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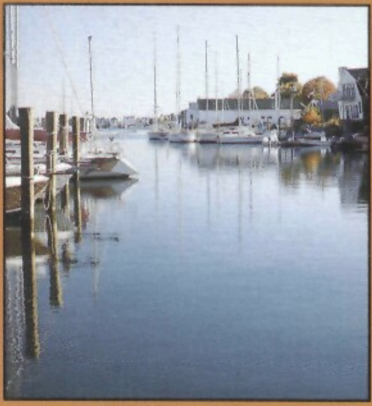

BROOKHAVEN NATIONAL LABORATORY

TECHNICAL SUPPORT ORGANIZATION

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On the Cover: Large photo: Brookhaven National Laboratory in 1969, around the time when the Technical Support Organization was formed. Small photo: A Long Island harbor scene.

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We've Come a Long Way

If all has gone as planned, in October I will be starting my second year as chairman. During this first year my goals have been to increase membership participation, complete committee charters and take a hard look at our management structure. I am happy to report that these goals or tasks will be completed. One indicator of increased participation is that we have identified vice-chairman for most of our committees. Unfortunately while increasing membership participation on committees the actual membership number slipped about 6%. (This is not a good sign.) With respect to committee charters the executive committee is scheduled to review final drafts at the annual meeting. Concerning management structure two ad-hoc committees were established. One to review what services we require or use and the second to evaluate how we fund the Institute. The committee reports will be presented at the Executive committee meeting in Orlando. If you have input on the future directions for INMM contact me or any of the Executive Committee. It is not too late to make INMM the professional society that you want it to be.

The coming year presents the INMM with some challenges which will require all of us to be involved. I have set a membership goal of 850. Putting that in perspective, if each member invites one new person to join, the success rate need only be 15% for us to achieve that goal. Surely we all know one person to ask and encourage to join. The Professional Recognition program will be in place. This program is Institute's solution to all the problems that surround the Certification Program. Paul Ebel has agreed to chair the committee working on this project. He needs your ideas, support and help if you are able. In all the columns I have written so far I have emphasized INMM's future. Without changing that focus I would like to document where we have been. I recently found

a copy of the proceedings from the first INMM annual meeting. Vince DeVito has encouraged me to gather information for a History of INMM. If you have material or are interested in doing a few years please give me a call at 513-865-3689 or FTS-774-3689. Last but not least on the agenda is to consider the recommendations of the ad-hoc committees on management structure and funding and to start planning for the Institute's fiftieth anniversary.

John F. Lemming
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This issue of the *Journal* celebrates the Twentieth Anniversary of the Technical Support Organization at Brookhaven National Laboratory. TSO marked the occasion of the anniversary by holding a Symposium and the papers are presented here. Our Technical Editor, Dr. William A. Higinbotham, "Willy," was there both at the beginning of TSO and the anniversary symposium. Brookhaven honored Willy at the Symposium by officially unveiling the William A. Higinbotham Safeguards Library at the site.

A New Challenge

While the whole world has an interest in arms control, the INMM interest is stronger because we are an international professional society engaged in safeguarding nuclear materials. The Intermediate-range Nuclear Force (INF) Treaty has focused the attention of several groups on arms control policy. As the policy issues have been discussed in meetings hosted by several organizations it has become obvious that future arms control agreements will rely on either bilateral or multilateral inspections. Until now the technology required for the inspection activities has received less attention than the policy. Many of the verification technologies share elements with the technologies used for safeguarding nuclear materials. INMM experience in inspection, surveillance, confirmation measurements, sampling strategies and so forth can help make arms control verification credible. Shouldn't the INMM provide a forum in its journal and annual meetings for these important discussions?

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U.S. Safeguards History and the Evolution of Safeguards Research and Development

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ABSTRACT

The nation's nuclear program which began during World War II was under strict military control for the development of atomic weapons. Congress passed the Atomic Energy Act of 1946 and transferred the nuclear programs from military control to civilian control, creating the Atomic Energy Commission as the new civilian agency, effective January 1, 1947.

In discussing the U.S. safeguards history and the evolution of safeguards research and development, five significant eras are identified. The period ending January 1, 1947, may be called the first era. Safeguards as known today did not exist and the classic military approach of security protection applied. The second era covers the period from 1947 to 1954 (when the Atomic Energy Act was completely rewritten to accommodate the then foreseen Civil Uses Program and international cooperation in peaceful uses of nuclear energy), and the first steps were taken by the Atomic Energy Commission to establish material accounting records for all source and fissionable materials on inventory. The third era covers the period 1954 through 1968, which focused on nuclear safeguards in its domestic activities and made major policy changes in its approach to material control and accountability. The fourth era, 1968 to 1972 saw a quantum jump in the recognition and need for a significant safeguards research and development program, answered by the formation of a safeguards technical support organization at Brookhaven National Laboratory and a safeguards Laboratory at Los Alamos Scientific Laboratory for the development and application of non-destructive assay technology. The fifth era had its beginning in 1972 with the burgeoning of international terrorism (e.g., the massacre of the Israeli athletes at the 1972 Olympic Games at Munich) and led to a major redirection of nuclear safeguards and an institutional combination of the separate offices of safeguards and of security into a single combined Office of Safeguards and Security, which continues today. The corresponding need for a strong physical protection research and development support program was responded to by the Sandia National Laboratory.

We are now entering an upcoming "sixth" and epochal era, characterized by a significant plant modernization effort, new and advanced technologies and systems, all framed and conditioned by major policy decisions concerning disarmament, INF, START, and other activities.

As we are all aware, the nation's nuclear program began during World War II in the Manhattan Engineer District Project, which was under strict military control for the development of atomic weapons. After the war ended, Congress passed the Atomic Energy Act of 1946 and transferred the nuclear programs from military control to civilian control, creating the Atomic Energy Commission as the new civilian agency, effective January 1, 1947. In discussing the AEC/ERDA/DOE safeguards policy history and evolution of the safeguards Research and Development program, this period ending January 1, 1947, may be called the first era. Safeguards as known today did not exist. Heavy reliance was placed on physical protection for classified information, and the classic military approach of security protection applied. Only one class of safeguards measures were in effect. The U.S. inventory of special nuclear materials for nuclear weapons purposes was extremely limited. In fact, through the entire period of the Manhattan Engineer District era there was no integrated safeguards accounting system for source materials or special nuclear materials which were then called "fissionable materials." The Manhattan Engineer District maintained no precise records of total inventory, transfers and processing losses, nor did they issue reports containing such information. Moreover, they had no system of periodic examinations to check the activities of the industrial contractors charged with handling these materials for the Manhattan Engineer District. The entire concept of nuclear materials safeguards was focused on security, physical protection and access control systems.

The second era began when the Atomic Energy Commission was established, January 1, 1947, and took over jurisdiction of the U.S. nuclear program which was still devoted to nuclear weapons. One of the first steps taken by the Atomic Energy Commission (AEC) early in 1947 was to embrace a program for achieving and maintaining material accounting records for all source and fissionable materials in inventory. The key features of that control program were:

- Contractors handling Government owned plutonium, uranium and thorium were required to measure and account for transfers and inventories of these materials.
- The contractors were required to report monthly to the AEC the amounts of these materials received, shipped, lost, on hand, etc.
- The AEC made periodic examinations of contractor source and fissionable material records, measurements and inventories, to find out whether correct information was being shown in the monthly reports.

It is noteworthy, however, that during this era the Atomic Energy Commission embraced a policy to place paramount emphasis on maximum production, as opposed to precise inventory recordkeeping when they were in conflict. This policy reflected the national security needs perceived at that time. Maximizing nuclear weapons production was seen as clearly more important than maintaining accurate inventory records.

The third era, 1954 through 1968, was perhaps the most significant in terms of the evolution of MC&A policy. By the early 50's, the potential for major peaceful uses of nuclear energy had grown so large and the U.S. national security interests in retarding the proliferation of nuclear weapons had become so well recognized that President Eisenhower initiated what historians now call the "Atoms for Peace Program." The program actually was a two-edged sword. On the one hand, it was truly a program aimed at improving the quality of life on a world scale by fostering the application of nuclear energy for electric power, agricultural and medical uses. It was also aimed at diverting nuclear materials in the Iron Curtain countries, as well as in the West, from contributing to the growth of nuclear weapons stockpiles. As such, it was the second major U.S. initiative aimed at constraining proliferation, the first being the Atomic Energy Act of 1946, which classified all nuclear data as Restricted Data and proscribed international cooperation. The program called for the U.S. and Soviet Union to contribute significant amounts of their fissionable material holdings to a proposed new international body that would make these materials available to developing countries for peaceful applications.

By 1954, the Atoms for Peace program was reflected in a major revision of the Atomic Energy Act, which permitted peaceful international cooperation in nuclear matters and, as many of you recognize, it led to the establishment of the International Atomic Energy Agency whose Statute was approved in 1956, and whose establishment came into force in 1957. During this era, the Atomic Energy Commission continued to rely primarily on security measures to guard against loss of special nuclear materials. The Atomic Energy Commission also had a system of accountability for special nuclear materials, which it imposed on those of its cost-type contractors handling such materials. The accountability regulations were reflected in what the Commission called control provisions in their contract arrangements. These control provisions, however, were quite different from the physical control features currently used as part of MC&A. The contractual control features for Atomic Energy Commission cost-type contractors were designed primarily to assure prudent resource management by demonstrating that there are appropriate measurements and records of receipts, production, removals, and through physical inventories, the quantities and location of materials on hand at the various facilities. The so called control system was designed to localize, within a given plant, where losses were occurring, in order to provide a basis for any needed investigation and possible corrective action.

There was a second category of domestic special nuclear material users created by the 1954 revision of the Atomic Energy Act. These were AEC licensed private U.S. companies entering the field of civil uses for nuclear energy. With respect to these users, the Atomic Energy Commission in early 1955 decided not to impose either AEC's security system or AEC's accountability system. The Commission concluded that licensees could be expected to adequately safeguard special nuclear material, because of its intrinsic value and their financial responsibility for loss or damage together with the severe criminal penalties provided by the Act. This policy of the Commission was known as the financial responsibility policy, and stood intact until the beginning of the next era.

The fourth era saw a major redirection of the Atomic Energy Commission's relaxed attitude toward nuclear material safeguards. The primary stimulant for the redirection was the discovery that a licensed nuclear materials processor could not account for a significant quantity of enriched uranium. Based on the throughput of such material in this processor's activities and the number of years during which this unaccounted for quantity accumulated, it was not unreasonable to expect normal processing losses in the amounts discovered by the Atomic Energy Commission. Notwithstanding, because of the large numbers involved and other related circumstances it led to a serious concern that materials may have been diverted by the processor to a foreign power, and this in turn led to an in-depth political inquiry. As a result, the Atomic Energy Commission undertook an in-depth analysis of its approach to nuclear safeguards, and this in turn led to the following salient changes in the Atomic Energy Commission approach:

1. AEC established for the first time in a single institutional unit all of its nuclear materials safeguards and management responsibilities, both domestic and international. Prior to that time, nuclear materials accounting records, international safeguards responsibilities, and nuclear materials management responsibilities had been dispersed among three unintegrated separate AEC organizational elements. The only safeguards related functions that were not consolidated in the single safeguards organization were those related to security, which included physical protection measures and personnel clearance matters.
2. The Atomic Energy Commission abandoned its re-

liance on licensees to protect nuclear materials holdings because of their financial responsibilities and adopted a policy of regulating licensees both with respect to security measures to protect material and with respect to accountancy measures to maintain records and provide reports.

3. The Atomic Energy Commission endorsed all 13 recommendations for strengthening the effectiveness of its safeguards requirements made by a special ad hoc advisory panel appointed in mid-1966 to review and appraise the AEC's safeguards policies and procedures.

The terms "materials control and accounting (MC&A)," however, began to appear for the first time in the safeguards context because the safeguards organization was not only responsible for assuring the Commission that recorded inventories of special nuclear materials had been verified and are in fact accountable; but also, the same organization was responsible for the prudent management of those materials, that is to assure that excessive and unneeded inventories were not maintained in one location while new production requirements for special nuclear materials were being established by another location. This latter materials management function was in fact what was meant by the terminology "materials control" at that time. In the course of this era, with the renewed emphasis on safeguards along with the development of measurement instruments under the aegis of the new Office of Safeguards and Materials Management, a doorway monitor was developed for the purpose of helping insure that nuclear materials did not exit a facility in a package where those materials were not authorized for removal or declared to be in the package. Upon development of this instrument, the new Office of Safeguards approached the existent Office of Security with a request that they specify the use of doorway monitors in the security directives. The Director of the Office of Security noted, upon receipt of this request, that the Atomic Energy Commission did not look favorably upon increased security expenditures and suggested that since the Commission did look favorably upon safeguards improvements, that the doorway monitors' use would fare better in a safeguards regulation. This led to a number of security type devices subsequently being specified in safeguards regulations, and gave new meaning to the phraseology "materials control." At that time safeguards and security continued to be separate institutional entities. This fourth era, 1968 to 1972, saw a quantum jump in the recognition and need for a significant research and development program in support of safeguards. This need was answered by the formation of a safeguards technical support organization at Brookhaven National Laboratory (the occasion of this 20th anniversary symposium) and a safeguards Laboratory at Los Alamos Scientific Laboratory for the development and application of non-destructive assay technology to the myriad of unsolved nuclear material measurement problems.

The fifth era had its origins in 1972 when the international community was shocked by acts of terrorism carried out at the 1972 Olympic Games. These acts heralded the onset of a major new concern with respect to nuclear material safeguards. The threat had figuratively exploded and the stakes suddenly became huge. This, in fact, led to the institutional combination of the separate Offices of Safeguards and of Security into a single combined Office of Safeguards and Security, which continues today.

These events greatly heightened the perceived need for a strong physical protection research and development support program to remedy identified vulnerabilities. This immediate need was responded to by the Sandia National Laboratory whose outstanding capabilities had long been established and demonstrated. Sandia's contributions are described in the paper by de Montmollin and Myre.

The precedent established in the previous era for including certain security measures in safeguards regulations and calling them materials control measures was already deeply rooted into the system, and thus materials control today remains one of the three major safeguard and security subsystems, the other two being material accountancy or "accountability" and security. The latter includes all those physical protection measures not incorporated as materials control measures, as well as all matters related to personnel clearance, human reliability, etc.

We are probably now entering into a sixth and epochal era which is characterized by a significant plant modernization effort, new and advanced technologies and systems, all framed and conditioned by major world policy decisions concerning disarmament, INF, START, and others. These will be exciting and challenging times.

Before closing, I would like to make a few remarks about the evolution of the safeguards research and development program.*

In 1957, one of our assignments was the development of a measurements program to support the materials control and accountability effort. In fulfilling this new assignment, we first identified the need for a standard reference materials program for nuclear materials and the need to collect, collate, and edit a new book on measurement methods for nuclear fuel cycle materials. These efforts were quite successful, but only through the outstanding cooperation of the NBS and our AEC contractor personnel.

At about this same time, we were requested by the Chicago Operations Office to provide assistance in finding ways to determine the U-235 buildup in the liners of muffle furnaces at the Argonne National Laboratory (ANL). With the cooperation of the Chicago Operations Office, scientists at ANL to built a small portable breadboard gamma spectrometer for the Chicago survey team. This was a cost-free project, since there was no R&D funding in the budget. The demonstrated success of this first breadboard model spearheaded the support for a larger, more sophisticated version. From a source, probably the Nuclear Material Production Division, we were able to obtain about $5,000, with which the Packard Instrument Company of Chicago agreed to build two improved and larger models of the ANL breadboard model. These two Packard instruments were subsequently used widely by AEC survey teams and others at AEC facilities. These field experiences demonstrated the applicability of non-destructive assay technology to many of the measurement problems so prevalent throughout the AEC complex. These same

Packard instruments later provided the measurement basis for determining the U-235 content of over 700 noncombustible air filters and several hundred bags of recovered burial ground wastes at the licensed nuclear material processor mentioned earlier in the investigation of a significant ID. The subsequent establishment of the plant inventory and its acceptance by the processor's management would not have been possible without the NDA capability of the Packard gamma spectrometers. This exercise demonstrated the value of NDA to safeguards, and helped establish it as a key element in nuclear materials measurement.

Soon afterward, in 1967-68, the safeguards office Director for funding support at LANL for a safeguards R&D program. Thus, began the LANL technical support program for safeguards. Also during 1968, we wrote a charter for a technical support organization at the Brookhaven National Laboratory (BNL), which was approved by the AEC and implemented. These two events proved to be the keystones of our growing safeguards R&D program.

The contributions of Brookhaven, Los Alamos, and Sandia have been specifically noted. A number of safeguards groups at other DOE facilities have been and are making important contributions to the improvement of the US national safeguards program. The US contributions to International Safeguards are covered in other papers in this issue.

*These closing remarks were made by Dr. McDowell, who presented the paper.

Early AEC Safeguards and TSO Beginnings

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ABSTRACT

In 1967, a committee at Brookhaven National Laboratory suggested that the Atomic Energy Commission (AEC) should establish a safeguards technical support organization at a national laboratory. In February 1968, the AEC established the Technical Support Organization (TSO) at Brookhaven. The AEC 1968 safeguards R&D program and the first TSO task assignments are summarized. To illustrate the nature of the national safeguards activities of TSO during the following 20 years, some of the many field exercises, systems studies, special project, and technical assistance on implementing safeguards measures are described briefly.

At Brookhaven, as at many other research institutions, there have been many who followed the ups and downs of the negotiations to halt the nuclear arms race. The Brookhaven Graphite Reactor was one of the three U.S. reactors which were voluntarily placed under IAEA safeguards in the early 1960s. We observed that the Republic of Ireland proposed a nuclear non-proliferation treaty to the UN General Assembly in 1959 and were encouraged when President Johnson decided to withdraw the U.S. proposal for a NATO Multilateral Nuclear Force, in the fall of 1966, and when the US, USSR, and UK announced a draft Non-Proliferation Treaty (NPT) in January 1967. From the *New York Times*[1] we learned that 100 kg of high enriched uranium was missing from a privately owned nuclear facility which was processing large quantities of this material for the AEC, and that the AEC had created a special advisory panel, headed by Dr. Ralph Lumb, to review the present safeguards policies and programs, both domestic and international.[2]

Many of the non-nuclear weapon states raised questions about the terms of the draft NPT. Discussions began at Brookhaven and five of us formed a committee to find out what was going on and to see if there might be some way for Brookhaven to contribute. The members were Dick Dodson and Gerhardt Friedlander (Chemistry), Herb Kouts and Frank Miles (Nuclear Engineering), and me (Instrumentation).

Early in 1967, the Atomic Energy Commission established two safeguards offices: the Division of Nuclear Material Safeguards, headed by Russ Wischow in the regulatory department, and the Office of Safeguards and Materials Management, headed by Delmar Crowson, under the General Manager. Safeguards R&D was assigned to the latter office. General Crowson organized a Symposium on Safeguards R&D which was held at Argonne National Laboratory, June 26-27, 1967.[3] Our Brookhaven committee attended to hear the talks by Glenn Seaborg (AEC Chairman), Prof. H.D. Smyth (U.S. delegate to the IAEA), Ralph Lumb, Wischow, Crowson, and other notables. Of particular interest to us were the papers on non-destructive assay by Bob Keepin, Bob Beyster, Norman Rasmussen, Warren McGonnagle, and Russ Heath. On the second day there was a general discussion of material accounting techniques, led by Bob Keepin.

Around the 4th of July, the Pugwash organization sent me to Europe to discuss safeguards with French and West German officials. By luck, I was able to visit Wolf Haefele and his very active safeguards group at the Karlsruhe Nuclear Center. They were designing systems, developing models, working on non-destructive and destructive assay methods, and on containment and surveillance.

From these experiences, our committee decided that the AEC needed a small, but broadly based, support group at a national laboratory to supplement the hardware and software R&D groups then existing or contemplated. Our committee draft proposal was similar to the technical support task description which the AEC circulated to its contractors in August. General Crowson and Sam McDowell visited Brookhaven to determine just who might be interested in the project and the commitment of the Laboratory. The administration was favorable but what made the difference, I'm sure, is that Herb Kouts was willing to head the group full time and to offer members of his fast-critical-assembly group to serve as a nucleus.

After carefully studying the responses it received from other contractors, the Commission formally defined the scope for the Technical Support Organization at Brookhaven on January 19, 1968.

The TSO Charter and the safeguards R&D conducted in calendar year 1968 are described in "Safeguards R&D" issued by the Atomic Energy Commission Office of Safeguards and Materials Management, January 15, 1969.[4] The projects supported during calendar year 1968 are listed as:

1. Technical Support Organization, BNL, $191,000
2. Pulsed Neutron Research, LANL, $885,000
3. Photoinduced Reactions, Gulf General Atomic, $406,000
4. Nuclear Process Analysis, Battelle NW, $132,000
5. Nuclear Process Analysis, Nat. Bureau of Standards, $125,000
6. Weight and Volume Measurements, Nat. Bureau of Standards, $42,000
7. Umpire Lab Qualification, Idaho Nuclear Corp., $423,000
8. Reprocessing Input Verification, Westinghouse[5], $89,000
9. Inventory Verification Guide, Battelle NW, $30,000
10. Resident Inspection Study, Battelle NW, $83,000

(Not included—projects terminated during 1968)

Items 2 and 3 were big programs on accelerator based interrogation techniques. Four and five were to develop computer models to design and analyze material accounting approaches for AEC contractor facilities (Battelle NW) and licensee facilities (NBS). The Umpire Laboratory Qualification program, which later became the Safeguards Analytical Laboratory Evaluation (SALE) program, provided well qualified samples of nuclear metals and compounds to interested analytical laboratories in the U.S. and abroad so that the measurement precision and accuracy achieved could be compared. The Westinghouse study provided a solid base for the development of the "gravimetric" method to determine the uranium and plutonium at the input to a reprocessing plant, techniques to measure the burnup of the contents of dissolver solutions, and the several approaches to verification of input volumetric measurements by isotopic and other correlation techniques. At that time the AEC was studying the advantages and costs of assigning resident inspectors to the privately owned, commercial nuclear facilities.

The TSO charter is presented on pages 1-3, along with the first set of task assignments. The accomplishments, which I shall review, are summarized on pages 4-7.

Task 1 was to study the Strategic Point concept which was incorporated into the NPT at the request of West Germany. Discussions with the West Germans showed that this approach should not hamper the IAEA.

Tasks 2 and 3 were to review safeguards R&D. It should be noted that both Brookhaven National Laboratory and the Atomic Energy Commission insisted that TSO avoid any possible conflict of interest, e.g., engaging in R&D which other contractors were pursuing. Any assistance was to be technical, not policy related. The AEC safeguards offices encouraged reviews from other sources and there was then a Safeguards Advisory Committee with many experts not directly involved in safeguards which had a very active R&D subcommittee.

Task 5 was to investigate portable gamma-ray spectrometers and was later broadened to investigation of passive non-destructive techniques. It should be mentioned that the Arms Control and Disarmament Agency (ACDA) was also supporting some R&D for the IAEA at that time. Lauren Stieff had a small contract with the Naval Research Laboratory to investigate passive gamma-ray and neutron techniques. The NRL group rediscovered Jaques Jaquesson's neutron coincidence technique, developed at Saclay in 1963, to distinguish fission from non-fission neutrons using moderated neutron detectors. What was needed was a very precise electronic means to generate delayed signal "gates." Robert L. Chase, then head of the BNL Instrumentation Division, designed the precision, clock-controlled gate circuits which everyone has used since then in such neutron coincidence instruments.

Task 6 was to study seals. Cesar Sastre and Tony Gody found a vulnerability in the seals used by the IAEA and devised a way to eliminate it. The Agency processes over 10,000 of such seals today. Cesar studied all available seals and designed the paper or adhesive tape seals now used for less demanding applications. For several years, TSO operated the seal system for AEC inspectors.

Task 7 was to work with Ralph Jones (OSMM) on the Special Analytical Study which OSMM prepared for the AEC that year. It now seems to be a weird document, but it suggested some of the trends in U.S. safeguards which did occur.

Task 8 was "Parametric Analysis of Nuclear Process Models", i.e., to review and comment on the models being developed by Battelle and NBS. This led TSO to obtain a systems analyst, Bill Marcuse, from MITRE Corp., who played an important role in TSO for many years.

Task 9 was to forecast the expansion of IAEA safeguards personnel for the next 20 years. Several wild guesses were circulating at the time. The TSO prediction, which turned out to be fairly close to the mark, was presented at Hearings of the Senate Foreign Relations Committee in July.[6]

Task 10 was to prepare a glossary of safeguards terms. Frank Miles did this, corresponding with just about everyone in the business, here and in Europe.[7,8]

Task 11, Plant Instrumentation Field Tests, took place in 1970. Since it is described in the INMM Journal, Vol. X, No. 3, 1981, there is no need to describe it here. The omitted tasks were minor scoping assignments.

In 1969, H.W. Kraner (Instrumentation/BNL) assisted TSO in recording gamma-ray spectra of uranium and plutonium samples. He constructed a stand with a lithium-drifted germanium detector which we intended to use on 10 liter bottles of plutonium-nitrate solution at the West Valley reprocessing plant. However, it was discovered in May that some of the mixed-oxide rods fabricated by NFS, Erwin, TN, for the SEFOR fast-breeder test reactor, located near Fayetteville, AK, did not contain the specified plutonium. This fact was discovered when the reactor went critical, so that the off-spec rods were somewhat radioactive. Kraner's detector was rushed to Arkansas and it was established that it was possible to measure the major plutonium lines in spite of the fission product gamma-ray background.

It might be mentioned that lithium drifted germanium detectors must be continuously cooled by liquid nitrogen to -200°C. So it was necessary to take the detector mounted on top of a big dewar flask filled with liquid nitrogen, strapped to a seat next to the scientist on commercial airlines. We had to explain to the pilot and stewardess that the flask would emit some vapor after the plane took off and the pressure in the cabin fell.

