon fibers.

CNTs also possess beneficial electrical properties. For example, a nanotube's chirality (i.e., twist) determines whether a CNT functions as a metal or a semiconductor. Metallic CNTs have ballistic transport (i.e., zero resistance along the tube), which means that they can produce conductivities 1,200 times greater than that of copper.



This graph plots the temperature-dependent electrical conductivity of Ultraconductus (blue circles) vs. copper (red crosses) over a useful operating range; 300 Kelvin is room temperature.



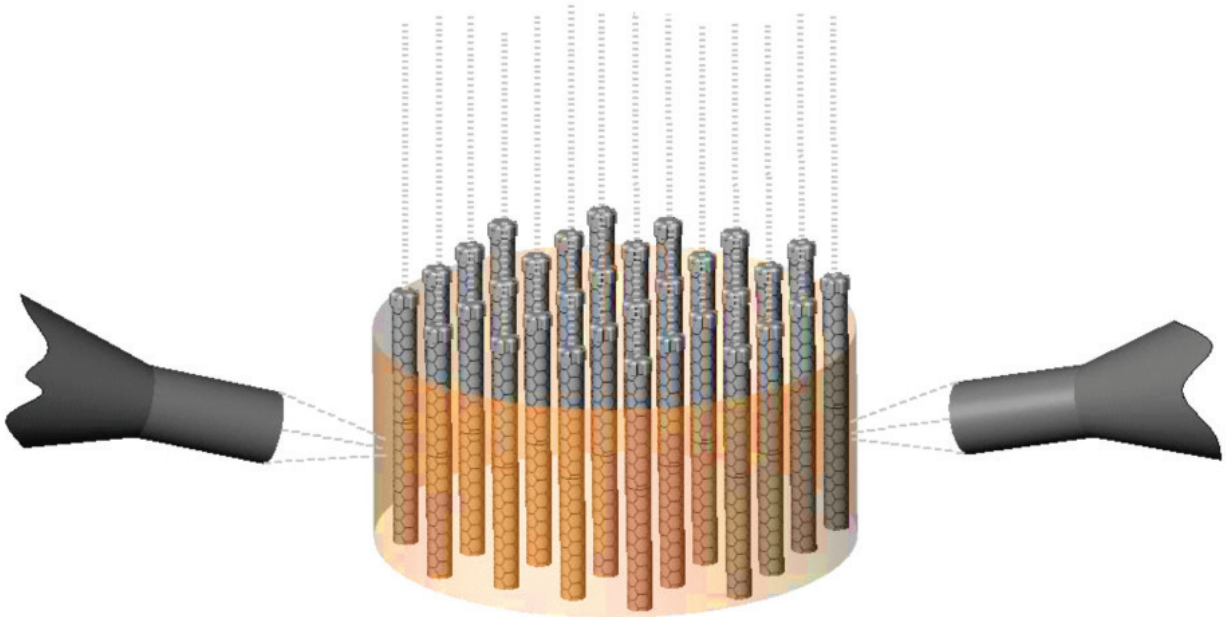
Left: Growth of aligned CNTs along the length of a wire using Ultraconductus. Observe the catalyst nanoparticles at the tips of the individual CNTs. The aligned nanotubes are subsequently coated with proprietary matrix metals. Right: Bundles of vertically aligned nanotubes grown selectively from a substrate that uses catalytic nanoparticles. Each "pixel" (i.e., column) contains roughly 370 million nanotubes in a cross-sectional area of only 25 x 25 microns—less than half the diameter of a human hair.

By replacing just one-half of present-day power transmission systems with Ultraconductus-produced cables and devices, the United States alone could achieve annual energy savings of approximately 150 billion kilowatt-hours of energy and an associated $15 billion in cost savings.

A metallic CNT wire's conductance does not depend on its length. Unlike traditional metal wires, in which electrical conductance is inversely proportional to the wire length (i.e., $G = A/pL$), the quantum conductivity of carbon nanotubes is $G = 2e2/h$, where e is the fundamental charge of an electron and h is Planck's constant. We call these "quantum" conductors. Note that there is no length specified in the CNT conductance equation. In such cases, there are only two states: either the metallic CNT conducts this value of current, or charge, or it conducts nothing. Hence, a CNT can act as an ideal conduit for electrical current.

