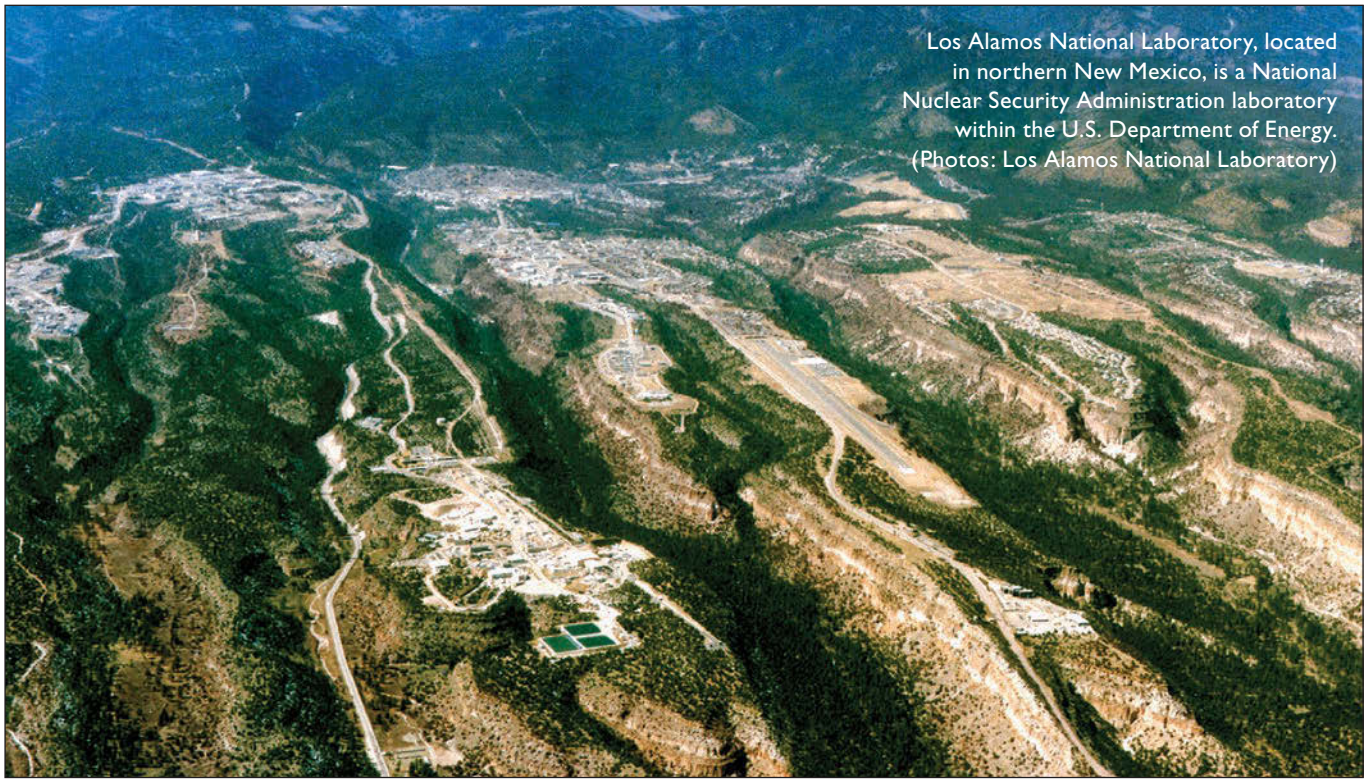


Los Alamos National Laboratory, located in northern New Mexico, is a National Nuclear Security Administration laboratory within the U.S. Department of Energy. (Photos: Los Alamos National Laboratory)

Los Alamos: Meeting the IAEA's evolving safeguards needs

For 50 years, Los Alamos National Laboratory has provided end-to-end international safeguards support to the IAEA, including developing technology, training inspectors, and providing experts.