Four of us visited the SEFOR reactor several times to measure the plutonium content of unirradiated and irradiated fuel rods using the germanium detector, a sodium iodide detector which was there, and a passive neutron detector from NRL with BNL electronics. The four were E.V. Weinstock, M. Zucker and me from TSO, and Charlie Strain of NRL. Eventually, one rod was dismantled so that pellets could be accurately analyzed and we were able to determine how much plutonium was missing (from a few recycle batches) to the extent required by the AEC. Weinstock and Zucker also made high solution gamma ray measurements of 55 gallon waste drums outdoors, in miserable weather, at the Erwin, TN plant. NSF eventually accounted for all of the plutonium.

These early assignments are typical of the variety which TSO has continued to be involved in. All members travel frequently. While there is a big file with progress reports and final reports, the file of trip reports is, in my view, a better summary of our activities. In the following, I can only summarize a few of the projects performed for domestic safeguards. In a following paper, David Gordon describes some of our international safeguards activities.

Few of our later assignments were hands-on, hardware activities. The major one in this category was the technical assistance that Marty Zucker provided until recently to the inspectors at the Chicago Operations Office and Region I of the Nuclear Regulatory Commission. This involved assistance in obtaining NDA instruments, assisting in their use, outfitting a van with NDA equipment, investigating anomalies, and making measurements of the "hold-up" of uranium in the equipment walls, and floors of a naval facility which was decommissioned.

In 1971, TSO was asked to draft a "conceptual design" for domestic safeguards. The elements were material accounting, physical protection, and internal controls. The latter included perimeter control, custodianship, procedures to control the materials and the activities of authorized insiders, and surveillance. Integration was emphasized (it continues to be rediscovered). This was presented to those responsible for safeguards at the major government nuclear facilities, to educate them and to refine the system using their experience. It was finally published in 1974.[9]

It was also in 1971 that TSO organized a symposium on passive gamma-ray applications for the AEC in Germantown. Papers were presented by representatives of 11 AEC facilities and seven licensees. Participants also came from AEC headquarters and field offices and the IAEA.[10] Then, as now, TSO was encouraged to keep in touch with those involved in developing and implementing safeguards programs at all levels. These personal contacts have been most valuable.

In 1974, TSO was asked to study the relative advantages of government as compared to private guard forces for AEC (later DOE) facilities.[11] It was also in 1974 that the AEC was split into the Nuclear Regulatory Commission (NRC) and the Energy Research and Development Agency (ERDA), soon to be reorganized as the Department of Energy (DOE). In 1975, we continued to work for ERDA and also became involved in several "special studies" for the NRC. Among the latter was an attempt to redefine safeguards objectives, studies of collocation for reprocessing and MOX fuel facilities, a re-examination of "fundamental nuclear material controls" (see 10CFR70.58), and "spiking." The last of these was performed with Ted Taylor. The conclusions were that spiking:

1. is not likely to be very effective in discouraging dedicated sub-national adversaries,
2. it would be expensive and increase radiation exposure of processing personnel, and
3. it probably is illegal since it is similar to the use of booby traps.[12] This subject resurfaces now and then.

"Nuclear Theft: Risks and Safeguards," by Willrich and Taylor[13] in 1974 focussed attention on physical protection. Sandia began to develop computer-based systems to evaluate physical protection systems, and TSO designed a simpler portable model. Soon after Harvey Lyon became head of the ERDA (now DOE) safeguards office, he decided to evaluate the physical protection systems at the major government nuclear production sites with the help of Sandia and TSO. The TSO program was on the central computer at Brookhaven. The facility parameters (barriers, guard locations, alarms, etc.) were sent, by phone line, to the computer and the results of one or more engagements promptly sent back to the field. Although the programs were not very sophisticated, the direct involvement of the facility personnel sometimes made it possible to plug holes on the spot. In any case, it ensured that all relevant facility data would be identified and recorded for more careful analysis later at Sandia.

During 1975-76, there was an emphasis on designing safeguards for reprocessing and MOX fuel facilities. Los Alamos, Sandia, and TSO visited the Office of Safeguards and Security in Germantown frequently and worked together on the designs and analyses. Then reprocessing was halted by President Ford and President Carter initiated the International Nuclear Fuel Cycle Evaluation. Everyone in and out of the government began to study the non-proliferation and other features of every fuel cycle which had ever been invented. TSO supplied two of the four members of the "Core Group" which assisted DOE and other agencies in describing the relevant safeguards features for enrichment, reprocessing, MOX fuel facilities, and for spent reactor fuel if it were to be buried.[14] The other two members were Jim de Montmollin of Sandia, and Paul Persiani of Argonne.

The assignments have continued to be as varied and as challenging. In connection with the President's offer to accept IAEA safeguards, TSO assisted DOE in defining the list of non-sensitive nuclear facilities which might be selected by the IAEA. Alan Bieber and others worked with General Electric on how the facilities should provide data to the IAEA through the Nuclear Materials Management and Safeguards System at Oak Ridge; and helped explain this process to those who would be affected.[15] He and others helped a DOE facility implement light-pen and on-line instrument data entry to its materials accounting system. Jerry Cadwell, who is a lawyer as well as an engineer, continues to provide assistance on, for example, the authority of guards to use weapons in defense of property.[16] Clemens Auerbach developed a computerized catalogue of NDA and containment/surveillance instruments, which is presently inactive due to lack of funding. Jon Sanborn[17] and others have made in-depth studies of material accounting problems at several of the major DOE facilities. Like the other safeguards laboratories, TSO has been involved in the several major safeguards reviews undertaken by the DOE and its predecessors, and is currently engaged, with Los Alamos, in drafting guides to explain how to meet the recently revised DOE Orders (regulations) on material control and accounting.

This brief survey may suggest the scope and to some degree the character of TSO's contributions to U.S. safeguards programs. All members have cooperated and contributed. It has been a busy twenty years.

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U.S. Department of Energy Safeguards Research and Development Program and The Brookhaven National Laboratory Technical Support Organization Role

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ABSTRACT

The Brookhaven National Laboratory (BNL) Technical Support Organization (TSO) has played a key role over the past 20 years in the evolution of much of the effective materials control and accountability systems implemented successfully at Department of Energy (DOE) facilities. The safeguards research and development program of the U.S. DOE is summarized, noting the contributions of the BNL-TSO. During 1977-79, the non-proliferation features of many nuclear fuel cycles were studied in support of the International Nuclear Fuel Cycle Evaluation. The Beirut bombings of 1982 led to increased emphasis on physical protection and to establishment of a Central Training Academy. High-level and all-DOE reviews of DOE safeguards and security led to major improvements in the management, operations, and assessment of DOE's safeguards and security programs during 1985-88. TSO is expected to continue to play a lead role in stimulating new research initiatives and in guiding the development that is necessary for future challenges in maintaining cost-effective and credible safeguards.

INTRODUCTION

It is an honor and a privilege to participate in this commemorative symposium marking 20 years of excellence in providing outstanding technical support to the Department of Energy (DOE) Safeguards and Security program by the Brookhaven National Laboratory. On behalf of the DOE Office of Safeguards and Security (OSS), I extend sincere thanks and congratulations to the charter members and all those who followed and made it possible to achieve so many notable successes. Having been associated with the Brookhaven National Laboratory (BNL) Technical Support Organization (TSO) program over the past 20 years, I believe you can face both the past with pride and the future with confidence.

Significant contributions have been made by BNL/Technical Support Organization to the evolution and present status of safeguards and provided a basis for evaluation and projection of the future role of nuclear materials safeguards on both the national and international levels. May I now discuss some of the more significant milestones and future promises of the DOE safeguards program.

SOME HIGHLIGHTS OF DOE SAFEGUARDS

The Department of Energy (DOE) was established by legislation in 1977 and took over the functions and personnel of the Energy Research and Development Administration which, you will recall, had taken over from the Atomic Energy Commission three years earlier. Upon establishment of DOE, there emerged a significant era for nuclear programs and safeguards and for BNL/Technical Support Organization. A reexamination of policies and practices underlying the Nonproliferation Treaty was underway, prompted by India's explosion of a nuclear device in 1974, and from the growing concern that worldwide growth of nuclear power and reprocessing of spent fuel would create large quantities of plutionium in the commercial sector. This led to questions, in some sectors, of whether safeguards systems could provide timely warning of diversion for the international community to take action. This resulted in a new U.S. position, announced by President Carter in April of 1977, to defer breeder reactor development and commercial reprocessing until after an evaluation of alternative nuclear fuel cycles. Sixty-six nations participated in the extensive two-year International Fuel Cycle Evaluation (INFCE) study which was published in March 1980. The study recognized the importance and continued growth of fission energy as a resource, but called for highly effective safeguards and nonproliferation measures.

There have been essentially five significant time zones since the beginning of DOE in the safeguards program to the present:

1. 1977-1979

Safeguards designs for several alternative nuclear fuel cycles were developed. The term "Inventory Difference," ("ID") replaced the term "Material Unaccounted For," as being more properly descriptive. A number of reviews were conducted and clarifying categories developed and incorporated in the DOE orders (requirements for DOE facilities). In August 1977, the first semiannual report of ID's was made public. These are now routine, with little media attention. An engineered systems approach was initiated for improvement projects at DOE facilities.

2. 1979-1981

Attention was increased on international safeguards and related R&D. A "collegial" approach was emphasized for cooperation between Headquarters and field operations. Efforts were made again throughout the organizational structure to recognize broader responsibility for all DOE safeguards and security oversight in addition to defense programs. A revision of DOE orders included requirements for measurement control and calibration programs.

3. 1982-1984

Beirut bombings heightened concern for protection of DOE facilities. Emphasis was on large-scale hardening and physical protection improvement projects and increased role in oversight of "cross-cut" (outlay program) funding activities. Threat guidance was updated in January 1983. OSS initiated buildup of training for response forces. Results of inspections and force-on-force exercises led to a number of "quick-fixes." Concerns of adequacy were raised by Congressional committees.

4. 1984-1986

Attention was focused on an integrated protection program and a "corporate" approach for consistent oversight activities. OSS was emphasized as the focal point, including validation of line-item safeguards and security projects. The Central Training Academy was established in Albuquerque, New Mexico. The impact of the results of inspections grew. Master Safeguards and Security Agreements (MSSAs) became a major initiative, followed by initiatives to improve materials control and accounting to maintain high performance and to help address potential insider threats. MSSAs between the DOE field offices, facility operators and program managers at headquarters were initiated to ensure, so far as possible, that the appropriate level of protective measures could be tailored for each facility.

5. 1986-1988

The conclusion of a major improvement effort, "Operation Cerberus" in November 1986 brought additional attention to the "corporate" that emphasized the need for good planning and coordination among those responsible for defining and implementing the programs. This effort led to the development of standards and criteria and a major DOE-wide effort to update relevant requirements in DOE Orders.

Consistent with its charter, TSO has continued to play a key role in each of these time frames for DOE. TSO was characterized by the Operation Cerberus R&D Committee as the DOE "Center of Excellence" for development of technical criteria for long-range policy and planning, and development of integrated protection programs and systems, including systems analysis and evaluations.

Results of Operation Cerberus are being drawn on to strengthen safeguards and security, including research and development and the establishment of a technical base to enhance our capabilities to counter the threat to DOE facilities and to improve international safeguards. New DOE orders, standards and criteria, and materials control and accountability guides place heavy emphasis on performance requirements and standards. TSO is currently making significant contributions in these areas.

TRENDS AND FUTURE DIRECTIONS

As we look to the future, DOE continues to emphasize the need for enhanced capability to counter the full spectrum of threats including "insider" concerns at DOE facilities, and to improve international safeguards. The R&D strategy is a program that is directed to user needs, and that is relevant to DOE safeguards and security objectives and to overall U.S. policy. In addition to solving problems and enhancing safeguards and security capabilities at DOE facilities, evaluation criteria emphasize that a proposed R&D project should offer potential reductions in operational outlay ("crosscut") budgets for safeguards and security. We have asked TSO to help us determine how and where the R&D program can provide additional leverage for cost-effectiveness.

Safeguards approaches for new DOE programs such as the Defense Program Modernization, fusion and waste storage will be needed. Strict nuclear materials control and monitoring of DOE operations under highly visible conditions and increased volume of nuclear materials from arms reduction will, in all likelihood, be needed along with a strong technology base in sensors, assessment, delay, communications, access control, and displays. The OSS-sponsored review by the National Academy of Sciences of the process of materials control and accounting has now been completed. The final report is expected to help us determine if there are more effective ways or a need for a change in emphasis. As one would expect, the roster of those involved in the National Academy of Sciences (NAS) study includes BNL/Technical Support Organization participants. The NAS study was chaired by Herb Kouts who was the first TSO group leader.

In the mid- to longer-term, R&D projects are expected to be needed in the following areas:

1. Science and Technology Base Development

New concepts are expected to be needed and investigated as they emerge from innovative ideas. Emphasis will be on better performance, lower cost, and the potential for reducing operational requirements. For example, measurement methods that incorporate rapidly increasing electronic and computer capability to improve performance and reduce dependence on operator's skills will be given a high priority. Additional needs have been identified for materials control technology to monitor the location of nuclear materials and for confirmatory measurement. R&D efforts in computer security will provide a leading edge on protection of classified and sensitive information.

Addressing insider threat concerns also demands that protection be developed for materials control and accounting software and data bases.

2. Basic Systems Design, Integration, and Evaluation

Specific efforts will be directed to determine the potential for reducing operational safeguards cost through integrated systems using new technology, and identification of R&D projects with high leverage in realizing such cost reductions. Needs have been identified for development of detailed designs including hardware and software for an integrated MC&A system which is applicable to multiple facility operations. A universally acceptable way of treating holdup in operational materials accounting systems is needed. Methods are needed for uniform cost/risk/benefit analysis of safeguards projects; for providing a basis for project prioritization and selection; and, for meeting the objectives of improved performance standards, criteria, and the Master Safeguards and Security Agreements.

3. On-site Test and Evaluation (OT&E)

Major system demonstrations that have evolved out of the technology base program combined with high-priority integrated designs will be performed. Emphasis is expected to be given to demonstration of various elements of a safeguards system not yet accepted nor implemented for improved performance standards and Master Safeguards and Security Agreements. Needs have been identified and more can be expected for advanced isotope separation processes, new DOE reactors, material storage areas, and high-throughput plutonium process facilities. Needs for technical expertise and training are expected to continue in response to operational problems and technology transfer requirements.

4. International

The number and complexity of facilities under International Atomic Energy Agency (IAEA) safeguards are increasing each year. Large bulk handling facilities, which are due to begin operation by the early 1990's, will place additional technical and resource demands on the IAEA. New safeguards concepts, approaches, and equipment that will contribute to improved efficiency and credibility of IAEA safeguards. Significant changes can be expected in bilateral agreements and technical exchanges with other countries as a result of the Omnibus Diplomatic Security and Antiterrorism Act of 1986.

CONCLUSIONS

In conclusion, the BNL/Technical Support Organization has played a key role over the past 20 years in the evolution of much of the effective materials control and accounting systems implemented successfully at DOE facilities. We congratulate all those who contributed to the many successes and especially to the first year charter team (Herb Kouts, Willy Higinbotham, Caesar Sastre, Frank Miles, Syl Suda, Gene Weinstock, Kenny Downs and Anita Cort) whose technical expertise, combined with dedication and keen personal insights have provided significant improvements in today's integrated safeguards and security systems. Under the leadership of Herb Kouts, Willy Higinbotham, Jack Cusack and now Joe Indusi, the BNL team has provided substantial contributions to the professionalism of safeguards and to nuclear nonproliferation. I certainly can attest to your enthusiasm and initiatives, and to your providing additional viability to the safeguards profession. The entire BNL safeguards team has demonstrated and I believe will continue to play a lead role in stimulating new research initiatives, and in guiding the developments that are necessary for cost-effective and credible safeguards.

Recent and Future IAEA Directions

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ABSTRACT

During recent years, the Agency has faced a zero-real-growth budget policy. This has forced the Secretariat to find more efficient ways to perform its tasks in order to cope with the growing demands placed upon it by Member States. These tasks must be completed within the additional constraint of a continuously increasing workload. Last year the Agency reached the extreme where certain essential activities were suspended due to lack of funds. There was even the possibility that staff would not be paid in November. Thus, there was a "red-alert" warning at the end of last year. This uncertainty in the Agency's financial situation established a new basis for a very detailed analysis of the proposed budget for 1989 and 1990. The proposed program and budget for the Department of Safeguards became the subject of intense scrutiny by Member States during meetings of the Board of Governors of the Agency and its Administrative and Budgetary Committee.

In order to cope with the tight financial situation in 1987 each Department of the Agency was required to justify, as clearly as possible, its requirements.

In recent years, the policy of the Agency has been to work in a more transparent way in order that Member States are able to judge and comment, not only about the budget, but also about the development and implementation of our activities. This is particularly evident in the Safeguards Department—our interaction with most Member States occurs at two levels: the governmental level and the industry or operator level. Our activities are governed by the IAEA-Member State Agreement for the Application of Safeguards. In subsidiary documents concluded under the Agreement we have to spell out how we intend to perform safeguards activities, inspections, evaluations, and other tasks in order to comply with established requirements.

The Safeguards Department has issued evaluation criteria covering all safeguards activities. Each year the Department issues a Safeguards Implementation Report in which detailed summaries of the previous year's activities are presented. There is a new initiative in this area. We have begun the development of a unified set of implementation and evaluation criteria which we hope will become effective January 1, 1990. The staff of the Safeguards Department is now working on the first draft of this document and we expect to conduct consultations with Member States during the early part of 1989.

Another initiative that is very important is our intention to be much more responsive to the requests of the Member States and the nuclear industry in addressing the operational exigencies of the nuclear facilities we inspect. We intend to be more effective, less intrusive, and as practical as possible in the performance of our tasks.

I. INTRODUCTION

Implementation of safeguards by the IAEA has reached a stage of early maturity, now that it is nearing the end of its third decade. After a period of rapid growth during the 1970's and early 80's the expansion of nuclear development in the world has slowed to a very small number of facilities coming on line in the last few years. This fact, although quite negative for the nuclear industry in general, has enabled the IAEA to consolidate safeguards implementation practices and procedures and to work towards improving the levels of accomplishment of its functions.

In addition to this panorama, internally the IAEA has faced a zero-real-growth budget policy during recent years. Furthermore, in the next few years the Agency will be meeting even greater challenges to increases in its productivity and to respond to the growing technical complexity of safeguards activities. The IAEA will need to make the best use of opportunities, such as enhanced cooperation with Member States, new safeguards technologies, further staff development, improved management skills and the continuing experience resulting from participation in the only international non-proliferation verification system ever devised.

In order to do this, we depend on good management, a competent, dedicated and motivated staff and very good, continuous and extensive support from Member States.

II. SAFEGUARDS ACTIVITIES IN PREVIOUS YEARS

During the 1980's, the number of countries with significant nuclear activities and the total number of installations under IAEA safeguards continued to increase albeit slowly, reaching 905 installations in 57 countries in 1987. Since 1980, a 50% increase took place in the number of power reactors to be safeguarded by the IAEA. (A summary of the number of different types of installations under safeguards at the end of 1987 is given in Table II.A.) The Agency carries out inspections at about two-thirds of these installations annually.

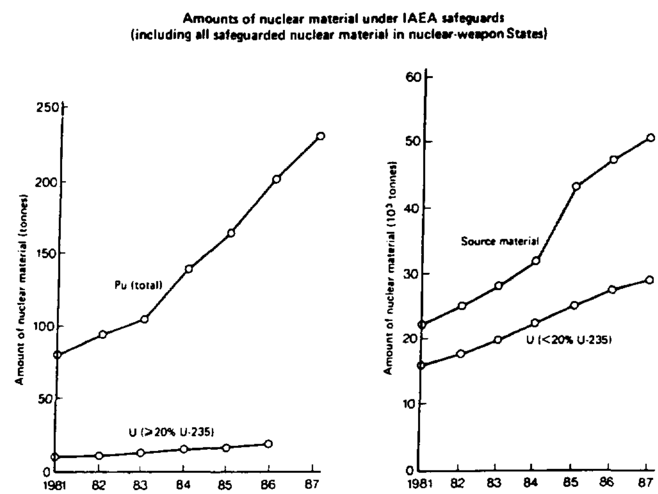
Table II.A
Installations in Non-nuclear-weapons States Under Safeguards or Containing Safeguarded Nuclear Material at the End of 1987

Installation Type	Number of Installations
Reactor-type facilities:	
Power reactors	186
Research reactors and critical assemblies	172
Bulk-handling facilities:	
Conversion plants	7
Fuel fabrication plants	40
Reprocessing plants	6
Enrichment plants	6
Separate storage facilities	34
Other facilities	46
Other locations	406
Non-nuclear installations	2
Total	905

A further indicator of the magnitude of safeguards activities is the amount of nuclear material under IAEA safeguards. There have been considerable increases in the amounts of plutonium, low-enriched uranium, and source material to be safeguarded during recent years (See Figure II.1). The total amount of plutonium includes that contained in irradiated fuel and separated plutonium, which constitutes only a small fraction of the total amount; currently nearly nine tons of it are under Agency safeguards.

The period of the 1980's has marked a certain maturing of the world nuclear industry. On the research and development side, some small or obsolete facilities have been closed down as nuclear research in general has been consolidated or concentrated in most countries with extensive programs. The associated reduction in Agency safeguards effort has been more than compensated by new safeguards tasks.

Four nuclear-weapon states have signed voluntary offer safeguards agreements and placed all or part of their civil facilities under safeguards, while negotiations were recently completed with the fifth nuclear-weapon state. The Agency has applied, *inter alia*, safeguards to the following types of facilities in nuclear-weapon states: fast breeder reactors, spent fuel storage ponds, enrichment plants, reprocessing plants, plutonium storage facilities, fuel fabrication plants, power reactors, and research reactors.



Note: Data for plutonium refer to the total amount of plutonium, i.e. that contained in irradiated fuel and separated plutonium.

Figure II.1 Safeguards

Finally, new technology reached the large prototype or commercial stage in substantial measure over the period. The Agency is now applying safeguards to the following new types of facilities: commercial MOX fuel fabrication plants (producing mixed PuO_2-UO_2 fuel), high-temperature gas-cooled reactors, fast breeder reactors, and uranium enrichment plants using centrifuge technology.

A very interesting aspect of the application of safeguards to these enrichment plants was the development of recommendations by the Hexapartite Working Group. For these facilities, the technology holders and the Agency together developed a safeguards approach which provides mutually acceptable assurances and which at the same time protects the sensitive technology used in these plants. At present several enrichment plants using centrifuge technology are being safeguarded under agreements negotiated on the basis of the safeguards approach developed by the Hexapartite Working Group.

During the late 1970's and early 1980's, increased resources were made available which enabled the Agency to keep up with the increasing demands for safeguards implementation. Since the mid-1980's, activities have been emphasized which contributed to increasing the quality of the Agency's work. Close co-operation within the Agency and especially within the Department of Safeguards and between the Agency and States have contributed very much to the progress achieved.

The human resources available for inspections, while doubling since 1979 and now around 200 man-years, has leveled off in recent years. The calculation of available inspection resources takes into account the fact that an inspector or inspection assistant can perform inspections only after having completed the necessary training and having been approved for designation by the state to be inspected.

Increased financial resources available to the Department of Safeguards have resulted in improved support for inspection work. Substantial advances were made in the development and purchase of equipment, the development of improved procedures, information treatment, evaluation of safeguards implementation, training, standardization, and administration.

The Agency has continued to place emphasis on achieving progress in safeguards implementation by improving co-operation with Member States. Liaison committees established according to the relevant agreements have continued their work. These committees and other regular forms of contact with facility operators have continued to make significant contributions to the solution of general and specific problems relating to safeguards implementation.

The establishment of IAEA offices in certain states has assisted the co-operation between the IAEA and these states. In May 1984, the IAEA office in Tokyo was formally established, after the successful experience with the IAEA field office in Toronto, Canada, which came into existence in September 1980. These offices provide logistic support to the IAEA staff on duty in Canada and Japan and have led to a considerable improvement in solving safeguards problems through day-to-day contacts between the IAEA and state officials. They also contribute to a more efficient utilization of inspection resources. Resident inspectors are able to perform about twice as many person-days of inspection as do inspectors stationed at Headquarters in Vienna. In addition, these offices make it possible to carry out inspection activities at short notice, which could not be performed by headquarters-based inspectors, thus improving safeguards effectiveness.

The support provided to the Department of Safeguards by a sizable number of Member States in the framework of their safeguards support programs had become an essential element in improving safeguards implementation. Many successful projects have been completed, providing useful equipment or information serving the immediate needs of safeguards operations.

The main result of the safeguards activities of the IAEA is expressed as the "Safeguards Statement" in the Annual Reports and the Safeguards Implementation Reports (SIRs) of the IAEA.

The overall result represented by this "Safeguards Statement" arises from both the efforts of the Department as a whole and the co-operation with and support of the Member States. Reporting on advances of safeguards implementation means at the same time acknowledging this strong support and this close co-operation. I would like to present some information which explains the basis for the safeguards statement.

Information on inspection effort.

The number of installations inspected by the Agency has increased by more than 50% since 1980 (393 installations in 1980, 631 in 1987), while the total inspection effort in Member States has more than doubled (3,985 man-days of inspection in 1980, 9,556 in 1987). Inspection effort is being concentrated on those stages in the nuclear fuel cycle involving the production, processing, use or storage of nuclear material from which nuclear weapons or other explosive devices could readily be made. The IAEA gives highest priority to the most sensitive facilities and to direct-use materials. In 1987 about 46% of the total inspection effort was spent at bulk-handling facilities although these installations represented only about 7% to the total number of installations; for power reactors these percentages were about 31% and 21% respectively.

In addition to the quantitative increase of inspection effort, measures have been taken to improve the effectiveness of IAEA safeguards. Examples are inspections without advance notice, and simultaneous physical inventory verification at all major facilities involved in the natural-uranium fuel cycle in one state.

Inspection goal attainment has continued to improve through the efforts described above. From 1980 to 1987 the number of facilities inspected and evaluated in the annual SIRs increased by 62%. In the same period the number of facilities where the inspection goals were fully attained for the whole facility increased by 110%, reaching 63% of all facilities inspected and evaluated in 1986.

In order to give an idea of the manpower available to perform our tasks the data is presented in Table II.B. It is clear that the Safeguards Department has steadily and substantially increased its production of mandays of inspection (MDI). The total increase in production is 44% over the period. At the same time, the number of posts in the Safeguards Department increased only by 9%. The increase in MDI production was well in excess of the increase in posts.

