Printed on recycled paper.

University of California
Lawrence Livermore National Laboratory
Science & Technology Review
P.O. Box 808, L-664
Livermore, California 94551

April 1997

Science & Technology REVIEW

Lawrence Livermore National Laboratory

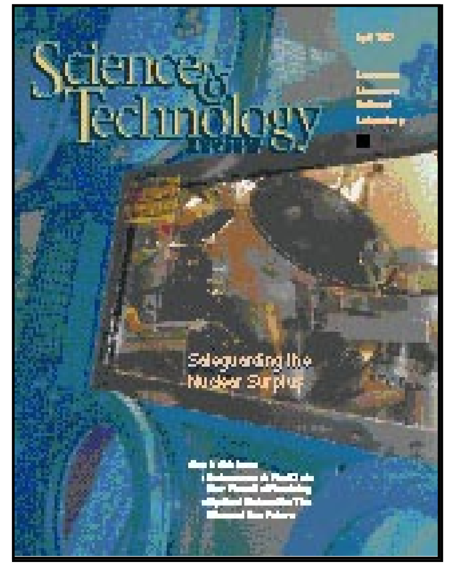
Safeguarding the Nuclear Surplus

Also in this issue:

- Volcanoes: A Peek into Our Planet's Plumbing
- Optical Networks: The Wave of the Future

About the Cover

Since the end of the Cold War, Lawrence Livermore scientists have been working with other DOE laboratories, stakeholder governments, and the National Science Foundation on the means for safeguarding the surplus of nuclear materials created by arms reduction. This month's cover features one result of the Laboratory's efforts to immobilize excess weapons plutonium. Pictured is a hydride/oxidation (HYDOX) furnace, which was designed, built, and tested at Livermore for eventual use at DOE's Savannah River Site. Its purpose is to convert weapons-grade plutonium to plutonium oxide, a necessary step before using the plutonium as reactor fuel or immobilizing it prior to permanent, long-term storage in a high-level-waste repository. For more information on Livermore's work on behalf of the U.S. Excess Fissile Materials Disposition Program, turn to p. 4.



What Do You Think?

We want to know what you think of our publication. Please use the enclosed survey form to give us your feedback.

Electronic Access

S&TR is available on the Internet at *http://www.llnl.gov/str*. As references become available on the Internet, they will be interactively linked to the footnote references at the end of each article. If you desire more detailed information about an article, click on any reference that is in color at the end of the article, and you will connect automatically with the reference.

About the Review

Lawrence Livermore National Laboratory is operated by the University of California for the Department of Energy. At Livermore, we focus science and technology on assuring our nation's security. We also apply that expertise to solve other important national problems in energy, bioscience, and the environment. *Science & Technology Review* is published ten times a year to communicate, to a broad audience, the Laboratory's scientific and technological accomplishments in fulfilling its primary missions. The publication's goal is to help readers understand these accomplishments and appreciate their value to the individual citizen, the nation, and the world.

Please address any correspondence (including name and address changes) to *S&TR*, Mail Stop L-664, Lawrence Livermore National Laboratory, P.O. Box 808, Livermore, California 94551, or telephone (510) 422-8961. Our electronic mail address is *hunter6@llnl.gov*.

Prepared by **LLNL** under contract
No. W-7405-Eng-48

S&TR Staff

Scientific Editor
Ravi Upadhye

Managing Editor
Sam Hunter

Publication Editor
Dean Wheatcraft

Writers
Arnie Heller, Katie Walter, and Gloria Wilt

Art Director
George Kitrinos

Designer
George Kitrinos

Internet Designer
Kathryn Tinsley

Compositor
Louisa Cardoza

Proofreader
Al Miguel

S&TR is a Director's Office publication, produced by the Technical Information Department, under the direction of the Office of Policy, Planning, and Special Studies.

Printed in the United States of America

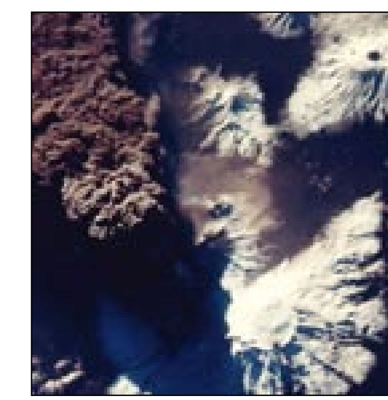
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

UCRL-52000-97-4
Distribution Category UC-700
April 1997

Science & Technology REVIEW

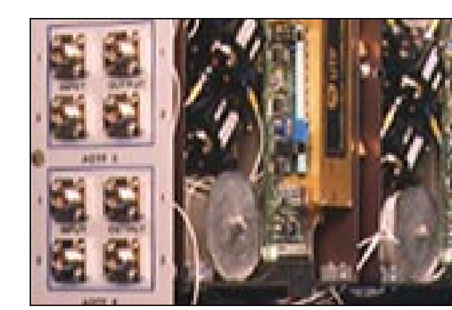
April 1997

Lawrence Livermore National Laboratory



Page 14

Page 4



Page 17

DOE gives go-ahead to NIF construction at Lab

DOE has approved the start of construction of the National Ignition Facility (NIF) at the Laboratory. The facility will house the world's largest laser, which will be able to create conditions similar to those at the center of the sun and other stars.

NIF will play a vital role in DOE's Science-Based Stockpile Stewardship and Management Program, the goal of which is to maintain the U.S. nuclear weapons stockpile without underground testing. Groundbreaking for the $1.2 billion, 192-beam, stadium-sized laser facility is anticipated in April.

Director Bruce Tarter said: "The National Ignition Facility will be a fundamental contribution to our technical understanding of aging nuclear weapons. The hundreds of men and women who have carried us to this point are now ready to begin converting this critical scientific effort into concrete, steel, and lasers."

Charles B. Curtis, acting Secretary of Energy, said that NIF "will help the United States meet the conditions of the Comprehensive Test Ban Treaty and reduce the global nuclear danger. The country will also benefit from cutting-edge science in astrophysics and fusion energy."

NIF will be designed, built, and operated by Lawrence Livermore, Los Alamos National Laboratory, Sandia National Laboratories, and the University of Rochester.

Funding to begin site preparation for NIF was included in the Fiscal Year 1997 congressional appropriation. Full construction funding is part of the Fiscal Year 1998 congressional budget request.

During the peak construction period (1998 to 2000), the NIF project will create about 6,000 jobs nationally and 3,000 locally. Operation of NIF will create almost 900 long-term jobs in the San Francisco Bay Area.

Contact: LLNL Media Relations (510) 422-4599 (garberson1@llnl.gov).

Desalination technology licensed to Arizona firm

Lawrence Livermore has entered into a licensing agreement with an Arizona water resource management company that wants to commercialize a promising Laboratory water purification and desalination technology called capacitive deionization (CDI).

The firm, Far West Group, says it initially wants to use the technology to provide simple water treatment to underdeveloped countries. Far West expects its first field demonstration to take place in Uzbekistan later this year.

In CDI, a solution is passed between closely spaced pairs of electrodes made of carbon aerogel, a material that has an enormous surface area. Ions such as sodium and chloride can be removed from the flow and held in an electric field on the surface of the aerogel. When the aerogel is saturated with contaminants, the voltage on the electrodes is reversed and the ions are dumped into a small waste stream.

Central to successful commercialization of CDI is reducing the cost of manufacturing aerogel. Currently aerogel costs are approximately $16 per square foot; mass production is expected to lower costs to less than $1 per square foot. Far West Group is addressing this challenge by licensing the carbon aerogel technology developed at Livermore to ensure a steady and low-cost supply of the material for its own needs.

Contact: Jennie De Pruneda (510) 422-1339 (hdepruneda1@llnl.gov).

Acoustic tools to evaluate heart valves nonsurgically

Lawrence Livermore is developing nonsurgical acoustic techniques to identify which implanted mechanical heart valves of one manufacturer are susceptible to failure. The Laboratory's new studies build upon nearly three years of research to find ways to detect, without surgery, "single-leg separations" of the Bjork–Shiley Convexo-Concave valves. The separations occur when one leg of the heart valve's outlet strut breaks free. When both legs break, the strut is said to fracture, a condition that causes the heart valve to lose control of blood flow to the heart, leading to death in about two of three cases.

As of November, 596 fractures of these Convexo-Concave heart valves had been reported. About 42,500 Convexo-Concave valves, marketed between 1979 and 1986, are estimated to be implanted in patients still living.

The aim of the studies is to use acoustic differences, not surgery, to identify which heart valves are normal and which have single-leg separations. If differences between the valves can be identified using acoustical screening techniques and if the U.S. Food and Drug Administration gives its approval to use the techniques, people with valves believed to have a single-leg separation could then have replacement surgery.

Contact: Graham Thomas (510) 422-7325 (thomas26@llnl.gov).

Shaping Nuclear Materials Policy

THE challenge of effectively tracking, managing, storing, and disposing of a mounting inventory of nuclear materials and wastes, both within the U.S. and abroad, has attracted increased attention during the past several years. With the end of the Cold War, many national experts agree that now is the right time, despite enormous technical and nontechnical challenges, to develop a systematic and rational framework for shaping policy regarding the use and management of nuclear materials.

On December 6, 1996, John A. Young, co-chairman of the President's Committee of Advisors on Science and Technology, wrote President Clinton urging him "to continue, strengthen, expand, and better coordinate these national and international efforts in the management, protection, and disposition of nuclear materials."

By law and federal policy, the Department of Energy is centrally involved in U.S. nuclear materials stewardship. The department's specific responsibilities are enormous:

- A growing inventory of spent fuel from commercial nuclear power plants, currently exceeding 32,000 metric tons.
- Over 2 million cubic meters of radioactive wastes of all types.
- Hundreds of radioactively contaminated structures, including reactors, chemical processing facilities, and laboratories.
- About 3.7 billion cubic meters of contaminated soil and groundwater at federal nuclear sites and other locations.
- Over 600,000 tons of nuclear production materials, including highly enriched uranium and plutonium.
- About 17,000 radioactive sources used for medicine, waste management, industry, and research.

Compounding the complexity of the current situation is the fact that each area of DOE's nuclear materials responsibility has compelling technical, policy, economic, legal, institutional, and political ramifications at both national and international levels. For example, plutonium left over from retired Cold War weapon systems can be viewed by different constituencies as a nuclear weapon material, an energy source, an international proliferation threat, or a hazardous waste. It is all of these.

As the article beginning on p. 4 illustrates, the management of plutonium disposition from large numbers of retired nuclear weapons has become an urgent task with significant environmental and security implications. We need sound disposition policies and plans to handle plutonium and enriched uranium in a safe and environmentally responsible manner. Such policies must also ensure that these materials never end up as part of makeshift nuclear weapons for a terrorist nation.

Even more important, we need to step back and develop a systematic and rational framework for understanding and dealing with all use and management issues related to nuclear materials. With this framework, DOE and the nation's decision makers could more easily take into account all of the (often competing) issues to identify and assess opportunities, risks, and costs for various nuclear materials stewardship options.

In the spirit of developing such a framework, DOE and Lawrence Livermore National Laboratory sponsored a two-day workshop at Livermore last October. The Nuclear Materials Stewardship Policy Review Workshop, the first of three planned, brought together more than 70 experts from DOE, other federal agencies, national laboratories, non-government organizations, and universities. The workshop afforded participants an opportunity to look at the bigger picture by reviewing the complex issues associated with nuclear materials stewardship, including the amounts and types of materials, the uses and disposition pathways of these materials, and nonproliferation implications. Following the workshop, organizers set up a dedicated Web site on the Internet to continue their discussion.

Through these workshops and other meetings, conferences, and communications, the DOE and the larger nuclear materials community are beginning to identify the information, tools, and resources needed to move ahead. Admittedly, this is an arduous task, but it is one that the public expects us to do and do well. As the remaining superpower, the U.S. has an opportunity and, in fact, an obligation to influence other nations' policies regarding the prudent management and use of nuclear materials in their care.

As we more forward, it is certain that Lawrence Livermore will play a significant role in helping to build this new framework for nuclear materials stewardship. As experts in a variety of nuclear materials and processes, Livermore scientists and engineers have much to contribute to an area that is sure to grow in importance in the years ahead.

■ Tom Isaacs is head of the Office of Policy, Planning, and Special Studies.

Dealing with a Dangerous Surplus from the Cold War

The proliferation of nuclear materials is a threat to national security and world peace. This threat complicates the safeguarding and management of fissile materials that have become surplus since the end of the Cold War.

TEARING down the Berlin Wall in 1989 symbolized the end of the Cold War. However, the real work of ending the Cold War—sharply reducing the number of nuclear weapons—remains to be done.

The governments of the United States and Russia have taken the first steps toward nuclear arms reduction by negotiating the Strategic Arms Reduction Treaties. Under START I, which was ratified in 1991, both countries agreed to reduce their large nuclear weapons arsenals to approximately 6,000 warheads and have already begun to do so by dismantling between 1,300 to 2,000 weapons each year. START II, when it is ratified, will reduce the numbers further to between 3,000 and 3,500.

The dismantling of weapons and the cessation of new nuclear weapons manufacturing, while positive for world peace, have raised a problem: what to do about the fissile materials recovered from the weapons or in inventories that will remain unused. These materials—primarily plutonium and highly enriched uranium—are environmental, safety, and health concerns. But of more urgency is the threat they pose to national and international security if they fall into the hands of terrorists or rogue nations. As arms reduction continues and amounts of surplus fissile materials increase, the potential for such security breaches will increase.

As part of bilateral nuclear nonproliferation work, both the U.S. and Russia have initiated scientific studies to find a way to dispose of surplus fissile materials. In the U.S., the Department of Energy is the technical lead for the disposition studies, acting as a member of the Interagency Working Group of the White House Office of Science and Technology. In this capacity, DOE has mandated separate studies for disposing of plutonium and highly enriched uranium, because of their different chemical characteristics. Lawrence Livermore is focusing primarily on the study of plutonium disposition.

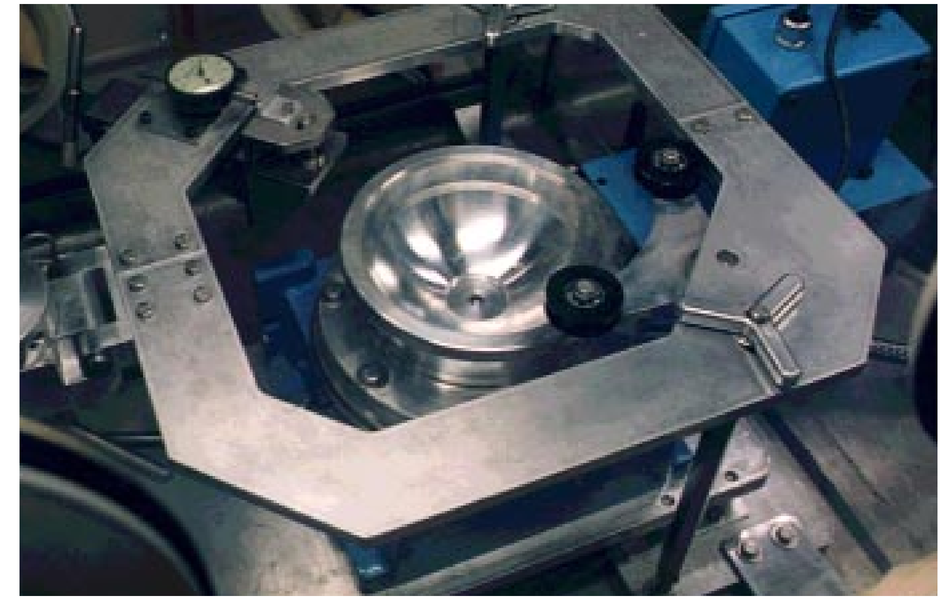


Figure 1. The prototype bisector was designed and tested at Livermore. Using a chipless cutting wheel, it can separate weapon pits into two half-shells in less than 30 minutes so that the plutonium in them can be recovered for disposition.

Plutonium Disposition

After a series of studies, including technical work for a preliminary environmental impact study, DOE selected three reasonable plutonium disposition alternatives for further study: using plutonium as reactor fuel; encasing it in other material, thereby immobilizing it and making it inaccessible; and burying it in a deep borehole.

Lawrence Livermore is involved in studying the front-end processes required to prepare plutonium for disposition and is performing research and development on two of the three specific disposition methods to determine their viability. Specifically, Lawrence Livermore is working with Los Alamos National Laboratory on a system for disassembling weapon pits (or cores, where detonation takes place), recovering the plutonium in them, and converting it into a disposable form. Livermore has also led the two teams studying the immobilization alternative and the deep burial alternative. Oak Ridge National Laboratory is studying the reactor-fuel alternative.

The *Programmatic Environmental Impact Statement* for plutonium disposition was published in December 1996. In January 1997, DOE announced its Record of Decision on plutonium disposition, recommending a dual disposition path: immobilize low-grade plutonium materials and use high-grade plutonium materials to fuel reactors. The alternative of burying surplus plutonium in a deep borehole ran into siting and licensing difficulties and was eliminated from consideration, despite the fact that Livermore studies proved it to be as technically feasible as the other two alternatives.

Recovery and Conversion

Lawrence Livermore and Los Alamos are designing a plutonium recovery and conversion system, the Advanced Recovery and Integrated Extraction System (ARIES). ARIES has five modules, which are used for: pit disassembly, converting plutonium into an oxide (for disposition), converting plutonium into a metal (for long-term storage), packaging plutonium for storage, and performing nondestructive assay to account for plutonium quantities. Lawrence Livermore is focusing on the first two modules.

Pit Disassembly

The pit disassembly, ARIES' first module, consists of a glovebox in which the weapon pit is received; remote handling devices that transfer pits onto a scale for weighing and then move them on to be inspected and have any appurtenant devices removed; and a bisector (Figure 1) that separates the pit into two half-shells by using a chipless cutting wheel. The bisector framework remains stationary while the pit is rotated.

The bisector design takes into account the dimensions, encapsulation methods, construction materials, and manufacturing techniques of these pits in order to incorporate the representative configurations that will be processed through ARIES. It also calls for a "no-hands-on" process to keep radiation exposures to the operator within acceptable limits.

Bisector improvements are being made and will be tested during 1997.

Producing Plutonium Oxide

To be suitable for most of the disposition methods, plutonium must first be converted into plutonium oxide, the job of ARIES's second module. Lawrence Livermore has been developing pyrochemical techniques to accomplish this conversion using various hydride/oxidation (HYDOX) reactions. Three such processes are being researched, all based on reactions in which pure hydrogen gas is used to remove plutonium from a pit by forming a plutonium hydride. The formation of the hydride causes the plutonium to break up into small particles and separate from the other pit materials. The plutonium hydride is collected and then converted to plutonium oxide either directly or after conversion to plutonium nitride.

The experiments on the HYDOX processes seek to minimize production cycle times and maintain safety while producing oxide particles to the required disposition specifications, particularly the more stringent specifications for oxide fuels used in reactors.

A prototype HYDOX furnace has been designed, assembled, and installed and is being used to test the various process options. An additional unit (Figure 2) is being assembled in a glovebox and will be installed and operated at Los Alamos as part of the ARIES demonstration.

The Spent Fuel Standard

Because most nations and even some terrorist groups are technically capable of converting surplus plutonium into nuclear weapons, the ideal disposition method eliminates the possibility of surplus plutonium being used for weapons. If a disposition method is not available within a reasonable time frame, the growing volume of plutonium surplus will make proliferation easier and render arms-reduction agreements meaningless.

Because total elimination is not a practical objective, a National Academy of Sciences study, commissioned by DOE's Office of Nuclear Energy, proposed the next best thing: minimized accessibility. Dubbed the "spent fuel standard" and accepted as the goal of plutonium disposition efforts by the U.S., Russia, and the seven other stakeholder nations, it defines "minimized accessibility" as equivalent to the accessibility of the plutonium found in spent reactor fuel. The spent fuel standard is a reasonable goal because the technology to accomplish it appears achievable within 10 years and implementation can be completed within 25 years. It is also a practical goal because, by definition, it excludes spent fuel plutonium—which comprises the larger part of the surpluses—from disposition and concentrates on weapons-grade plutonium.

The Immobilization Task

Lawrence Livermore is researching plutonium immobilization with the Savannah River Technology Center, Argonne National Laboratory, and Pacific Northwest National Laboratory. Several U.S. universities and private industries are also partners, as are several other nations (including Australia, the United Kingdom, France, and Russia) with interest and experience in immobilization.

Immobilization technology achieves the spent fuel standard by encapsulating plutonium inside a waste form specifically tailored for this function, adding a radiological barrier to increase inaccessibility to the plutonium, and sealing the resulting material inside a stainless-steel canister. Like spent reactor fuel, these canisters would be stored for an interim period before being placed inside a geologic repository. The size, weight, composition, and radiation barrier of the filled canister are intended to make the plutonium in it roughly as difficult to steal and recover as the plutonium in spent fuel.

Before the immobilization alternative can be fully developed and implemented, three decisions need to be made:

- What waste form is to be used for encapsulating the plutonium and what technology is to be used for encapsulation?
- Is the radiological barrier to be internal, that is, mixed with the plutonium, or external, in a separate container that surrounds the plutonium container?
- Where will the plutonium immobilization take place?

Immobilization Options

A great deal of information about stabilizing radioactive material by embedding it in another material has been published. An extensive literature search identified 45 forms considered previously for immobilizing radioactive waste.

These 45 forms were subjected to a formal, two-step screening process to derive top candidates for comprehensive technical evaluation. The two top-ranking forms were borosilicate glass and Synroc (synthetic rock), a ceramic material developed by scientists at the Australian National University, Lawrence Livermore, and Savannah River.

The glass and ceramic forms were evaluated in five variations of the immobilization process to look at various permutations of forms, radiological barrier concepts, and facilities in which the work could be done. As in all other disposition methods, the plutonium must first be converted into an oxide, and then a neutron absorber mixed with it for criticality control.

Three Glass Variations

Variation 1: Internal Radiation Barrier. In this two-stage process, plutonium oxide reacts with glass frit containing a neutron absorber to prepare a plutonium–neutron-absorber–glass frit (Figure 3a). First, 4 kilograms or less of plutonium as plutonium oxide are combined with neutron absorber and glass frit to form plutonium–glass frit.

Figure 2. To be suitable for most disposition methods, the excess weapons plutonium must first be converted into plutonium oxide by various hydride/oxidation (HYDOX) methods. The prototype HYDOX furnace design originated at Livermore and has been used to test various HYDOX process options. Livermore technicians William Kuhl (left) and Terry Ludlow assemble a HYDOX furnace in a glovebox. The unit will be used for further testing at Los Alamos National Laboratory.

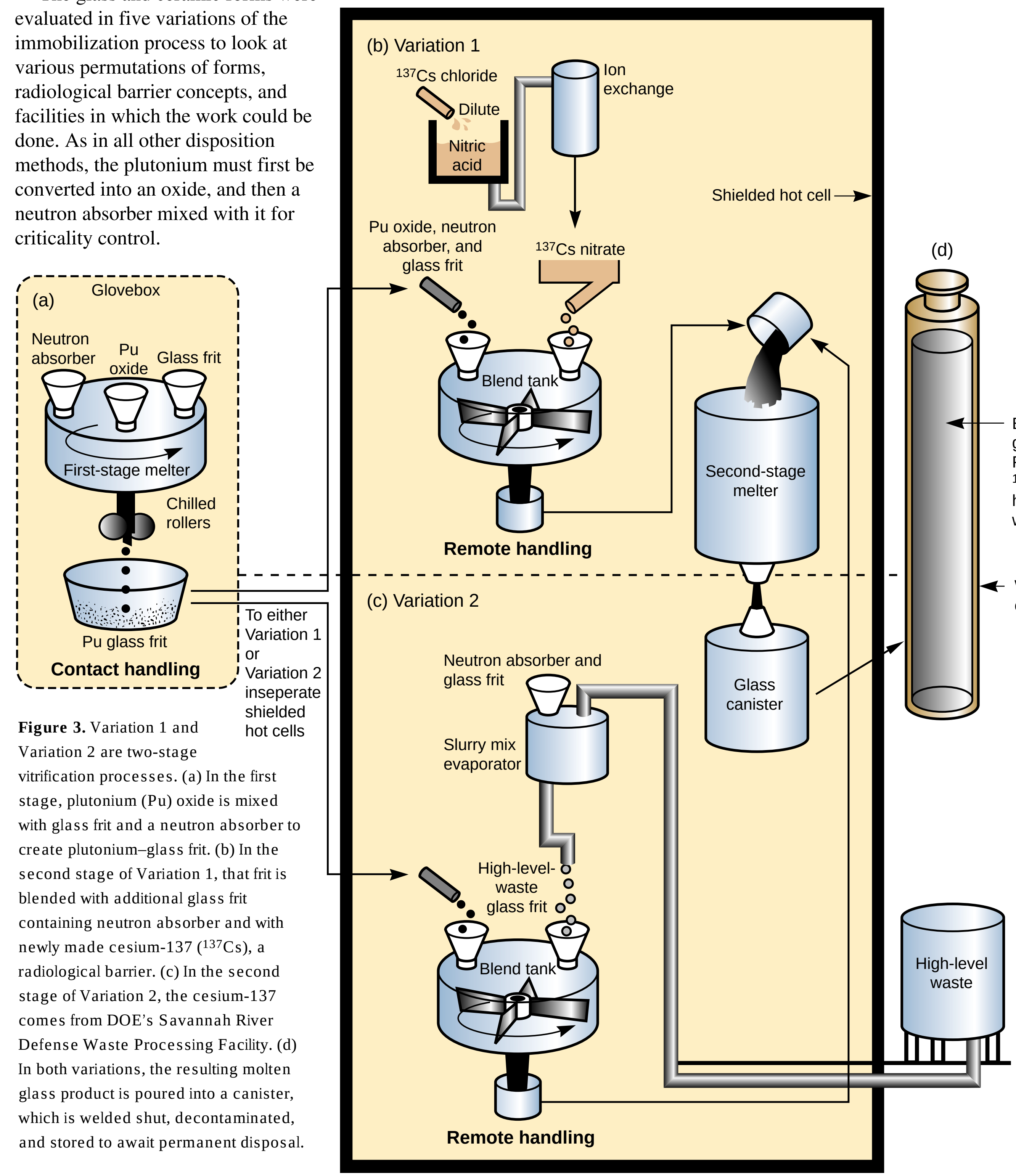


Figure 3. Variation 1 and Variation 2 are two-stage vitrification processes. (a) In the first stage, plutonium (Pu) oxide is mixed with glass frit and a neutron absorber to create plutonium–glass frit. (b) In the second stage of Variation 1, that frit is blended with additional glass frit containing neutron absorber and with newly made cesium-137 (^{137}Cs), a radiological barrier. (c) In the second stage of Variation 2, the cesium-137 comes from DOE's Savannah River Defense Waste Processing Facility. (d) In both variations, the resulting molten glass product is poured into a canister, which is welded shut, decontaminated, and stored to await permanent disposal.

The second step (Figure 3b) blends batches of 50 kilograms or less of plutonium as plutonium–glass frit with additional neutron-absorber-containing glass frit and cesium-137, where the cesium is used as a radiological barrier. The resulting molten glass product is poured into a canister, which is welded shut, decontaminated, and stored until permanent disposal in a high-level waste repository (Figure 3d).

Variation 2: Internal Radiation Barrier. This two-stage process is similar to Variation 1 but would use existing, modified facilities. The first-stage melt of plutonium oxide and borosilicate frit (containing a neutron absorber) is made in an existing facility at Savannah River, and the second-stage melt (Figure 3c), which incorporates the cesium radiological barrier, will be done at a new melter to be built next to Savannah River's Defense Waste Processing Facility. The high-level-waste fission product cesium-137 will come from the Savannah River tank farms.

Variation 3: External Radiation Barrier. This is a "can-in-canister" concept in which plutonium is immobilized in borosilicate glass that contains a neutron absorber. Then the mixture is poured into cans, which are in turn placed in canisters into which molten high-level-waste glass is poured (Figure 4). The high-level-waste glass comes from the Defense Waste Processing Facility at Savannah River.

Two Ceramic Variations

Variation 4: Internal Radiation Barrier. Plutonium oxide is first converted to plutonium nitrate and then blended with mineral-forming oxides (ceramic precursors), a neutron absorber, and a titanate that contains cesium. The mixture is calcined (heated but not fused), loaded into bellows, and hot pressed into a dense form (Figure 5). Twenty of these forms are loaded into a canister and packed with titanium oxide granules. The canisters are stored until they can be sent to a high-level-waste repository.

Variation 5: External Radiation Barrier. This is a can-in-canister approach similar to Variation 3. The ceramic form is made by blending plutonium oxide with ceramic precursor materials and a neutron absorber. The mixture is calcined, cold pressed, and sintered (heated but not melted) into a dense form that is loaded into small cans. The small cans are put inside a storage canister, where they are surrounded by glass made with high-level waste (Figure 6).

Progress Report

For the five process variations, the task team developed process flowsheets and preconceptual plant designs; gathered the required environmental data; and determined the workforce, cost, and schedule requirements for implementing them.

At the end of these tasks, the team recommended the can-in-canister concept to DOE and has proceeded to the research and development stage to determine whether glass or ceramic should be the immobilization form. Research on vitrification forms is being done with Savannah River, Pacific Northwest, and Argonne laboratories,

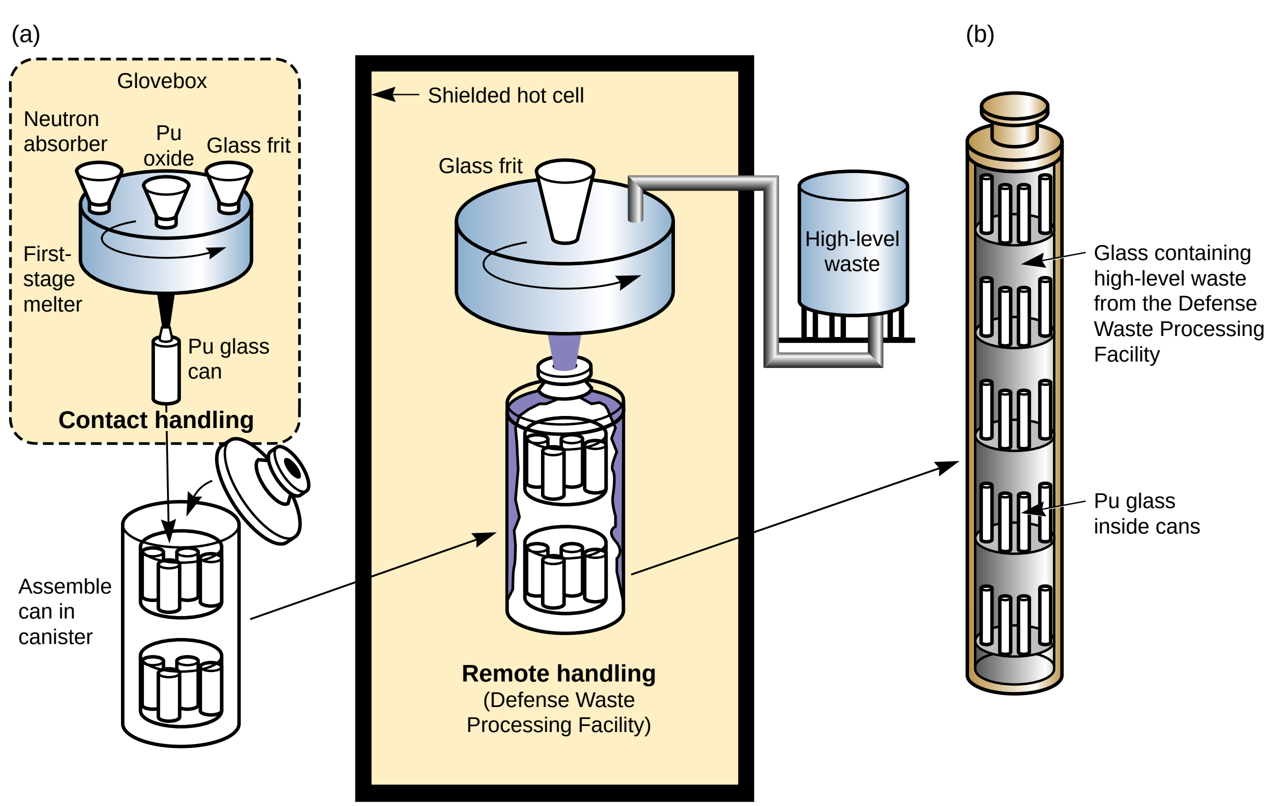
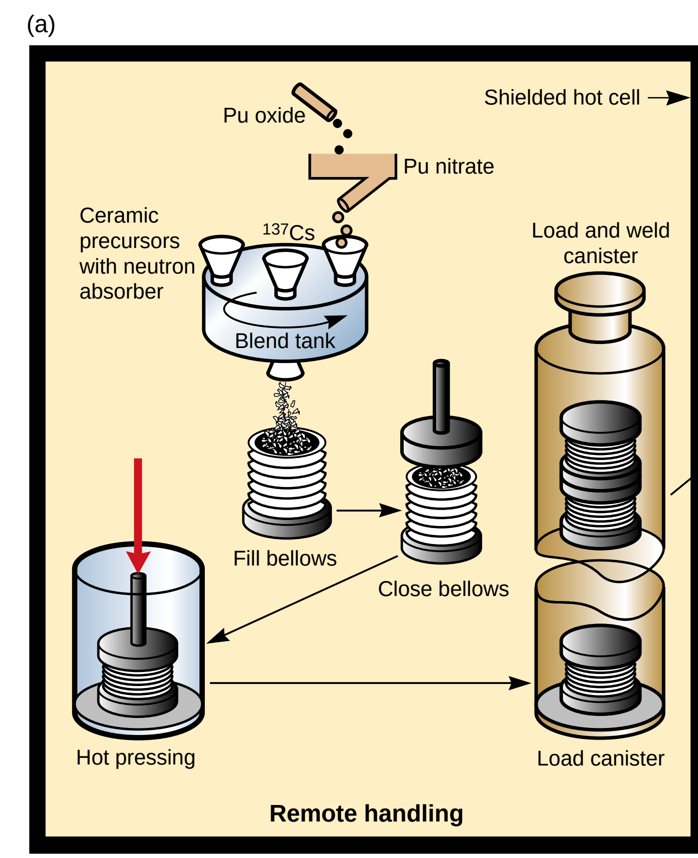


Figure 4. (a) Vitrification Variation 3 is a "can-in-canister" concept in which plutonium (Pu) immobilized in borosilicate glass is poured into a can, which is then placed in (b) canisters into which molten high-level-waste glass from the Defense Waste Processing Facility at Savannah River is poured. The outer canister provides an external radiation barrier.



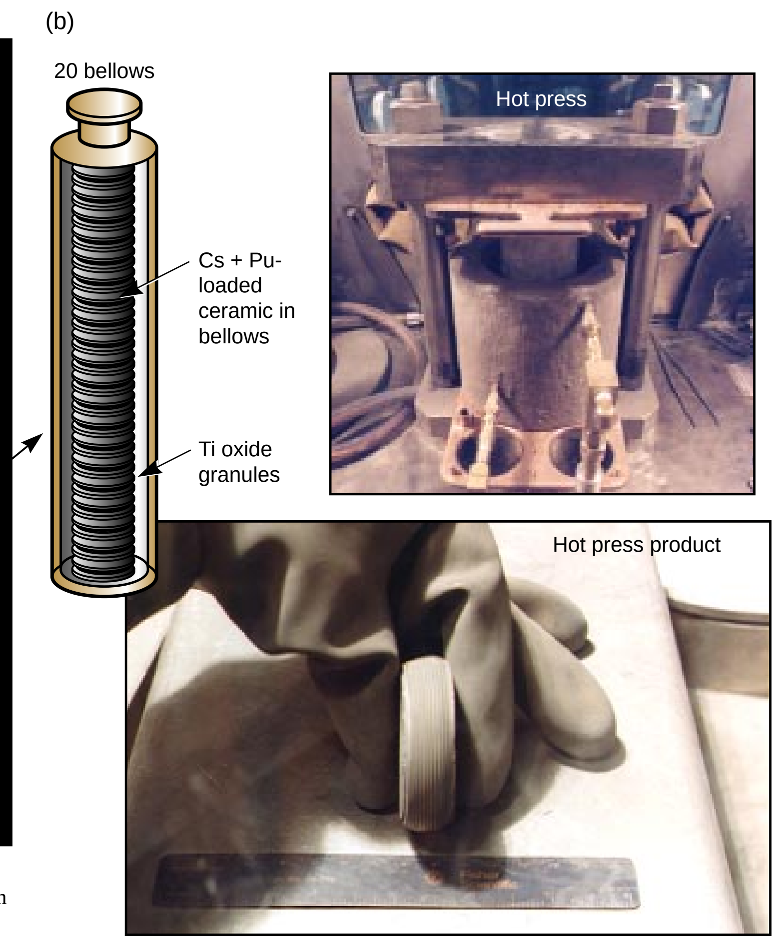


Figure 5. (a) Variation 4 is a ceramic process using an internal radiation barrier. Plutonium (Pu) oxide is converted to plutonium nitrate and then blended with mineral-forming oxides (ceramic precursors), a neutron absorber, and a titanate-containing cesium (Cs). The mixture is heated, loaded into bellows, and hot pressed into a dense form. The hot press is in the photo, upper right; the dense-form product is pictured lower right. Twenty of these products will be loaded into (b) a canister, packed with titanium (Ti) oxide granules, and sent, ultimately, to a permanent high-level-waste repository.

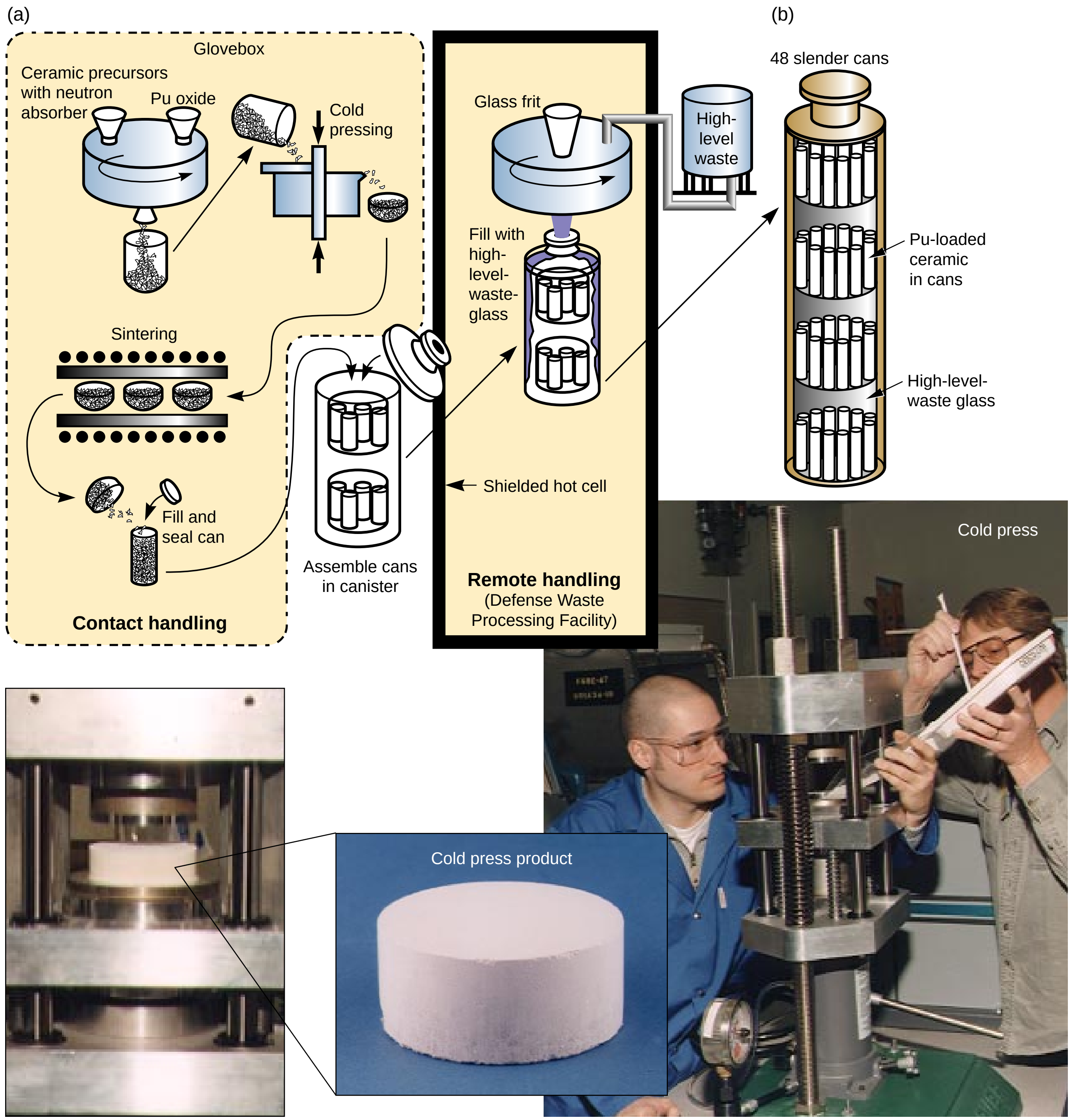


Figure 6. (a) Variation 5 is also a ceramic process, but it involves a "can-in-canister" (or external-radiation-barrier) approach like Variation 3. The ceramic form is made by blending plutonium (Pu) oxide with ceramic precursors and a neutron absorber. The mixture is heated, cold pressed, and sintered (heated but not melted) into a dense form. The cold press is in the photo, lower right; the dense-form product is pictured lower left. The ceramic product is loaded into small cans, which are put inside (b) a storage canister and surrounded by glass made with high-level waste.

while the Australian Nuclear Science and Technology Organisation (ANSTO) and Savannah River are Lawrence Livermore's partners in ceramic form research.

Desirable Glasses

All the ways to use glass to immobilize plutonium require further research into improving the solubility of plutonium in the glass melts, determining the most effective neutron absorber, understanding solubility interactions between the neutron absorber and plutonium, and analyzing how impurities affect the quality of the waste form. Glass-forming chemicals must be formulated to dissolve the greatest amounts of plutonium oxide, neutron absorber, and any uranium and other impurities present. Moreover, these chemicals should have the best processability and chemical durability characteristics. Finally, to prevent leaching, the glass product they form should ideally be homogeneous, with no separated crystalline or amorphous phases.

Two new candidate glasses have been formulated. The first, an alkali-tin-silicate (ATS) glass formulated at Argonne National Laboratory, was to be used in the process in which cesium would be an internal radiation barrier. However, because the preferred immobilization process appears to be the can-in-canister concept, work on this glass stopped.

A second glass formula, proposed for use in the can-in-canister process variation and now the preferred formulation for vitrification, produces glass similar to commercial Löffler optical glasses that contain 55% by weight or less of rare-earth oxides. (Because this glass requires a very high operating temperature, highly volatile cesium cannot be used as an internal radiation barrier.) The chemistries of actinides (the chemical family of plutonium) and rare-earth elements are similar, so the solubility of plutonium is expected to be comparably high in this formulation. In the latest experiments, this glass has dissolved greater than 10% by weight of plutonium. Now it is being optimized and further characterized for plutonium solubility, the influence of required additives such as the neutron absorber, tolerance to process variations, processability, resistance to radiation damage, and long-term chemical durability.

Ceramic Forms and Processes

Since the late 1970s, ceramic waste forms have been considered for use in immobilizing high-level waste. But no industrial experience base exists for this technology, so it is not as mature a technology as the borosilicate glass forms.

Like glass, ceramic forms must be characterized for plutonium solubility, the influence of required additives such as a neutron absorber, tolerance to process variations, processability, resistance to radiation damage, and long-term chemical durability.

The most advanced ceramic formulation to date is Synroc. ANSTO initiated development of Synroc in 1978 and completed a demonstration plant in 1987 that operated at a commercial scale of approximately 10 kilograms per hour and produced more than 6,000 kilograms of Synroc.

Fabrication processes for ceramic forms also determine how much plutonium may be incorporated into the forms. The best demonstrated process for ceramic fabrication, especially ceramic with an internal radiation barrier, is hot pressing. The process has been demonstrated full-scale with high-level-waste surrogates, but only on a laboratory scale with plutonium. At Livermore, a hot press capable of producing about 0.5-kilogram ceramic in a 7.5-centimeter-diameter bellows has been built and installed and has produced ceramic product containing about 60 grams of plutonium.

Repository Performance

An immobilization form is judged acceptable for disposal in a federal geologic repository according to a fitness-for-purpose criterion that includes regulatory, licensing, and long-term performance factors. The main long-term, post-emplacement performance considerations are criticality safety and the potential of the form to contaminate the biosphere. In the U.S., the regulatory performance period for high-level waste and spent fuel in a geologic repository has been specified as 10,000 years. (The pertinent regulations are currently under review and may change.) However, the emplaced plutonium and its uranium-235 decay product remain fissile over much longer periods (hundreds of thousands of years for plutonium and billions of years for uranium-235), over which criticality safety may need to be assured.

Scenarios for criticality events can be divided into three categories of criticality safety: safety of the essentially undisturbed emplacement waste package, safety of disrupted waste packages, and safety of disposed fissile materials released from the disposal form followed by possible transport within the repository or in the geosphere. In general, the criticality safety of the first category of scenarios can be assured with very high confidence, but assuring the safety of the latter two categories is more difficult and will depend on such factors as the fissile material content of the disposal form, canisters, and waste package; the geometry of the disrupted configuration; and the degree of degradation of the disposal form and its interactions with surrounding rock and water.

Notwithstanding the complexity of the problem, key properties of disposal forms that affect criticality safety have been identified. They are fissile loading of disposal forms, concentration of the neutron absorber, and neutron absorption properties of the immobilization matrix. Other factors are resistance of disposal form constituents to release and transport by groundwater and the rates and relative timing of releases of different components. Characteristics of elemental release from disposal forms may be very different for different disposal forms (especially glass and ceramic) and are affected by compositions of water and disposal form, solubility of the constituents, active surface areas available for reaction with water, compositional and thermal stability of disposal forms, physical and chemical homogeneity of disposal forms, and radiation effects (damage in disposal form and radiolysis in water). Researchers are particularly concerned about the susceptibility of the disposal form to cracking during fabrication and after emplacement and to the development of permeable channels within the disposal form caused by preferential dissolution of certain phases or along grain boundaries.

Lawrence Livermore and its partners are providing needed information for DOE's final immobilization technology decision, expected by September 1997. By then, they will have defined formulations for the glass and ceramic immobilization forms, characterized them for proliferation resistance and performance in the geologic repository, and developed the information needed to evaluate concepts for production processes.

Science to End Cold War

The surplus weapons plutonium disposition program is but one of several programs to help implement political agreements and maintain safeguards and security for the nation. In light of the complexity of the disposition program, both in terms of scope and required scientific expertise, declaring the Cold War over was simpler than implementing its end. At Lawrence Livermore, scientific progress is being made to contribute to that end.

—Gloria Wilt

Key Words: ceramics, deep boreholes, fissile materials, immobilization, nuclear waste repository, plutonium disposition, plutonium oxide processes, spent fuel standard, Synroc, vitrification, waste forms, weapon pits.

For further information contact Leonard Gray (510) 422-1554 (gray5@llnl.gov).

Leonard Gray, the chief scientist for Lawrence Livermore's Excess Fissile Materials Disposition Program, with a prototype stainless-steel canister, which is 3 meters (10 feet) tall and 60 centimeters (24 inches) in diameter and weighs 1,680 kilograms (about 2 tons).

About the Livermore Team

Members of Livermore's Fissile Materials Disposition Program team (clockwise from lower left): MARK BRONSON holds a B.S. in metallurgical engineering and an M.S. in metallurgy from the University of Utah. In addition to being leader of the defense-related projects in the Isotope Separation and Advanced Manufacturing Program at Livermore, he leads the plutonium pyrochemistry work of the Fissile Materials Disposition Program. Particular accomplishments are development of the pit splitter for recovering excess plutonium from the cores of nuclear weapons and the hydride/oxidation process that converts plutonium to plutonium oxide prior to immobilization. He came to the Laboratory in 1988 by way of DOE's Rocky Flats facility in Colorado, where he concentrated on research and development in the field of plutonium pyrochemical technology.

BARTLEY EBBINGHAUS joined the Laboratory in 1991 after earning his doctorate in chemistry at the University of California, Berkeley. He is currently task leader for Livermore's ceramic immobilization work on DOE's Fissile Materials Disposition Program. He co-designed the formula and fabrication process for the proposed ceramic form (a variation of a material called Synroc) that is able to incorporate and immobilize excess plutonium. He has also demonstrated the successful preparation of a large plutonium-bearing ceramic pellet that meets preliminary design expectations.

GUY ARMANTROUT joined the Laboratory in 1965. He holds a doctorate in electrical engineering and physics from Purdue University. He is a project leader in the Fissile Materials Disposition Program responsible for the development and demonstration of production-scale processing systems for the immobilization of plutonium in glass and ceramic in preparation for disposal in a geologic repository.

LEONARD GRAY (Ph.D., University of South Carolina) has been a part of DOE's Fissile Materials Disposition Program since its inception in 1990, when he was asked to organize and lead an international team responsible for developing the immobilization portion of the program. After a 20-year career as a staff chemist at DOE's Savannah River Site, he joined the Laboratory in 1988 as a section leader for plutonium process development in the Special Isotope Separation Program. He is currently chief scientist for Livermore's contributions to the Fissile Materials Disposition Program.

Abstract

Dealing with a Dangerous Surplus from the Cold War

In the aftermath of the Cold War, the management of surplus fissile materials has become an urgent task with profound environmental, national, and international security implications. Lawrence Livermore is a key player in a study launched by the Department of Energy to find a way to dispose of surplus weapons plutonium. The Laboratory's work consists of engineering to retrieve plutonium from nuclear weapon pits and to process it into a form usable for disposition as well as research and development for two disposition methods—immobilization by a ceramic or glass waste form and burial in deep geologic boreholes. DOE recently selected immobilization as one method of the dual disposition path it will implement for plutonium. Lawrence Livermore's work continues with research in ceramic and glass formulations to provide a scientific basis for DOE's decision on the method for immobilizing plutonium.

■ *Contact:*
Leonard Gray (510) 422-1554 (gray5@llnl.gov).

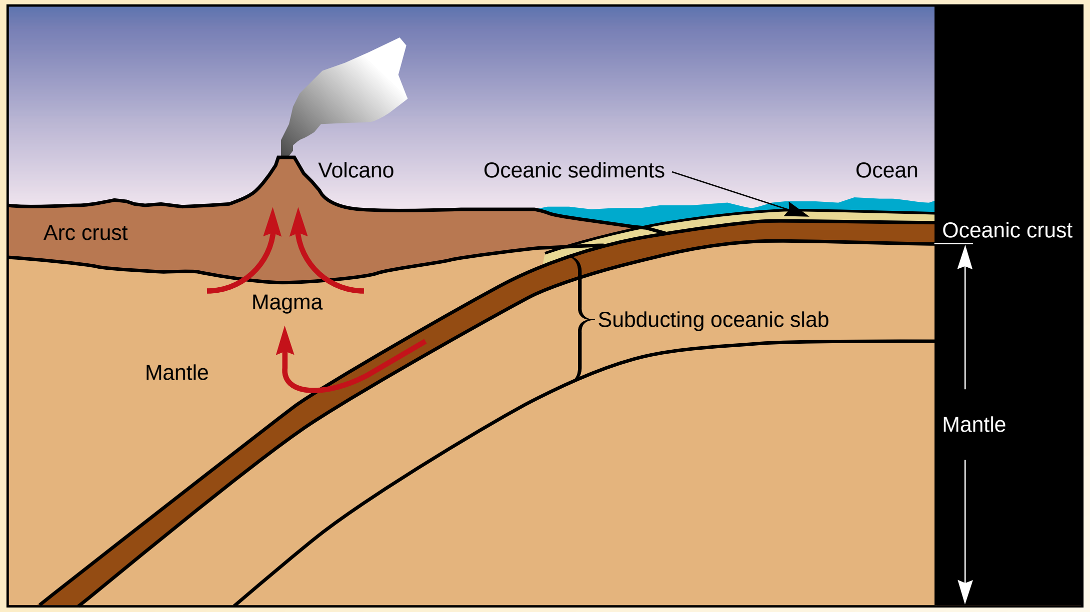


Figure 1. The oceanic slab subducts into the adjacent mantle. The oceanic slab includes the oceanic crust and part of the mantle, but whether it also includes oceanic sediments is a matter of some controversy among scientists.

Volcanoes
A Peek into Our Planet's Plumbing

MOST of us think of volcanoes as awesome or tranquil, depending on whether or not they are erupting. But we seldom consider that the magma belched up during an eruption represents a recycling of our Earth's most basic components—molten rock and gases that formerly lay deep within the mantle migrate up and finally are thrust skyward to become part of the crust and atmosphere. This activity not only forms new islands, mountain ranges, and large lava plains but also provides a brief glimpse into the dynamic processes that shape our Earth.

Volcanoes that lie along the edge of the Earth's great tectonic plates, like those in Japan, Indonesia, and the Aleutian Islands, constitute over 75% of all volcanoes that erupt above sea level. Known as island-arc volcanoes, they are the dramatic result of continuous interactions between the oceans, crust, mantle, and atmosphere.

Along deep oceanic trenches, the oceanic slab is thrust or subducted into the mantle bringing with it water from the ocean (see Figure 1). Water reduces the melting temperature of rock so that, as water is introduced to the mantle, the mantle melts. This melted material, known as magma, rises buoyantly until it erupts on the Earth's surface to form island-arc volcanoes. These eruptions are thought to be the major process by which mantle material is transferred to and becomes part of the Earth's crust. The gases from these eruptions also contribute to the formation of our atmosphere.

Understanding the chemical recycling at subduction zones has practical implications. For example, these volcanic eruptions affect global climate by releasing greenhouse gases into the atmosphere. The 1991 eruption of Mt. Pinatubo in the Philippines provided a stunning example of the effect that a volcano can have on global climate.

Annie Kersting, a geochemist with Livermore's Institute for Geophysics and Planetary Physics, recently completed a study of island-arc volcanoes on the Kamchatkan Peninsula, Russia, and on the island of Honshu, Japan, with scientists from Australia and Japan (see Figure 2). Her studies were designed to learn more about the processes that control the generation of new crust at island arcs. The consensus among geologists is that island-arc magmas are composed mostly of material from the mantle, with fluids from the subducting oceanic crust providing the mechanism for melting. But they are unsure to what extent the subducting oceanic sediments and/or oceanic crustal material mixes with the mantle and to what extent the thin arc crust immediately beneath the volcanoes contributes to the chemistry of the lavas that these volcanoes produce.

To determine the components of the magmas being studied, Kersting used long-lived isotopes of lead (Pb), strontium (Sr), and neodymium (Nd) as tracers. The so-called parental materials of lava—the mantle, oceanic crust, sediments, and arc crust—are isotopically distinct from one another, and the erupted lava will have the isotopic tracer or fingerprint of one or more of these parents.

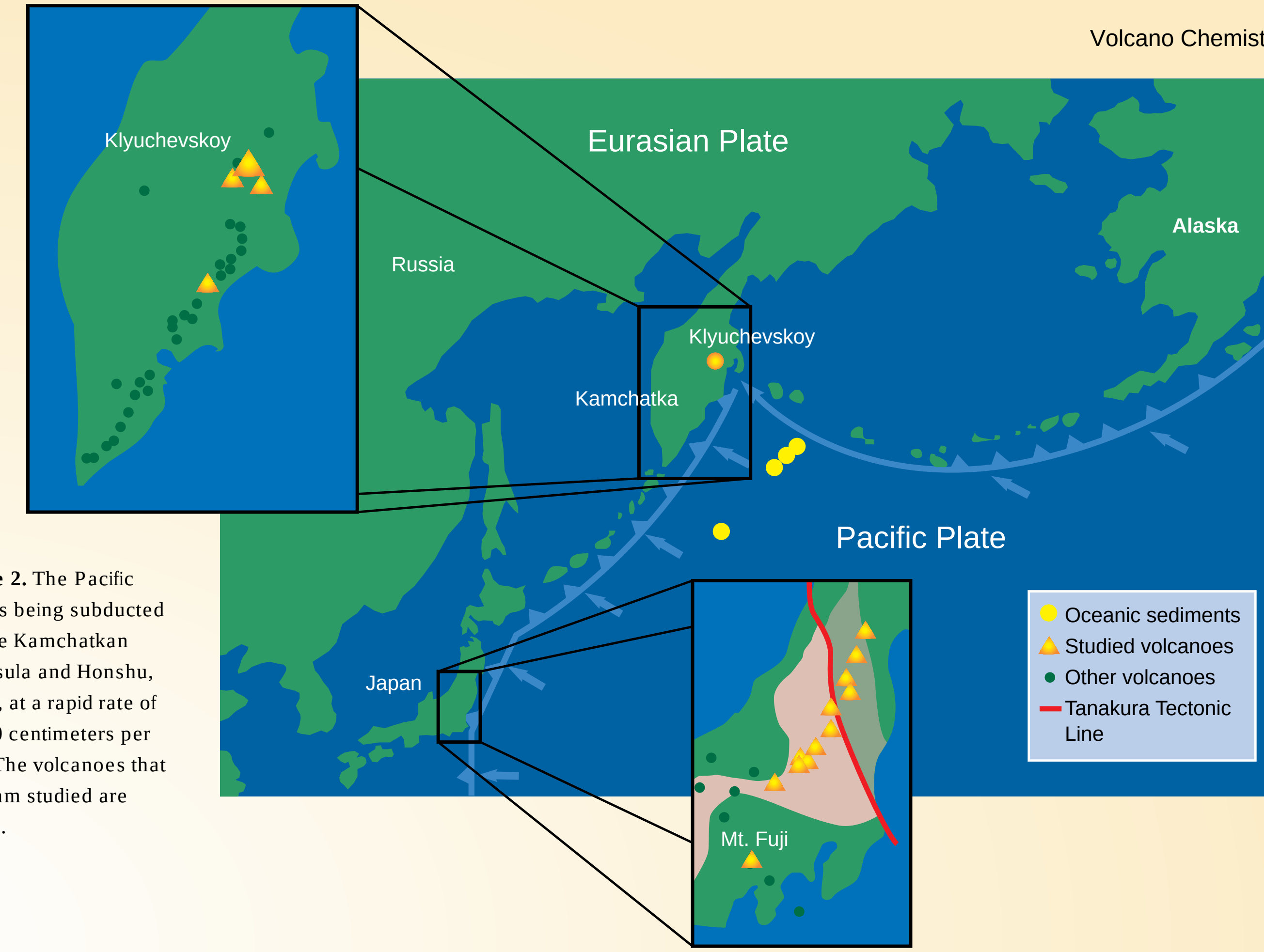


Figure 2. The Pacific Plate is being subducted into the Kamchatkan Peninsula and Honshu, Japan, at a rapid rate of 8 to 10 centimeters per year. The volcanoes that the team studied are shown.

Are Oceanic Sediments Involved?

Kersting's study of Klyuchevskoy volcano in Kamchatka, Russia, evaluated the influence of oceanic sediments in the generation of island-arc volcanoes. Klyuchevskoy is the most active island-arc volcano in the world (see Figure 3). A recent eruption blew volcanic material 15 to 18 kilometers above sea level and required the diversion of international airline traffic as a safety precaution.

The team first measured Pb, Sr, and Nd isotope ratios in basaltic rocks from Klyuchevskoy. They used Livermore's thermal ionization mass spectrometer, which can measure extremely low levels of these isotopes. The same ratios were measured in oceanic sediments from the North Pacific, parallel to the Kamchatkan arc. These sediments are the best analog for sediments that might have previously subducted with the oceanic slab beneath Kamchatka.

In all cases, the isotopic ratios of the lavas and Pacific sediments were different. Even a 1% sediment contribution to the lavas would be detectable, but there was none. Instead, the isotopic fingerprint was that of a purely mantle source. To verify these figures, the team also looked at three other Kamchatkan volcanoes and found similar results.[1]

"One area of controversy among geologists is whether oceanic sediments are carried down with the subducted oceanic slab and if so, whether they are melted and recycled into the arc crust via volcanism or scraped off and not subducted. This study indicates that sediments are not required in the production of island-arc volcanoes," says Kersting. In contrast, previous studies of other island arcs indicate that sediments are involved in magma generation. This work has shown that the involvement of sediment in the chemistry of arc magmas varies from arc to arc.

The Arc Crust's Contribution

In Japan, Kersting's team evaluated the effect that a relatively thin (30-kilometer) arc crust has on the magmas that pass through it. This research tested the widely accepted theory that only very thick (70-kilometer) arc crusts, such as those in the Andes, can influence the chemistry of lavas from the mantle.

Northeastern Honshu, Japan, is an excellent place to study this theory. The Tanakura Tectonic Line, a fault that penetrates the arc crust, cuts across an arc of active volcanoes

Figure 3. This NASA image of Klyuchevskoy was taken from the Space Shuttle at the time of a recent eruption that spewed material 15 to 18 kilometers into the atmosphere. The blue area is land, the white is snow-capped volcanoes, and the smoke in the upper left quadrant is coming from Klyuchevskoy, which is in the center of the photo.

so that the volcanoes form on two different arc crusts. The volcanoes are close together, which helps to minimize variations in other parameters that might influence the volcanoes' chemistry—the depth to the subducting oceanic slab, distance to the oceanic trench, thickness of the arc crust, and composition of the mantle and subducting oceanic crust and sediments. Thus, any differences in the isotopes from volcanoes on opposing sides of the fault must result from the compositional differences in the arc crusts through which the magmas rise.

After collecting rock samples, the team measured isotope ratios at Livermore and found significant differences in the Pb, Sr, and Nd ratios in the lavas from either side of the fault. According to Kersting, the different geochemical signatures between the volcanoes immediately north and south of the fault must result from chemical "contamination" by the arc crust as the magmas traverse it.

More recently analyzed data from Mt. Fuji, which lies on a third type of arc crust on Honshu, substantiates the team's findings, adding strength to the argument that the mixing of basalts from the mantle with the arc crust is an important process in island-arc volcanism. Even a thin arc crust is an active geochemical filter for magmas that move upward through it.[2]

Scientists are still a long way from fully understanding island-arc volcanoes and their effects on our planet and its atmosphere. But Kersting's work contributes to the body of knowledge that helps scientists define how the chemical exchange between the crusts, mantle, and atmosphere at subduction zones influences crustal growth and global climate dynamics.

—Katie Walter

Key Words: crustal growth, global climate, island-arc volcanoes.

References

1. A. B. Kersting and R. J. Arculus, "Pb Systematics of Klyuchevskoy Volcano, Kamchatka, and North Pacific Sediments: Implications for Magma Genesis and Sediment Recycling in the Kamchatkan Arc," *Earth and Planetary Science Letters* **136**, 133–148 (1995).
2. A. B. Kersting et al., "Lithospheric Contributions to Arc Magmatism: Isotope Variations Along-Strike in Volcanoes of Honshu, Japan," *Science* **272**, 1464–1468 (1996).

For further information contact Annie Kersting (510) 423-3338 (kersting@llnl.gov) or Frederick Ryerson (510) 422-6170 (ryerson1@llnl.gov).

Optical Networks
The Wave of the Future

WHEN our ancestors built fires on distant hilltops to signal to one another, they were using an early form of optical communication. This idea of using light to send information began to be developed scientifically in the 1800s, when British physicist John Tyndall demonstrated that he could (although just barely) direct light down a stream of water. He found that light could be guided by transparent materials if those materials were denser than air, and his insight, when followed by other scientific inquiry, culminated in fiber-optic technology.

Fiber-optic technology takes electric signals from our phones, computers, and televisions and transmits them more efficiently than other methods, making it possible to deal with the volume and variety of communications that constitute modern life. The information-carrying capacity of fiber optics is so great that it is far from fully exploited. It is being counted on to help solve problems such as the traffic bottleneck on the Internet.

The members of the National Transparent Optical Network (NTON) consortium are among those counting on fiber optics. The consortium (Figure 1) has received matching funds from the Department of Defense's Advanced Defense Research Projects Agency to test and demonstrate advanced optical components in a high-speed, all-optical communication network. The network is based on existing Sprint and Pacific Bell fiber-optic lines and has been operational since February 1996. Currently, it is being tested by users of large, emerging applications, and the consortium is actively soliciting the interest of other such test users.

The project's two components—next-generation optical technologies and the emerging applications used to test these technologies—are bound into one ambitious objective: to provide a transmission capability for a multitude of complex, advanced uses, at speeds of billions of bits per second, with complete security and reliability. NTON members are thinking beyond the needs of the Internet cruiser's ability to download large graphics files. They are envisioning users such as physicians of the future, who will be able to retrieve a host of complex medical records from various remote locations, perform remote telesurgery, or practice space telemedicine.

The Context for Livermore's Work

Lawrence Livermore leads the work on the prototype network, which is to integrate new, developing technologies into a logical and efficient working system. It is a fitting role not only because of the Laboratory's broad expertise in optics and large-scale computing but also because of its neutral perspective on work that ultimately must be commercialized.

Integrating the new technologies into a high-service-quality, high-speed network on which new high-capacity applications can be tested will promote the advanced applications and demonstrate the commercial feasibility of the new technologies. One important goal of NTON is to convince private-sector investors that the new optical components are worthy of commercialization and that the fiber infrastructure should be upgraded. But as Bill Lennon, Lawrence Livermore's project leader from the Advanced Telecommunications Program, points out, "While these innovations are necessary for technological advancement and

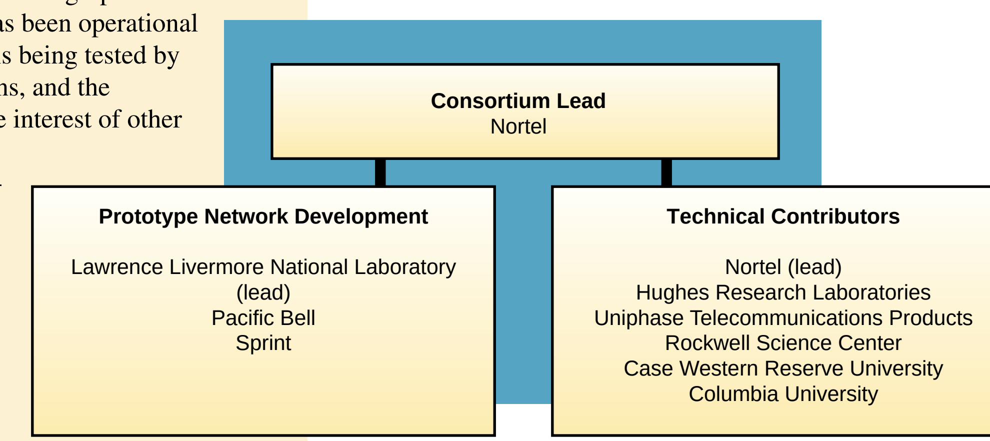
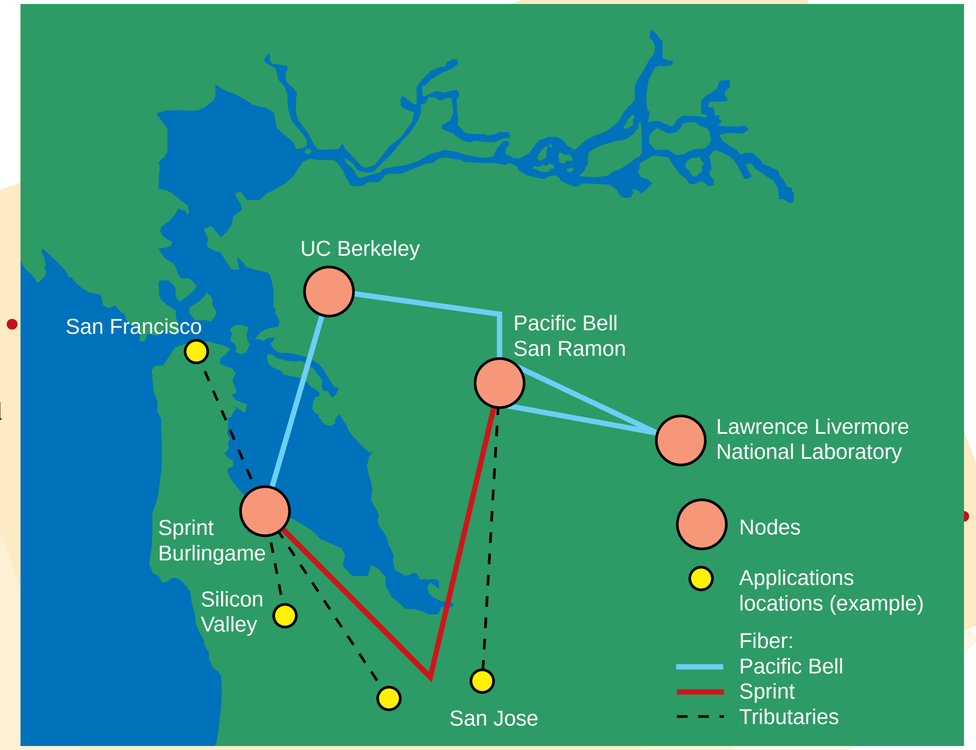


Figure 1. The National Transparent Optical Network is a consortium joining Lawrence Livermore with private-sector firms and institutions of higher education.

Figure 2. Currently, the National Transparent Optical Network consists of four backbone nodes connected by 600 kilometers of fiber that offer access to the network and route the streams of data passing through them. Tributary fibers will link them to other user sites where some 30 advanced applications are being developed and tested.



global competition, change is costly and investors are fiscally conservative. Investors must be totally assured of good returns on their money."

Making More of Optical-Fiber Bandwidth

The all-optical network used in this demonstration resides in the San Francisco Bay Area and at present consists of four backbone nodes—at Pacific Bell in San Ramon, Sprint in Burlingame, the University of California at Berkeley, and Lawrence Livermore. The nodes, connected by approximately 600 kilometers of fiber, offer access to the network and route the streams of data that pass through. Tributary fibers will link them to other user sites, where currently some 30 advanced applications are being developed and tested (Figure 2).

The high speed and great capacity of the network are based on the inherently large bandwidth of optical fibers. Bandwidth is the expression of a medium's communications capacity. Optical bandwidth offers, of course, the speed of light. But it also offers the whole rainbow of light frequencies. Having this capacity range can be likened to having a musical keyboard of many octaves, which can be used to play far more complex melodies than a keyboard of one octave.

NTON enlarges optical bandwidth capacity even more through a technique called wavelength division multiplexing (WDM), wherein each optical fiber is used to carry more than one wavelength. The various wavelengths do not interfere with each other, so each can be used as a different communication channel. (In the keyboard analogy, this characteristic would be tantamount to simultaneously playing a different song with each available octave.) The use of wavelength division multiplexing increases fiber capacity without the need to install more fiber cable.

The NTON fiber carries four wavelengths at present, but plans are to expand to eight ultimately. The capacity expansion that occurs with WDM requires new devices for regulating the resulting voluminous traffic. One of the new devices used in the network is being developed into a new product by Uniphase Telecommunications Products, a consortium member. It is an acousto-optic tunable filter (AOTF), whose function is to route the multiple wavelengths through the different regions of the network. Made of lithium niobate glass, the four-port filter selectively and simultaneously switches many wavelengths on their way to different destinations. Some other wavelengths are isolated by routing them to network-access equipment that "maps" their signals to a different wavelength. Because those signals are isolated by this blocking, their former wavelengths can be used elsewhere in the network. This wavelength "reuse" makes the system scalable, that is, able to indefinitely increase the volume of information being switched through (Figure 3).

A Flexible, Transparent Network

NTON is intended to be an open network; it must therefore be easily accessible to heterogeneous systems and formats (including future ones such as high-definition television), and users should work at their desktops without any awareness of its operations. In short, the network must be flexible and transparent.

These characteristics are achieved through the use of standards, the rules that enable systems to "talk" to each other. When different systems use different local formats, standards provide them with a common interchange language. Various standards are used in different layers of

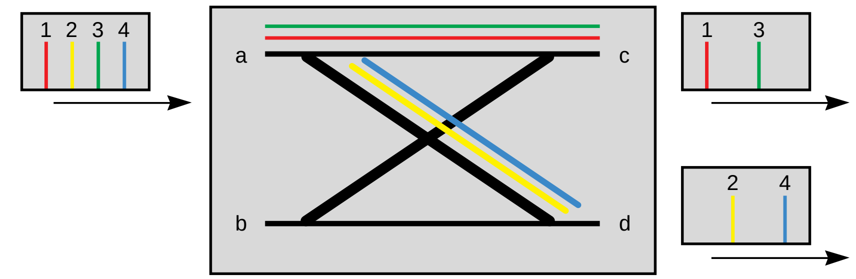


Figure 3. Uniphase Telecommunications, an NTON consortium participant, is developing an acousto-optic tunable filter (at right) whose function is illustrated above. Its ability to switch or block wavelengths enables their reuse, and thus the volume of information being switched through the system can increase indefinitely.

the network architecture to provide a hierarchy for signal transmission. The hierarchical process may be compared to having sheets of paper packaged into envelopes and delivered to an envelope handler who repacks them into boxes of envelopes, which are delivered to a box handler to turn into boxes of envelopes inside trucks, and so on through the delivery sequence until the packages arrive at their destination, where the reverse process yields the sheets of paper to the addressee.

NTON uses two standards developed specifically for advanced networks. First, signals from various user formats such as video, data, and voice are fed into the network and converted into a standardized common format by means of the Asynchronous Transfer Mode (ATM) standard. ATM not only makes the signals insensitive to transmission format, it also assigns transmission space and priority according to the needs of the terminals, thereby making best use of network capacity and efficiency. After ATM, the signals must undergo another conversion to package them for optical-fiber transmission. This packaging is the function of the Synchronous Optical Network (SONET) standard.

SONET is particularly efficient. It keeps a signal and its management information together, and it synchronizes signals to a common clock to simplify handoff between the networks worldwide. These features make the signals easily and quickly extractable for distribution or routing. The SONET signals are the ones that are transmitted over one of the switchable wavelengths of the optical layer.

Demonstration Applications

The applications being tested on the network run the gamut from accessing digital libraries to accessing offshore geophysical data via satellite, from on-line collaborations on manufacturing design to remote processing or visualization of radiological records, angiogram analyses, motion rehabilitation therapies, and tomography images.

Recently, SRI's Terra Vision, a three-dimensional terrain visualization program that runs on a high-performance graphics workstation, used the network to access multiple remote data servers; obtain real-time, high-quality terrain and battlefield data from these various locations; and transmit them as a computer visualization to another remote site. The visualization was a helicopter pilot's roving-eye view of terrain in a military installation.

Another demonstration of the network involved an advanced simulation of magnetic fusion plasma turbulence, which was run in real time on a Cray supercomputer at Livermore and displayed on a high-performance graphics terminal at a conference booth in San Jose. The test illustrated that with high bandwidth, remote visualization of supercomputing simulations was possible.

More of these futuristic applications are on the way, and the work of NTON aims at making them happen sooner rather than later.

—Gloria Wilt

Key Words: acousto-optic tunable filter (AOTF), Asynchronous Transfer Mode (ATM), fiber optics, National Transparent Optical Network (NTON), remote visualization, standards, Synchronous Optical Network (SONET), wavelength division multiplexing (WDM).

For further information contact William Lennon (510) 422-1091 (wjlennon@llnl.gov).

Patents and Awards

Each month in this space we report on the patents issued to and/or the awards received by Laboratory employees. Our goal is to showcase the distinguished scientific and technical achievements of our employees as well as to indicate the scale and scope of the work done at the Laboratory.

Patents

Patent issued to	Patent title, number, and date of issue	Summary of disclosure
Nicholas J. Colella Joseph R. Kimbrough	**Radiation-Tolerant Imaging Device** U.S. Patent 5,576,561 November 19, 1996	An apparatus and method for improving the performance of charge-coupled devices (CCDs) in the presence of ionizing radiation. A wafer-scale charge isolation technique inhibits or reduces the flow of electrons created by the passage of ionizing radiation in the bulk regions of a silicon CCD. Used in devices operating in the infrared wavelength band, the technique prevents a charge from reaching the active charge collection volume of a pixel in a CCD. Because the only process changes required are at the wafer level, a manufacturer's normal semiconductor processing and testing can be applied; incremental costs are minimal.
John F. Cooper	**Production of Zinc Pellets** U.S. Patent 5,578,183 November 26, 1996	A method for producing zinc pellets of uniform size and shape for use in zinc–air fuel cells having a stationary or moving slurry zinc particle electrode. The method involves the cathodic deposition of zinc from zinc-containing electrolyte, a zinc–air-fuel-cell reaction product. The zinc is deposited on an electrode substrate to which the zinc does not adhere, e.g., stainless steel or magnesium. The mossy zinc may be removed from the electrode substrate by the action of gravity, entrainment in a flowing electrolyte, or mechanical action. The finely divided zinc particles are pressed into pellets and are returned to the fuel cell in a pumped slurry.
Thomas J. Karr Lee C. Pittenger	**Projectile Stopping System** U.S. Patent 5,578,784 November 26, 1996	A projectile interceptor that launches a projectile catcher into the path of a projectile. Signals indicative of the path of a projectile are received by the projectile interceptor. A flinger mechanism has a projectile catcher that can be launched from the flinger mechanism. A controller connected to the flinger mechanism uses the signals indicative of the path of the projectile to determine the launch parameters of the projectile catcher. The controller directs the flinger mechanism to release the projectile catcher, launch it into the path of the projectile, and intercept the projectile.
Glenn A. Meyer Marcus A. Schildbach	**Carbide and Carbonitride Surface Treatment Method for Refractory Metals** U.S. Patent 5,580,397 December 3, 1996	A process for the refractory treating of the surfaces of metal components used in aerospace, automotive, petroleum, and chemical processing applications to improve abrasion and corrosion resistance. The components are placed in a reaction chamber, which is evacuated and heated to 800–1,400°C. A reaction mixture of nitrogen gas and hydrogen gas and/or water vapor is induced into the chamber and maintained at a partial pressure at which a carbide or carbonitride surface preferentially forms on the component. The mixture is held at that partial pressure long enough for the surface that forms to harden.
Thomas E. McEwan	**Range Gated Strip Proximity Sensor** U.S. Patent 5,581,256 December 3, 1996	A sensor using one set of sensor electronics and a distributed antenna or strip that extends along a perimeter to be sensed. A micropower radio-frequency transmitter transmits a sequence of pulses on the strip to form a sensor field. A receiver and detector circuit at the opposite end of the strip detect motion or presence within a sharply bounded radial region around the strip by mixing the radiofrequency signal carried on the line with reflected signal from a target. The strip forms a leaky transmission line. The detection range is continuously adjustable from nearly zero to several tens of feet by changing the duration of the radio-frequency pulses, which last less than 10 nanoseconds. The sensor is particularly suitable for low-cost volume applications, such as automotive parking assistance and home security.
Conrad M. Yu	**Microminiature Gas Chromatograph** U.S. Patent 5,583,281 December 10, 1996	A microminiature device used to identify the molecular composition of a gas. It features a gas injector system that is contained within two silicon wafers bonded together and that includes two normally open injector valves and one normally closed injector valve, The valves are made of flexible silicon nitride. Carrier gas is drawn through the normally open valves into a gas chamber. A pressure pulse forces a membrane to bulge down into the chamber, which then forces the normally open valves to close and the carrier gas to flow through a channel, past the normally closed valve and into the analysis column. Sample gas to be analyzed is pumped into the injector system at a higher pressure than that of the carrier gas and opens the normally closed silicon carbide valve. The sample gas flows into the channel and thence to the column for separation analysis.

Awards

George Caporaso, Kwok-Tsang Cheng, Alex Friedman, Dieter Schneider, Thomas Weaver, and **George Zimmerman** were named **Fellows** of the **American Physical Society**.
Caporaso, project leader for the Advanced Radiography Machine/Experimental Test Accelerator-II Project, was cited by the APS for "original contributions to the design and analysis of high-current electron accelerators, especially for instability studies which have greatly extended the utility of induction linacs."
Cheng, a designer in the Defense and Nuclear Techologies Directorate, was cited for "important contributions to the theory of atomic structure and dynamics, particularly to the understanding of relativistic and quantum-electrodynamic effects in highly charged ions."
Friedman, who is a project leader for fusion research, was cited for "innovations in computer modeling of fusion plasmas, laser–plasma interactions and charged particle beams, and design of high space charge accelerator components."
Schneider, a physicist in the Physics and Space Technology Directorate, was cited for "contributions to the understanding of ion–atom collisions through electron spectroscopy and for his experiments elucidating the collision dynamics of very highly charged ions."
Weaver, a physicist in the Physics and Space Technology Directorate, was elected because of "his crucial contributions to our understanding of massive stars and their evolution, supernovae, and the origins of the chemical elements."
Zimmerman, leader for the Inertial Confinement Fusion Code Development Group in the Physics and Space Technology Directorate, was cited for "his creation, and subsequent development of the LASNEX simulation code, which has been used extensively to guide the development of the National ICF Program, from its inception to this day."

John Nuckolls, former Laboratory Director, and **Charles McDonald,** Associate Director at Large, will receive the **Secretary of Defense Outstanding Public Service Award** for their help in conducting the first-ever assessment of the health of the nation's nuclear stockpile. The U.S. Strategic Command announced that they were among the eight recipients being honored for their work as members of the Strategic Advisory Group.

Laboratory employees have garnered three awards for **excellence in technologies that led to products in the marketplace** from the **Federal Laboratory Consortium** of Sequim, Washington. The winners, all of whom are from the Laser Programs Directorate, are: physicists **Luis Zapata** and **Lloyd Hackel** and former Laboratory technology transfer official **Damon Matteo** for their work with Intevac Inc. of Rocklin, California, on a machine to help manufacture flat-panel displays; electronics engineer **Tom McEwan**, now a part-time consultant for the Laboratory, with technicians **Pat Welsh** and **Greg Dallum**, for their assistance to companies that have licensed McEwan's popular short-pulse micropower impulse radar as an electronic dipstick; and physicists **Booth Myers** and **Hao-lin Chen** along with engineers **Glenn Meyer** and **Dino Ciarlo** for collaborating with American International Technologies Inc. of Torrance, California, in developing a new electron-beam system for processing materials.

Theoretical physicist **Charles Alcock** is the recipient of the 1996 **E. O. Lawrence Award** in physics for his distinguished leadership in the hunt for dark matter, a leading mystery in astronomy. The award, which is presented annually by the Department of Energy, cites Alcock's "scientific and technological leadership in making the first definitive observations of massive compact halo objects (MACHOs) that may account for a significant fraction of dark matter in the universe." (See the April 1996 *S&TR*, pp. 6–11, for a report on Alcock's work.)

U.S. Government Printing Office: 1997/583-059-60013