By Nina D. Rosenberg and Stacey L. Eaton

When G. Robert Keepin returned to Los Alamos Scientific Laboratory (now known as Los Alamos National Laboratory) in 1965 after serving for two years at the International Atomic Energy Agency, he knew that the United States needed to play a bigger role in the IAEA's emerging safeguards mission. Keepin—who was a national delegate to the First United Nations Atoms for Peace Conference in Geneva, Switzerland—was a true visionary. While at the IAEA, serving first as a senior research physicist and then as head of the Physics Section, Keepin recognized that nuclear measurement techniques could be used to detect and assay nuclear materials to promote the safeguards that the IAEA was establishing. Keepin believed that the United States should take a lead in this key area and that Los Alamos was the right place to grow safeguards science and technology because of its unique nuclear weapons mission. In short, Los Alamos had both the expertise and the facilities necessary for the required research and development effort. The lab's director at the time, Norris Bradbury, agreed.

While Los Alamos is not the only U.S. organization supporting international safeguards, the experts working here on the high-desert mesa, 7,000 feet above sea level, have made very significant contributions over the past 50 years, contributions made possible through the support of the U.S. National Nuclear Security Administration's Office of Defense Nuclear Nonproliferation and the U.S. State Department. Los Alamos has supported the IAEA since the agency's beginnings by developing technology, training inspectors, and providing experts. In addition, Los Alamos is home to one of 18 analytical laboratories located outside of Austria in nine different IAEA member states that make up the IAEA Network of Analytical Laboratories.

The beginning

The IAEA was established in 1957, following President Eisenhower's December 1953 "Atoms for Peace" speech at the United Nations, to promote the peaceful use of nuclear technology while ensuring that the assistance provided would not be

Nina D. Rosenberg (<nina@lanl.gov>) is the Program Director for Nuclear Nonproliferation and Security, and Stacey L. Eaton (<seaton@lanl.gov>) is the Nonproliferation and Nuclear Engineering Division Leader, both at Los Alamos National Laboratory.

used to further develop nuclear weapons. To carry out this mandate, the IAEA was authorized to establish and administer international safeguards, a set of technical measures through which the IAEA seeks to independently verify member states' declarations to ensure that nuclear facilities are not misused and that nuclear material is not diverted from peaceful uses. Later, Article III of the Treaty on the Nonproliferation of Nuclear Weapons required that all nonnuclear-weapon states accept IAEA safeguards. Today, 182 states have safeguards agreements in force. IAEA safeguards needs and challenges have continued to evolve as a result of technological changes, practical experience, and the need to strengthen effectiveness and improve efficiency. [1]

After Keepin's return from Vienna, he argued that Los Alamos needed to take a central role in promoting safeguards, and the Los Alamos Safeguards R&D Program was launched on December 1, 1966. Six months later, the U.S. Atomic Energy Commission (AEC) established the Office of Safeguards and Material Management at its Washington, D.C., headquarters, as well as the new Division of Safeguards in the AEC Regulatory Branch (now the Nuclear Regulatory Commission). Los Alamos hosted the first international safeguards technology conference in 1969, with participation by many U.S. and foreign institutes. In the early 1970s, the Los Alamos Nuclear Safeguards program became the premier safeguards R&D effort in the United States and abroad. The international program benefited greatly from strong synergy between the needs of the IAEA for safeguards technology and the needs of Los Alamos for better material control and accountancy for its own nuclear material, as well as the material accountancy needs at other U.S. nuclear facilities. [2]

Developing technology

Los Alamos pioneered a wide range of IAEA measurement tools that are in use today, in particular its nondestructive assay (NDA) instrumentation for quantifying nuclear material inventories. NDA systems, which provide a rapid, nonintrusive characterization of nuclear material, have traditionally been the backbone of the IAEA mission to confirm the accuracy of a nuclear facility operator's declaration of nuclear material holdings. The IAEA uses more than 100 different NDA systems to verify, check, and monitor nuclear materials. These NDA instruments range in size and complexity from small portable units used by safeguards inspectors during on-site verification activities to large *in situ* systems designed for continuous unattended use at nuclear facilities.

Gamma and neutron detectors are the fundamental instruments upon which Los Alamos safeguards technology development has grown over the past decades. Most of the safeguards challenges being addressed today, including unattended and remote monitoring, portable detectors for in-field measurements, material holdup, and modeling for optimizing safeguards equipment, have their origins in instrumentation pioneered at Los Alamos in the 1960s and 1970s.

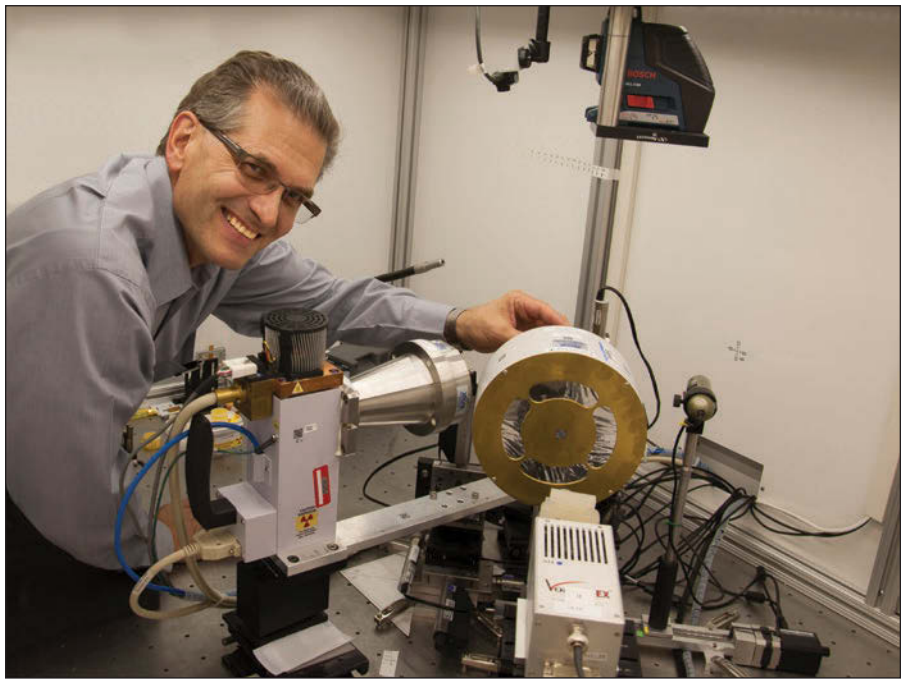
In addition to the instruments themselves, Los Alamos has been deeply involved in the development, and often the commercialization, of specialized data acquisition electronics and analysis software to support NDA systems. The software in routine use at the IAEA for neutron assay measurements—the IAEA Neutron Coincidence Code—is a Los Alamos development, as is the gamma analysis software FRAM.

Los Alamos experts have continued to develop new safeguards technology, often through engagement with partners in other countries. Johnna Marlow, Los Alamos program manager for International Nuclear Safeguards, notes in particular the long-standing and successful safeguards technology development partnership between Los Alamos and Japan, a nonnuclear-weapon state with full nuclear fuel cycle civilian facilities and, therefore, significant safeguards obligations under the international nonproliferation regime. According to Marlow, "Many of the safeguards systems designed in the 1980s and 1990s are being leveraged currently for the large-scale commercial fuel cycle facilities in Rokkasho, Japan. As Japan moves toward operation of its commercial spent fuel reprocessing plant and completion of its mixed uranium-plutonium oxide (MOX) fuel fabrication plant (J-MOX), Los Alamos remains closely engaged."

Los Alamos collaborates with many international partners to strengthen safeguards. To improve the capability of NDA techniques for safeguarding spent fuel, for example, we partner with Sweden and Euratom, working together on joint field tests. Other examples include our long-standing, productive relationship working with colleagues in South Korea on safeguards technology development, and our partnership with Ukrainian scientists and engineers on Chernobyl safeguards issues. A predecessor to the uranium enrichment monitor identified in the Joint Comprehensive Plan of Action with Iran was developed by Los Alamos in collaboration with URENCO and field tested at Capenhurst, in the United Kingdom.

One promising new technology is high resolution X-ray (hiRX) assay, which is being developed by Los Alamos chemist George Havrilla. It offers a novel NDA approach for plutonium quantification in spent fuel matrices that is rapid, accurate, and precise. The current uncertainty of the measurement is less than 5 percent, with the ultimate goal of less than 1 percent. Initial performance testing conducted at the Savannah River National Laboratory analytical facility with spent nuclear fuel has been very encouraging. Havrilla won an award for his presentation on this technology at the 2014 IAEA Symposium on International Safeguards, held in Vienna.

An example of synergy between the safeguards mission and the other missions



Los Alamos chemist George Havrilla pictured with the hiRX breadboard system for development and feasibility testing.

of Los Alamos is laser-induced breakdown spectroscopy (LIBS), a technology that can determine the elemental composition of the target from more than 20 feet away. LIBS was originally developed to look for material within gloveboxes at the lab's plutonium facility. A backpack LIBS unit has been developed for consideration by the IAEA to address the needs of environmental sampling and analysis for international safeguards. (LIBS is also the basis for the ChemCam laser unit on the current Mars Curiosity rover; the next-generation SuperCam instrument has been selected for the Mars 2020 mission.)

In addition to developing hardware and software, Los Alamos experts have supported the development and evaluation of safeguards concepts and approaches as they have evolved over time. This has included the development of advanced facility-level approaches for emerging nuclear fuel cycle facilities, such as pyroprocessing, and strengthened safeguards that take advantage of authorities derived from the Additional Protocol. From the IAEA's Integrated Safeguards program through the current State Level Concept, Los Alamos has innovated and expanded the use of acquisition path analysis for safeguards planning and evaluation. These efforts are focused on the overall performance of safeguards as a system in providing timely detection of proliferation.

Training inspectors

Los Alamos has long been instrumental in helping IAEA inspectors become fluent in performing NDA measurements critical to their mission. Since it began domestic safeguards training in 1973, Los Alamos has conducted over 320 courses, training more than 5,600 people from a variety of domestic and international agencies and backgrounds. Training IAEA inspectors is a significant part of the lab's more general safeguards training program and a core element of its support for the IAEA.

The "signature" class at Los Alamos for IAEA inspectors is the basic NDA Inspector Training course, which was initiated in 1980 and has been offered more than 60 times to date. Since 1980, all new IAEA inspectors (more than 800) have taken the Fundamentals of Nondestructive Assay course at Los Alamos as part of their core training. The goal of this course is to teach inspectors the underlying fundamental physics of NDA measurement techniques and have them gain experience in performing measurements and assessing the quality of the results.

This course begins with lectures on the fundamentals of NDA measurements. The main focus, however, is on hands-on laboratory exercises and includes gamma-ray and neutron-based NDA measurement techniques of both uranium and plutonium. Instrumentation for the class includes NaI, LaBr, and HPGe detectors for the gamma ray–based measurement techniques and an assortment of neutron instruments using He-3 detectors (High Level Neutron Coincidence Counter [HLNCC], Active Well Coincidence Counter [AWCC], and Uranium Neutron Collar [UNCL]) for the neutron-based measurement techniques.

Bill Geist, current safeguards technology training coordinator at Los Alamos, explains nuclear detection concepts to class participants.

According to Bill Geist, who heads the safeguards training program at Los Alamos, "The strength of this course is the quality of the Los Alamos instructors—Los Alamos technical experts who are actively involved in the research, development, and application of NDA instrumentation, and some of whom have also worked at the IAEA." Geist returned to Los Alamos to take this position in 2015 after spending three years at the IAEA in Vienna as a nuclear instrumentation training expert in the Department of Safeguards.

Furthermore, the class uses an extensive inventory of real nuclear material, which represents both typical materials that an inspector may encounter during an inspection and unusual material that an inspector should not encounter. Standards in the class include pure and impure plutonium of varying burnup, uranium standards of varying enrichment, a fresh fuel assembly, and a Materials Testing Reactor fuel assembly. Training with a set of materials allows an inspector to be able to differentiate between typical nuclear materials that occur in a peaceful nuclear program and the unusual nuclear material that may be indicative of nonpeaceful uses.

Since the mid-1990s, Los Alamos has also hosted courses on Advanced Plutonium Verification Techniques for the IAEA. These courses are intended for senior inspectors who are responsible for performing inspections in facilities that handle plutonium. The training is focused on neutron- and gamma ray–based NDA techniques to verify plutonium items.

Los Alamos staff have also been involved in a variety of other IAEA training activities outside of Los Alamos. For example, in the past, Los Alamos instructors traveled to Vienna to support the Introductory Course for Agency Safeguards. In addition, Los Alamos hosted an IAEA Small Quantities Protocol Training Course in Santa Fe, N.M., and co-organized with the IAEA several previous offerings of the class. Los Alamos staff also participated in and helped organize many offerings of the State Systems of Accounting and Control courses for IAEA member states from the late 1970s until about the mid-2000s. Los Alamos experts also conducted training on unattended and remote monitoring systems at the IAEA from the mid-1990s through 2014.

Los Alamos also offers a wide range of nuclear safeguards training classes to individuals from domestic and international organizations other than the IAEA. These classes include Advanced Hands-On Gamma-Ray NDA Techniques, Advanced Hands-On Neutron NDA Techniques, Plutonium Calorimetric Assay, NDA Holdup Measurements of Special Nuclear Materials, Statistical Concepts in Nuclear Safeguards, and Material Accounting in

Participants in the 59th IAEA Nondestructive Assay Inspector Training Course at Los Alamos in 2016

Nuclear Safeguards. Variations of these courses are also offered to international partners through bilateral engagements.

Providing experts

Ever since Keepin returned from his assignment at the IAEA, Los Alamos experts have been supporting the IAEA Department of Safeguards (as well as other departments at the agency) by taking leaves of absence from their jobs to take temporary assignments in Vienna. Los Alamos experts at the IAEA come from a broad range of backgrounds, including those with expertise in NDA, electronics, statistics, software, training, and nuclear physics and engineering. Staff spend from one to seven years at the agency. According to Nancy Jo Nicholas, an associate director at Los Alamos, this is a three-way win. "Los Alamos staff members provide a valuable service to the IAEA while advancing their individual careers," she said, "and they return to Los Alamos with valuable new knowledge and insights on the needs and workings of the IAEA, which allows us to better support the agency."

In the past 10 years, approximately 25 Los Alamos employees have taken assignments at the IAEA, with an average of 10 Los Alamos staff working in Vienna at any one time. Most of these experts are supported as cost-free experts, which are extra-budgetary positions with salary and benefits reimbursed by the United States. These assignments, as well as all U.S. technical support to the IAEA's Department of Safeguards, are overseen by the U.S. Support Program and are coordinated by the International Safeguards Project Office at Brookhaven National Laboratory, regardless of the source of funding.

In addition to their taking temporary assignments at the IAEA, Los Alamos experts are often asked to go to Vienna for short-term consultancies on specialized topics, such as nuclear forensics, insider threat, or radiological source use and disposal. A Los Alamos safeguards expert is currently serving as the U.S. member of the Standing Advisory Group on Safeguards Implementation, providing technical advice to the IAEA director general on policies and procedures.

NWAL

Los Alamos is home to one of the analytical laboratories located outside of Austria that make up the IAEA Network of Analytical Laboratories (NWAL). Los Alamos supports the IAEA's environmental safeguards program by providing routine fission/activation product and actinide isotopic and concentration measurements. Environmental samples—usually 10 cm × 10 cm cotton- or cellulose-based swipes, are collected by IAEA inspectors during inspections at sites around the world for verification purposes. These samples are returned to the IAEA safeguards laboratory in Seibersdorf, Austria, where they are packaged, logged, screened, and distributed to the network laboratories.

Los Alamos chemists analyze 25–40 swipes per year using state-of-the-art radiochemistry, gamma-ray, and mass spectrometry techniques. Radiochronometry (age determination) and trace element analysis services are provided on an as-needed basis. In addition, subject matter experts from Los Alamos have provided technical expertise to the IAEA for facility design, construction, and operational protocol development, as well as on-site training for radiochemistry and mass spectrometry technical staff.

The next 50 years

We at Los Alamos are proud of our 50-year legacy in international safeguards supporting the IAEA. The next 50 years promise to continue to be challenging. Advanced fuel cycle facilities with high throughputs will need approaches that extend beyond the accountability of traditional materials to include additional safeguards measures, such as process monitoring. Making use of the ever-expanding availability of information and data analysis capabilities will be valuable in understanding nuclear programs, and yet, information and cyber vulnerabilities raise new concerns.

A key objective of the current international safeguards program at Los Alamos is to continuously adapt to deal with evolving needs and challenges. We are actively developing the next generation of safeguards professionals who will help us continue our program of developing technology, training inspectors, and providing experts, as well as maintaining our IAEA NWAL capabilities. We look forward to seeing what the future holds.

References

1. <www.iaea.org/sites/default/files/safeguards_web_june_2015_1.pdf>

2. For further reading, see G. Robert Keepin, "Nuclear Safeguards—A Global Issue," and Roddy B. Walton and Howard O. Menlove, "Nondestructive Assay for Nuclear Safeguards," both in *Los Alamos Science,* Vol. 1, No. 1, Summer 1980. NN