The large increase in productivity in MDI production from 1984 to 1987 was achieved mainly by changing conditions over which the Agency had significant control, such as internal organization and computerized headquarters activities, and as a result of increased cooperation and assistance from Member States.

III. IMPLICATIONS OF THE ZERO-GROWTH POLICY

During recent years, the Agency has faced a zero-real-growth budget policy. This has forced the Secretariat to find more efficient ways to perform its tasks in order to cope with the growing demands placed upon it by Member States. These tasks must be completed within the additional constraint of a continuously increasing workload. Last year the Agency reached the extreme where certain essential activities were suspended due to lack of funds. There was even the possibility that staff would not be paid in November. Thus, there was a "red-alert" warning at the end of last year. This uncertainty in the Agency's financial situation established a new basis for a very detailed anal-

Table II.B
Inspection Effort and Available Manpower

	1984	1985	1986	1987
Mandays of inspection (MDI)	6609	7682	8257	9548
Total safeguards posts	434	435	455	471
Inspectors' posts	198	193	201	197
Percentage of inspectors' posts	45.6	44.4	44.2	41.8

ysis of the proposed budget for 1989 and 1990. The proposed program and budget for the Department of Safeguards became the subject of intense scrutiny by Member States during meetings of the Board of Governors of the Agency and its Administrative and Budgetary Committee (A & B Committee).

It has become apparent during recent budget discussions in Vienna that the Safeguards Department must improve its communications with the Board of Governors during budget preparation and approval.

The budget briefing papers must contain more background information on the many factors affecting the use of human resources, permitting more extensive review and questioning by Member States. This must be done while respecting the confidentiality of the basic facility information. The Safeguards Department has accepted this challenge and is in the process of consulting actively with Member States to develop an improved budget consultation process.

We consider that it is possible to improve further our efficiency if the experience gained through almost 20 years of applying safeguards could be a factor in the actual formal agreements and working procedures. For instance, existing inspection scheduling arrangements should be reviewed carefully by Member States and the Agency. It is possible that some of these scheduling arrangements were agreed many years ago when the workload was less and the nuclear fuel cycle less developed. The states and the Agency must cooperate to streamline inspection scheduling and to maximize productivity.

In addition, Member States and the Agency should not be reluctant to re-examine existing safeguards procedures if improvement in goal attainment or reduction of manpower can be achieved. Sometimes there is a mutual reluctance to discuss procedures or facility attachments which were difficult to negotiate in the past. It is important for both the Member States and the Agency to be willing to review any facility attachment or safeguards approach where substantial savings or better goal attainment might be achieved.

Furthermore, we should aim to explain clearly to Member States the limitations we may experience in order to increase the amount of mandays spent in the field by inspectors, taking into account all the activities of the inspectors' lives including the pre- and post-inspection functions they need to perform when they return to Headquarters.

If we could pass this message to Member States, not only with regard to inspectors' activities but including the Department of Safeguards as a whole, we may develop a good understanding on which we could base the proper ground rules to perform our tasks.

IV. OUR FUTURE DIRECTIONS

In the 1990's the Safeguards Department will be faced with a new generation of bulk handling nuclear facilities of an unprecedented size and complexity. It is expected that most or all of our material handling will be automated, with little opportunity for traditional access required for NDA or sampling. These plants also will have very modern nuclear materials management systems, which will produce a very large flow of data either on magnetic media or direct from facility computer to Agency computer. The information will also be very prompt or near real time. The hardware and software that operates these plants will be complex and difficult for the Agency to authenticate. The size of the output will challenge the Agency verification system and the sample transportation costs may challenge both budget and available laboratory facilities.

Introduction into the field of instruments for the destructive analysis of samples must be considered given the time delay and cost penalties arising from central sample analysis.

Reprocessing may not be a fertile job field in some states, but it is alive and well in others. In addition to the pilot and mid-size plants now under safeguards, two commercial plants are expected to come on stream under IAEA safeguards in the mid 1990's.

There are exciting challenges to develop the basic safeguards concepts and approaches for these new facilities. Use of traditional inspector-intensive techniques would be very expensive and the results might not be satisfactory. The Agency must reduce the total MDI per ton of Pu processed, reduce the time required to process safeguards information and improve the quality of knowledge of nuclear material in the plants.

How do we intend to prepare ourselves for these challenges?

As you know, in 1975 the Director General established the Standing Advisory Group on Safeguards Implementation (SAGSI) in order to secure the continuing advice of an independent expert body operating under a broad mandate. In 1988, the role of SAGSI as an advisor to the Director General has assumed added importance in light of the requests by several Member States for a comprehensive review of safeguards implementation practices.

During its meetings held from 25-29 April 1988 SAGSI completed a detailed review of proposed "Long Term Safeguards Evaluation Criteria" drafted by the Secretariat in the context of INFCIRC/153 (NPT-type) safeguards agreements. SAGSI's report to the Director General on this matter is expected to be submitted by mid-1989.

In September 1988 SAGSI will begin a similar review of proposed "Long Term Safeguards Criteria for INFCIRC/66-type safeguards agreements." It is expected that SAGSI's advice on this matter will be submitted to the Director General by mid-1989.

More recently, the Director General has undertaken a number of initiatives in response to his assessment of safeguards-related developments which have occurred during the past few months. These new initiatives constitute a comprehensive, multi-dimensional review of the Agency's current safeguards program and they will address a broad spectrum of issues which exist at present or which are expected to arise during the next few years. These include:

i) Member States Safeguards Support Programs

At present, 13 Member States operate formal safeguards support programs under which more than 400 individual projects are being pursued. Without these support programs the Agency would not have achieved the high standards of effectiveness and efficiency which currently characterize its safeguards program. However, the administrative, liaison and coordination functions performed by the Agency in cooperating with Member States in the pursuit of their safeguards support programs is very appreciable.

The Secretariat began a review of the modus operandi of safeguards support programs on 1 April, 1988. The review is being conducted by a senior member of the Secretariat with the assistance of a Project Team. It is expected that the Project Team will submit its report to the Director General by 31 December 1988. The Team's recommendations will address the Secretariat's actions vis-a-vis support program-related functions for the next several years.

ii) The Safeguards Manual

An initiative which has now been completed was the preparation of a "standard safeguards operating policies and procedures" document, commonly known as the Safeguards Manual or SM. The Safeguards Manual together with a number of departmental and divisional instructions, and more importantly, the provisions of safeguards agreements, subsidiary arrangements and facility attachments, is appropriate, govern actual safeguards implementation practice. It has become apparent that a continuing effort to unify the legal requirements, principles, policies, practices and procedures is required to achieve the necessary enhancement, coordination and optimization of the Agency's safeguards program.

iii) Safeguards Implementation and Evaluation Criteria

The Secretariat began the development of a unified set of safeguards implementation and evaluation criteria on 1 April 1988. The review is being conducted by a senior member of the Secretariat with the assistance of a Project Team. It is expected that the Project Team will submit its recommendations governing INFCIRC/153 type agreements by 31 December 1988, and the final report governing all types of safeguards agreements by 30 April 1989.

iv) The Organization of the Department of Safeguards

The present organizational structure, modus operandi and assignment of responsibilities were approved by the Director General in 1983. This decision enabled the Secretariat to respond very effectively to the circumstances of the mid-1980's. As in the case of all international organizations the geopolitical, economic and technical developments in the rapidly changing environment of the late 1980's prompted the Director General to request an evaluation of the appropriateness of the present organizational structure, modus operandi, and assignment of responsibilities.

v) The Establishment of Safeguards Field Offices

In 1980 with the consent of the Canadian Government, the Agency opened a field office in Toronto and in 1983 the Tokyo Office was opened. It is evident from the experience gained from these two offices that the operational effectiveness and efficiency of the Agency's safeguards program in Canada and Japan have been significantly enhanced.

The Secretariat has initiated an updating of earlier analyses performed in connection with the Toronto and Tokyo field offices to determine the feasibility of additional field offices.

In addition to these initiative we have to take care of development of the Agency's most essential resource, the resource that will enable the Agency in the future to meet goals or to fail: *the staff.*

First, because of the nature of the new plants described earlier, the average inspector must be better trained, more experienced—older and wiser in other words. The time to design, build and commission these facilities is long, which will place challenges on continuity of management and project control.

Because increased experience and better continuity of management will be needed, a reasonable proportion of the Agency Inspectorate will need to be long-term employees. The balance of long- and short-term employees and the inventory of technical and management skills will need continual review by senior management.

V. CONCLUSION

It seems that the problems and conditions mentioned above are very demanding, but the Department of Safeguards is confident that, given the necessary support from Member States, the challenges can be met. The future may be difficult, but we intend to be prepared for it.

In recent years, the risk of proliferation remained, but the world community has so far been remarkably successful in containing it. The possession of nuclear weapons was widely perceived not only as a danger to the community of nations, but also as useless or dangerous to the individual state. However, several states that have so far chosen not to commit themselves to either the Treaty of Tlatelolco or the Treaty on the Non-Proliferation of Nuclear Weapons (the NPT) had felt that the continued production of nuclear weapons by a few states, and the retention by those states of huge arsenals, did not convey the conviction that these weapons were useless. Moreover, among the states party to those treaties, "many have voiced impatience about the fact that their foregoing the nuclear weapons options has not yet helped to bring about substantive nuclear disarmament measures, as anticipated in Article IV of NPT".

Maybe some words on the safeguards role would be in order. The IAEA safeguards system should not be compared with a police investigatory system, but rather with bank accountancy and independent audits. It is instituted not out of distrust, but to create confidence. It uses the accounts kept by the inspected party and checks them. It verifies that the materials reported on in the accounts really are there. Discrepancies and inconsistencies are routinely found, pursued—and resolved.

IAEA inspectors are not nuclear policemen with a mission to intervene against any diversion of fissionable material or misuse of nuclear installations, but international observers with a duty to report. The same will be true of other inspection systems that may be created. They are observation systems, alarm bells that can trigger a variety of actions by international or national organs. Safeguards cannot read intentions—they can only verify the absence of any violations. They cover only declared facilities—perhaps a verification system designed today would include a way to verify that there are no undeclared facilities. Nuclear installations are becoming increasingly complex and sophisticated—the safeguards system must continuously develop and adapt in order to deal with new closed, remotely controlled and automatized systems. Verification techniques must undergo research and development—although more and more techniques become available for automatic control and verification, as they do for automatic operation of nuclear activities, we feel very strongly that the use of the experienced on-site inspector will remain valuable.

In addition, we could mention that verification—like development assistance—requires *adequate, predictable,* and *dependable* financing. The world has to get used to and accept the costs of verification, whether bilateral or multilateral. It would be somewhat paradoxical if we were to succeed in solving political and security problems of arms control and disarmament agreements and find that we cannot reach consensus on how to adequately finance the verification systems we set up.

Finally, let me say that the IAEA safeguards system was revolutionary when it started. It has helped the world, including the nuclear-weapon states, to get used to on-site inspection and to understand the very tangible advantages that flow from it in the field of confidence. The world should build further on this experience and create even better systems underpinning and securing disarmament and peace.

A State Department Perspective on IAEA Safeguards

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ABSTRACT

The maintenance of effective international safeguards is a fundamental tenet of U.S. non-proliferation policy. The U.S. Department of State plays a substantial role not only in articulating U.S. non-proliferation policy, but in the implementation of that policy, including a substantial role in all aspects of U.S. support of IAEA safeguards. The State Department's role in supporting IAEA safeguards ranges from considerations related to bilateral agreements for cooperation in peaceful uses of nuclear energy and export control to many rather technical aspects of safeguards such as the U.S. Program of Technical Assistance to IAEA Safeguards (POTAS) and negotiation of Facility Attachments for U.S. nuclear facilities subject to IAEA safeguards. TSO plays an important role in support of these efforts by providing technical advice on a broad range of matters where technical and policy issues are closely intertwined.

Today I want to describe the Department of State's perspective on IAEA safeguards, and describe our role in the inter-agency process by which the U.S. supports IAEA safeguards. I will also describe how Brookhaven's Technical Support Organization has supported the State Department in implementing U.S. policy towards the IAEA and its safeguards functions.

Let me begin by discussing for a moment the policy of the United States on the subject of nuclear non-proliferation. The Nuclear Non-proliferation Act of 1978 identifies the following themes for U.S. policy in this area:

- Active pursuit of effective international controls over the transfer and use of nuclear materials and equipment and nuclear technology for peaceful purposes in order to prevent the proliferation of nuclear weapons or explosives;
- Confirmation of the reliability of the United States in meeting its nuclear supply commitments to nations which adhere to effective non-proliferation policies;
- Strong encouragement for all nations to ratify the Treaty on the Non-Proliferation of Nuclear Weapons (NPT); and
- Cooperation with other countries in identifying and adapting suitable alternative technologies for energy production.

While it is important to recall that this legislation was written as the centerpiece of President Carter's nuclear non-proliferation policy, it is striking that this legislation opens with a statement of policy quite consistent with the major themes of U.S. nuclear non-proliferation policy over the preceding several decades, and by and large with the positions articulated by President Reagan in his July 16, 1981 statement of nuclear non-proliferation policy. It is the relative emphasis, not the themes, which change.

The maintenance of effective international safeguards is a fundamental tenet of that U.S. nuclear non-proliferation policy. Safeguards are a principal means for a state to demonstrate that its nuclear programs are peaceful, and do not constitute a threat to its neighbors or the international community. To some extent this is true of all nuclear safeguards, but it is most important when safeguards fill the role of an international verification of a state's treaty commitments regarding non-proliferation. International safeguards also assure supplier states that they are not acting contrary to their own interests and the security of the international community in their role as suppliers.

As one would expect, the Department of State plays a principal role in articulating U.S. non-proliferation policy. The Department also plays a large role in implementing that policy, including a substantial role in all aspects of U.S. support for IAEA safeguards. U.S. reliance on IAEA safeguards as a foundation stone for our non-proliferation policy means that our interests in that safeguards system are extensive and complex.

U.S. law requires the application of IAEA safeguards to any nuclear exports made under an agreement for cooperation with a non-nuclear weapon state. U.S. law also requires for each export a finding that the export is not inimical to our common defense and security. Thus the nuclear safeguards implemented by the International Atomic Energy Agency must be technically effective. They must in fact verify that nuclear material is not diverted to nuclear weapons or other nuclear explosive devices.

The political credibility of IAEA safeguards is also of substantial interest to the United States, and to the State Department. To a large degree we address this issue by maintaining the technical effectiveness of safeguards. However, political credibility involves additional factors, among them maintaining an international consensus supporting the IAEA safeguards system, and providing information concerning the nature and procedures of international safeguards to the public.

At the same time, U.S. support for IAEA safeguards is not without constraints. We must balance our interest in a strong international safeguards system with a wide range of competing priorities for the same resources, whether budgetary or political. This is one reason the U.S. has supported the policy of zero-real growth for the IAEA budget (that is, increases only to offset inflation).

The U.S. has a relatively complex inter-agency structure to coordinate our various activities and to ensure, to the degree possible, that our objectives are met. The capstone of this structure is an Inter-agency Steering Group on IAEA Safeguards. This group, referred to in our charming fashion as the ISG, consists of representatives from the State Department, the Arms Control and Disarmament Agency, the Department of Energy, the Nuclear Regulatory Commission, and the National Security Council staff. The Department of Defense is also a member when the ISG considers certain matters related to the U.S. Voluntary Offer safeguards agreement. Representation is at the deputy assistant secretary or office director level. The ISG oversees the work of a number of working groups or committees consisting of senior technical experts, some of which are familiar to you.

Originally there were two such working groups, the Action Plan Working Group and the Technical Support Coordinating Committee, each established in 1976-77. At that time, as most countries with significant nuclear programs ratified the NPT, the number of nuclear facilities and the quantities of nuclear material subject to safeguards increased very rapidly. In addition, a number of those facilities were larger and more complex than any previously subject to IAEA safeguards. The result was great stress on the IAEA's safeguards capabilities, which generated a crisis in confidence in the IAEA—specifically in the ability of the IAEA to continue to implement effective international safeguards.

The Action Plan Working Group (APWG) was established to provide a coordinated U.S. approach to correcting this situation. The APWG was charged with formulating and implementing a program of activities to resolve the strains in the system and to restore justifiable confidence in IAEA safeguards. As these U.S. efforts, in coordination with those of a number of other countries and the IAEA Secretariat, have resolved these problems, the role of the Action Plan Working Group has evolved. Today this group is largely responsible for coordinating the activities and technical views of the various U.S. agencies on safeguards matters, and serving as a vehicle for consultations on safeguards matters with our principal allies.

In the mid 1970's there was concern that the IAEA did not have the equipment necessary to apply effective safeguards, especially as its safeguards responsibilities were rapidly expanding. To address this concern the U.S. established a voluntary Program of Technical Assistance to IAEA Safeguards (POTAS). This U.S. program was placed under the guidance of a second inter-agency group, the Technical Support Coordinating Committee (TSCC). Like the Action Plan Working Group, the TSCC consists of experts from State, Energy, ACDA, and the NRC. Originally conceived as a $5 million program over 5 years, POTAS is now in its thirteenth year and is funded at $6.7 million for the fiscal year. Although miniscule in comparison with many other Federal programs, POTAS has proven to be singularly effective. Twelve other countries and the Commission of the European Communities have established similar programs.

Another set of inter-agency groups has its origins even earlier, though the groups were not formally established until 1980. As negotiations on the NPT were drawing to a close, a number of countries considering adherence to the NPT were concerned with the burdens they foresaw IAEA safeguards creating for their commercial nuclear industries; burdens that the competing industries in the nuclear weapons states would be free of. In particular these countries were concerned with an international inspectorate having access to commercially sensitive information, and with safeguards increasing the costs of commercial activities such as fuel fabrication. In order to allay these concerns, the United States and the United Kingdom each offered in December 1967 to accept safeguards on its respective civil nuclear industries. By this voluntary acceptance of safeguards we sought to demonstrate that the burdens imposed by safeguards would be small, and that any such burdens would not unfairly disadvantage commercial firms in Western Europe and Japan.

The U.S. Voluntary Offer safeguards agreement entered into force in December 1980, following entry into force of the NPT safeguard agreements of the non-nuclear weapon states of EURATOM and Japan. To manage the process of implementing IAEA safeguards in the U.S., two additional inter-agency groups were created. The Safeguards Agreement Working Group (SAWG) is responsible for monitoring and coordinating the routine activities of implementing our safeguards obligations. These include reviewing inspectors proposed by the IAEA for designation to the U.S., maintaining the list of U.S. facilities eligible for IAEA selection, and coordinating implementation of U.S. responsibilities to the IAEA with the implementation of domestic safeguards. The SAWG also provides a forum to ensure that all agencies are informed of the results of safeguards implementation at U.S. facilities selected by the IAEA. A second group, the Subsidiary Arrangements Negotiating Team, is responsible for negotiating Facility Attachments as U.S. facilities are selected for safeguards, and for negotiating what are known as Transitional Facility Attachments for facilities the IAEA selects under the Protocol to our safeguards agreement.

Our experience with safeguards at U.S. nuclear facilities has proven to be very informative. For example, the process of negotiating a Facility Attachment for a U.S. commercial fuel fabrication plant provides new insight into the complexities of ensuring effective safeguards implementation while preserving the interests of the facility operator. Similarly, experience with the many sources of potential discrepancies that may arise in the course of an inspection is instructive for understanding the comments of other governments and foreign facility operators, as well as views expressed by inspectors regarding inspection procedures. Safeguards are a complicated and very detailed business, and participation provides valuable insights.

Recently another working group was established to coordinate recruitment of qualified candidates for positions in the IAEA Department of Safeguards and placement of those individuals in jobs important to the U.S. This group, known as the Working Group on International Safeguards Staffing, is composed of the same four agencies as the other working groups. At present this group is working with the TSCC to develop an orientation course for U.S. citizens going to work in the Department of Safeguards. This course has several objectives. First, it is intended to ensure that these recruits understand the nature of international safeguards and how they differ from domestic safeguards. Second, the orientation course is to ensure that Americans joining the Agency's safeguards staff understand the role that IAEA safeguards play in U.S. nuclear non-proliferation policy, and how the IAEA relates to other international organizations. Finally, and of great importance, the orientation course will assist new recruits in the transition from living in the U.S. to living as part of an international community in a foreign country. For many Americans joining the IAEA is their first experience living abroad, and they are at first faced with an overwhelming number of unfamiliar details. One of the primary objectives of the new orientation course will be to give these new recruits information on life in Vienna and where they can get help on various aspects of adjusting to their new environment.

So far I have described how IAEA safeguards are a fundamental element of U.S. nuclear non-proliferation policy, and the fabric of inter-agency relationships involved in implementing that policy. Now I would like to describe the role that the State Department plays in all this.

International safeguards can be looked at from many perspectives. The establishment of an international safeguards system and the decision to participate in the system are political matters, reflecting basic policy decisions at the national level. I have referred to the decision of the United States to participate in establishing and maintaining an international safeguards system, and to make participation in that international safeguards system a requirement for our peaceful nuclear cooperation with other countries. Implementing that policy involves a number of more narrowly defined policy and legal issues as well. These are the perspectives people normally associate with the State Department's role in various areas of foreign policy.

International safeguards also involve a wide variety of more technical issues. In some cases reference to technical issues indicates matters with important direct policy content, such as defining the level and nature of inspection activities which constitute adequate verification of a State's undertakings. In other cases reference to technical issues relates to details of how inspections are performed—matters bearing directly on the work of individual inspectors and facility operators, such a defining the situation and procedures for using a specific non-destructive assay technique.

The State Department's role in implementing U.S. policy is directed towards policy issues rather than technical issues. However, the line between policy matters and technical matters is, like beauty, in the eye of the beholder. Within the community represented here today, the State Department is perceived to focus on policy issues related to IAEA safeguards. This is also true of the State Department's role in the various inter-agency groups described above. At the same time, within the Department, those of us who work on IAEA safeguards matters are perceived to be primarily technical, as focusing on the tools used to implement a broader policy objective: the maintenance of an effective international non-proliferation regime, of which safeguards is a cornerstone, but only that, one part of the foundation. Our specific concern in State is with how the realities of technical feasibility constrain our pursuit of policy objectives, and with ensuring that the technical implementation of safeguards is consistent with our policy objectives.

It is in this interface between the technical and the policy aspects of international safeguards that we in the State Department work, and it is at this interface that Brookhaven's Technical Support Organization has played a key role. TSO's staff consists of experts who have substantial technical competence in a wide variety of areas. They are also conversant in the broader political context within which international safeguards, and domestic safeguards, operate, and in which those safeguards are judged to fulfill their purpose or to fall short.

Over the years TSO has been involved in many projects supporting the U.S. Government, and specifically the State Department. TSO was involved in examining the domestic implications of accepting IAEA safeguards on our civil nuclear activities, and in developing the regulatory structure necessary to blend our obligations to the IAEA into an already well developed and complex domestic safeguard system.

As new uranium enrichment technologies have been developed and become issues for IAEA safeguards implementation, TSO has also played a substantial role. Commercialization of gas centrifuge enrichment technology created a significant new challenge for the safeguards community: how to ensure that effective IAEA safeguards are applied while also ensuring that information of great sensitivity is adequately protected. TSO assisted the U.S. Government during the multinational Hexapartite Safeguards Project, in which a new safeguards approach was developed for gas centrifuge enrichment plants in NPT states. TSO continued to play a vital advisory role during negotiation of the Facility Attachment for the Department of Energy's Gas Centrifuge Enrichment Plant. TSO is now working on the definition of safeguards approaches for atomic vapor laser isotope enrichment technology.

TSO has been a major contributor to U.S. support for the IAEA through POTAS. In the early years of POTAS this support included work on non-destructive assay instrumentation, including the famous Brookhaven Stabilized Assay Meter, or BSAM. TSO has long had a role in efforts to assist states and operators in fulfilling their safeguards obligations, including development of guidance on preparing facility design information for the IAEA and establishing state systems of accounting and control for specific types of nuclear facilities. TSO has worked on methods for evaluating safeguards implementation, and on optimization in the choice of verification techniques for bulk plutonium materials. Finally, TSO performed seminal work on computerized methods for allocating inspection resources.

The U.S. member of the IAEA Director General's Standing Advisory Group on Safeguards Implementation has repeatedly called on TSO for support in analyzing issues before that body. In this capacity TSO has studied such matters as fuel cycle safeguards concepts, and the technical implications of different thresholds for detection probabilities.

TSO has also been called upon to assist the State Department directly. Special studies of such issues as the implications of zero-real growth in the safeguards budget for maintenance of an effective international safeguards system have provided a valuable technical base for evaluating policy choices. The impact of their work has not always been readily apparent to those at TSO who assisted us, but their efforts in defining the structure of the problem and the likely products of the policy choices have made an important contribution to the policy debate within the U.S. Government.

Today we face a challenge similar to that of a decade ago: the resources available for international safeguards are not growing, even as the scope and complexity of the safeguarded nuclear industry continue to grow. It is vital that we maintain an IAEA safeguards system which provides effective verification of member states' undertakings concerning the peaceful uses of nuclear materials and facilities. It is also vital that the IAEA system continues to be perceived by member states and the public to be doing so; that we maintain a system which is credible in the international community. This will require that we continue to examine new technologies, and that we continue to reassess established assumptions and approaches.

Technical Support Organization Efforts in Support of IAEA Safeguards

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ABSTRACT

The Technical Support Organization (TSO) of the Brookhaven National Laboratory has been carrying out tasks in support of International Atomic Energy Agency (IAEA) safeguards since 1968, when TSO was founded. These tasks have been funded by both the Department of Energy Office of Safeguards and Security and by the United States Program of Technical Assistance to IAEA Safeguards (POTAS). These tasks have included a variety of systems studies (e.g., the zone approach to IAEA safeguards, the Safeguards Effectiveness Assessment Methodology, and international safeguards for uranium enrichment plants), development of instruments (e.g., the automated electromanometer and the load-cell-based weighing system for UF_6 cylinders), preparation of guidance documents, training of inspectors, and the development and evaluation of safeguards seals. This paper reviews some of the highlights from this program of support.

I. INTRODUCTION

The technical Support Organization (TSO) of the Brookhaven National Laboratory (BNL) has been carrying out tasks in support of International Atomic Energy Agency (IAEA) safeguards since 1968, when TSO was founded. These tasks have been funded by both the Department of Energy (DOE) Office of Safeguards and Security (OSS) and by the United States Program of Technical Assistance to IAEA Safeguards (POTAS). These tasks have included systems studies, development of instruments, training of inspectors, and the development and evaluation of safeguards seals (e.g., paper seals, Type-E seals, seals for light-water-reactor fuel assemblies, and seals for UF_6 cylinders). In this paper, I will describe some of the highlights from this program of support.

II. AUTOMATED ELECTROMANOMETER

The flows of nuclear material to and from a nuclear-fuel reprocessing plant are typically determined by measuring the volume and concentration of solutions contained in the input-and output- accountancy tanks. Liquid-level (and thereby volume) measurements for process tanks using liquid-column manometers have been made routinely at such plants for over 30 years. However, these measurements have been performed manually, and thus were slow and prone to reading and transcription errors.

As part of the Tokai Advanced Safeguards Technology Exercise (TASTEX) which took place during the period 1978-1982, TSO staff members developed an automated electromanometer system to measure the volume and density of solutions in the input- and product-accountancy tanks of the Tokai Reprocessing Facility in Japan. The automated electromanometer system involved the first application of the following three types of equipment to such measurements:

- an electromanometer of laboratory precision and accuracy for routine process measurements;
- a controlled pneumatic scanner for measurement of multiple pneumatic lines in each of several tanks using a single electromanometer; and
- a desktop computer to control the measurements and equipment for on-line data acquisition and routine data analysis.

It was the integration of the above equipment into a unified system that made the measurement method unique. All of the components of the automated electromanometer system are commercially available. The advantages of the automated electromanometer system are:

- digital data read-out of the liquid-level measurements;
- overall measurement error on the order of 0.1% in the liquid density and volume;
- on-line computerized acquisition, processing, storage, and analysis of the measurement data;
- visual (CRT) displays of current measurement values and time response status plots; and
- prompt and accurate hard-copy summary reports of the input- and plutonium-product tank volumes.

This work has been described in detail in a series of reports.[1-5]

II.A. Measurement of Solution Volume and Density with Bubbler Probes

The typical arrangement of bubbler probes in a process tank is shown in Figure 1. The bubbler-probe technique is based on the measurement of the back pressure on the metered air being blown through a probe installed in the tank. The liquid level is measured as differential pressure relative to the tank vapor head and is proportional to the weight of the column of liquid above the effective tip of the bubbler probe. The volume of liquid in the tank is a function of the liquid level and geometry of the tank, and is determined by calibrating the level against known quantities of liquid. The density of the liquid is determined by measuring two liquid levels using bubbler probes of unequal length. Typically, the level bubbler probe is used for one pressure leg and a second bubbler probe, about 25 centimeters shorter than the first, is installed to provide the other pressure leg.

II.B. Principle of Electromanometer Operation

The principle of operation of the electromanometer is shown in Figure 2. The pressure sensor consists of a hollow spiral quartz Bourdon tube with a small curved mirror mounted on the free end and with two wire-wound coils suspended from the body of the tube. These coils are positioned in the field of permanent magnets which are anchored to the Bourdon-tube case. The curved mirror is positioned on the Bourdon tube so that it reflects a light onto a pair of photocells. At the zero reference point, the photocell output is balanced to create a null signal condition.

As test pressure is introduced into the Bourdon tube, the light beam reflected by the mirror traverses the balanced photocells, generating an off-null signal. This electrical current is amplified and fed through the force-balancing coils creating an electromagnetic torque equal and opposite to that caused by the pressure in the tube. This current is then passed through a precision resistor, creating an analog voltage directly proportional to the pressure in the system. Because of the high degree of linearity of the servo loop, the results can be displayed on a digital voltmeter in any convenient pressure units by appropriately scaling the signal.

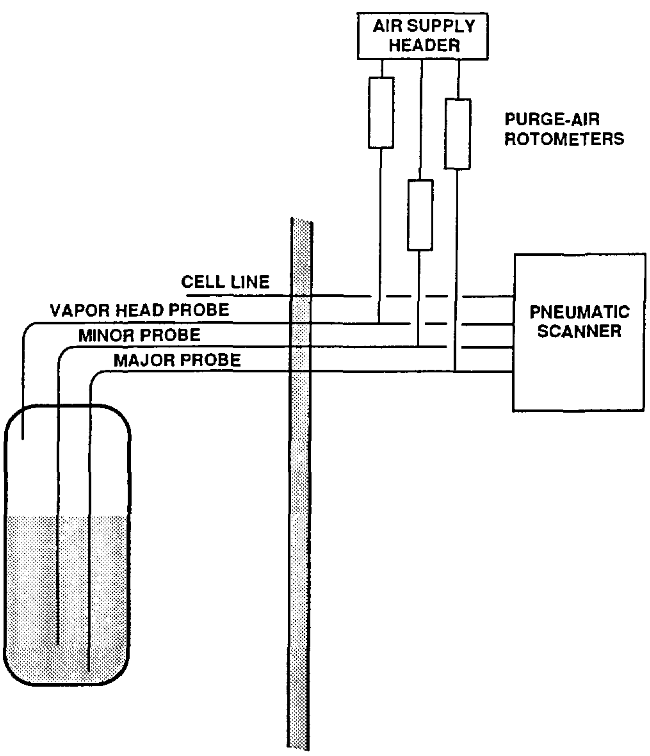

Figure 1. Schematic of Bubbler-Probe Lines in a Process Tank

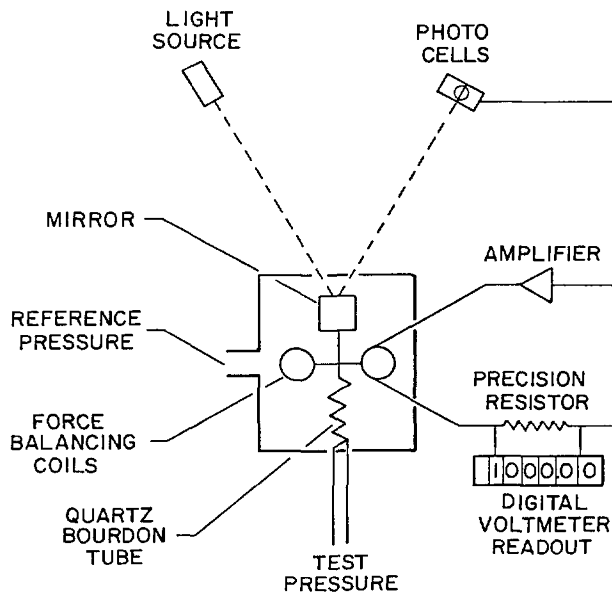

Figure 2. Principle of Operation of the Electromanometer

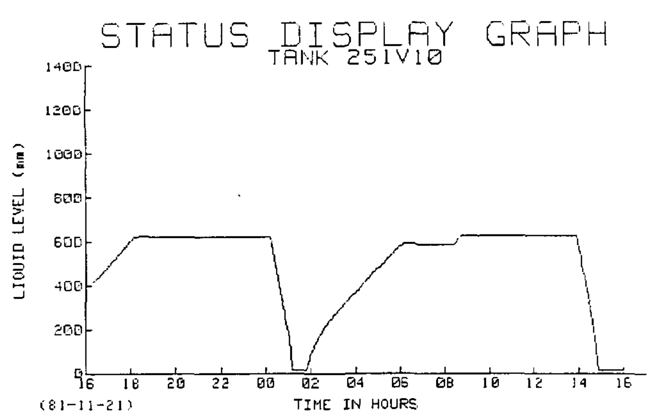

Figure 3. Liquid-Level Monitoring for the Input Accountability Vessel of a Reprocessing Plant

II.C. Pneumatic Scanner

The scanning of different pneumatic lines is accomplished with a pulser-controller and a fluid-switch wafer assembly. The fluid-switch wafer is equipped with 12 input channels and a common output line which is connected to the electromanometer. A solenoid drive is used to step the fluid-switch wafer. Mounted on the same drive shaft are two electronic-switch wafers. The electronic-control switch wafers are used by the pulser-controller to locate the channel selected by the computer.

II.D. Results and Current Status

The BNL automated electromanometer is being used to provide continuous, on-line acquisition and processing of calibration and measurement data of solution volume and density for both the input- and plutonium-product accountability vessels at the Tokai plant. The operator makes use of these data for process and material-accountability purposes, while the IAEA uses them for flow and physical-inventory verification purposes. An example display of liquid level as a function of time for the input-accountability vessel is provided in Figure 3. The facility is under continuous inspection so that the inspectors can verify all flows and inventories; accountability is carried out on a near-real-time basis. Arrangements have been made between the facility operator and the IAEA for authentication of the measurement results. For example, the inspector can substitute IAEA software for the operator's software when verifications are to be performed, and backup measurements using a liquid-column manometer can also be performed.

Calibration and measurement tests of the system at Tokai, the Barnwell Nuclear Fuel Plant and the Idaho Chemical Processing Plant in the US, and the EUROCHEMIC facility in Belgium have demonstrated that the system has an overall relative accuracy and precision of better than 0.1%.

Continuing this highly successful program, a TSO staff member installed an automated electromanometer system in the IAEA bulk-measurement training laboratory as a part of POTAS Task A.144, and participated in the training of IAEA inspectors in the use of this and related equipment as part of the Introductory Course on Agency Safeguards (ICAS). Under POTAS Task A.156, the staff member is currently assisting the IAEA in developing inspection procedures for, and a training course on, the verification of tank calibrations.

III. LOAD-CELL-BASED WEIGHING SYSTEMS FOR UF_6 CYLINDERS

III.A. System Design

To apply IAEA safeguards to low-enriched uranium (LEU) in enrichment and fuel-fabrication plants, it is necessary for the IAEA to have independent means of verifying the weights of UF_6 cylinders. Filled 30-inch diameter cylinders have masses of the order of three metric tons, and it is thus not possible for an inspector to carry appropriate check weights with him. The use of facility scales, calibrated with facility standard weights, does not provide the required independent verification capability for the IAEA inspector. To satisfy the need for such an inspector's tool, the U.S. National Bureau of Standards (NBS), under the Program of Technical Assistance to IAEA Safeguards (POTAS), developed a portable, highly accurate, load-cell-based weighing system (LCBWS), using commercially available, off-the-shelf components. The system also is intended to be easy to assemble and operate. TSO has assisted in the field testing and implementation of the system.

The original design, which was developed and calibrated by NBS,[6] is illustrated in Figure 4. The core of the system is a load cell, about 4 kg in weight, approximately 15 cm long and 10 cm in diameter. In weighing operation, the cylinder being weighed is suspended below, and in series with, the load cell. As the cylinder is raised from its support, the load cell elastically deforms in response to the weight of the cylinder. This elastic deformation is sensed by electrical-resistance strain gauges that are bonded to the primary load-supporting element of the load cell in an electrical full-bridge configuration. The electrical resistance of the gauges changes by an amount that is proportional to the force (weight) exerted by the UF_6 cylinder. A small electronic instrument called a "transducer indicator" provides a digital readout of the bridge imbalance. One additional passive electronic device is needed: the transducer simulator or "standardizer". This is a network of stable precision resistors which, when connected to the

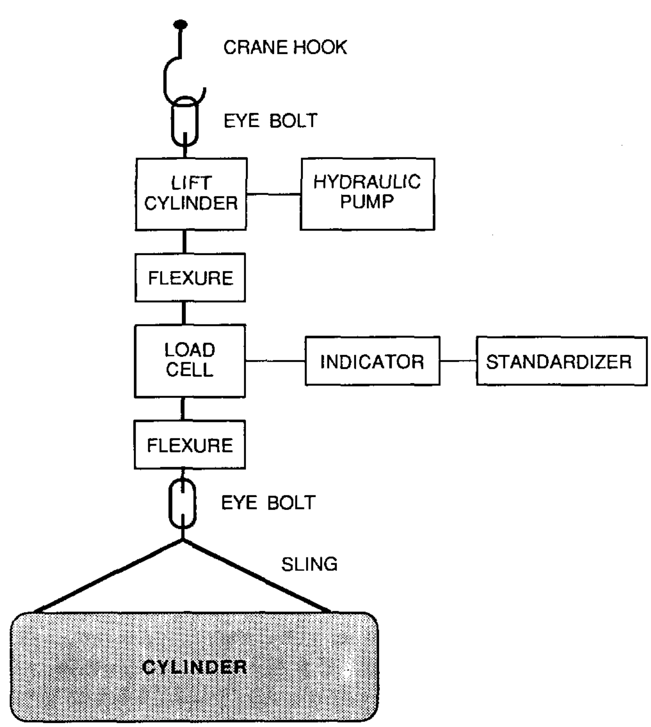

Figure 4. Original U.S. National Bureau of Standards Design for the Load-Cell-Based Weighing System

indicator, simulates the electrical response of the load cell in precisely known steps. The simulator is used to assure that the characteristics of the indicator electronics have not changed substantially since the last calibration. Two intricately machined devices, called "flexures", are connected to the load cell, one at each end, by means of threaded rods. Their function is to assure the absence of nonaxial forces, which could cause weighing errors; the flexures bend through small angles to compensate for nonaxial loads. In addition, a lift cylinder, actuated by a hydraulic pump, served as a means of gently raising and lowering the cylinder.

After the initial design and development of the LCBWS by the NBS, TSO was asked to assist with the field-testing and implementation (including preparation of operating, maintenance, calibration, and shipping and packing manuals). In addition, IAEA inspectors had noted that the lift cylinder and flexures increase the weight and bulk of the system, and thus part of the field testing was intended to determine if these components could be eliminated without serious loss of performance. The LCBWS was demonstrated and tested during 1981 and 1982 at the Capenhurst Works in the United Kingdom, the Exxon Nuclear Company, Inc. fuel-fabrication facility and the Oak Ridge Gaseous Diffusion Plant in the United States, the Ningyo-Toge Works in Japan, and (under the German Support Program) the NUKEM facility in the Federal Republic of Germany.[7-9]

III.B. Results and Current Status

The field tests showed that raising and lowering the cylinder using the facility-operator's crane or other equipment could be performed without damaging the load cell or significantly affecting the measurement results. In addition, while elimination of the flexures did degrade the measurement performance somewhat (accuracy and precision went from about 0.3 kg to about 1 kg), the accuracy and precision achieved without them are quite adequate for the IAEA's purposes. Thus, these components have been eliminated.

Based on these field tests, it has been shown that the current LCBWS has the following characteristics:

- light and portable, with the load cell weighing about 4 kg and the remainder of the system weighing about 5 kg;
- measurement accuracy and precision of better than ± 1 kg for weights up to about 3000 kg;
- easy to operate, and reads measurement results directly in kg;
- rapid, with an assembly time of about 5-10 minutes, a warmup time of about 20 minutes, and a measurement rate of about 10-15 cylinders per hour in areas serviced by an overhead crane; and
- non-intrusive to the operator.

The LCBWS had been authorized by the IAEA for routine use in inspections, and is being thus used at uranium-enrichment and fuel-fabrication facilities. A LCBWS capable of weighing the heavier 48-inch diameter cylinders, which are often used for UF_6 feed and tails and have weights up to 15,000 kg, is under development.[10]

IV. GUIDELINES FOR SSACS

IV.A. Origin of the Work

The development and maintenance of a State System of Accounting for and Control of Nuclear Material (SSAC) can be directed toward two primary objectives. One is a national objective to provide for detection of nuclear-material losses or unauthorized use or removal of nuclear material. The other is an international objective to provide the basis for the application of IAEA safeguards pursuant to the provisions of Agreements between the State and the IAEA. To assist member states with regard to the system directed toward the international objective, the IAEA issued the guidance document IAEA/SG/INF/2 in 1980.[11] Although that document provided a basic structure for an SSAC, some states had expressed a need for more detailed guidance with regard to the technical elements in the design and operation of SSACs for both the national and the international objectives. To meet this need TSO, in cooperation with the IAEA, prepared a set of guides describing the technical elements of an SSAC in considerable detail.[12-21]

The descriptions in the guides are not meant to be prescriptive in nature; rather, they should be regarded as illustrative and representative of good practice. SSACs designed and operated at the facility level along the lines described in the guides are capable of meeting national system objectives as well as fulfilling the undertakings of the state with respect to international safeguards, and of enhancing the ability of the IAEA to carry out its responsibilities.

It was intended that these guides would not only assist states in establishing their national systems, but contribute to their understanding of the IAEA's needs in carrying out its obligations, and thereby help make international safeguards more effective, efficient, and less burdensome to the state and operator. It was also hoped that the guides will be a useful training tool for those responsible for the operation of an SSAC at either the state or the facility level.

IV.B. Content of the Guides

Guides were developed for a variety of facility types, as well as at the state level, and include the following:

- State Level
- Research Laboratory Facilities
- Critical Facilities
- LEU-Conversion and Fuel-Fabrication Facilities
- Mixed-Oxide Fuel Fabrication Facilities
- Research Reactors
- Light-Water-Moderated (off-load refueled) Power Reactors
- On-Load Refueled Power Reactors
- Irradiated Fuel Reprocessing Facilities
- Centrifuge Enrichment Facilities.

For each facility type, the documents provide detailed descriptions of:

- the reference facility;
- nuclear-material measurements;
- measurement quality;
- records and reports:

- physical-inventory taking; and
- material-balance closing.

The chapter on nuclear-material measurements for the reference facility describes the material-balance areas, key measurement points, materials and material types, measurement methods, bulk measurements, sampling, analytical measurements, nondestructive assay (NDA), and documentation needs.

The chapter on measurement quality provides detailed descriptions of measurement-system qualification; standards and calibrations for bulk measurements, analytical measurements, and nondestructive analysis; and the measurement-control program, including measurement monitoring, measurement-control data evaluation, and documentation.

The chapter on records and reports includes detailed descriptions of the accounting records, including the ledgers, the inventory-change journals, and the supporting documents; the operating records; the accounting reports, including the Inventory Change Reports, Material Balance Reports, and the Physical Inventory Listing; and the handling of data, including material-balance area (MBA) and facility records, source data and operating records, data flow, shipper-receiver differences, and internal controls.

The chapter on physical-inventory taking includes detailed descriptions of inventory measurement, inventory organization and planning; the conduct of the inventory; and post-inventory activities.

The chapter on material-balance closing includes detailed descriptions of the material-balance equation and the evaluation of material-unaccounted for (MUF), including statistical analysis.

The SSAC guides are now used as the standard reference books in SSAC training courses at the IAEA and in several countries around the world.

V. ZONE APPROACH TO IAEA SAFEGUARDS

V.A. Origin of the Work

The structure and content of Agreements between the IAEA and states required in connection with the Treaty on the Non-Proliferation of Nuclear Weapons are defined in INFCIRC/153 (Corrected). According to Para. 81 of that document, the actual number, intensity, duration, timing, and mode of routine inspections of any facility shall take into account the characteristics of the state's nuclear-fuel cycle, including the number and types of facilities containing nuclear material subject to safeguards, the characteristics of such facilities relevant to safeguards, and the extent to which information from different material-balance areas can be correlated.

However, at present, the IAEA designs its safeguards approach with regard to each type of nuclear facility so that the safeguards activities and effort are essentially the same for a given type and size of nuclear facility wherever it may be located. According to this conventional, facility-oriented approach, material accountancy applied to each MBA within each facility is the fundamental safeguards technique. Thus, each component (i.e., flows and inventories) of the material balance should be verified by the IAEA for each MBA. Conclusions regarding a state are derived by combining the results of safeguards verifications for the individual facilities within it. An IAEA Consultants Meeting on the Application of Safeguards to Multiple Facility Fuel Cycles, held in 1984, recommended that three of the proposals discussed (approaches based on information correlation, randomization, and extended material-balance areas or "zones") deserved further study. The underlying goal is to enhance the efficiency and effectiveness of IAEA safeguards inspections, particularly for large fuel cycles. This is even more important now, since the IAEA has had in the recent past and is faced with a zero-growth budget for the foreseeable future.

V.B. Description of the Zone Approach

According to the zone (extended MBA) approach, material accountancy is applied to a collection of facilities in a fuel cycle instead of to a single facility. The essence of the zone approach is then the elimination of measurement verifications of interfacility (or inter-MBA), intrazone nuclear-material flows and the determination of verified inventories for all of the nuclear material within the zone for the beginning and end of the zone material-balance period. Interzone flows would continue to be verified. Since material accountancy would be verified for the zone material balance but not for the material balance for each facility, the particular facility at which there is a nuclear-material discrepancy could not in theory be determined from information verified by the IAEA. A determination of the zone material unaccounted for (MUF) requires that the physical inventory of the zone be verifiably determined at the beginning and end of the material-balance period. A conceptually simple way to do this is by carrying out simultaneous (or nearly simultaneous) physical-inventory verifications (PIVs) at all the facilities within the zone. They must extend over a time sufficiently long to allow all the material in transit between the facilities in the zone to be received for verification. An additional benefit of simultaneous PIVs is the prevention of concealment of diversion of nuclear material at one facility by the "borrowing" of substitute material from another.

TSO staff members have begun a study of the application of the zone approach to a reference advanced nuclear-fuel cycle which includes a UF_6-to-UO_2 conversion plant, three LEU fuel-fabrication plants, twenty-one light-water reactors of the pressurized-water-reactor (PWR) and boiling-water-reactor (BWR) types, a reprocessing plant, and three mixed-oxide (MOX) fuel-fabrication plants. The facilities of the fuel cycle are divided into three zones that contain nuclear material with different safeguards significance and different timeliness goals: unirradiated LEU, irradiated fuel assemblies, and unirradiated plutonium. Thus, in this study, the first ("fresh-fuel") zone includes the conversion plant, the LEU fuel-fabrication plants, and the fresh-fuel storage areas of the reactors. The second ("irradiated fuel") zone includes the cores and spent-fuel storage pools of the reactors and the spent-fuel storage pool of the reprocessing plant. The third ("plutonium") zone includes the separation and nitrate-to-oxide conversion portions of the reprocessing plant, and the mixed-oxide fuel-fabrication plants. The intention is to develop an approach which will make it possible to compare the technical effectiveness and the inspection effort for the facility-oriented approach, for the zone approach, and for some reasonable intermediate safeguards approaches.

V.C. Results and Current Status

Thus far, the TSO staff members have applied the zone approach to the fresh-fuel zone of the reference fuel cycle in order to ascertain the savings in IAEA inspection effort that might be achieved in comparison with the current facility-oriented approach.[22-25] The analysis considered the safeguards inspection activities that would be required for auditing of records and reports; material-balance-verification bulk measurements, sampling, and analysis; containment and surveillance; and miscellaneous activities. In addition, the analysis included estimates of the amount of time required for each activity. In the "maximal facility-oriented approach", complete flow-measurement verification at each of the bulk-handling facilities in the zone required 770 man-days of inspection effort; however, it should be noted that this approach is more stringent than current IAEA practice. A variation of the facility-oriented approach which more closely approximates current practice would require 617-644 man-days. In comparison, according to the zone approach, some or all of the intrazone flows would not be verified. Application of the zone approach would require 488-548 man-days for the safeguards inspections. Thus, for the fresh-fuel zone, one expects that the zone approach could result in a 20-30% savings in inspection effort as compared with the facility-oriented approach.

One requirement of the zone approach is the performance of nearly simultaneous physical-inventory verifications (PIVs) for all of the facilities in the zone, which in turn depend on simultaneous physical-inventory takings (PITs) by the operators of the facilities. Thus, implementation of the approach by the IAEA would require significant cooperation by the facility operators and the state. However, fewer inspection resources would be required at some facilities, and as a consequence, the burden of inspections on facility operations would be reduced. Conducting simultaneous PIVs at all facilities within a fuel-cycle zone would force the IAEA to concentrate a large number of inspectors in one state nearly simultaneously, leading to questions regarding the availability of trained, acceptable inspectors and appropriate measurement equipment. These questions need further consideration.

Under POTAS Task C.71, TSO staff members are now studying the application of the zone approach to the plutonium facilities of the reference LWR fuel cycle, slightly modified for the present work. Comparable percentage savings may not accrue for the facilities within this "plutonium zone". A major difference characterizing such a zone is that the timeliness goal for Pu requires monthly interim inventory verifications at facilities handling Pu, whereas the timeliness goal for U-235 at LEU facilities equals the one-year time between PIVs. Thus inspection visits to Pu facilities would have to be very frequent even in the complete absence of flow verification. Nevertheless, in assessing the improvements in safeguards efficiency that might result from the zone approach, it will be useful to determine the level of savings that can be achieved here as well.

VI. SAFEGUARDS EFFECTIVENESS ASSESSMENT METHODOLOGY (SEAM)

VI.A. Development and Description of the Methodology

In 1979, the IAEA initiated a series of consultants meetings whose purpose was to address the problem of devising a general method of assessing the technical effectiveness of IAEA safeguards. The Consultants Group prepared and approved two documents: an overview of the proposed methodology and an example application of the methodology to a light-water-reactor safeguards approach.[26] In 1981, a 13-nation Advisory Group was convened by the IAEA to review the work of the Consultants Group.[27] It concluded that the basic principles of the methodology were sound and recommended further testing and application.

The methodology can be described briefly as having the following components:

- Description of the facility, including material types and amounts and other safeguards-relevant data.
- Specification of the technical safeguards objectives, including detection goal quantity and timeliness goals.
- Definition of the safeguards approach. This includes a description of the different types of inspections planned and the timing of each type of inspection. It includes the set of safeguards activities to be performed, both in the field and at headquarters. It also includes a description of the set of anomalies that might be observed as a result of these activities, and the follow-up activities that would be needed to resolve those anomalies.
- Diversion-path analysis, which systematically identifies the possible methods by which nuclear material might be diverted and the logical combinations of concealment methods that might be used to conceal each possibility.
- Assessment, for each diversion path, of the probability that an anomaly will be detected by the defined safeguards system, should diversion occur in the manner described by the path.
- Categorization of the set of diversion paths (and hence detection probabilities) into three levels of "technical complexity," depending on the degree of difficulty involved in carrying out the diversion and/or concealment strategies. It is clear that some diversion paths are more readily implemented than others and are more important to protect against. It is desirable to be able to allocate IAEA resources so as to cover the more important paths more effectively.
- Summary of results. Basic results are bar charts giving the set of detection probabilities, categorized by technical-complexity level. It is sometimes useful to reduce these results to a more transparent and manageable form. One method of doing this is to present a histogram of the detection probabilities of the

paths for each complexity level. Further data reduction, by means of a formula (or "aggregate measure") combining detection probabilities into numerical indices, was also considered, although there was no agreement on any particular formulation.

VI.B. Applications of the Methodology

Three modes of application were envisioned for the assessment methodology:

1. "Design assessment," in which a safeguards approach is evaluated *a priori*, based on realistic but generic assumptions with respect to a representative facility, in order to evaluate safeguards-design concepts;
2. "Implementation assessment" in which a safeguards approach to a specific facility is evaluated; and
3. "Performance evaluation" in which an assessment is made on the basis of inspection activities as carried out in the field over a specified period.

Two of the above types of studies were undertaken with the SEAM methodology; the "case-study" applications to safeguards-system design assessment involving various facility types, and the trial application of the methodology to actual inspection reports (a performance evaluation) for a number of pressurized-water reactors.

The "case studies" were based on a well-defined (but not necessarily real) facility and a hypothesized safeguards approach involving techniques which are within the current capabilities of the IAEA. The effectiveness of the approach was analyzed in detail. Case studies were carried out for several types of facilities, including light-water reactors (LWRs), a mixed-oxide (MOX) fuel-fabrication facility, and a reprocessing plant.[26,28-34]

In a "trial application" of the methodology in 1982, the Safeguards Evaluation Section of the IAEA analyzed the inspection reports obtained for 15 pressurized-water reactors over a period of a year.[35] However, the trial application and the conclusions that could be drawn from it were limited because certain information needed for the analysis was not available.

VI.C. Summary

The development of the methodology and the process of applying it have had a number of beneficial effects.[36] A number of concepts and procedures that are now accepted as standard at the IAEA evolved with the development of the methodology; for example, the development of standard "Model Inspection Activity Lists" and the designation of particular sets of anomalies relating to specific facility types as part of the reporting procedure for inspections. Information and analysis developed for case-study and diversion-path-analysis work both at the IAEA and under POTAS have contributed to safeguards design and evaluation procedures. Even the difficulties that were experienced in the trial application pointed out the need to develop an "evaluation data base" necessary to support any type of serious safeguards evaluation. The methodology as it now stands is much more acceptable in the "design" mode, to analyze in detail a specific hypothesized situation, than in the "performance" mode to reach general conclusions about a large number of facilities, as was done in the trial application.

VII. IMPROVED SAMPLING PLANS

The IAEA has adopted a material-balance-verification strategy which is designed to detect effectively and efficiently both diversion into MUF and falsifications of material-balance quantities by large and small amounts. It proves useful for the IAEA to make measurements at two levels of accuracy and precision; these are called "attributes" and "variables" measurements. An "attributes" measurement is one which can be performed quickly but which may have a relatively poor precision and accuracy; such a measurement is performed on a relatively large fraction of the items in the material balance in order to detect large falsifications. A "variables" measurement is one which has high precision and accuracy but which is often time-consuming and expensive to perform; it uses the IAEA's most accurate measurement method for an item. Variables measurements are performed to detect small falsifications (i.e., falsifications small enough to escape detection by the attributes measurement) and to detect biases. This two-level strategy of attributes and variables measurements is efficient because

1. the attributes test can be performed quickly, and
2. if the attributes test is performed, a divertor wishing to avoid detection is forced to make a larger number of falsifications of a smaller size; this enables the inspector to reduce his variables-test sample size.

A TSO staff member has developed improved sampling plans for the attributes/variables measurement method for verification of the operator's material balance. These improved sampling plans include

a. improvements for the standard two-level approach described above; and
b. development of a three-level approach, including the extension of the technique to an arbitrary number of levels of measurement precision and accuracy.

The first improvement has been made for two-level sampling plans, involving attributes measurements and variables measurements in the attributes mode.[37,38] The savings in the number of variables measurements required to achieve a given detection probability ranged from 38% to 70%, as compared with the standard calculational methods available at that time.[39,40] These savings resulted from better (but still conservative) approximations used in the analysis of derived detection probability. In particular, they arise from two features of the calculation. First, the method specifies that an alarm generated by a gross-attributes test of an item is followed by a confirmatory variables measurement of that item; this allows a higher false-alarm rate in the gross-attributes test. Second, the method explicitly recognizes that either the attributes test or the variables test can produce a detection for item falsifications in the region around three standard deviations in the measurement uncertainty for the gross-attributes test.

The second improvement has been the development of a three-level approach in which there are three measurement methods with three levels of accuracy and precision. These could be a gross-attributes measurement (e.g., a neutron-based NDA method with a measurement standard deviation of 10%), a fine-attributes measurement (e.g., calorimetry plus high-resolution gamma spectrometry with a standard deviation of 2%), and a variables measurement in the attributes mode (e.g., sampling and destructive analysis with a standard deviation in the range of a few tenths of a percent). TSO staff members have applied this three-level technique to the verification of material-balance strata containing PuO_2 and mixed-oxide powders and pellets.[41] Finally, the theory has also been generalized to include the case where there are multiple levels of measurement accuracy and precision.[42]

VIII. SAFEGUARDS FOR URANIUM-ENRICHMENT PLANTS

TSO has been involved with the development of international safeguards for uranium-enrichment plants since 1971, beginning with work on safeguards for gaseous-diffusion and gas-centrifuge plants. There are two principal safeguards concerns at uranium-enrichment facilities which are subject to IAEA safeguards and which have been declared for the production of low-enriched uranium. These are the following:

- Timely detection of the production of a significant quantity of uranium at an enrichment greater than declared, in particular highly enriched uranium (HEU); and
- Timely detection of the diversion of a significant quantity of uranium, especially low-enriched uranium (LEU).

In addition, the inspections should make efficient use of scarce IAEA inspection resources as well as being effective. At the same time, the facility operator has several concerns, including:

- Protection of sensitive enrichment technology; and
- Costs and impact on operations.

The goal in the development of international safeguards approaches is to satisfy simultaneously these sometimes conflicting objectives. TSO has helped develop approaches for, and performed assessments of, international safeguards at enrichment plants based upon:

- Gaseous Diffusion
- Gas Centrifuge
- Atomic Vapor Laser Isotope Separation (AVLIS)
- Molecular Laser Isotope Separation (MLIS)
- Plasma Separation Process (PSP)

In this paper, I will touch upon some of the principal developments since 1971.

TSO staff members performed effectiveness analyses during 1971-1972 of a variety of IAEA access and non-access safeguards approaches for gaseous-diffusion and gas-centrifuge enrichment plants.[43,44] For gaseous-diffusion plants, these analyses considered four levels of access:

a. Level 1—access up to the perimeter fence, to UF_6 cylinders passing control points at the perimeter fence, and to UF_6 cylinders in storage yards;
b. Level 2—access as in Level 1, plus verification of feed and withdrawals at the cascade;
c. Level 3—access as in Level 2, plus access up to the walls of the diffusion cells and verification of the cascade isotopic gradient; and
d. Level 4—access as in Level 3 plus access within the cells, but not to the interiors of the separative equipment. Similar cases were studied for safeguards at gas-centrifuge plants.

TSO staff member assisted the Department of Energy and the Arms Control and Disarmament Agency in preparation of the US contribution to Working Group 2 of the International Nuclear Fuel Cycle Evaluation (INFCE) in 1979.[45] The paper provided a methodology for estimating the potential effectiveness of selected IAEA safeguards strategies for gas-centrifuge and gaseous-diffusion plants, taking into account various levels and timing of inspector access to the plants. Five cases were studied:

a. Perimeter access beginning at or after the start of operation;
b. Perimeter access during construction and during operation;
c. Perimeter access from the start of operation, and a one-time inspection of the cascade area just before operation begins;
d. Free access to the cascade area during construction but perimeter access only, after operation begins; and
e. Cascade access, as defined in the IAEA-State Agreement, during construction and during operation.

During the period 1978-1985, TSO staff developed the material-balance-verification approach proposed by the US for IAEA inspections at the Portsmouth Gas Centrifuge Enrichment Plant (GCEP).[46-49] This work included descriptions of the facility, the nuclear-material-handling procedures, the material-balance accounting performed by the facility operator, methods by which the IAEA could verify the anticipated nuclear-material flows and inventories (with the exception of the cascade gas-phase inventory), attributes and variables sampling plans, and the expected IAEA capability for detection of diversion. In addition, TSO staff performed effectiveness evaluations of US-developed approaches for detection of HEU production, which included area monitoring based on gamma-ray and neutron measuring equipment, gamma-ray measurements on individual centrifuges, and gamma-ray monitoring of cascade header pipes. A TSO staff member served as a technical advisor to the US negotiating team during the Hexapartite Safeguards Project (HSP) in 1981-1983,[50] and again during the Facility Attachment negotiations for the Portsmouth GCEP in 1984-85.

TSO staff members performed assessments of domestic and international safeguards for the DOE Process Evaluation Board (PEB) during the enrichment-process selection in 1982 (when the AVLIS process was selected in preference to the MLIS and PSP processes) and again in 1985 (when the AVLIS process was selected in preference to the Advanced Gas Centrifuge process).

At present TSO is assisting the Department of Energy with the development of an international safeguards approach for the planned AVLIS uranium-enrichment plant, including a capability for detection of both HEU production (should it occur) and diversion of uranium. In addition, as part of POTAS Task A.155, TSO (in cooperation with Los Alamos National Laboratory and Martin Marietta Energy Systems, Inc.) is preparing detailed documentation of the IAEA inspection procedures (except for activities associated with the Limited Frequency Unannounced Access approach) at gas-centrifuge enrichment facilities at Almelo (The Netherlands), Gronau (Federal Republic of Germany), Capenhurst (United Kingdom) and Ningyo-Toge (Japan).

TSO has maintained expertise in, and assistance with development of, domestic and international safeguards for uranium-enrichment plants for almost twenty years. We anticipate that this experience and capability will be useful to the US Government and the IAEA for many years to come.

IX. SUMMARY AND CONCLUSIONS

TSO has a long history of providing assistance to IAEA safeguards, with the view of making them more effective and efficient while at the same time recognizing the needs and concerns of the facility operator. The work is both interesting and challenging, and we look forward to providing continued support of this kind for many years into the future.

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Los Alamos Safeguards Program Overview and NDA in Safeguards

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ABSTRACT

The safeguards R&D program at Los Alamos will be outlined briefly, from its formal beginning in December 1966 to the present. From the start, an important factor in the success and ongoing achievements of the Los Alamos program has been a close technical liaison between safeguards researchers and the materials processing experts in the Laboratory's extensive nuclear material processing facilities. Some of the major contributions of the program to safeguards technology development and its effective implementation will be highlighted, together with a brief overview of the several ongoing safeguards training courses at Los Alamos for IAEA inspectors and safeguards professionals from the United States as well as many advanced and developing countries around the world.

It is a pleasure to be here at Brookhaven with so many long-time friends and colleagues to participate in this special Symposium celebrating the Twentieth Anniversary of the Technical Support Organization at Brookhaven National Laboratory. The wide-ranging activities of the TSO as well as ISPO and the POTAS program of technical assistance to the International Atomic Energy Agency and international safeguards have through the years interacted closely with safeguards activities in various laboratories, including the safeguards research and development (R&D) program at the Los Alamos National Laboratory, on which I've been asked to speak.

To understand the origin and thrust of safeguards R&D generally, and the Los Alamos safeguards program in particular, it is necessary first to set the relevant historical perspective. From the very dawn of the nuclear age the dangers and potential for misuse of nuclear fission energy were clearly recognized, and by the close of World War II some statesmen held the hope that placing all nuclear activities under international ownership and management could provide a basis for preventing, or at least restraining, the proliferation of nuclear weapons. In 1946, the Baruch plan proposed the creation of an international atomic development authority, to be entrusted with all phases of the development, use, inspection, and control of nuclear energy. The plan delineated the need for restraint in nuclear-weapon development and for international safeguards and penalties to prevent diversion of nuclear materials from civilian nuclear power programs. It also proposed that all nations forego the production and possession of nuclear weapons. Although many elements of the Baruch plan were eventually incorporated into international safeguards, in its time the plan was rejected and by 1952, three nations had produced nuclear weapons. Secrecy became the fundamental nuclear policy of the United States and other nations. By the early 1950's, many nations were seeking ways to acquire the benefits of nuclear technology and to develop their own nuclear energy programs. This burgeoning activity had an inherent potential not only for peaceful uses but also for military applications. The situation clearly called for renewed attempts to arrive at some form of international understanding, consensus, and constraint.

President Eisenhower's 1953 proposal, the widely-hailed "Atoms for Peace" program, marked a fundamental change in U.S. nuclear policy. The program was designed to promote international cooperation in the peaceful uses of nuclear energy and, at the same time, to establish international controls to ensure that the products of this cooperation would not be diverted to military uses.

A major event early-on in the Atoms for Peace program was the first United Nations Conference on the Peaceful Uses of Atomic Energy; this unprecedented worldwide conference convened in September, 1955 in Geneva, Switzerland. Here, for the first time, scientists from the West and the East met to discuss the technical problems and challenges of nuclear energy. I recall clearly that many of us in the U.S. delegation to the first Geneva Conference were filled with a sense of history, and some amazement too, at the open reporting of previously restricted information on fuel-cycle processes and plant operations. Nearly every day, after late-night meetings of the U.S. delegation at the headquarters Hotel du Rhone, we saw new areas of cross-section and fission-process data disclassified and released to the public domain. During this historic conference, I could not help but remember my earlier days as a

University of Chicago freshman. There, on the way to our freshman calisthentics class under the West Stands of the Stagg field football stadium, we would occasionally pick up black dust on the soles of our tennis shoes as we passed a sealed-off, heavily guarded area posted with the warning: U.S. Government Metallurgical Project—Keep out. As I was to learn years later, the black dust was graphite, the neutron slowing-down or "moderator" material used by Enrico Fermi and his coworkers to achieve the world's first self-sustaining fission chain reaction on December 2, 1942. To me, the unprecedented open spirit of international cooperation that marked the first Geneva Conference was in stark contrast to the wartime secrecy that had of necessity characterized nuclear activities just 13 years earlier in Chicago.

Two years after the first Geneva Conference in 1955, the International Atomic Energy Agency, a cornerstone of the "Atoms for Peace" implementation was created (in October 1957) to focus on, and carry out the promotion and control of the peaceful uses of nuclear energy in countries around the world.

Fostered in large part by the Atoms for Peace program, throughout the 1960s peaceful nuclear energy programs flourished in many countries because supplier nations, including the United States, offered an extremely attractive long-term source of nuclear fuel, in part to discourage the development of other supply sources. Concurrently with this peaceful development, the 1960s also saw the number of nuclear weapons nations increase from three to five with the addition of France in 1960 and the People's Republic of China in 1964. These and other events led to steadily increased concerns about nuclear weapons proliferation—both the further build up within nuclear-weapons nations and especially the possible acquisition by new nations. In the mid-1960s, intensified efforts to reduce the risk of proliferation led ultimately to the Treaty on the Nonproliferation of Nuclear Weapons (NPT), which was first implemented in 1970.

During this very active period of the mid-1960s, I had the unique (at that time) opportunity to serve with the Headquarters staff of the International Atomic Energy Agency in Vienna, Austria. Over the course of my two year assignment (1963-1965) with the IAEA, I along with many others, became acutely aware of the growing importance of stringent safeguards and controls over sensitive nuclear materials, and the global challenge of nuclear nonproliferation generally. Thus, by the time I returned to the United States in the Fall of 1965, I was firmly convinced that a vigorous R&D program should be launched to develop new nondestructive assay (NDA) techniques and instruments that would, in time, provide the technical basis for meeting the increasingly stringent safeguards requirements that were inevitable. This led, in due course, to establishment of the Los Alamos Safeguards R&D program in late 1966. Six months later, in June 1967, the AEC established the Office of Safeguards and Materials Management at its Washington Headquarters, as well as a new Division of Safeguards in the AEC Regulatory Branch (now the Nuclear Regulatory Commission).

Typical of new programs in their early stages, the new safeguards R&D staff at Los Alamos was highly enthusiastic and fully committed to the mission and challenge before us. With a team of top notch people, the Los Alamos safeguards program got off to a head start in the newly established field of safeguards R&D. An important factor in our success was the implementation early on of a special technical liaison working group involving safeguards researchers and the nuclear materials processing experts in the Laboratory's Chemistry and Metallurgy (now Materials Science and Technology) Division. This very effective technical liaison activity performed the essential function of identifying and following through on needed applications of NDA instrumentation techniques to materials measurement, accountability, and safeguards problems. Through the years, ongoing close interaction between safeguards researchers and the Laboratory's materials processing experts have contributed significantly to Los Alamos' leadership in safeguards research and development on both the domestic and the international level.

During the 1970's a continuing series of unsettling incidents and problems led to growing deep concerns about the adequacy of physical security and protection of nuclear facilities in the United States. In response, a high-priority national program was undertaken in the mid-1970s to upgrade significantly the physical security of sensitive nuclear facilities around the country. In addition to the high-profile primary concern about physical security and the "outsider threat," the 1970s also saw the beginning of increasing concerns about its counterpart, the "insider threat" i.e., the possibility of diversion or theft of nuclear materials by people working in or having access to plant equipment and materials. In response to these concerns, in late 1973 Los Alamos was asked to look into possible new and more incisive approaches to the problem of the insider threat. In cooperation with the materials processing people in our chemistry and metallurgy division, we came up with the Dynamic Materials Accounting and Control (DYMAC) concept that was put forward in its original form in 1974. The DYMAC concept involves dividing a nuclear facility into discrete accounting areas or so-called unit process accounting areas (UPAAs) and drawing material balances around these areas. Actually unit-process-based accounting had been successfully employed in material process lines at Los Alamos since the early 1960s; of necessity the early system was based on manual data entry and traditional measurement techniques (i.e., sampling and chemical analysis, mass spectrometry, etc.).

Basically, the DYMAC concept was a synergistic combination of

1. Los Alamos' proven unit-process-based system of accounting, with
2. the "in-line" or "at-line" rapid measurement capability of newly developed NDA instruments, and
3. the distinct advantages of computerized data entry, storage, analysis, and retrieval.

Thus, DYMAC offered for the first time the possibility of incisive materials accounting on a timely or "near-real-time" basis, and as such DYMAC can be viewed as a forerunner of the now-familiar concept of near-real-time accounting systems. The prodigious task of translating a concept such as DYMAC into practical reality in an operating nuclear facility—even for a single glove box line—involves extensive development, appropriate systems studies and design, thorough in-line (or at-line) test and evaluation, etc. By the mid-1970s the importance of a comprehensive system approach to modern safeguards design, evaluation and implementation had become abundantly clear, and in 1976 programmatic funding was specifically earmarked for needed systems studies on designated generic nuclear facility types. Over the next two years the systems studies effort grew sufficiently in scope and importance that a separate Safeguards Systems Studies Group was formed in February, 1977. A highly productive cooperative R&D effort between instrument developers, safeguards systems analysts, and materials processing experts is actively ongoing today with the overall objective of developing near-real-time material accounting and control systems for demonstration, test and evaluation in various facility types, including the new Plutonium Processing Facility at Los Alamos.

Over the years the Los Alamos safeguards program has developed, tested, and implemented a broad range of passive and active NDA instruments (based on gamma and x-ray detection and neutron counting) that are now widely employed in safeguarding nuclear materials of all forms. Here we shall survey, very briefly, the major categories of gamma ray and neutron based NDA techniques, give some representative examples of NDA instruments currently in use, and cite a few notable instances of state-of-the-art NDA technique development. First, in the familiar "workhorse" area of passive gamma ray assay, many different instruments have evolved employing the two well-known types of gamma-ray detectors, i.e. low resolution NaI(Tλ) scintillation detectors and the high-resolution germanium solid-state detectors. Necessary corrections for sample attenuation are carried out using either an external gamma ray source or by suitable analysis of the measured response to the sample's own internal gamma rays. Gamma-ray measurements using the so-called "enrichment meter" principle are based on the fact that for fixed detector-sample geometry and for samples that are thick relative to the penetration depth of the 185.7-KeV ^{235}U gamma rays, the count rate due to the 185.7-KeV gamma rays is directly proportional to enrichment. When performed with care, NDA enrichment measures can achieve 0.1 to 0.2% precision at one standard deviation.

In the case of plutonium isotopic composition measurements by gamma ray spectroscopy, achievable accuracies are typically the order of 1% or better for ^{239}Pu and ^{241}Pu. Among many passive gamma ray assay instruments currently in use, we mention here only two:

1. the widely used Portable Mini MCA, a battery powered 2K/4K multichannel analyzer that can acquire, display, analyze, and record gamma ray spectra from either NaI or high resolution germanium detectors and
2. the Segmented Gamma Scanner for measuring samples up to 200 liters in volume and employing a transmission source that is viewed through a horizontal collimator slit to assay the sample as a series of horizontal segments and then measuring sample response and the transmission correction segment by segment.

This technique nominally assumes sample homogeneity or minor heterogeneity, whereas much of the scrap and waste in operating facilities does not satisfy this assumption. One important source of bias arises from the presence of lumps in the sample being assayed. To address this problem as well as the problem of sample heterogeneity generally, a method of detection and correction for the presence of lumps is under development that involves assaying the sample at different gamma ray energies.[1]

The second major category of NDA techniques is active gamma-ray assay, represented by the complementary techniques of gamma-ray densitometry and x-ray fluorescence. In the densitometer a gamma-ray beam is passed through an assay sample and a gamma-ray detector measures the transmitted beam whose reduced intensity is a function of the gamma-ray energy and the amount, or concentration, of nuclear material between the source and detector. The isotopic sources, ^{57}Co and ^{75}Se—with 122.0-KeV and 121.1-KeV gamma rays respectively—nicely (and fortuitously) bracket the 121.7-KeV K-absorption edge of plutonium. These sources are utilized in the so-called compact K-edge densitometer developed for in-line concentration measurements of Pu solutions in glove box lines without breaching or affecting in any way the glove box containment. An installed ^{57}Co-^{75}Se K-edge densitometer system has been used for nearly 10 years for assay of product solution in the analytical laboratory of the Tokai fuel reprocessing plant at Tokai-Mura, Japan.[2] Generally the accuracy and precision of K-edge densitometer measurements is better than 1% and can approach 0.1%; in practice they are often combined with isotopic composition measurements. In the case of other elements (e.g., uranium, thorium) such fortuitous isotopic sources with gamma-ray energies that happen to lie just above and just below a desired absorption edge, generally do not exist, so x-ray generators must be used as the transmission source for densitometry measurements.

In the complementary technique of x-ray fluorescence (XRF), again a gamma-ray beam is passed through an assay sample, but here the absorbed, rather than the transmitted, gamma rays are used to provide an assay signal. The absorbing atoms are raised to excited states from which they decay by emission of x-rays; the energies of these x-rays are uniquely characteristic of the elements in the absorbing material, and their intensities are proportional to the amounts present. As may be inferred from the foregoing, gamma-ray densitometry and x-ray fluorescence have been applied most successfully to the measurement of uranium and plutonium concentrations in solutions. The complementarity of the two techniques is further evidenced in a very practical way: densitometry is best suited for SNM concentrations above ~ 10 g/λ, whereas XRF is best suited for concentrations below this level. At least two hybrid assay systems have been built that combine densitometry and XRF. One is used to assay uranium and plutonium in light-water-reactor reprocessing solutions at Kernforschungzentrum Karlsruhe in the Federal Republic of Germany,[3] and the other is designed for routine use in the recovery section of the Los Alamos plutonium facility.[4]

Concerning advanced NDA technique development in the area of gamma-ray assay, it should be noted that two novel methods for determination of Pu concentration (and isotopic distribution) have recently been developed that require no external radioactive sources or x-ray generators, but rely only on the natural radiations from Pu. The methods are ideally suited to the assay of reasonably pure Pu solutions such as the product solutions of a reprocessing plant and the eluate solutions from anion exchange columns. The methods can be applied to aged or freshly separated Pu and can be used to measure Pu concentrations in pipes or tanks. The first method uses the MGA2 isotopic program developed at Lawrence Livermore National Laboratory.[5] In this program a relative detection efficiency curve is fitted from 59 KeV to 208 KeV including the discontinuity at the Pu K-absorption edge. For fixed sample thickness, the magnitude of the discontinuity is proportional to the Pu concentration of the solution. Applying this method to Pu solutions with concentrations ranging from 60 g/l to 320 g/l it was found that the Pu concentrations can be determined to 1.9% with precisions of 1.5%.

The second method[6] uses the ratio of a pair of gamma-ray or x-ray peaks from the Pu sample: one above the K absorption edge and one below the edge so that the absorption coefficients (mu) are substantially different. The mu values of 129 KeV gamma (^{239}Pu) and 111-KeV x ray (U K_b from ^{241}Pu) differ substantially, so the ratio of these two lines is a strong function of Pu concentration, and for a fixed solution thickness the function can be used to determine Pu concentration from a measurement of 111/129 ratio. Applying this ratio method to Pu solutions with concentrations ranging from 10 g/l to 320 g/l, it was found that the Pu concentrations can be determined to 0.26% with precisions of 0.2%. Calculations show that while the ratio method is insensitive to the amount of low Z absorber ($Z < 10$), for best results the medium Z matrix ($Z < 40$) in the solution should be less than 6% of the Pu concentration, and the high Z matrix should be less than 3% of the Pu concentration. Therefore, the ratio method is not for nondescript Pu solutions, but if the concentration of impurities in the Pu solution is less than the amounts given above, the method can be used to determine Pu concentrations from 10 gm/l to 300 gm/l with less than ½% bias. When the solution is very thick, the ratio approaches a unique asymptotic value such that an increase in the sample thickness beyond a certain minimum thickness will not change the observed ratio. As a very practical result, the ratio method can therefore be used to determine Pu concentrations in tanks or bottle without drawing samples.

Turning now to neutron-based NDA techniques, we address first passive neutron methods; it will be recalled that neutrons originating in nuclear materials are primarily due to

1. spontaneous fission (largely in Pu-238, 240, and 242) and
2. (α,n) reactions in light elements (e.g., in oxides and fluorides or in B, Be or Li impurities).

An additional source of neutrons can arise, especially in larger samples, from induced-fission multiplication in the sample. In general passive neutron detection provides a convenient assay measurement, especially in larger samples, from induced-fission multiplication in the sample. In general passive neutron detection provides a convenient assay measurement, especially for plutonium samples, because of high neutron yields, detector simplicity, and neutron penetrability through the sample and storage or shipping containers. The most frequently used neutron detector for NDA instrumentation is the ^{3}He proportional counter, chosen for relatively high neutron detection efficiency, insensitivity to gamma rays, reliability and long-term stability. Spontaneous fission "coincident" neutrons are distinguished from (α,n) "singles" neutrons by coincidence counting techniques based on high resolution "shift register" coincidence electronics.[7] In the somewhat unique case of UF_6 the high cross section of the (α,n) reaction on fluorine provides a useful uranium assay signature, which has been used to measure highly enriched UF_6 cylinders and liquid UF_6 at the product load-out point of enrichment plants.[8]

The well-known High Level Neutron Coincidence Counter, HLNC[9] is widely used for the assay of bulk plutonium samples ranging from 10-g to several kilograms of plutonium, and ^{240}Pu content from a few per cent to ~ 30%. The HLNC can assay samples containing 500 g or more of plutonium in 300 seconds with a precision and accuracy of better than 1%. The utility of the basic HLNC system has been greatly extended by the development of a whole family of HLNC-like detectors with specialized detector heads, but all employing the same basic "shift-register" coincidence electronics. Individual detector heads vary greatly depending on the materials and configurations to be measured (e.g., ranging from heads for small inventory samples to large fast reactor fuel assemblies).

Many nuclear material samples exhibit a measurable neutron multiplication value, especially the larger samples with hundreds or thousands of grams of either ^{235}U or ^{239}Pu. Thus, passive neutron measurements can be altered by neutron moderators (e.g., moisture), reflectors, and absorbers in or near the sample. Conventional coincidence counting procedures have worked reasonably well for pure PuO_2 materials; however for highly multiplying samples, impure oxides, samples with high ^{241}Am content, and salts with high (α,n) yields, the procedure fails because of the unknown multiplication and induced fission rates. A method was developed several years ago to correct for multiplication effects based on measurement of the real coincidence rate, R, together with the ratio of R to total neutron count rate, T, i.e., the "reals to totals" ratio.[10] More recently, detailed multiplication corrections have been applied to special cases, e.g., a neutron self-interrogation technique for assay of plutonium in high (α,n) materials.[11] Also, Monte Carlo simulations of neutron coincidence counter assays have been successfully applied[12] to passive assay of large, moist PuO_2 samples for which erroneously high assay values are obtained by conventional coincidence counting procedures.

Notwithstanding the significant progress that has been made in developing coincidence counting corrections, the major area of development in neutron assay techniques continues to be focused on finding better ways to measure and correct for sample multiplication effects. The basic difficulty that has long haunted passive neutron counting is familiar from elementary algebra, i.e., inability to solve a set of equations because of one-too-many unknowns. In passive neutron counting there are three principal unknown variables: plutonium mass, sample self multiplication, and (α,n) rate, but there are (have been) only two measured parameters (real coincidence rate, R, and total neutron count rate, T). This difficulty is currently being approached in two quite different ways, although both involve the development of innovative prototype neutron counting systems. One is a fast neutron counter using liquid scintillator detectors and gamma ray/neutron pulse shape discrimination.[13] This detection system is designed to measure all three of the unknown quantities noted above, and is not limited by gamma-ray response of the scintillators.

The second innovative neutron counting system is the "neutron multiplicity counter" designed and constructed at Los Alamos[14] to investigate the use of neutron multiplicity distributions (i.e., the different numbers of neutrons emitted in a given fission process) for NDA of plutonium samples. The key to this new approach to neutron assay of plutonium is the fact that the average number of prompt neutrons produced by a fission of ^{240}Pu is higher for the neutron-induced fission of ^{239}Pu than for the spontaneous fission of ^{240}Pu. Thus, the analysis of neutron multiplicity distributions can be used to determine the neutron multiplication in plutonium samples.

We move now from passive to active neutron assay techniques. Unlike plutonium, the passive neutron signal from uranium is too low to provide a reliable measurement signature, so a radiation signature must be induced in order to perform neutron assay on uranium materials. Active neutron assay uses neutron irradiation to induce fissions in fissile uranium material (^{235}U), and the resulting emitted fission neutrons (prompt and/or delayed) can provide a signature for accurate NDA. Since neutrons are both the interrogating and the assay radiation, it is essential to separate the two, and this can be accomplished by energy or time (e.g., coincidence) discrimination, or both.

Neutron coincidence counting techniques, first developed for Pu assay, have been very successfully applied to active neutron NDA instruments for uranium assay. Here we discuss briefly two representative instruments; first is the Active Well Coincidence Counter (AWCC) for assay of ^{235}U content in enriched uranium materials. Two (α,n) neutron sources (AmLi, each $\sim 5 \chi 10^4$ n/s) located above and below the sample well are used to interrogate the sample, and the induced fission neutrons are counted with standard shift register coincidence electronics. Coincidence counting effectively discriminates against the single (α,n) neutrons from AmLi sources while detecting coincident neutrons from neutron-induced fissions in the ^{235}U present in the sample. The AWCC is used to measure bulk UO_2 samples, high enrichment uranium metals, LWR fuel, pellets, ^{233}U-Th fuel materials having high gamma-ray backgrounds, and more recently even mixed-oxide samples.[15] A second important application of active neutron coincidence counting is the Uranium Neutron Coincidence Collar (UNCL). The UNCL can be operated in both the active and the passive mode to measure the ^{235}U and the ^{238}U content, respectively, of both PWR and BWR assemblies. The ^{235}U response sensitivity enables detection of the removal or substitution of 3-4 rods in a PWR assembly and one rod in a BWR assembly.

We note here a third active neutron technique for uranium assay, the ^{252}Cf Shuffler,[16] which utilizes yet another type of time discrimination between the interrogating and the assay neutrons—namely the time delay between prompt and delayed fission neutrons. The heart of the ^{252}Cf Shuffler is an annular neutron detector. A large ^{252}Cf source (10^7 to 10^{10} n/s) is repetitively cycled ("shuffled") into and out of the detector cavity region to irradiate the sample and induce fissions in the ^{235}U present. Between successive ^{255}Cf neutron irradiatons the detector is gated "on" to count delayed neutrons from the induced ^{235}U fissions. Properly calibrated, this delayed neutron signal then provides a measure of the amount of ^{235}U in the sample. The shuffler "delayed neutron interrogator" technique has been adapted to different measurement problems and container sizes from small vials to 200-λ (55 gallon) drums. The shuffler can measure highly radioactive samples, such as irradiated fuel and reprocessing waste, because the ^{252}Cf source strength can be increased as necessary to override the background radiation.

Many of the instruments described in this paper exemplify an important trend in NDA instrumentation development, namely computerization and standardization of measurement equipment and procedures for safeguards inspection and verification. Insofar as possible the new, "intelligent" NDA instruments are equipped with software programs for performance self-diagnostics, calibration and measurement quality control. Some instruments, such as the Portable Mini-MCA, also feature interactive-display prompting of the user (e.g. safeguards inspector) through the proper detailed measurement procedure, and perform all necessary calculations to give direct on-the-spot measurement and verification results. These "intelligent" NDA instruments offer many important advantages in inspection performance in the field, in new equipment acceptance and inspector training, as well as significantly reduced equipment maintenance and field-logistics problems. Major emphasis today is placed on the practical field implementation of these new instruments, which together with containment and surveillance techniques, provide the technical basis for increasingly effective safeguarding of nuclear materials in all types of fuel cycle facilities.

Much of the current NDA development effort is directed toward modifying and improving existing techniques; e.g., improved methods for neutron multiplication correction, gamma-ray peak area evaluation, and gamma-ray attenuation in heterogeneous materials. One example of work on new technique development is the application of laser-induced breakdown spectroscopy to high-sensitivity measurements of flowing uranium and plutonium solutions as well as to highly-radioactive solutions.[17] Clearly a key area of ongoing safeguards R&D is the increasingly accurate characterization of bias and precision for all NDA techniques.

In concluding this brief overview of nondestructive assay instruments and techniques, it is noteworthy that many NDA techniques are complementary in the sense that combining two or more techniques can give a more complete and/or more accurate measurement and at the same time increase confidence in the assay result. Gamma rays and neutrons clearly exhibit very different and complementary absorption properties, so when measurements using both types of radiation agree, this provides a high degree of confidence in the assay result—and indeed the converse is just as important as a "red flag" in cases where gamma ray and neutron measurements disagree.

In addition to transportable and in-plant NDA systems for quantitative measurement of SNM, Los Alamos also has an active ongoing effort in the development of rugged, hand-held instruments for use by relatively untrained personnel for search and detection of special nuclear materials. For instance, two recently developed instruments provide the capability for direct, on-the-spot verification of the presence or absence of certain sensitive nuclear materials.[18] One instrument uses a ^{6}LiI(Eu) scintillator and pulse-height analysis to verify the presence or absence of plutonium by measuring neutrons emanating from a container surface. The other instrument uses an LED-stabilized NaI(Tl) scintillator and three single-channel analyzers to measure and strip Compton background from a gamma-ray peak or region of interest to verify that certain isotopes of plutonium or particular enrichments of uranium are present or absent. These new instruments are lightweight, have low power requirements, and are easily operated in the field by nonspecialists.

The nation's Safeguards R&D program[19] is committed to the development and application of state-of-the-art NDA instruments, techniques, and systems to meet the user needs of the DOE complex and commercial nuclear facilities, as well as the needs of safeguards inspection authorities, both domestic and international. As a general indication of the scope of Los Alamos safeguards technology transfer, assistance and support on the domestic level, we cite below some recent examples of safeguards projects and support activities* within the DOE complex:

- Development, test, and evaluation of NDA technology and data analysis systems for designated HEU facilities. Current R&D efforts (at the Oak Ridge Y-12 plant) include:
  1. development of a four-gamma-ray technique for rapid confirmatory measurements on HEU;
  2. stationary and portable instruments for assay of HEU solids holdup; and
  3. assistance in the design and implementation of specialized NDA instruments and a data transmittal system for shipper/receiver confirmatory measurements.
- Development, testing and evaluation of integrated safeguard systems, including requisite NDA instruments, in new and upgraded production facilities at the Savannah River Plant (SRP) complex. Activities include:
  1. evaluation and upgrading of assay instrumentation at the SRP HEU facility;
  2. system-wide test and evaluation of the recently installed integrated system of automated NDA instrumentation (high resolution gamma-ray spectrometers supplied by Livermore, neutron coincidence counters by Los Alamos, and calorimeters by Mound Laboratories) for nuclear materials accounting and process control at the new Pu scrap recovery (NSR) facility;
  3. development and implementation of NDA equipment and data processing/data management system for the Savannah River RAF facility and
  4. in cooperation with SRP, development of materials accounting software that will be the basis of a near-real-time system demonstration at the new plutonium scrap recovery facility.
- At Los Alamos, the ongoing cooperative R&D effort between safeguards instrument developers, systems designers, and materials processing experts is directed toward the long-range objective of developing integrated safeguards systems for test, evaluation and eventual application in operating facilities, including specifically the Laboratory's Plutonium Facility. A case in point is the CAMCAS project[20] (CAMCAS = Computer-Aided MC&A System) with the objective of designing a near-real-time system for demonstration in a selected process area in the Los Alamos Plutonium Facility.

Turning from the domestic to the international domain, the Los Alamos Safeguards R&D program, working in close cooperation with TSO, ISPO and POTAS colleagues here at Brookhaven, plays a well known major role in helping the IAEA take full advantage of modern safeguards technology in order to meet its increasingly stringent worldwide safeguards inspection and verification commitments. Other technical support activities in the area of international safeguards in which the Los Alamos safeguards program is currently involved include: (1) evaluation of verification needs in reprocessing plants that may in the future implement near-real-time materials accounting systems; (2) collaboration in the development of monitoring systems for spent fuel movements in the THORP facility at Sellafield, UK, and at Darlington and other CANDU reactors in Canada; and (3) development of instrumentation for mixed oxide fuel fabrication facilities, in particular the new, large (5 ton MOX/year output) Plutonium Fuel Production Facility (PFPF) at Tokai Mura, Japan, that will supply mixed oxide fuel for breeder reactors (MONJU and JOYO) as well as future Pu-recycle light water reactors.

The PFPF facility, just cited, will utilize a variety of NDA instruments that are currently being developed by Los Alamos in cooperation with the Japanese PNC (Power and Nuclear Fuel Development Corporation) and PFPF under a formal U.S.-Japan agreement for cooperation in the peaceful uses of nuclear energy. Passive neutron NDA instruments already completed or under active development include: (1) Canister Counters to measure MOX powder received at PFPF from a conversion facility; (2) Material Accounting Glove Box (MAGB) counters to measure material in process (feed material and powder and pellet handling and transfer from glove boxes to intermediate storage, and vice versa); (3) a Pin Tray Counter to measure MOX fuel pins in trays; (4) a Capsule Counter to measure complete fuel assemblies; (5) a neutron-based system for process-line holdup measurements; and (6) a waste monitoring system for 55 gallon drums. Performance and acceptance testing have already been completed on the first units of the Canister and Capsule Counters, and the software for unattended data collection, evaluation and storage is nearing completion. All material handling and processing operations are carried out by automated, remote control so that all the in-process MOX material is, in effect, confined within a sealed "containment envelope" from the input of feed material to the final output of finished MOX fuel assemblies. The PFPF facility clearly represents a very significant advancement in modern nuclear fuel fabrication technology and as such represents a correspondingly significant challenge and opportunity for the development, test, and implementation of state-of-the-art safeguards technology in a state-of-the-art high-throughput nuclear production facility.

As we have seen, impressive progress has been made, and is indeed continuing, in safeguards technology design, development and implementation. However, the effectiveness of nuclear safeguards clearly depends not only on technology and hardware, but also on the people involved—both the safeguards inspectors and the "inspectees" in nuclear facilities. As in all human endeavors, the actual implementation of effective and workable safeguards must be carried out by people—and moreover by qualified people with the requisite training, knowledge, and motivation. Toward this absolutely essential goal of effective safeguards training and technology transfer, the Los Alamos safeguards program for its part conducts approximately 10 courses each year involving more than 200 trainees, instructors, and support people. Our safeguards training curriculum embraces several categories of courses including: 3-5 training courses per year for DOE and NRC inspectors and safeguards officials from government and industry; 3-4 IAEA inspector training courses per year; approximately 2 Physical Inventory Verification (PIV) exercises per year, designed to improve and advance IAEA inspection procedures and overall safeguards effectiveness.

Effective operation of the overall international safeguards regime depends not only on a well trained IAEA inspectorate, but also on the effectiveness of the State (i.e., national) safeguards system whose performance the international system must independently verify. It is therefore essential to have in place an ongoing program of training and technology transfer for key personnel in Member States who are responsible for the State's safeguards system (including, of course, safeguards at the State's nuclear facilities), and for the interface between the State system and the IAEA. The need for steadily improved State Systems of Accounting for and Control of Nuclear Material (SSAC) led to the series of IAEA Basic SSAC Training Courses that were begun by the Agency in 1976; in recent years these have been strongly augmented by SSAC implementation courses given alternately in the U.S. and in the USSR, both in close collaboration with the IAEA. The latest in the ongoing series of SSAC Courses in the USA was held in Los Alamos/Santa Fe, New Mexico and Richland, Washington from April 13-May 1, 1987. There were 37 course attendees from 22 nations, and lecturers from eight nations, the IAEA, and the EURATOM Safeguards Directorate in Luxembourg. The next SSAC course (focusing on discrete item facilities) will be convened November 14-26, 1988, at Tashkent, Uzbekistan, in the USSR. This will be followed next Spring in the USA by an advanced SSAC course (focusing on bulk handling facilities) to be held in Los Alamos/Santa Fe, New Mexico and Richland, Washington, from May 1-9, 1989. Many years of experience have shown that the IAEA inspector courses as well as SSAC courses contribute not only to the technical effectiveness, acceptance, and credibility of safeguards, but also help to build a spirit of cooperation, friendship, mutual confidence, and a shared sense of common professional commitment among safeguards people from around the world.

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* It should be noted that the implementation portions of these projects and support activities receive no funding from our R&D budget, but rather are funded by the appropriate DOE Program Office, DOE Field Office, or frequently by the facilities themselves. All of these activities provide substantial returns on the nation's investment in safeguards technology, not only in raising the general level of safeguards effectiveness, but also in providing direct feedback through practical field experience in operating facilities.

Physical Protection—A History and Overview

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ABSTRACT

Serious concern about physical protection of nuclear facilities began around 1972. R&D was initiated at Sandia National Laboratories which had developed techniques to protect weapons for many years. Special vehicles, convoy procedures, and a communications system previously developed for weapons shipments were improved and extended for shipments of other sensitive materials. Barriers, perimeter alarms, portal and internal control systems were developed, tested, and published in handbooks and presented at symposia. Training programs were initiated for U.S. and foreign personnel. Containment and surveillance techniques were developed for the IAEA. Presently emphasis is on computer security, active barriers, and techniques to prevent theft or sabotage by "insiders."

We are pleased to be invited to participate in this conference commemorating twenty years of safeguards R&D at Brookhaven. During most of that time, under broad sponsorship, Sandia has conducted an R&D program on physical protection, complementary to other Laboratories' work on material control and accounting. Together, these two distinct programs form the major part of DOE's development work in the combined safeguards and security area.

Physical protection is a function that is as old as the possession of property. Industrial security—the protection of industrial activities and resources—developed in an evolutionary fashion over many years, and consisted largely of measures to control access. Usually the values at risk were the financial replacement costs. Such measures were considered adequate in the pre-nuclear age, and were successfully used to protect the many industrial and military installations during WWII.

Protection of nuclear activities during the war and the years following was dominated by the need to protect classified information; the consequences of failure were potentially much more serious than the monetary value of the resources. The approach taken was more intensive application of conventional measures, particularly guard forces; there was little innovation or R&D to support technical solutions.

Developments beginning around 1960 led ultimately to renewed emphasis on physical protection. Nuclear materials, formerly owned exclusively by the government, were transferred to private ownership and to other countries. Since the materials and processes outside weapons programs were no longer classified, the AEC considered that the high monetary values at risk would induce the owners to protect them against loss. In the case of exported material, safeguards were imposed to protect against diversion for weapon use by the state, but it was taken for granted that the state would be motivated by its own interests to protect the material against loss or seizure.

As non-military use of nuclear materials became more widespread, critics began to point out the danger that the materials might be obtained by unauthorized persons and used to fabricate explosives. During the same period IAEA safeguards were gradually being applied, drawing attention to the risk that peaceful nuclear activities might lead to the further spread of nuclear weapons. The advent of the Nuclear Nonproliferation Treaty in 1970 greatly widened discussion of nuclear dangers, and the terrorist attack at the 1972 Olympic Games in Munich called public attention to the potential threat of nuclear terrorism. Ted Taylor, a former weapon designer, was particularly influential in calling for stringent physical protection of nuclear materials. Responding to the growing concerns, congressional hearings were held in early 1973; this resulted in substantial DOD, DOE and NRC programs on physical protection R&D.

Before that time, with AEC and DOD sponsorship, Sandia had done considerable work aimed at generating technological solutions for the control and protection of nuclear weapons. Features had been incorporated in weapon designs to prevent unauthorized use. Secure containers and weapon-storage structures had been developed. A safe-secure transportation system, originally intended for weapons and other classified shipments, had been developed. The transportation system included hardened vehicles and a centralized command and communication system. When the DOE fixed site physical protection

R&D program was initiated in early 1973, Sandia was designated the lead laboratory for physical protection R&D. A dedicated organization was established within Sandia as a focal point for this DOE lead-laboratory role, as well as physical protection work by other agencies.

Much of the work in the 1970s was directed at the technological development of subsystems such as intrusion detection, personnel identification, penetration-resistant barriers, hardened vehicles, and long-range communications. Commercially-available equipment was evaluated, innovative approaches were investigated, and computerized design and evaluation methods were developed. Subsystem and system development continued, and Sandia was becoming recognized as a center of physical protection expertise. The unclassified results of that work are widely disseminated through symposia, a series of handbooks, and direct contacts with DOE facilities, other government agencies, and industry. With growing concerns as to the adequacy of existing physical protection systems, this expertise has been used to assist in facility upgrades worldwide.

The increased DOE emphasis on physical protection provided the forum for a concentrated bilateral exchange program. In the 1973-1979 time frame, under the sponsorship of the DOE, some 65 formal bilateral exchanges were held at Sandia, involving 24 nations. These exchanges have continued in recent years, at a somewhat lower level, concentrating on specific technical aspects of physical protection with individual countries. The major DOE support to the international community occurs through the IAEA in the conduct of the International Training Course on Physical Protection, which is discussed later in this paper.

The development of concepts for integrated, plant-wide systems proceeded from the beginning of the program. In 1973 it was expected that the back-end of the commercial fuel cycle would soon be in operation; in fact, the expected commercial use of plutonium fuels on a large scale was the reason for much of the concern over physical protection. In 1974 AEC released the Generic Environmental Study of Mixed-oxide Fuels, generally known as GESMO. The study concluded that although the means were not then fully available, the back-end of the commercial fuel cycle could be safeguarded against diversion or violent seizure. Seventeen technological measures were listed, many of which were beyond existing state of the art. GESMO added fuel to the raging controversy over the difficulty of safeguarding plutonium operations. In the legislation that abolished AEC and created NRC later that year, NRC was directed to conduct exhaustive studies to examine the status and effectiveness of technological safeguards and security measures. Sandia managed and coordinated the physical-protection portion. These studies provided a comprehensive evaluation of the current state of the art in material accounting and physical protection, suggested strategies for training and operating guard forces, and described a set of threat envelopes. The information was presented in a multivolume report known as "The Special Safeguards Studies" which became the basis for initial NRC regulatory actions, improved system design practices, and future research and development efforts by government laboratories and the commercial sector. We worked closely with Los Alamos on conceptual designs for various types of facilities, taking into account the roles of physical protection, material control, and accounting.

Further development of the safe-secure transportation system, an early version of which was operational before 1973, has continued. The advancing state of the art in communications and information processing has been incorporated in successive improvements, and innovative delay mechanisms have been incorporated in the transport vehicles. The system has become widely recognized as a model advanced system for the transport of cargoes of high strategic significance, and the concerns that were widely expressed in the early 1970s over the perceived vulnerability of the transportation link have been greatly alleviated.

The role of guard forces as the central and essential element of physical protection has been recognized from the beginning. Limiting factors as information display, response times, force strengths, armament, training, legal constraints, and performance under stress have been recognized in system designs and subsystem requirements. One particular development relating to guard capabilities under stress is worthy of special mention. A laser scoring system, in which weapons and personnel are instrumented for simulated combat in evaluation and training exercises, was adapted to small-force exercises and successively improved. It is used in training DOE guard forces at operational sites and at the DOE Central Training Academy. It has been used by many others, including law-enforcement agencies and armed forces, and it is recognized as a significant advance in terms of realism and unobstructiveness.

The major expenditures associated with modern security systems are the operational costs—manpower and maintenance. R&D efforts to reduce these costs continue to contribute to more efficient use of resources. One example is the development of activated barriers, which reduce the requirements for dedicated standby response forces. A number of active barriers, consisting of materials that are activated only when needed, are under continuing development. Materials undergoing evaluation include cold smoke, stabilized aqueous foam, rigid foam, and sticky thermoplastic foam. These systems can be incorporated with other elements to provide an extremely effective physical security system. Studies indicate that active barriers, many times used synergistically with passive barriers and guard forces, are the most cost-effective delay systems against high-level threats. In addition to deterrent value, they can, in many cases, defeat most adversaries.

As a spin-off from the nuclear weapons protection efforts, the Sandia program has included work in support of international safeguards. The Sandia involvement has been directed towards applying appropriate technologies developed within the physical protection program to our development program in containment and surveillance. Although physical protection is the responsibility of each sovereign state and not that of the IAEA, the IAEA supports enhancing physical protection in the states by developing recommended standards and by conducting periodic training courses. DOE, in compliance with the US Nuclear Nonproliferation Act of 1978, funds Sandia to conduct a continuing series of training courses on physical protection for the IAEA, known as The International Training Course on the Physical Protection of Nuclear Facilities and Materials. The participants in these courses are selected people from IAEA member states, and to date, seven courses have been conducted, with the eighth scheduled for fall 1988. A total of 166 students from 42 countries attended the first seven courses. The training courses are an effective medium by which the advanced concepts and technology developed through the Sandia program can be disseminated to key personnel in less-developed countries.

During the past twenty years, the physical security technologies and system design capabilities aimed at the terrorists threat have improved significantly. An area of concern that is receiving increasing attention today is the matter of insiders operating either alone or in collusion with other terrorists. Single or small numbers of well-placed insiders can increase an adversary's effectiveness a great deal. Even a single insider, acting alone, has the potential for inflicting damage, both to nuclear programs and to the public. Much of the R&D that is going on today is aimed at addressing this problem. The solutions are neither easy nor simple.

We salute Brookhaven on their twenty years of safeguards R&D, and we are proud to have been associated with them through our complementary program. There has been much progress over these years in both domestic and international safeguards.

Department of Energy Defense Programs Perspectives on Safeguards, Security, and Classification

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ABSTRACT

This paper discusses why national and international safeguards and the protection of sensitive information are important to the United States and to other nations. It demonstrates that while the opposite consequence appears logical these functions will probably become even more important if the major powers agree on further arms reductions. Some of the steps taken by the U.S. Department of Energy to improve the effectiveness of its safeguards, security, and classification programs are reviewed. The valuable contributions in these areas since 1968 and 1976, respectively by the Technical Support Organization and the International Safeguards Project Office at Brookhaven are noted.

I am delighted to have this opportunity to discuss the Department of Energy (DOE) safeguards, security, and classification program perspective with such a distinguished audience of experts. Troy Wade, the Acting Assistant Secretary for Defense Programs, who was scheduled to make this presentation, asked me to express his sincere regrets and to assure you that only direct orders from higher authority forcing his attention elsewhere this afternoon could keep him from being here on this most auspicious occasion. He sends his congratulations to the Technical Support Organization for having endured the pressures of these programs for the last 20 years as a technical arm of the DOE Office of Safeguards and Security and, for the last five years, as a technical arm of the DOE Office of Classification. In any event, I consider it my good fortune that Troy could not be here this afternoon, since it was this development that afforded me the opportunity to be here in his place.

The Brookhaven National Laboratory Technical Support Organization has been a most important player in the development of domestic and international safeguards and security for the past 20 years, and in the modernization of the classification programs for five of those years as well. As nuclear energy programs have progressed on a world scale in the past 20 years, and more particularly, as international terrorism and proliferation concerns have forced their way on to the attention of world leaders, the Brookhaven Technical Support Organization has experienced increasingly heavy burdens from DOE as one of its principal technical arms in addressing non-proliferation policy issues and threats affecting safeguards, security, and classification activities. The maturity and technical expertise brought to bear by TSO in responding to the ever-increasing DOE reliance on their technical counsel and input has proven its worth many many times over. For many years, I was an interested observer and beneficiary from the perspective of my former position at our Nuclear Regulatory Commission (NRC), and I can assure you that since my recent arrival as Director of the Office of Safeguards and Security in DOE, I have become even more acutely aware of the value of the Brookhaven TSO contribution. I wish you well on this occasion, and look forward to the next 20 years of your continued valuable support.

It is an intriguing challenge for me to address the topic of this talk, Defense Programs perspective on Safeguards, Security, and Classification Programs in DOE, particularly because I am the newest member of Defense Programs. However, my experience in the safeguards and security programs of the NRC and the long history of close collaboration between the NRC and DOE in both domestic and international safeguards and security matters has helped prepare me for the challenge I now face in DOE, and particularly for the task of addressing Defense Programs perspectives. I fully recognize the higher sensitivity of nuclear activities in DOE, which is concerned with the nation's nuclear weapons and military nuclear programs, in contrast with those of NRC; and I assure you that I have paid acute attention to these differences in the briefings I have received to date on DOE affairs.

A most important DOE Defense Programs perspective I would like to emphasize this afternoon is our recognition that safeguards, security, and classification programs are extremely important elements of the national security of the United States. From a production and operational perspective we may take these programs for granted or as merely overhead functions. They are, however, by definition, national security programs, and as vital to the security of the nation as our nuclear deterrent or our continued supply of adequate energy. The protection of national security assets includes classified information and material, special nuclear material, strategically important facilities, and nuclear reactors. Control and appropriate use are important to our nation's security and fulfill our global responsibilities to prevent proliferation and state-sponsored or subnational nuclear terrorism.

Even in an era of increasing success in achieving arms control agreements, safeguards, security, and classification programs will not diminish in their importance. They, in fact, will very likely escalate significantly in their importance. For example, as the major nuclear powers of the world begin the process of reducing their nuclear weapons inventories, and hopefully reliance on nuclear weapons for their national security posture, the concern with horizontal proliferation, that is proliferation by heretofore non-possessors of nuclear weapons, will become more acute, while concern with vertical proliferation, that is proliferation in terms of quantity or sophistication of weapons design, will diminish. It will become more important for us to limit the dissemination of sensitive technology and to guard even more rigorously those nuclear materials which could contribute to acquisition of nuclear weapons capabilities by nations that are not party to arms control agreements. I can't emphasize this point too strenuously, and for the sake of ensuring against misinterpretation, let me repeat it one more time in another way. As the major nuclear weapons powers in today's environment begin the process of nuclear disarmament, it behooves those same powers to increase their vigilance in limiting the spread of nuclear weapons technology and in preventing the diversion or theft of nuclear weapons usable materials.

A major element of our nation's nuclear policy through all of the Administrations that have occupied the White House since the end of World War II has been non-proliferation of nuclear weapons. While realization of the objectives of that policy involves many international political and diplomatic initiatives, international safeguards has been consistently recognized as a major element. It is in this area of international safeguards that DOE has been working with NRC, the Department of State, and ACDA to continually improve the effectiveness of the International Atomic Energy Agency's (IAEA) safeguards activities. The objective is to maximize the assurances provided by international safeguards that our proliferation goals are being met. In this area, the TSO has served the Department and the nation outstandingly well. From its very inception in 1968, the TSO has carried out and helped manage innumerable technical programs directly aimed at improving IAEA's Safeguards effectiveness.

At this point, my attention is directed at another arm of the Brookhaven National Laboratory, which is not a part of the TSO. I would be remiss if I failed to acknowledge the extremely important role played by the International Safeguards Project Office (ISPO) since 1976. All of ISPO managed tasks, which number in excess of 300, are directly aimed at improving IAEA safeguards effectiveness, and the outstanding quality of effort contributed by TSO is worthy of the nation's highest esteem.

Within DOE, our commitment to both domestic and international safeguards and security is evident in the increased emphasis and funding for safeguards and security reflected in the Department's crosscut estimates. Spending for safeguards and security has reached about 800 million dollars per year. Our return on investment is the quality of our protection programs in the Department. Our challenge for the future is to stabilize the spending for safeguards and security, while improving vigilance and maintaining state-of-the-art protection for the Department's unique and varied assets.

In the environment of nuclear disarmament and the need for more vigilance against the spread of nuclear weapons technology, we will undoubtedly be placing greater emphasis on integrating the sometimes mutually separate disciplines that play a role in the control of sensitive information, just as we have integrated the disciplines that play a role in safeguards and security over the past 20 years. As this audience surely knows very well, safeguards and security activities embrace personnel security measures, physical security measures, materials control measures, and materials accountability measures. As a matter of fact, the way in which these measures are all mixed to achieve a desired level of effectiveness may be different from activity to activity. For example, in weapons program manufacturing activities we may place greater reliance on materials accountability measures; while in non-weapons activities, greater reliance on materials accountability may find its way into the mix with perhaps somewhat less reliance on personnel security and physical protection. The key word here, however, is integration.

In the area of information control, we need to look at how we can integrate the contributing elements of classification, operations security practices (OPSEC), and security measures relative to protection of information. As a current example, the OPSEC procedures require activities to identify the critical items of sensitive information, totally independent of classification guide decisions, and then to examine those operational activities which may inadvertently provide a casual observer with the ability to deduce one or more of those critical items. This reveals a perfect candidate for integration, since the level of classification should reveal the importance (sensitivity) of any item assigned that level, thereby minimizing the task of separately identifying the critical items of sensitive information required by OPSEC.

It is also our goal to reduce the number of items requiring protection in the program and to increase the effectiveness of the security systems applicable to their protection by both greater use of the OPSEC procedures and continued refinement of the security procedures applicable to classified items. At the same time that we recognize the need for protecting truly sensitive information, we must also recognize that Defense Programs have also developed substantial capabilities in a broad range of advanced technologies that could be of tremendous value to American industry in maintaining and re-taking its competitive edge in the world marketplace. Recognizing that a strong national security posture necessarily means a strong U.S. economy and industrial base, Defense Programs have undertaken an important initiative to look at the ways in which we can safely move technology from the laboratory to the marketplace.

At this point, let me give you a Headquarters perspective on DOE's classified document control and accountability program, the problems we are encountering, recent initiatives to improve our program, and areas where we need to continue our efforts at improving our program.

Late in 1986, DOE established a Classified Document Control Action Team to improve classified document control and accountability throughout the Department and its contractor-operated facilities. This action team visited several sites, gathering pertinent data from observations, reviews of security surveys and I&E inspections, and so forth.

The facilities visited represented a broad range of Departmental interests. The Action Team produced two reports:

- One, known as the "RED" book, highlighted problem areas and presented 34 recommendations to improve our program.
- The other, known as the "GREEN" book, recommended how we should go about fixing the problems within reasonable time frames.

The Action Team drew the following conclusions concerning the classified document control and accountability program: insufficient management awareness and support; unclear and/or fragmented requirements; lack of classified document control and accountability emphasis and oversight; archaic tracking methods; no method for inventory "Reconciliation;" widely variant education and training programs; and lack of standardized inventory reduction criteria and procedures.

Quite frankly, much work needs to be done to improve our classified document control and accountability programs, using these reports as our road map for steering the course in better attaining effective classified document control and accountability programs. While the reports were not very flattering concerning the condition of our document control, much work has been accomplished since 1986. I think it is also very important to keep in mind that there were two other initiatives underway during the 1986-1987 time frame which served to improve our document control posture:

- The "Safeguards and Security Standards and Criteria" (which identified S&S policy "Gaps"), and
- The Aquilina Safeguards and Security (S&S) Policy Task Force (which served to update/revise most of our S&S orders, incorporating many of the "Standards and Criteria" mentioned above.

DOE Order 5635.1A was published on 2/12/88. This new order, revised as a result of the Aquilina initiative, is one of the key improvements to our classified document control and accountability policy. The "new" order incorporates more than 40 "Standards and Criteria," and contains much more specificity in many important areas. In addition, this policy document requires:

- A 100%, wall-to-wall inventory of all SECRET-level documents by 6/1/89, or within 3 years of your last 100% inventory, whichever is greater. This requirement, interpreted for the entire DOE complex, probably represents more than two million (YES MILLION) documents that need to be formally accounted for, inventoried, and tracked. However, the exact number is unknown, because we have no previous, across-the-board inventory data bases upon which to draw comparative data. One National laboratory alone probably has between 600,000-800,000 documents to inventory.
- In addition, each document must now contain an individual document number (a practice employed by most of our facilities already). This is in addition to the usual documentation marking (i.e., 1 of 1, Series A), and is intended to maintain a more individualized identity for the document, taking into consideration computerized accountability systems which utilize such a numbering system.
- "Accountability" is much better described, and perhaps more importantly, defined.
- Eight years of updated requirements are now incorporated:
- Transmission of Confidential documents is tightened.

I can honestly say that our security education program has also been revitalized and, at least at the Headquarters level, more attention and resources are being committed to enhancing this area. Some examples: The OSS Newsletter is now published quarterly, and contains current S&S happenings, events/items of interest. A revised poster program has been implemented. Production of four to six video tapes over the next nine months, to address such basic areas as "Need to Know;" document marking and control; TOP SECRET controls; security termination briefing; annual refresher briefing; and so forth.

The main intent of a more active program is to at least begin the task of addressing the recommendation made in the "RED" book, and to provide a more consistent, centralized treatment of our security education program, hopefully, resulting in a more effective product.

Finally, it is our intention to increase international collaboration in classification policies and information control methodology and practice.

I believe the challenges ahead in the areas of safeguards, security, and classification are of vital importance to the nation's national security; and that the cooperation of competent organizations such as those represented here at this meeting, and particularly by our host at this meeting, will enable us to successfully meet the challenge.

The Role of the Office of Security Evaluations (OSE)

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ABSTRACT

The fundamental role of OSE is to assess the effectiveness of Safeguards and Security (S&S) policies and programs in the U.S. Department of Energy (DOE). To achieve this objective, OSE conducts a management-oriented Inspection and Evaluation (I&E) program which is one of the three levels of S&S oversight in the DOE; i.e., 1) operating contractor self-audit; 2) field office survey of contractor; and 3) Headquarters I&E.

The I&E management-oriented and independent oversight program reports to the Secretary through the Assistant Secretary for Defense Programs. The I&E effort involves an evaluation of field office and contractor management of the S&S program. The inspection (I) activity is a "vertical" assessment of a particular field office over the spectrum of up to eight topics. The Evaluation (E) activity reviews specific elements or topics across the DOE; hence these are described as "horizontal" assessments. These I&E activities include both compliance and performance tests—the latter includes such topics as response forces, nuclear material control capabilities, and computer security, etc. The I&Es are performed on "59 key facilities" on an 18-month cycle.

This paper describes the background leading to the current OSE, the basic organizational structure, the accomplishments achieved in 1986-88 the directions of the program up to the end of June 1988, and new avenues to enhance the effectiveness and credibility of the program.

THE INSPECTION AND EVALUATION FUNCTION

The Inspection and Evaluation (I&E) function was established in December 1981 under the Office of Safeguards and Security (OSS) with the responsibility for assessing the effectiveness of the Department of Energy's (DOE's) protection policies and programs through inspection activities at all DOE sites. The results of the I&E's were disseminated not only to the inspected facility/field office but to all field offices, Assistant Secretaries and the Secretary for appropriate corrective actions, lessons learned and technical/policy advice.

The Headquarters oversight function has existed at the Atomic Energy Commission, but was subsequently deemphasized under ERDA and for a period of time in the newly created DOE. The oversight role which had been performed by an independent assessments staff was phased out due to continuing controversy over staff objectivity and methods utilized to perform audits. In the early 1980's, Congressional/GAO oversight revealed safeguards and security/inadequacies that, in principle, should have been detected and corrected had there been an adequate oversight program. The independent I&E activity was reestablished within the Office of Safeguards and Security (OSS) and was formally chartered in January 1984 by action of Secretary Hodel in order to identify Safeguards and Security vulnerabilities within DOE.

The I&E function, when placed within the organizational structure of the OSS, was a natural outgrowth of that office. It existed within the OSS framework with a staffing allocation of six inspectors. The need for a move from OSS was created with the awareness of the potential conflict of interest within OSS. OSS with the responsibility for oversight of the field office's safeguards and security (S&S) operations and programs as well as their own S&S research and development programs should not be in a position to grade itself because of the inherent conflict of interest. The I&F function, therefore, was placed within the Office of Security and Quality Assessments (OSQA) from late 1984 through January 1986.

The question remained whether the I&E function should stay inside or outside the realm of the Defense Programs (DP) organizational structure. Several options became evident; the Inspector General examined whether the function should be assigned to him as well as how his office could effectively perform the I&Es. Up to this point, the OSQA had been responsible for the I&E function as well as the tasking of Quality Assessments (QA) of environment, safety and health related issues. With the creation of an Assistant Secretary for Environmental Safety and Health, it was natural that the QA function should be the responsibility of that office while it was still necessary to have the Security function under the umbrella of the

Assistant Secretary for Defense Programs (DP) organizational structure. Thus, the decision was made to lift the I&E function from the OSQA office and retain the function in DP. This latter decision was based on the fact that DP possessed the technical capabilities (i.e., security and nuclear weapons background), as well as sufficient fiscal resources to efficiently perform this function.

When the Office of Security Evaluations (OSE) was established within DOE, two seemingly diverse functions were merged into a single DP staff office: Inspections and Evaluations, and Radioactive Material Packaging Certification (RAMPAC). RAMPAC had its origin within the Office of Defense Waste and Transportation Management (ODWTM). However, both functions had in common the fact that they performed vital oversight missions for the Assistant Secretary for Defense Programs and the DOE.

The shift between office levels of management (OSS/OSQA/OSE) of the I&E function proved to be a direct result of various interests manifested outside of DOE. Levels of threat awareness increased during this period (1976-1986), as security concerns reached new proportions on the national level (e.g., the emphasis on airport security).

Other external pressures resulted in fluctuations in security activities. Increased Congressional oversight brought about significant changes in the scope and depth of the activities, especially those associated with resources assigned to inspections and the location of the I&E activity within the organizational structure. The environment changed from one in which emphasis on "compliance only" type audits was reduced in favor of more "performance type" audits. These changes focused on identifying the necessary and sufficient solutions to safeguards and security vulnerabilities.

At inception, the I&E activity was fundamentally an adhoc evaluation function under the oversight of OSS. The evaluating team was not constituted from an established organization instead, it was composed of representatives from various Headquarters, field and laboratory organizations selected prior to the specific visit. Further, the I&E was viewed as a singular sampled data collection system, in both space and time, to assess the status of protection policies and programs at a specific field office/facility. Over time the auditing priorities shifted to accommodate external pressures (e.g., Congressional oversight) and varying management philosophies. The basic I&E auditing concept inherently requires that the depth and intensity of the I&E process should be inversely proportional to the bureaucratic level of each of the organizations participating in the I&E process. In this context field offices and their associated facilities should conduct the more in depth and intensive I&E while the Headquarters DOE conduct this evaluation at least once every eighteen months of every field office/facility. Similarly, evaluations conducted by the DOE Inspector General, GAO and/or a particular Congressional committee are somewhat sporadic and more event driven rather than a continuously planned and executed effort. The overall status of the effectiveness of protection programs policies should be determined by the Headquarters I&E program by integrating all results available DOE-Wide at the time of the specific I&E at the particular field office/facility.

Initially, the OSS I&E program focused on the implementation of three general tasks:

1. An assessment of the field office and contractor management of the safeguards and security programs;
2. A review of specific elements or topics of the protection program; and
3. The performance testing of response force and nuclear materials control capabilities.

The field claimed that the degree of subjectivity employed by the I&E inspectors was very high. Also, the lack of standards and criteria resulted in an inhomogeneous inspection regime, and the value of the physical protection operations testing was somewhat exaggerated. The scope and manner in which these elements had been executed was tailored to accommodate legitimate field concerns. A wider range of protection topics was included and the performance testing was broadened to examine the full spectrum of capabilities.

The assessment of the field office and management of the safeguards and security program has been the underlying goal of the inspection program since 1982. This concept of program execution provided "vertical" assessments of the particular field office and its representative facilities under evaluation. The terminology "vertical" is used in contrast to "horizontal" and used to emphasize that a *particular* field/office and facility(ies) under that field office are sampled in space and time to evaluate the effectiveness of protection programs and policies at both the facility and field office. This should be contrasted with "horizontal" evaluations of one or more topics throughout the complex. In executing these vertical assessments, several topical areas are selected to be audited. Typically, at least four topics are audited during a given inspection; but in some instances, a maximum of seven topics may be examined.

Topical Areas Used for Inspections

- Personnel Security
- Protection Programs Operations/Physical Systems
- Protection Programs Operations/Protective Forces
- Computer Security
- Material Control and Accountability
- Information Security/OPSEC
- Security Surveys

Initially, the topically related audits tended to focus primarily on strict implementation of regulations, i.e., compliance-oriented I&Es rather than on management issues. Current I&E philosophies have shifted to focus on management issues of utmost importance to the facility, consistent with the I&E charter and therefore emphasizing performance-oriented I&Es. In recent times, the specific topic selection has been dictated partially by risk assessment—i.e., consideration of threats, potential vulnerabilities, and consequences associated with a particular combination of threat, activities, and materials present at the inspected site, as well as practical considerations of personnel availability and scheduling. This risk assessment methodology is a modified version of a risk analysis developed by BNL for OSS. As a result of this management shift, the I&E teams are currently emphasizing management-level evaluations of the effectiveness of protection policies and programs across DOE.

There are three levels of safeguards and security oversight within the framework of the DOE:

- Operating contractor self-audits
- DOE field office survey of contractors
- Headquarters inspection and evaluations (I&Es)

Theoretically, the oversight function performed by OSE should be a straightforward validation of the safeguards and security measures in place. Inspections performed by OSE should be easily passed by field offices having an effective survey program. The survey program should be much more comprehensive than the I&E inspection. In the same vein, an effective contractor self-inspection program will be much more detailed than the survey program and is the key to an effective safeguards and security program.

The I&E function under OSS and OSQA consisted of inspections on a "who's next" basis, utilizing in the most effective manner whatever personnel were available. Reinspections were dictated by findings in the field (i.e., if a site received an UNSATISFACTORY rating, a reinspection would occur within a given period of time). No standards and criteria were available as a basic document for the inspection team or the field offices; objectivity was left to the inspectors, based on their experience in the field with a particular audit topic.

OSS inspection teams had initially stressed compliance-oriented audits with some performance-oriented exercises particularly in the area of physical protection operations. Under OSE, greater emphasis was placed on management-oriented audits with a high degree of emphasis on performance-oriented audits while giving appropriate consideration to compliance issues. The development of Safeguards and Security Standards and Criteria in 1987 improved the effectiveness, fairness and professionalism of the auditing methodology used in the field. The development of these Standards and Criteria gave impetus to the concomitant development of site-specific inspection handbooks and guides for all the I&E topical areas.

OSE ACCOMPLISHMENTS 1986-1988

Inspections

OSE has conducted field inspections at a rate of approximately 12 per year. Since the development of the DOE Safeguards and Security Standards and Criteria (S&C) in 1987, inspection personnel have developed site-specific inspection handbooks and guides for the selected topical areas. This has resulted in the inspected operations offices attaining a better understanding of the scope of the inspections along with a reduction in the friction between the inspected facility and the I&E teams. However, publication of the Safeguard and Security Standards and Criteria (S&C) was withheld pending issuance of DOE Orders incorporating the S&C. The new orders only paraphrased the S&C and in turn, these orders were projected into an edited version of the S&C—about to be published and distributed sometime toward the end of 1988. This has led, once again, to the potential problem of placing OSE inspection team personnel in a policy interpretative position particularly on matters pertaining to inspectability of the S&C.

Inspection planning has also been improved with topic selections focusing primarily on management issues of highest priority to the operations office, consistent with the I&E charter.

Topic selection has been dictated partially by risk assessment—i.e., consideration of threats, potential vulnerabilities, and consequences associated with a particular combination of threat, activities, and materials present at the inspected facility.

OSE continues to stress Limited Scope Performance Tests (LSPTs) in place of single force-on-force (FOF) exercises. These LSPTs examine and audit each of the protective elements of the "defense-in-depth" strategy of the facility under inspection. This approach has also provided a more representative overview of protection program performance rather than a one shot pass or fail test.

Evaluations:

OSE has established a cross-cutting safeguards and security Evaluation Program as a necessary complement to the Inspection Program. This cross-cutting evaluation is what was previously called a "horizontal" assessment/audit; i.e., one or more safeguard and security topics across the overall DOE complex. The evaluations are unrated and are intended to advise the Assistant Secretary for Defense Programs, the Field Office Managers, and OSS of protection program policy issues that need management attention.

An Evaluation Program Plan was formulated in 1988. Since its inception four topical evaluations (Computer Security, Personnel Security, Protection Program Planning and Delay Systems) have been completed with three others underway. Additionally, OSE performs appropriate special studies of protection programs in cooperation with other DOE organizations. Examples include DOE Emergency Management System in cooperation with the Office of Emergency Operations (DP-6), and a study of insider attributes in cooperation with OSS.

A new thrust of the Evaluations Division of OSE will be towards analysis of data gathered during a field inspection, focusing on trends in weaknesses and strengths of protection program topics. It should be noted that, in the interest of efficiency, the evaluations-related data is collected simultaneously with the inspection data.

Management Support:

Management support is a functional management activity which provides the overall program planning and analysis and resource management of OSE. This includes contractor support, development and implementation of program plans, information resource management, and fiscal and personnel resource management required to carry out tasking for the three primary functional activities of OSE:

1. Inspection and
2. Evaluation and Support, and

3. Radioactive Materials Packaging Certification (RAMPAC).

The most significant set of institutional accomplishments of OSE have been the formal documentation and dissemination of I&E and RAMPAC policies and procedures, including:

- DOE Order on I&E (DOE Order 5630.12: Safeguards and Security Inspection and Evaluation Program)
- DOE Safeguards and Security Standards and Criteria (S&C). The responsibility for these S&Cs was transferred to the Office of Safeguards and Security for incorporation into protection program policies and to maintain the S&C as a live document.
- Inspection handbooks which provide details on how a particular topic is to be inspected.
- I&E field procedural guide which provides the basic techniques to be utilized by inspection teams at DOE sites and facilities.
- Protocols for OSE I&E—performance testing. This terminology describes the process by which rules-of-engament (ROE's) for performance, as opposed to compliance oriented, evaluations/audits are developed; e.g., I&E Protocols for Physical Protection Operations (PPO), I&E Protocols for Material Controls and Accountability (MC&A), etc.
- A DOE Review Guide for RAMPAC (safety analysis reports analyzed by RAMPAC and ANL technical review staffing).
- OSE Program and Operating Plans.

Because these documents are widely shared with the field and at Headquarters, the programs subject to inspection and evaluation now have a priori, a written understanding of how OSE works. Although there are still misunderstanding of interpretation since publication of the above documents, experience has shown that such misunderstandings are much easier to resolve and can usually be adjudicated at the local level without involving upper management.

Resource Management:

When OSE was established in 1986, it had no budget authority of its own; instead, funds were obtained as a "tax," which came principally from two DP fiscal accounts specifically Military Applications Program (Management Direction line team) and from the Office of Defense Waste and Transportation Management. The total funds available at the beginning of FY 1986 were approximately $5 million from all sources. There was no formal documentation (other than the DP mission and functional statement) as to OSE's role, policies, or procedures. Although the I&E function was in existence and operating, it had almost none of the attributes of true management such as control over its funding, staffing allocations, and program management responsibilities.

OSE now has its own item in the Defense Program budget (under the Military Applications Program Direction line item) and has achieved a stable growth rate, going from $10.3 million in FY 1987 to a projected target of $14.565 million in FY 1991. This has allowed OSE to establish a viable baseline of contracting support through its support service contract—Battelle Columbus Division—as well as through key DOE prime contractors, among them Lawrence Livermore National Laboratory, Argonne National Laboratory, Brookhaven National Laboratory, and EG&G. These organizations provide additional technical support and manpower to augment the OSE in-house manpower. This contractual support, runs at a level of about 75% of the total funds available to OSE. OSE has also increased its staffing ceiling from 16.5 in FY 1986 to 29 in FY 1990.

The current prime I&E support contract will expire during FY 1989. OSE has, with the support of DP-50, initiated a Request for Proposal (RFP) for a new prime multi-million dollar competitive contract (approximately $20-25M). The new multi-year contract will provide OSE with continuity of technical support and augmentation of in-house manpower for a period of three years plus two additional years at the option of DOE/OSE.

Information Resource Management

OSE has developed both the foundation and some key products for a comprehensive information resource management (IRM) system. The foundation was provided in 1987 through the completion of an IRM Conceptual Design based on the information flow and requirements both inside and outside of the OSE.

Specific IRM products include an automated Full Text Retrieval system that contains the text of the DOE Standards and Criteria, current DOE Orders, and other policy guidance documents used by the OSE; an automated Findings Presentation System that will rank the relative safeguards and security risks at key DOE facilities. These products will be fully installed and operational within the few months remaining in CY 1988.

NEW APPROACHES FOR OSE

In surveys conducted by OSE personnel and prime support contractor personnel, it was revalidated that present OSE resource cannot meet the Secretarial-mandated 18 month inspection intervals for all key DOE facilities. A plan was devised whereby OSE inspection teams could inspect sites and facilities at varying frequencies, with the highest priority facilities inspected more often than the lower priority facilities.

The facility order of priority was based on a technical methodology that assessed the potential impact on national security. Considerations taken into account in this ordering included the Protection of SNM, classified matter, vital equipment, and the programmatic mission of a given facility. The DOE facilities were categorized into three priority groups UPPER RANGE: This is a listing of the 19 key facilities scheduled for inspection at 2 year intervals; MIDDLE RANGE: This is a listing of the 32 key DOE facilities to be inspected at 3 year intervals; LOWER RANGE: This is a listing of the 15 key facilities scheduled for inspection as needed.

In addition to developing an order of priority for DOE sites and facilities, a two inspection team concept was formulated for the enhancement of effectiveness during the actual inspection period at the field offices. The utilization of Team A and Team B would provide for training and more efficient planning phases and would reduce potential burnout of team members, as one team would be traveling while the second team would be performing office duties at Headquarters, participating in training sessions and preparing for the next inspection. Each team would be responsible for selected Field Elements and team members would monitor specific fields of expertise.

OSE has consistently taken technical and management related initiatives designed to enhance the credibility of the I&E functional activity while reducing contentious situations with the field to an absolute minimum. OSE is definitely becoming a recognized, established institution in the inspection and evaluation field, striving to work cohesively with field offices and headquarters to perform quality, fair inspections. However, there are various remaining steps which OSE and management at DOE must take in order to ensure that OSE will continue to fully perform its mission area responsibilities; e.g., provide proper level of staffing (of the order of at least 40 people for the total I&E function), provide adequate resources to insure continuity of contractual support, and provide high level management support to insure the continuing cooperation of the field and associated activities, etc.

1. Inspectability of the Standards and Criteria

During FY 1988, BNL has prepared a study of the inspectability of the Standards and Criteria (as modified). This study is expected to highlight some problem areas. OSE action will be required to develop appropriate solutions in each area which are acceptable to the Field, to interested Headquarters elements and which will provide for a reasonable validation of facility SYS programs during and I&E. This situation is further complicated by the recent editing done to the final version of the Standards and Criteria (S&C); i.e., delaying publication to wait for the new orders to be published then filtering the S&C to be consistent with the new orders. Unfortunately, in the initial process of creating new orders from the baseline S&C's, there were many key areas that were left out or modified. As a result, the editing of the S&C's eliminated some substantive concepts resulting in the dilution of the S&C's and in some cases creating unnecessary ambiguity. The resolution of this issue is key to the future success of the OSE mission, since the use of uniform standards and criteria during I&Es are the fundamental building block of OSE credibility in the field, at Headquarters, and with outside agencies and activities.

2. Integration of the MSSA into the I&E Process.

The Master Safeguards and Security Agreements (MSSAs) which have been validated and approved for some key facilities act as modifiers and interpreters of other DOE polity guidance and to the Standards and Criteria. OSE must continue to develop methods and procedures to integrate the MSSAs into inspections, as well as to audit the completeness and accuracy of the MSSA risk assessment and its supporting data. An additional factor which must be considered is the logic and consistency of the residual risk assignment which is made as a result to the risk assessment and the concomitant decisions related to the management of residual risks.

3. Information Resource Management (IRM)

As shown in previous studies, the commodity in which OSE deals is information. The efficient management of OSE's information resources is an absolute requirement for OSE effectiveness. There is a continuing requirement for a centralized IRM to enable OSE staff to maximize their effectiveness in both information gathering and retrieval. This need dictates not only a fully computerized system, but also the presence of a well defined and understood system. In addition to a centralized system, the IRM, or key, site-specific elements of it, must be portable in order to provide information storage and retrieval support to OSE staff while in the field.

4. Utilization Of Field Surveys.

The field survey system represents a vast information source and feedback mechanism, not only for OSS but also for OSE. Utilization of survey results in inspection planning can provide tremendous leverage for the limited OSE resources by allowing the OSE inspection process to focus on past/current issues or ongoing safeguards and security problems or to confirm that remedial action has been effective.

5. Reduction in Manpower Required For an Inspection.

A goal of OSE management has long been to reduce the manpower required to conduct an inspection of a facility without reducing the quality of the inspection. This achieves the dual purpose of allowing OSE to conduct more inspections within their resource constraints and of reducing the impact of the I&E process on the inspected facility. The most promising approach to achieve this goal is the completion of an IRM. Use of an IRM system, as a significant management and planning tool will maximize inspector efficiency by reducing administrative burden, by morale improvements to be expected by a better-managed personnel program, by more efficient time scheduling, and by improved availability of required data.

6. Reduction of Polarization and Adversarial Relationships.

This has been an area of great emphasis in the past and is one of the most promising avenues for improving the I&E process in the future. By the nature of the I&E, it is inevitable that a certain polarization will be observed between the inspector and the inspectee. The continued emphasis on professionalization and institutionalization of the I&E process, however; will increase the professional respect accorded the inspector and this, in turn, will reduce the adversarial relationship between inspector and inspectee. A reduction of this adversarial relationship will allow both parties to concentrate their energies on the protection of DOE security interests, rather than on interpersonal conflict.

7. Necessary and Sufficient Safeguards and Security Envelope.

The continuing focus of OSE must be to assist DOE in determining and maintaining the necessary and sufficient safeguards and security envelope within which each facility must lie in order to provide optimum protection for DOE security interests with the resources available. A key element in this process is the proper management of the residual risk at each facility and across the DOE as determined by the overall program of self-audits, surveys, and I&Es. The OSE evaluation function must take the lead in this area by analyzing policy, policy implementation, Inspection Reports and other factors in order to report on overall status of the Safeguards and Security Program. Methodology and tools for this analysis are not currently available, but an effort in this area perhaps offers OSE's greatest opportunity for service to the DOE and to national security. An understanding of the envelope and an assessment of current status would allow a fine-tuning of the application of S&S resources. This might support a reduction in spending in the Safeguards and Security area, but would certainly support as never before the prudent and efficient allocation of resources to achieve a sufficient security level across the whole of DOE.

The Role of the Weapons Laboratory in Nuclear Security

William R. Barry
Air Force Weapons Laboratory
Nuclear Systems/Surety Division
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ABSTRACT

The role of the Nuclear Systems/Surety Division and its relationship to the Air Force Weapons Laboratory will be described. The Function and goals of the security section within that division, under basic DOD guidance, will be considered. Reference will be made to work on ballistic protection shrouds for Minuteman II and III and Air Force nuclear weapon shipping containers. BNL-TSO contributions to AFWL study projects will be explained. This involvement has existed since 1984 in regard to security improvements for SAC alert aircraft. The work involves ballistic screening and development of a taxiway-gap cable vehicle barrier. Future activities may deal with alert system upgrades, access denial systems, security seals, comprehensive security analysis, and criteria development.

I. INTRODUCTION

The United States Air Force's Weapons Laboratory is under the overall direction of Headquarters, Air Force Systems Command. The Weapons Laboratory reports directly to the US Air Force Space Technology Center and the Center is under the Air Force Space Systems Division. It is located at Kirtland Air Force Base in Albuquerque, New Mexico. The Nuclear Systems/Surety Division reports to the Nuclear Technology Office of the Weapons Laboratory.

The Nuclear Systems/Surety Division consists of an administrative staff and three separate branches. Those branches are the Nuclear Weapons Branch, the Missile Branch and the Airborne Branch. The Nuclear Weapons Branch is responsible for identifying the requirements and development of all United States Air Force nuclear weapons. Those requirements include the nuclear weapon systems military characteristics, operational parameters, and the stockpile-to-target sequences throughout the entire lifetime of the warhead's service with the Air Force. The Missile Branch is responsible for evaluating and assisting in the fielding of certified Air Force ground launched nuclear warhead missile delivery systems and their associated ground handling equipment. The missile systems must incorporate the Air Force required surety provisions to obtain operational certification. Those ground launched missile systems include both mobile and fixed-site systems. The branch must also ensure the continued safe and secure performance of those certified ground launched missile systems and equipment during the rest of their operational lifetime. The ground launched missile systems also require an Unauthorized Launch Analysis study be performed under the Nuclear Systems/Surety Division's direction. The Airborne Branch, in a similar role, is responsible for evaluating, assisting in the fielding and supporting the continued satisfactory performance of certified Air Force nuclear capable aircraft, both transport and combat. This includes the same certification responsibilities for all airborne launched or released nuclear weapons and all airborne nuclear weapon ground handling equipment. The Airborne Branch is also responsible for development, obtaining approval and maintaining all Air Force aircraft release procedures and airborne nuclear weapon transportation procedures for employment in an aircraft or with ground handling equipment.

The Air Force Nuclear Surety Program—surety meaning a combination of security and safety—is based directly on the Department of Defense (DOD) Nuclear Safety Standards. The four DOD Nuclear Weapon System Safety Standards in DOD Directive 3150.2 are the basis for the safety design and evaluation criteria for nuclear weapon systems and the nuclear safety rules governing nuclear weapon system operations. The first and third rules are primarily safety related, and the second and fourth rules are security related. DOD Directive 5210.41 identifies the security criteria and standards for protecting nuclear weapons, and DOD 5210.41M is the nuclear weapon security manual to accommodate the directive. The Air Force has generated a series of regulations based on the DOD directives and manual. These regulations identify and expand on the application of the DOD criteria to Air Force operations. System surety compliance is required during the entire stockpile-to-target sequence and through retirement for any nuclear weapon system. Operational certification is obtained for the Air Force system after all surety criteria compliance is ensured and maintained. Failure of a nuclear weapon system to satisfy the criteria could result in a failure of our surety systems, with possible international consequences. It is critical to the Air Force defense role performance the Nuclear Systems/Surety Division to maintain an active research and development (R&D) program to support our surety system criteria development and analysis requirements. It is within the operations of this R&D program the Nuclear Systems/Surety Division has been working with the Brookhaven National Laboratory Technical Support Organization (BNL-TSO).

II. RECENT ACCOMPLISHMENTS

The Air Force Weapons Laboratory Nuclear Systems/Surety Division's primary task is to support existing certified nuclear weapon systems and to support and assist in the certification of new advanced nuclear weapon systems for the defense of our country and the free world. In the last 10 years the WL/NTS Division has conducted several surety evaluations and R&D projects.

Special security evaluation studies on nuclear weapon systems were completed on overall US Air Force worldwide operations. The first study reviewed the Continental United States airbase operations, including off-base ground transportation convoy equipment and procedures. The second study centered on the worldwide US Air Force aircraft nuclear weapons transportation equipment and procedures. The third study considered the United States Air Force European (USAFE) base operations. One study in particular covered the Minuteman II and Minuteman III systems. Another study focused on all US Force aircraft launched or released nuclear weapon systems. In addition to those studies, computer analyses have been conducted on two ground launched missile systems. One analysis reviewed Minuteman II and III ground transportation convoys and launch facilities maintenance procedures. The second analysis was concentrated on the initial operations concept of the ground launched cruise missile system, now named the Gryphon system.

R&D projects have included the development of protective shrouds to enhance the surety of both the Minuteman II and Minuteman III reentry vehicle ground transportation operations. An air-transportable nuclear warhead/bomb secure shipping container prototype was developed for test and evaluation. A Cable Vehicle Barrier System (CVBS) prototype has been developed and is currently under test and evaluation. The CVBS provides enhanced vehicle access control across wide areas, under all weather conditions. A proposed aircraft obscuration screen system, which has to perform under extreme airfield operational conditions, has been developed and is currently in test and evaluation.

III. JOINT OPERATIONS

In late 1983, the Nuclear Systems/Surety Division discovered, by chance, a source of similar nuclear systems experience at BNL-TSO. It seemed BNL-TSO had developed an experienced staff in nuclear surety operations as a result of their organization providing technical support since 1968 to the Atomic Energy Commission in both domestic and international nuclear system safeguards. It was determined by the Weapons Laboratory that a working agreement between the Nuclear Systems/Surety Division and BNL-TSO would be a cost-effective solution to completing or satisfying several required tasks. As a result, the division and BNL-TSO have been engaged in joint working projects since the summer of 1984.

Joint projects have included work on a study requested by Headquarters Strategic Air Command (HQ SAC) on Nuclear Alert Systems Security Technology issues. Then a "relook" study was conducted on USAFE weapons transport operations and equipment. Assistance was provided in developing system security criteria for an Air Force Nuclear Weapons System Certification Plan and a separate military standard. This was followed by a project to develop, test and evaluate prototype systems to upgrade the surety of alert systems for HQ SAC. This currently involves the evaluation of a cable vehicle barrier system and an obscuration screen system.

IV. FUTURE DIRECTIONS

The Nuclear Systems/Surety Division has been very satisfied with the results of the working relationship with BNL-TSO. Joint working projects are still anticipated to occur in several possible candidate areas in nuclear weapon systems surety; for example, in access denial systems, both passive and/or active are employed to enhance the surety of current operational systems. Security seals development and application to possible aid in reduction of manpower requirements may also be an applicable work area to pursue. Another area might be to apply current DOE computer security analysis techniques on Air Force nuclear weapon systems for evaluation and modification studies and to determine the analysis technique's usefulness to the Air Force. Possible future assistance may then be utilized in nuclear weapons systems criteria development for application in upgrading Air Force surety regulations, design manuals/instructions, and test/evaluation plans and requirements.

The Weapons Laboratory Nuclear Systems/Surety Division has a goal to gain experience in surety system design, construction, performance, operations, limitations, evaluations and future trends. It is then critical for the division to apply that knowledge in updating and developing the best possible surety criteria for the Air Force nuclear weapon systems. This action allows the division to pass on the lessons learned and insure that the Air Force and our country have the best and most cost effective nuclear defense.

Recent and Future TSO Directions

Joseph P. Indusi
Division Head, TSO
Brookhaven National Laboratory
Upton, New York U.S.A.

ABSTRACT

For most of TSO's 20 years of existence, the emphasis has been on safeguards, security, and international safeguards systems. Recently, TSO has been asked to support related activities in the Department of Energy and the Department of Defense. Through a combination of the efforts of the TSO staff members and key people in the sponsoring agencies, TSO has been able to meet these new challenges. Recent TSO activities have been in support of the DOE Office of Classification and Technology Policy, the DOE Office of Security Evaluations, the DOE Office of Arms Control, and the Air Force Weapons Laboratory. A brief description of these technical support programs is given in this talk. Also to be discussed are issues related to the management of a technical support group such as TSO.

I. INTRODUCTION

TSO's history, and the history of nuclear safeguards has been amply covered by those who have spoken over these last two days. In planning for this symposium I left the task of describing our recent and future directions to myself. Describing our recent activities is of course much easier than predicting what the future will hold. However, I will do my best to give my perception of where we are heading.

Our activities in the recent past have taken us into areas related to safeguards and security systems but each with somewhat different emphasis. Let me say that our successes in these new areas are the direct result of the efforts of people at BNL and in the sponsoring agencies. My thanks therefore go to the members of the TSO staff, both past and present, who have made our efforts in these new areas a success. Thank also are due to those people in the sponsoring agencies who have had the foresight to initiate and support these new programs. In particular, I would like to recognize the efforts of Dr. Julio Torres in regard to our continuing program of support for security evaluations, Mr. Herbert Fernandez and Mr. William Barry for our program in Air Force nuclear security systems, and Mr. Thomas D'Agostino for our program of technical support in classification. Throughout these last five years of expansion and growth I have always had the full support of my predecessor Dr. John Cusack and the support and encouragement of the department chairmen Dr. Herbert Kouts and Dr. Walter Kato.

II. RECENT ACTIVITIES

In the last 20 years, we in TSO have been working in safeguards and security, both domestic and international, on a continuing basis. These activities have been described adequately by others and so I will concentrate more on our new programs which have come into being during the last five years.

Our program of technical support to the DOE Office of Classification and Technology Policy began with a short study on proposed guidance for vulnerability information in the safeguards and security area. This program has expanded over the last four years to include technical support for development of classification guidance in advanced isotope separation methods, radioactive material dispersal, safeguards and security information and space nuclear power. Other work involves guidance development for unclassified but controlled information such as Unclassified Controlled Nuclear Information as authorized under section 148 of the Atomic Energy Act. TSO has also supported the Office of Classification and Technology Policy in their appraisal program and in the education and training program. In support of training, TSO has developed a complete training system including training videotapes, a level three interactive videodisc system, and a Classification Training Institute. The videodisc, "The Authorized Classifier," is, to our knowledge, the best interactive and stand-alone classification training system in the U.S. government. This system also won first prize in a national videodisc competition in the category of government or military.

A major TSO contribution to the OCTP appraisal program was the development of the Classification Appraisal Procedural Guide. This guide provides a systematic method of reviewing and appraising classification management practices in the field. It includes criteria to objectively assess performance in such areas as classification practices, education, management awareness and support, declassification, and review of sensitive non-nuclear technology information. TSO carried out several training sessions to familiarize personnel with this Procedural Guide and the associated portable computer systems. Recent work has been focussed on how UCNI and other forms of information control may be incorporated into the appraisal program.

TSO was also a major contributor to the Classified Document Control Action Team. TSO effort was considerable, with about three persons nearly full time for about nine months. This effort was not an inspection but a fact finding mission across a broad range of DOE security interests. More details regarding this effort and its importance to DOE were discussed in Elizabeth Q. Ten Eyck's paper presented at this Symposium.

For many years, TSO supported the safeguards and security inspection program when it was a group within the Office of Safeguards and Security. With the establishment of the Office of Security Evaluations (OSE), TSO's role expanded considerably as OSE expanded. Today we provide technical experts for inspection activities in the area of material control and accountability (MC&A), MC&A surveys, physical protection surveys, protection program planning, and related areas. TSO also supports DOE-wide evaluations of specific safeguards systems and conducts studies on safeguards issues as directed by OSE.

The frequency of inspections at field facilities has been approached in several ways. Rather than a fixed interval between inspections, TSO proposed that inspection frequency be based on the relative safeguards risk associated with each facility. The relative risk was defined as a numerical ranking that took into consideration the potential threat, potential vulnerability, and potential consequences of a successful malevolent act at a facility. The time between inspections would be shorter for higher "risk" facilities and longer for lower "risk" facilities. This system would be self-correcting in the sense that as a facility corrected perceived vulnerabilities the time between inspections could be made longer. Similarly, the effect of consequence mitigating systems would also lower the risk. Work to systematize and formalize this concept was carried out with OSE and other contractor support.

TSO also provided an early-on review of the new and emerging Safeguards Standards and Criteria first developed by OSE. OSE did not involve TSO in the drafting of the Standards and Criteria (S&C) but recognized that the experience of the TSO staff could be utilized to provide an objective review of the S&C prior to their formal release. The S&C now are the responsibility of the Office of Safeguards and Security.

In 1984, TSO began a program of support to the Air Force Weapons Laboratory in the area of nuclear systems security. These efforts were primarily associated with the security of nuclear weapons systems under control of the major operating commands such as the Strategic Air Command (SAC) and the United States Air Forces in Europe (USAFE). In regard to these issues, TSO has developed solutions to several problems associated with aircraft, alert areas, and transport activities. TSO approaches have been adopted and are being deployed at several key Air Force facilities. In this program, TSO developed the underlying protection concepts, assessed feasibility, developed engineering costs estimates, and participated in the testing of these systems. We are now involved in prototype testing in operational areas at two Air Force bases.

A key TSO contribution to the security of alert aircraft areas was the design of the aircraft taxigap control corridor and the cable vehicle barrier. This concept provides protection to adversaries on foot as well as vehicle bombs. This integrated security system is the only known and tested method of protecting security areas where vehicle and aircraft ingress and egress must be rapidly achieved across an opening several hundred feet wide. A variation of the original TSO design is being used to protect one of the special flying command posts for the Commander of SAC and the system has been under consideration for protection of the new Boeing 747 that will serve as Air Force One.

To accommodate these new initiatives, TSO has been organized into a four group division as shown in the TSO organization chart. The entire division consists of 21 scientific and professional staff members, four secretaries, and a full time professional librarian. The TSO library, dedicated to Willy Higinbotham, consists of a broad collection of nuclear safeguards and security, non-proliferation, nuclear technology, and arms control books and reports. The entire collection is computer retrievable and TSO maintains the capability to search several government and commercial databases.

III. FUTURE DIRECTIONS

Where are we headed? In domestic safeguards we are probably going to see more emphasis on insider protection and performance oriented requirements. There will also be continued interest in integrating more fully the elements of material accountancy, material control, and physical protection. As nuclear generated power continues to grow worldwide, this will place a greater burden on international safeguards operations. In addition, more nations will enter into safeguards agreements with the IAEA, as the Peoples Republic of China has done last week, and this will require additional international safeguards inspection effort and related support in the areas of nuclear instrumentation and computerized safeguards information management.

In the area of classification and technology policy we see new challenges as we strive to improve technology transfer from the national laboratories to private industry while protecting certain technologies which have direct military application or nuclear proliferation concerns. Information on new technologies such as space nuclear power and laser driven isotope separation methods will need to be fully evaluated to allow protection of certain critical information while assuring full dissemination of scientific knowledge.

In the area of safeguards and security evaluations there is much work to do in evaluating system performance requirements in addition to verifying compliance type requirements. Investigations are now going on in regard to improving the credibility of the field office survey programs. The role of OSE inspections may then be directed, for certain topical areas, to verifying the adequacy of the field office surveys. This will require that the field offices have the resources and equipment to carry out independent verification of contractor performance.

TSO's efforts in support of the Air Force will continue to be concerned with alert area security improvements. Work may also be directed to applying security technology for transport operations and to control the need for security manpower. The concern for controlling security manpower is not restricted to DOD, the concern in DOE is also real. The DOE Safeguards and Security Crosscut budget in FY 1988 was about $840 million of which $740 million was for operating costs. Of this, over 1/3 was for maintaining security manpower.

Finally, I am happy to announce that in a few days we will begin a program of technical support to the DOE Office of Arms Control. The INF treaty represents a long awaited breakthrough in reducing nuclear armaments and the answer to the hopes of many people. We can expect that in the near future we may have a strategic arms reduction treaty and a chemical weapon treaty as well. TSO will work to apply its experience and knowledge of verification methods for safeguards systems to the related problems of verifying arms control agreements.

IV. MANAGING TSO

I wish to spend only a few minutes to discuss some issues relevant to managing a technical support group such as TSO.

Recently, there has been a trend toward aligning research and development projects with identified needs in the safeguards community. I have long supported this approach even before it became popular. The need to move in this direction is clearly understandable in view of the increased workload on field operations and the desire to improve the payoff from R&D expenditures. TSO has taken this trend very seriously and for several years we have directed all staff effort to meeting agreed-to deliverables and deadlines. I am concerned however, that we leave time and some latitude for our technical experts to carry out R&D in solving problems that they see as important. I know of several safeguards innovations that are the result of independent efforts not described in an official "statement of work."

Some research into the effectiveness of scientists and engineers in different types of R&D establishments was reported in "Science," the journal of the American Association for the Advancement of Science in 1967. The title of the paper was "Creative Tensions in the Research and Development Climate" by Donald D. Pelz. The author conducted a study of 1,300 scientists and engineers at 11 research and development laboratories. They looked at a number of factors, including the level of coordination versus freedom in the organization and the mix of functions ranging from research, to development, to technical services. Among the conclusions reached were the following:

- "In departments having moderate coordination, it seems likely that individual autonomy permitted a search for the best solution to important problems faced by the organization", and
- "Effective scientists, in short, did not limit their efforts either to the world of pure science or to the world of application but were active in both".

Those who manage R&D programs must therefore seek an optimal distribution of R&D effort so that we find solutions to problems without stifling individual innovation.

The story of TSO would not be possible without recognition of the people who make it possible. The collective abilities and experience of the TSO staff and similar groups elsewhere constitute a national resource. You may call them a "lead laboratory" or a "center of excellence" but the meaning is the same. The government sponsors have nurtured and supported these organizations and in doing so they have secured for themselves technical resources from which to make future progress in critical areas. Each individual contributes his experience and skills to create the whole. It takes years to develop technical skills in these areas and for this and other reasons there is only a finite and not easily expandable body of expertise in existence. In the past we have experienced funding cutbacks followed by periods of expansion. We must be careful to appreciate what we have created and to recognize how difficult it would be to rebuild any one of these technical resources if it were to be abandoned. DOE is somewhat unique in the technical resources it commands, both within the agency itself and at the national laboratories and contractor sites. This strength, inherited largely from the Atomic Energy Commission, must be preserved to serve the future needs of our nation.

This concludes my remarks and signals the end of this symposium. My thanks go to the speakers, participants, and members of the BNL staff who have made this symposium possible.

Twentieth Anniversary Symposium 1968-1988

Author Biographies

Technical Support Organization
Brookhaven National Laboratory
Associated Universities, Inc.
September 25-27, 1988

William Barry

William Barry's early years were spent in Albuquerque, NM. In 1972, he was graduated with a B.S. in mechanical engineering from the University of New Mexico at Albuquerque. He worked for the Spacecraft Electro-mechanical Systems Division of Hughes aircraft for two years. Mr. Barry joined the Aerospace Ground Equipment group at the Air Force Weapons Laboratory in 1974. In 1977 he started the systems section. He attended UNM MAME in 1981. Currently, he is the NTS Division Technical Advisor for Security Technology.

Ruben Bello

Ruben Bello has been the Director of the Division of Operations B, Department of Safeguards at the International Atomic Energy Agency since September 1987. He was born in Poza Rica, Veracruz, Mexico in 1936, studied Mechanical Engineering at Escuela Militar de Ingenieros in 1964, obtained an M.S. in Nuclear Engineering from the Instituto Politechnico National in 1972. He served as Quality Assurance Manager of the Laguna Verde nuclear project from 1971-1974; Director General (CNSNS), Mexican Regulatory Authority from 1979-1982; and Director General, Nuclear Research National Institute, Mexico from 1982-1987.

Leonard M. Brenner

Leonard M. