tability and control systems, many quite similar to DYMAC, are being tested and evaluated at a number of nuclear facilities in the US and abroad. As these in-plant test and evaluation programs are completed, the resulting technology and operational experience will be available for introduction into various types of domestic and international fuel-cycle facilities.

Emergency Response and Recovery

Its excellent record notwithstanding, if a safeguards system should fail and nuclear materials are missing from a facility, there must clearly be a demonstrated response capability to recover materials rapidly, and to apprehend the offender. Likewise, an emergency response plan and demonstrated field-operational capability is essential in responding to nuclear emergencies, accidents, acts of terrorism, blackmail, and sabotage. LASL's special qualifications and experience in both national defense programs and safeguards technology provide a unique capability for innovative design and development of instrumentation for surveillance and search-and-recovery applications. This capability includes the design of hand-held monitors for searching personnel and vehicles at facility-access areas and the development, testing, and evaluation of SNM portal monitors, vault monitoring systems, and enclosure detector arrays. It also includes passive and active NDA techniques for SNM identification and verification as applied, for example, to a variety of thorny problems that arise in safeguarding SNM movements into and out of a rigidly proscribed "perimeter" around sensitive technology areas in domestic or international fuel-cycle facilities, or in safeguarding defense-related activities and facilities.

A major component of emergency-response capability is the NEST—Nuclear Emergency Search Team—activity. This program provides emergency response to incidents of nuclear extortion, nuclear weapon accidents, lost or stolen nuclear materials, and terrorist threats. Portable and mobile nuclear detection systems having high sensitivity and real-time data processing and analysis capability have been developed and deployed for field test, evaluation, and operational use. A related effort involves the development and field testing of instrumentation and procedures for detection, diagnosis, and disabling of improvised or otherwise unknown nuclear devices. Suffice it to say, these efforts require extensive coordination with other DOE laboratories and federal agencies, primarily the FBI and the Department of Defense, all of whom share with LASL major responsibilities in the nation's emergency response system.

The 1980s as the Decade of Technology Transfer

If the 1970s can be regarded as the decade of modern safeguards technology development, the 1980s must be the decade of the transfer of this technology to nuclear facilities—both existing and new. As indicated in Table III, interactions between the LASL program and nuclear facilities of all types, in both the government and private industry sectors, involve the gamut of safeguards R&D activities from instrument development, calibration, test, and in-plant evaluation to the design, optimization, and performance analysis of overall facility safeguards systems. On the international level, there is growing interest, particularly among other industrialized nations, in the design, optimization, and practical in-plant implementation of integrated safeguards systems incorporating state-of-the-art materials

TABLE III

LASL INTERACTION WITH US FUEL CYCLE FACILITIES

Fuel Cycle Facilities	MC&A[a] Systems Studies	Location for Test and Evaluation of NDA Instrument	Process Info to LASL	LASL Instrument Specs to Vendor or Facility	Training	Consultation
Fuel Fabrication						
Westinghouse Corporation	●	●	●	●	●	●
General Atomic Company		●	●	●	●	●
General Electric Corporation		●	●	●	●	●
Nuclear Fuel Services			●	●	●	●
Babcock & Wilcox				●	●	●
Spent-Fuel Reprocessing						
Allied-General Nuclear Services	●		●	●	●	●
INEL, Idaho Falls		●	●		●	●
Oak Ridge National Laboratory	●		●	●		●
Savannah River Plant	●	●	●		●	●
Nitrate-to-Oxide Conversion						
Allied-General Nuclear Services			●	●	●	●
Savannah River Plant	●	●	●		●	●
General Electric Company	●		●		●	●
Rocky Flats Plant			●	●		
Waste Handling and Solidification						
Allied-General Nuclear Services			●		●	●
SROO-SRL	●		●		●	●
INEL, Idaho Falls			●	●	●	●
Rockwell, Hanford			●	●	●	●
Uranium Enrichment						
Union Carbide	●	●	●	●	●	●
Goodyear Atomic		●	●	●	●	●
TRW	●		●			●
LLL, Livermore	●		●			●
Critical Facilities						
Argonne National Laboratory	●	●	●	●	●	●
Nuclear Instrumentation Vendors				●	●	●

[a]Materials control and accountability.

measurement and accountability technology, materials control, and physical security including effective use of containment and surveillance techniques.

A major component of effective technology transfer is education and training in the use of modern NDA instrumentation and information-handling and analysis systems. The entire area of safeguards professional training has received marked impetus from the Three Mile Island nuclear reactor accident and the resultant three main "lessons learned": the need for (1) better professional training of reactor operators, (2) better measurement instrumentation, and (3) better emergency response. One notable example of the effective transfer of modern safeguards technology to plant operators and safeguards inspectors alike is DOE's ongoing Safeguards Technology Training Program conducted by LASL through four separate course offerings per year:

1. **Fundamentals of Nondestructive Assay of Fissionable Material Using Portable Instrumentation.**
2. **In-Plant Nondestructive Assay Instrumentation (to be succeeded in 1981 by a course on advanced instrumentation based on neutron detection methods).**
3. **Gamma-Ray Spectroscopy for Nuclear Materials Accountability.**
4. **Advanced Systems for Nuclear Materials Accounting.**

These training courses attract well over 100 participants annually. Participants from the United States represent both the government and private sectors and those from the IAEA inspectorate represent a large number of countries around the world.

Technology transfer and assistance to the IAEA encompasses not only development, test, and evaluation of instruments, but also personnel training (of highest priority to IAEA), technical consultation, and direct assistance to the IAEA safeguards staff by visiting consultants and resident experts on loan from member states. Two examples are US participation in the IAEA International Working Group on Reprocessing Plant Safeguards and in the IAEA Advisory Group on Fuel Element Fabrication. Both groups are concerned with the application of IAEA safeguards to the advanced large-scale fuel-cycle facilities that are foreseen for the future. Four LASL safeguards staffers are currently assigned to the IAEA Department of Safeguards at Agency headquarters in Vienna.

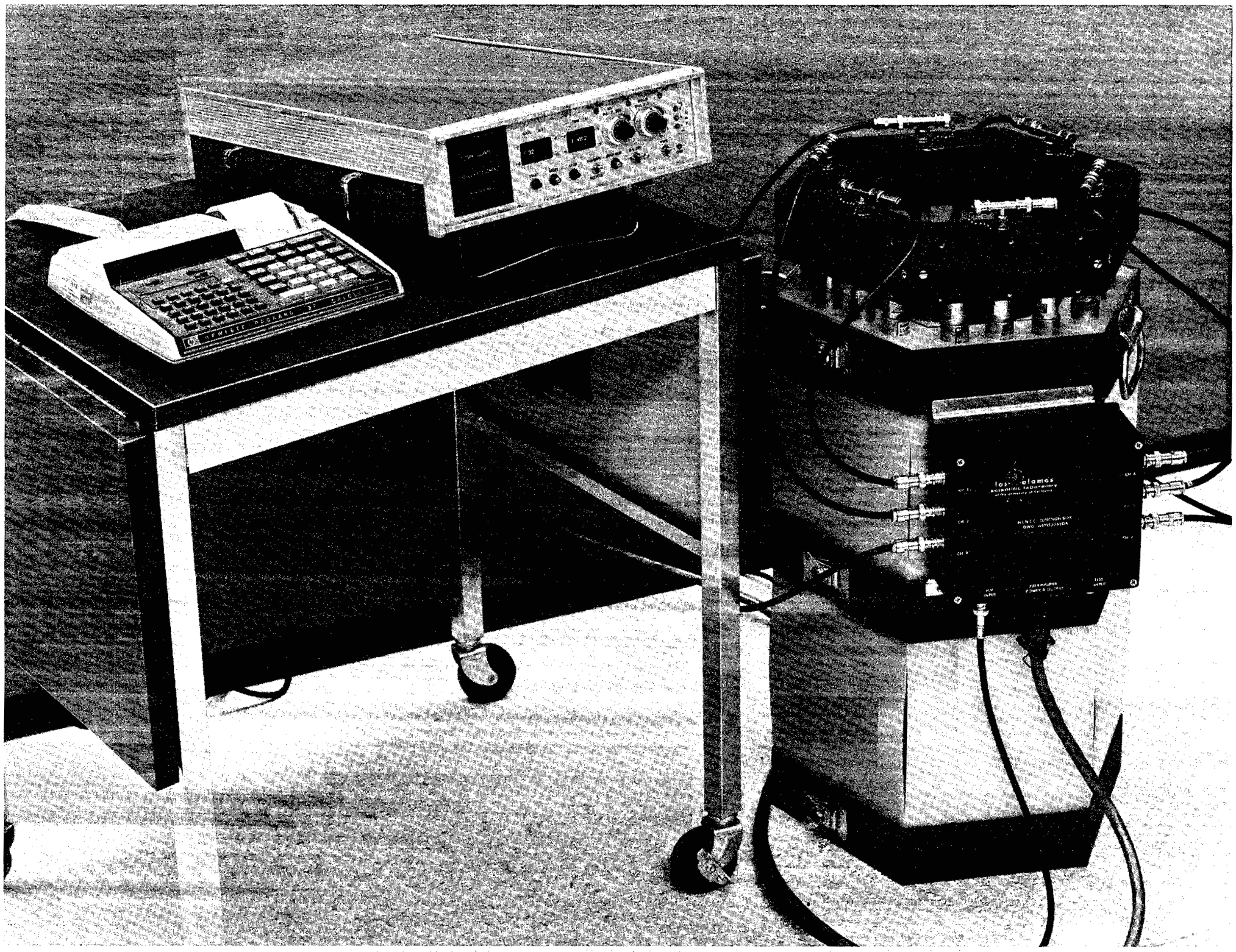
A new component in the safeguards technology transfer program at LASL is the International Training Course on Nuclear Materials Accountability sponsored by DOE in cooperation with IAEA. This course, authorized by the US Nuclear Non-Proliferation Act, was conducted May 27-June 6, 1980, at Bishop's Lodge near Santa Fe, New Mexico. The course provided to foreign governmental and institutional managers the basic knowledge needed to develop national safeguards regulations and requirements for their individual countries, and to plan toward implementation of domestic safeguards systems that will serve national needs as well as those of the IAEA International Safeguards System of inspection and verification. Lecturers for the course were experts drawn from the IAEA, United States, Canada, Czechoslovakia, Germany, and Japan. Delegates from over 25 countries participated in the course. A similar DOE/IAEA-sponsored course on the physical protection of nuclear materials is conducted by Sandia Laboratories each fall.

Emerging Impact and Role of International Safeguards

Recent expansion of the US safeguards program in areas of technical support for the IAEA and cooperative agreements with other countries reflect the growing importance of international safeguards. IAEA needs can be grouped into two major categories: (1) present requirements for portable measurement instrumentation, inspection and verification capability in direct field inspection applications (for example, the HLNCC instrument shown in Fig. 4) and (2) future requirements for methods, instruments, and techniques to be developed for independent verification of different types of advanced in-plant material accountability and control systems, such as DYMAC.

A major international effort is the TASTEX program, in which the United States, Japan, and IAEA are participating jointly in the development, test, and evaluation of advanced instrumentation and safeguards techniques at the Tokai spent-fuel reprocessing plant in Tokai Mura, Japan. In this program, a K-edge densitometer is used for nondestructive assay of plutonium nitrate product solution. The densitometer, which measures *elemental* (total plutonium) concentrations in solutions, provides a valuable complement to gamma-ray spectrometry, which measures plutonium *isotopic* composition. Successful in-plant experience with this type of new NDA instrumentation is expected to lead to the deployment of a wide range of automated NDA instruments at nuclear processing facilities. This should, in turn, provide a sound technical basis for future implementation of near-real-time material measurement and accountability systems in various types of plants and facilities throughout the nuclear fuel cycle.

As regards the outlook for the future, it is significant that this first year of the 1980s will see a number of important developments in international safeguards and nonproliferation. In March, INFCE endorsed stringently safeguarded plutonium-based nuclear energy systems



for the future, including the judicious deployment of plutonium breeder reactors (again under strict safeguards and controls) as the only means of avoiding future shortages of uranium fuel. Today the total plutonium inventory of irradiated civilian reactor fuels is easily the order of 100 metric tons and is increasing at a rate of 25-30 tons per year. Although breeder reactors eventually will reduce this inventory, concerns about such potentially large stockpiles of plutonium—in whatever form—have given rise to several international studies

Fig. 4. The high-level neutron coincidence counter (HLNCC) detects neutrons from the spontaneous fission of ^{240}Pu using ^{3}He proportional counters in a polyethylene moderator. A shift register coincidence technique is used to distinguish fission neutrons from background. The instrument is portable for use by IAEA inspectors. The electronics to operate the detectors and analyze the coincidence data are contained in the package on the table, next to a programmable calculator that is interfaced to the shift register unit.

and evaluations, involving both technical improvements and institutional arrangements, designed to place sensitive materials and fuel-cycle facilities under multinational or international control.

Proposed institutional arrangements include (1) regional fuel-cycle centers, in which large fuel reprocessing and fabrication plants would be co-located to provide economy of size and operational efficiency and to minimize vulnerability to theft and diversion; (2) an international fuel authority responsible for providing fuel service and allocating fuel resources; (3) establishment of international plutonium storage centers under IAEA control (foreseen in the Agency's Statute, Article XII, A.5); and (4) the concept of regional nuclear waste repositories, fuel reprocessing plants, and enrichment facilities under international or multinational authority. Working out the details of any such international or multinational arrangements would be a monumental task indeed, and could only be done by the potential participants themselves. With such proposals, some of them strikingly similar to the international ownership/custody/management concepts in the original Baruch plan, we have, in some sense, come almost full circle in the evolution of international safeguards.

Also in this pivotal year, 1980, two important international safeguards agreements are pending ratification by the US Senate. The first is the US-Australian Agreement on the Peaceful Uses of Nuclear Energy, the first renegotiated safeguards agreement under the new, more stringent safeguards provisions of the NNPA. The second is the US-IAEA Agreement for the Application of IAEA Safeguards in the United States, pursuant to the US 1967 offer to implement IAEA safeguards in all US facilities except those having direct national security significance. A similar voluntary agreement, already in force with the United Kingdom, is enabling the IAEA to gain valuable experience in the inspection of a fast-breeder plant and related reprocessing facility. President Carter recently asked the US Senate to take up the US-IAEA Agreement this spring so that ratification can be completed before the (potentially contentious) NPT 5-year review conference of the 116 NPT signatory nations at Geneva in August of this year. The US-IAEA Agreement, an act of good faith on the part of the United States, may help to alleviate a certain hardening of position by some countries against the NPT, which some nations view as an unequal treaty that discriminates in favor of the nuclear-weapons states and thereby against all others.

To make the NPT as equitable and acceptable as possible, the IAEA is working hard to upgrade and standardize the applications of NPT "full-scope" safeguards. Measurement and surveillance techniques used by IAEA inspectors are being improved continually both by the IAEA staff and through technical support programs of the United States and other IAEA member nations. Also, through IAEA field-inspection experience, better methods of inspection, inventory verification, reporting, and assessment are being evolved constantly to maximize inspection efficiency and effectiveness while minimizing intrusion into plant operations and production. Implementation of the US offer to place its peaceful facilities under IAEA safeguards should do much to facilitate further improvement of the IAEA system.

Another key aspect of NPT acceptability and workability is the assurance of an available supply of nuclear fuel—at present, uranium. Irrevocable fuel supply assurances are essential to the fundamental *quid pro quo* of the NPT agreement and should be extended promptly to nations that meet their nonproliferation undertakings. Uncertainties and doubts about supply assurances in recent years have had serious repercussions throughout the world nuclear community. An oft-quoted international safeguards slogan succintly states the basic *quid pro quo* of the NPT Treaty: "Irrevocable safeguards for irrevocable supply."

As many have pointed out (especially to safeguards technologists!), there is no question that safeguards and nonproliferation issues are first and foremost a political problem. However, it is also clear that safeguards technology development, coupled with "real world" operational experience, is indispensable in (1) providing the technical understanding and input essential to prudent planning and decision making, even at the highest political levels, and (2) providing the demonstrated technical means to implement the hardware and systems called for in those plans and decisions. Within severe budget limitations, the IAEA is making every effort to anticipate and prepare for the sophisticated fuel cycles of the future and the commensurately sophisticated technical capabilities that will be needed to carry out its essential inspection and verification functions effectively.

In concluding, I can do no better than to cite a poignant and timely question posed in a recent National Academy of Sciences report:

Which represents the greater threat to peace? The dangers of proliferation associated with the replacement of fossil resources by nuclear energy, or the exacerbation of international competition for fossil fuels that could occur in the absence of an adequate worldwide nuclear-power program.

Many hope, as I do, that this first year of the new decade will prove to be a milestone of significant progress toward worldwide implementation of effective, workable, and acceptable nuclear safeguards as an indispensable, vital contribution to safe,and safeguarded,nuclear energy for the benefit of mankind.

THE AUTHOR

G. Robert Keepin joined the LASL staff (Critical Assemblies Group) in 1952 after being an Atomic Energy Commission Postdoctoral Fellow at the University of California, Berkeley, and a Consultant to Argonne National Laboratory and to LASL. He was a US Delegate to the First United Nations Atoms for Peace Conference in Geneva in 1955, and IAEA Technical Advisor to the Third Geneva Conference in 1964.

From 1963 to 1965 Keepin was with the Headquarters Staff of the International Atomic Energy Agency in Vienna. Following his return to the United States in 1965, he established the Nuclear Safeguards research and development program at LASL. In 1973 he received a Special Award for Nuclear Materials Safeguards Technology from the American Nuclear Society for his early recognition of the need for NDA instrumentation, his demonstration of practical passive and active assay methods, and his leadership in implementing these techniques and gaining wide acceptance for their use. He is now Program Manager at LASL for Nuclear Safeguards affairs.

Keepin is a Fellow of the American Physical Society and the American Nuclear Society and is National Chairman of the Institute of Nuclear Materials Management. He is widely published in the fields of nuclear and fission physics, reactor kinetics and control, and nuclear safeguards technology, and is an internationally recognized authority in the field of nuclear safeguards and nondestructive assay technology.

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