Ultraconductus Process

The Ultraconductus process can grow very long metallic CNTs (100s of mm to 10s of cm) while simultaneously cladding them within a metal matrix. Embedding CNTs in a metal matrix facilitates current flow between tubes along with ballistic transport from end to end, thereby increasing the net electrical conductivity of the metal matrix. This "nanocomposite" material accretes the benefits of both the CNTs and the added metal, providing both increased conductivity and structural strength over that of the metal conductor by itself. A conductor produced using the Ultraconductus process possesses an increase in



This figure shows the fabrication method for Ultraconductus cabling. The aligned carbon nanotubes are approximately 10 nm in diameter. The tubes are embedded in a metal cladding, thus ensuring conduction horizontally between tubes. There is very little resistance along their length (i.e., they are ballistic or quantum conductors).

conductivity by a factor of 10 to 100. The improvement is even greater with increasing temperature.

The difficulties with using CNTs to make an ultraconductor are fourfold: (1) there must be a route through which electrons can enter and leave the nanotube's conductive path, (2) there must be a means for electrical conduction from nanotube to nanotube within the bundle, (3) it must be possible to make long and continuous nanotubes, and (4) sufficiently high percentages of metallic nanotubes must be created.

The Ultraconductus process resolves all four issues. Like everything else in the universe, nanotubes possess defects. These defects/impurities can serve as routes through which electrons can enter and leave a nanotube's conductive path. A common defect in carbon nanotubes is a "diode" in which structures in a pair exist side by side, one with a five-member ring (the "n" material) and the other with a seven-member ring (the "p" material).

During synthesis, these diodes can be created by mismatches and damage to the lattice. Moreover, impurities and missing atoms from the lattice also provide routes of entry to and egress from the quantum conductor. CNTs are also somewhat unique in that they can be readily doped with boron and nitrogen, thus providing stable n- and p-type diode materials for entry and egress. Maxwell and his team create conductive paths in and out of the CNTs, as well as paths between the nanotubes, by appropriately doping the CNTs, coating them lightly with proprietary metals, and then embedding them in a metallic matrix.

To fabricate long conductive nanotubes in a matrix, Ultraconductus employs laser-induced chemical reactions and selective chemistry to first form nanotubes and then physically and chemically infiltrate a metal matrix between the tubes. The Ultraconductus process begins when a primary set of laser beams is focused on a pressurized chamber containing a retractable mandrel coated with catalytic nanoparticles. Hydrogen and an appropriate hydrocarbon then flow through a nozzle onto the laser foci, where vertically aligned carbon nanotubes are grown into the laser beams. If the beams remain stationary, CNTs will grow into their respective beams along the laser axis. When the focused laser spots are drawn backward, the CNTs follow, thus yielding long strands of newly grown material. In each laser focus, there are many millions of CNT strands.

Once the strands reach critical length, a second set of laser beams is focused near the lower end of the bundles while simultaneously flowing trace quantities of metallic precursor gases across these laser foci. A chemical reaction occurs at this second set of foci, resulting in the formation of a metal matrix between the nanotube strands. This two-step process then continues onward, as the newly formed nanocomposite wires are drawn backward and spooled outside the chamber through a vapor trap.

Because of their very low energy dissipation, CNTs can carry approximately 10,000 times greater current densities than superconducting wires.

Applications for Ultraconductus Products

Ultraconductus represents a leap forward in technology comparable to Thomas Edison's first economically viable system of central generation and distribution of electric light, heat, and power. The revolutionary Ultraconductus manufacturing technology easily produces wires and cables that have greater conductivity than any other metal alloy, possess 10 times the tensile strength and up to 100 times the conductivity of copper, operate at both room temperature and high-temperature environments, do not require cooling, and are not subject to current density and magnetic field or temperature quench. Additionally, the normalized cost of Ultraconductus cables, expressed in terms of dollars per meter for 100-ampere capacity, is at least four times less expensive than copper and at least 25–30 times less expensive than high-temperature superconductors.

This technology has a wide range of applications, for example, high-voltage cables used to transmit power to homes and businesses around the world, motors and generators that power everything from simple electronics to complex manufacturing systems, electrical wires used in everything from simple electronic devices such as cell and specialized phones and televisions, and specialized applications in which the tensile strength of copper or aluminum is insufficient.

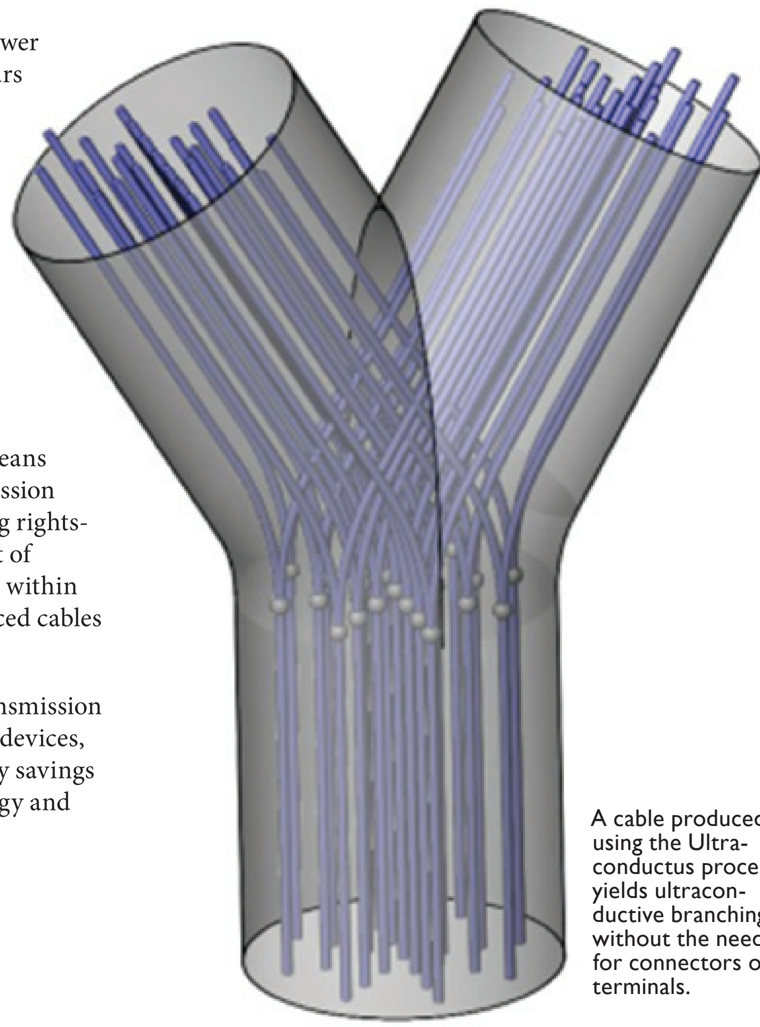
One of the limiting factors of high-voltage, high-power transmission lines, for example, is the sag that occurs under heavy load and high ambient temperatures. Under these conditions, overheated lines can sag to restrictively low levels requiring taller towers, additional conductors, or reduced power transmission. Tower heights and load currents need to be sized to prevent the lines from sagging too low and endangering people or equipment. An improved solution for this case is one from the company 3M, which sells a product called ACCR aluminum matrix cable, which is designed to carry more power—that is, more current (I2R loss) with minimal sagging. These cables are marketed as a means to upgrade the power capability of existing transmission lines without replacing towers or impacting existing rights-of-way. Their conductivity remains the same as that of aluminum, so they can be run hotter while sagging within acceptable limits. Note that Ultraconductus-produced cables completely eliminate all these problems.

By replacing just one-half of present-day power transmission systems with Ultraconductus-produced cables and devices, the United States alone could achieve annual energy savings of approximately 150 billion kilowatt-hours of energy and an associated $15 billion in cost savings.

As technology in specialized areas continues to mature, products created using Ultraconductus will play a pivotal role in their implementation. For example, Ultraconductus can be used to fabricate nano and/or micro tubes designed as conductors or insulators. Such devices could be used for biological sensors in which critical elements include scale (the smaller the better) and the ability to select various molecules. Other possible applications include microscale tubes and heaters that can be placed on tumors to heat and destroy them and nano- and micro-fibers designed to purify water and gas.

As the world continues to face ever-increasing power demands, Ultraconductus will play a pivotal role in solving constraints associated with energy generation and consumption.

–James L. Maxwell, Chris R. Rose, and Octavio Ramos Jr.



A cable produced using the Ultraconductus process yields ultraconductive branching without the need for connectors or terminals.

It's an ENVIRONMENTAL Th-ING

THORIUM IS NOW GREEN

Imagine an element that when used in a nuclear reactor is so safe that it may never lead to the possibility of the type of catastrophic meltdown that threatened the reactors in Japan. Picture one ton of such an element producing as much energy as 200 tons of uranium or 3,500,000 tons of coal. Imagine an element that right now is trapped in 3,200 metric tons of nuclear waste waiting for final disposition at the Nevada National Security Site.

The element is thorium, a silvery-white metal that is slightly radioactive. It was named after the Norse god Thor by Jöns Jakob Berzelius, who discovered the element in 1828. During the last decade, thorium has been labeled the "green nuke" because, unlike other actinides such as uranium and plutonium, it cannot be easily used in nuclear weapons and, if used in nuclear reactors, is so safe that it would never be the cause of a nuclear meltdown.

In nature, thorium (such as the sample shown here) is found as thorium-232. Countries such as Russia, India, and China have plans to use thorium for their nuclear reactors, partly because of its safety benefits.

Anhydrous halide complexes are key starting materials for synthesizing transition metal, lanthanide, and actinide compounds. However, preparing thorium halides—the key to unlocking thorium's potential—has proved expensive and has been further complicated by environmentally harmful processes that involve tricky reactions that require harsh, unsafe reaction conditions. For example, one process costs as much as $5,000 per kilogram to yield thorium compounds and materials, whereas another process requires high temperatures and hazardous chemicals for its production yields.

To resolve these complicated matters, Jaqueline L. Kiplinger and her team at Los Alamos National Laboratory have developed a novel method known as Th-ING (Thorium Is Now Green), which circumvents the hazards and cost issues of conventional methods to produce a new thorium chloride reagent, $ThCl_4(DME)_2$. This cost-effective, safe, "green," and scalable method will revolutionize the use of thorium in nonaqueous thorium chemistry and materials science. This method also stands to play a crucial role in creating one of the world's future sustainable energy sources.

Producing a New Thorium Chloride Reagent

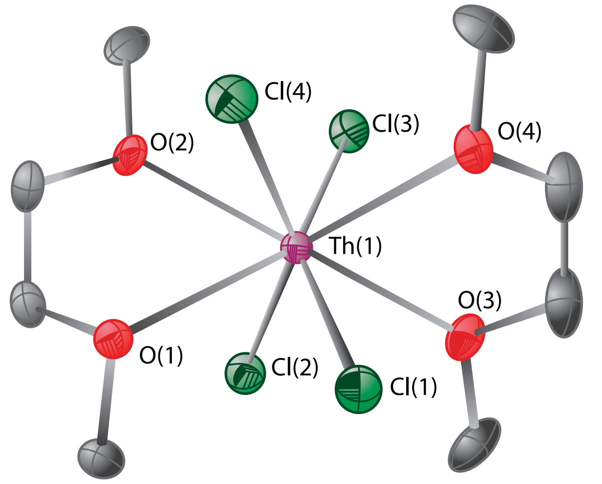
The principal building block of this new method is thorium nitrate, $Th(NO_3)_4(H_2O)_5$, which serves as the starting material. Los Alamos scientists react thorium nitrate with aqueous hydrochloric acid under mild conditions. The reaction produces $ThCl_4(H_2O)_4$ in quantitative yield. Scientists then use a novel combination of anhydrous hydrochloric acid and trimethylsilyl chloride (Me_3SiCl) to remove the coordinated water molecules and replace them with dimethoxyethane (DME) to make the thorium chloride reagent, $ThCl_4(DME)_2$.

$ThCl_4(DME)_2$ is an excellent synthetic precursor to a wide range of thorium(IV) compounds containing Th-O, Th-N, Th-C and Th-X (X = F, Cl, Br, I) bonds. Overall, the reaction chemistry with $ThCl_4(DME)_2$ can be performed at multigram scales and is high yielding (>88%).

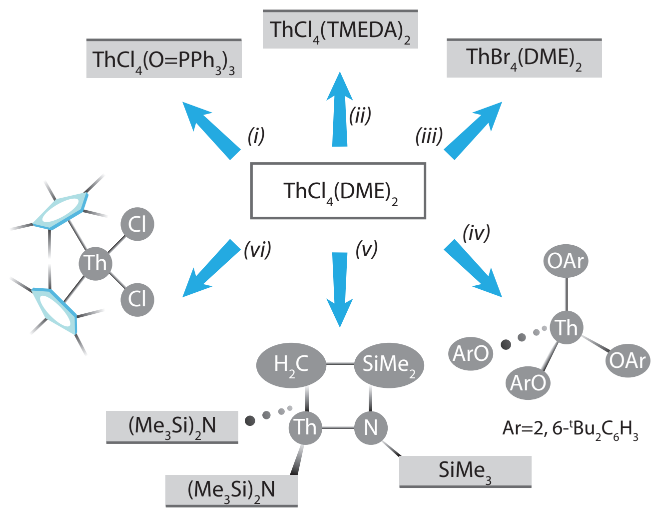
Mild and Safe Manufacturing Conditions

Conventional methods used to manufacture $ThCl_4$ require the use of hazardous gases, such as sulfur chloride, chlorine, phosgene, and carbon tetrachloride. Such processes also require expensive custom equipment, such as tube furnaces, and operational temperatures greater than 450°C.

Manufacturing $ThBr_4(THF)_4$ requires the use of bromine, which is volatile, corrosive, and toxic. Thorium metal is pyrophoric (spontaneously ignites) and must be cleaned with nitric acid before use. Moreover, the reaction temperature must be maintained at 0°C or polymerization of the tetrahydrofuran solvent will take place.



This graphic shows the molecular structure of $ThCl_4(DME)_2$ with thermal ellipsoids projected at the 50% probability level. Hydrogen atoms have been omitted for clarity. The thorium(IV) metal center features a distorted dodecahedron geometry. The average Th–Cl bond distance of 2.690 Å compares well to those presented by other reported thorium(IV) tetrachloride complexes [e.g., $ThCl_4(O{=}PPh_3)_3$, $Th{-}Cl_{(ave)}$ = 2.736 Å; $ThCl_4(TMEDA)_2$, $Th{-}Cl_{(ave)}$ = 2.689 Å], and the average Th–O bond length of 2.596 Å is consistent with those measured in $ThBr_4(DME)_2$ ($Th{-}O_{(ave)}$ = 2.588 Å).



$ThCl_4(DME)_2$ is an excellent synthetic precursor to a wide range of thorium(IV) complexes containing Th-O, Th-N, Th-C and Th-X (X = F, Cl, Br, I) bonds: (i) 3 equivalent $Ph_3P{=}O$, THF, 100% yield; (ii) excess TMEDA, THF, 100% yield; (iii) excess Me_3SiBr, toluene, 24 h, 100% yield; (iv) 4 equivalent KOAr(Ar = 2,6-${}_tBu_2C_6H_3$), THF, 99% yield; (v) 4 equivalent $Na[N(SiMe_3)_2]$, toluene, reflux, 12 h, 93% yield; (vi) 2 equivalent $(C_5Me_5)MgCl(THF)$, toluene, reflux, 24 h, 88% yield.

Th-ING uses hydrochloric acid to convert thorium nitrate, $Th(NO_3)_4(H_2O)_5$, to $ThCl_4(H_2O)_4$, which is converted to the new thorium chloride reagent. The reaction conditions are comparatively mild (temperature of 100°C) and can be performed using conventional glassware in a traditional laboratory. The reaction does produce some NO_x, but a ventilation hood keeps the process safe. Subsequent drying with trimethylsilyl chloride is also done using the mild temperature of 50°C. Moreover, thorium nitrate is not pyrophoric.

It's an Environmental Th-ING

Synthesizing $ThBr_4(THF)_4$ also requires thorium metal, an expensive material available only at a small number of institutions. Thorium metal is not readily produced. For example, it is possible to obtain the metal by reducing thorium oxide with calcium metal or by reducing thorium tetrachloride with calcium or magnesium metal at high temperatures (~1,000°C) under an atmosphere of argon. Each of these processes requires subsequent separations and produces mixed (radioactive/hazardous) waste. The actual $ThBr_4(THF)_4$ synthesis also tends to be wasteful (maximum 60% production yield) and is usually low yielding because of the formation of unwanted byproducts caused by the ring-opening/polymerization of the solvent THF. Additionally, the $ThBr_4(THF)_4$ complex is thermally sensitive and decomposes at room temperature.

Synthesizing $ThCl_4$ requires dangerous and environmentally harmful protocols that involve reacting thorium dioxide with hazardous sulfur chloride, chlorine, phosgene, or carbon tetrachloride vapors at elevated temperatures (450°C–1,000°C) for several days. Although these reactions produce highly pure $ThCl_4$, they tend to give poor yields (maximum ~80% production yield) because the product $ThCl_4$ must be sublimed from unreacted ThO_2. The hazardous gases are used in excess and released into a hood and ultimately the atmosphere.

In contrast to the synthesis of $ThCl_4$ and $ThBr_4(THF)_4$, which are incomplete reactions resulting in thorium waste, Th-ING is superior in that the synthesis is quantitative (95% production yield). The consistent high yields provided by the Los Alamos process translate into less mixed (radioactive/hazardous) waste compared with the syntheses of $ThCl_4$ and $ThBr_4(THF)_4$. Unlike the synthesis of $ThCl_4$, Th-ING does not release hazardous gases into the atmosphere. Finally, Th-ING avoids the wasteful solvent ring-opening/polymerization that frequently occurs when preparing $ThBr_4(THF)_4$.

Taking Advantage of 3,200 Metric Tons of Waste

From 1957 to 1964, the Department of Energy's predecessor agency, the Atomic Energy Commission, acquired more than seven million pounds of thorium nitrate in more than 21,000 drums. In 2004, some 20,000 drums (3,200 metric tons) of thorium nitrate from the Defense Logistics Agency/Defense National Stockpile Center (DLA/DNSC) Depots in Maryland and Indiana were transferred to the Nevada National Security Site for disposal. The price tag for such disposal was estimated at more than $60 million, putting the effort on hold and leaving the waste in storage since that time.

Nuclear power plants produce electricity by using nuclear fission to heat water and produce steam. Current power plants use uranium and plutonium. However, thorium is a much safer alternative, as the metal can avoid nuclear meltdowns. Moreover, thorium cannot be used in nuclear weapons, making it an ideal alternative when it comes to addressing issues related to the proliferation of materials used in nuclear weapons.

Los Alamos' Th-ING process could use this waste as the starting material for producing the thorium chloride reagent. Not only would Th-ING provide a nondestructive path forward for this "waste," it would resolve a $60 million issue that has to this day been difficult to overcome.

The Thorium Fuel Cycle and Other Uses

Using the $ThCl_4(DME)_2$ reagent, it will be possible to develop a safe and secure thorium fuel cycle, which in turn could lead to a sustainable energy future. In theory, thorium is a superior nuclear fuel, one that has several important advantages over uranium for the following reasons:

- ✦ Thorium-powered nuclear reactors are more efficient and produce less than one percent of the waste of today's uranium nuclear reactors.
- ✦ Thorium reactors are safer (never the cause of a meltdown), less expensive, and smaller; they can be configured to eliminate the possibility of meltdown or other types of accidents.
- ✦ Fission of thorium does not produce much plutonium, and thus its use could effectively eliminate further weapons production in volatile regions without sacrificing energy production. The use of thorium could also help reduce the proliferation of nuclear weapons at a global scale.

Approximately 20,000 drums (3,200 metric tons) of thorium nitrate await disposal. However, such waste is ideal as a starting material for producing the $ThCl_4(DME)_2$ reagent that in turn would lead to the use of such stockpiled nuclear waste as fuel for thorium-based nuclear reactors.

According to the World Nuclear Association, as of January 2011, there were approximately 440 nuclear power plants in operation globally, with 60 more under construction. There are also 320 new nuclear plants either planned or proposed around the world, with approximately one-fifth of those plants commissioned for construction within the next seven years.

Thorium and thorium compounds have numerous applications, including aircraft engines and spacecraft, to heat-resistant ceramics, high-quality lenses for cameras and scientific instruments, and mantles for natural gas lamps, oil lamps, and camping lights. Th-ING will enable, for the first time, easy and safe access to thorium chemistry and materials research. Of particular importance is the fact that the Los Alamos Th-ING process can be performed on a large scale, which is necessary for industrial production. Possible new applications of thorium(IV) include (1) developing routes to thorium-nitride/carbide/oxide/fluoride fuels and (2) enabling sol-gel science for nuclear materials storage, processing, and fuel. Los Alamos' homogeneous thorium complex will also be invaluable for grafting thorium onto solid supports for industrial or large-scale applications.

Cost-effective, safer, and environmentally friendly, Th-ING stands to revolutionize thorium chemistry and materials science, address the elimination of waste that has been in storage since 1957, and play a crucial role in creating one of the world's future sustainable energy sources. With Th-ING, the future for thorium is now as bright as the metal's own luster. ✦

–Jaqueline L. Kiplinger and Octavio Ramos Jr.

DETERRENT CAPABILITIES IN THE 21st CENTURY

MARK DOMZALSKI

U.S. policymakers generate the words and prose that our government officials sign, creating declarative policy. It is a community that Los Alamos National Laboratory works in every day, in different ways. At the Laboratory, policy analysis efforts are often translated into commentary at the request of federal officials, and sometimes proffered back to a broader community in the form of discussion or white papers. Some Laboratory staff members are asked to take external assignments, to provide technical support and subject matter expertise to NNSA and other federal departments and agencies. In the external assignments, Laboratory personnel provide essential information, in the form of facts, data, experience, and expert opinion, allowing senior officials to understand opportunities and risks as policy is crafted.

Late in 2006, the Director for the National Security Office asked me to consider taking an Interagency Personnel Act assignment to the Office of the Secretary of Defense (OSD) for Policy, in Strike Policy and Integration.

Some folks may be wondering about the difference between Policy and Nuclear Matters; allow me to explain. The basic difference is that Policy determines what must be done and Nuclear Matters under its parent, Acquisition, Technology and Logistics, determines how to provide the tools to support the policies. So very simply, Policy is the "what" and Nuclear Matters is the "how."

My assignment to Policy was an education and a memorable experience. I was thrown into action immediately upon arrival at the Pentagon. The previous administration, while largely silent on the issue of nuclear weapons, other than regarding the Moscow treaty, was actively working to set the stage for the next Nuclear Posture Review (NPR). In the face of Congressional disinterest and spotty funding for anything related to modernization of the U.S. nuclear weapons stockpile, I was tasked to produce a statement to be signed by the secretaries of state, defense, and energy attesting to the continued need for nuclear deterrence and the need to modernize the nuclear weapons stockpile and infrastructure. The three-page statement, transmitted to Congress in 2007, was followed in late 2008 by a white paper, in both classified and unclassified versions. As a reference for both previous and current administration officials, that previous body of work was the foundation for the 2010 NPR.

Along with working on high-level Policy statements and papers, providing Nuclear Weapons Council read-ahead packages for the Under Secretary of Defense for Policy and the Deputy Assistant Secretary of Defense for Nuclear and Missile Defense Policy were my ongoing tasks, in addition to attending weekly Action Officer meetings and staffing Policy coordination or Policy decisions to the Under Secretary or the Secretary of Defense.

While leading a seemingly dry and bureaucratic existence, I was fortunate to have the privilege and responsibility of representing Policy and the U.S. government when we engaged our NATO allies to seek their input for B61 Life Extension Program operational requirements. Since the United States had never before asked for requirements input from NATO allies, new ground was broken, and the positive results from the interactions may have helped some of our allies strengthen their resolve against the anti-nuclear "remove the U.S. weapons from Europe" rhetoric and press. As I worked through the B61 meetings and travel, I was also asked to represent OSD Policy at the NATO School in Oberammergau, Germany, to provide insight for NATO Policy courses and training exercises.

Was it worth it? Absolutely. Was my experience a challenge? Absolutely. Would I do it again if asked? Absolutely. The opportunity to provide critical support to senior governmental officials, through experience and drawing on the collective resources at Los Alamos, has been a broadening, humbling, and proud experience.

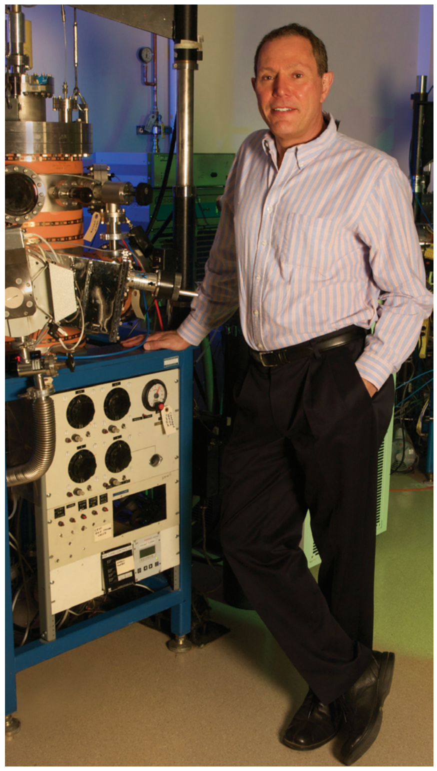
Nastasi Named Materials Research Society Fellow

Michael Nastasi of Los Alamos National Laboratory's Center for Integrated Nanotechnologies has been selected as a 2011 Materials Research Society (MRS) Fellow. The Fellows are outstanding MRS members whose sustained and distinguished contributions to the advancement of materials research are internationally recognized. Each year, no more than 0.2 percent of the current membership of the society is elected to the status of Fellow.

Nastasi's award citation reads, "For seminal contributions to the field of ion-solid interactions and radiation effects, including synthesis of novel materials using energetic ions, with applications to energy, manufacturing, nanotechnology, and advanced microelectronics."

Nastasi's research includes irradiation effects in nanostructured materials, irradiation-induced phase transformations, ion-enhanced and plasma synthesis of materials, mechanical properties of metastable materials and nanoscale structures, and materials analysis using ion beam techniques.

Nastasi, who has a doctorate in materials science and engineering from Cornell University, is a Fellow of the American Physical Society and a Laboratory Fellow. He directs the Center for Materials at Irradiation and Mechanical Extremes (CMIME), a DOE Energy Frontier Research Center. Previously, Nastasi was the nanoelectronics and mechanics thrust leader at the Center for Integrated Nanotechnologies and the team leader of the nanoscience and ion-solid interaction team in the Structure/Property Relations Group.



Michael Nastasi

LANL Receives FLC Awards

Los Alamos National Laboratory received the Federal Laboratory Consortium (FLC) award in January from the National Nuclear Security Administration for superb technology transfer. The technologies recognized were the Adaptive Radio Technology (ART) for Satellite Communications and the Genie Pro software.

LANL's ART is a communications-system prototype. Used on miniature satellites, it can enable advanced functions such as imaging and video streaming. Genie Pro is an interactive tool that works with an analyst to gain highly accurate image output from hyperspectral satellite data, aerial imagery, standard color imagery, and various types of medical imagery. The software is able to distinguish between different features that share spectral characteristics. One application uses the software to identify cancer cells in histological images.

The FLC award honored LANL for its advancement in technology and successful commercialization. FLC is a nationwide network of federal laboratories that helps link the laboratories to the marketplace.

LANL Staff Honored by Department of Energy

The Field Intelligence Element (FIE) team from Los Alamos National Laboratory was honored by the Department of Energy's (DOE) Office of Intelligence and Counterintelligence Director Bruce Held. The team received the DOE's Exceptional Service Award in March for its role in providing important information to the nation's senior national security policymakers.

The award recognizes exceptional contributions to the U.S. Intelligence Community. The FIE's unique science and technology expertise has played an important role in providing critical information to the policymakers.

LANL Director Michael Anastasio said, "The unique science and technology expertise of our staff allows us to answer difficult questions for the intelligence community." According to William Rees, Jr., Director for Global Security, LANL has a long history of important contributions to national security. Rees offered his appreciation to LANL's devoted employees who impact the country's national security.

AD BUILDING STOOD AS WITNESS TO LAB HISTORY

The old Administration Building at TA-3 was torn down this year, slowly reduced to small piles of rubble and rebar. But the building will always stand at the center of Los Alamos National Laboratory's history.

Built in 1956 as an integrated administration and science laboratory building, the Administration Building eventually became the nerve center of the Laboratory, its reinforced concrete construction on the South Mesa site solidifying the Laboratory's transition away from the town site and its Manhattan Project wartime roots to its role as a permanent scientific institution.

The building's history spans the very history of nuclear weapons in this country, from the early Cold War and nuclear weapons research, design, and testing, to stockpile stewardship and research into increasingly diverse fields of national security science and technology.

Seven Laboratory directors (Norris Bradbury, Harold Agnew, Donald Kerr, Siegfried Hecker, John Browne, Peter Nanos, and Robert Kuckuck) led the Laboratory from its fourth floor offices, directing the Laboratory's administrative and scientific work and accomplishments over five decades. Interestingly, the building's lifespan also corresponds to the years the Lab was managed by the University of California.

"The significance of the building is the significance of the Laboratory," said Laboratory historian and archaeologist Ellen McGehee of Environmental Stewardship. "All the work of the Laboratory was directed from there. It represents all the history of that time."

The building encompasses a history so extensive, a recent two-volume historical report on it, "SM-43, Nerve Center of a National Laboratory," needs nearly 1,000 pages to tell its story. The report recaps not just the building's beginnings (its first design included a request for a barbershop) and its years of planning and construction (the design criterion was one of "spartan simplicity," its style "pragmatic utilitarianism") but also summarizes the 50 years of remarkable science that transpired around and through this Lab focal point.

Lab Director Norris Bradbury oversaw the building's construction and the moving in of 12 administrative organizations, five science divisions, including the Gadget, Mass, and Explosive (GMX) Division, and a library.

"Bradbury had a vision that the Laboratory was going to be permanent, and this building was a symbol of how to make it happen and how to build a modern Laboratory," McGehee said.

During the building's first years, scientists conducted major research in the building. In the most significant research, carried out in the building's basement, scientists achieved the world's first controlled thermonuclear plasma, using the device called the Perhapsatron (a device named in response to a skeptic who called it an "impossibilitron").

The auditorium, designed with help from United Artists Theater, played host to the weekly colloquia, perhaps the Lab's most treasured tradition, whose roots trace back to the Manhattan Project's weekly lectures.

The working scientific laboratories eventually moved elsewhere, the library moved to Oppenheimer Study Center in 1977, and some administrative functions moved to the new Otowi Building in 1982. In 2008, the utility and structural systems were declared unsafe, and the building was closed.

"It is reasonable to say that the SM-43 decommissioning and demolition is the highest-profile D&D to take place since the Lab moved out of the town site," said Randy Parks of the Lab's Infrastructure Planning Division.

Long-range site plans, fittingly, include a major line item facility of a scale similar to the Metropolis Building to support the Laboratory's mission.

–Caroline Spaeth

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May 6, 2011: LANL Principal Associate Director Charles McMillan and Director Michael Anastasio (left to right) peruse historical artifacts documenting the Laboratory's esteemed history. Items include Trinity detonation negatives, Fat Man drawings, Nobel Laureate signatures, and significant patents. Anastasio retires from LANL in June.

Issue 2 2011 LALP-11-015

National Security Science highlights ongoing work in the weapons programs at Los Alamos National Laboratory. Current and archived issues of *NSS* can be accessed on the Web at http://www.lanl.gov/orgs/padwp/. *NSS* is an unclassified publication funded by the Weapons Programs Directorate.

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Los Alamos NATIONAL LABORATORY EST. 1943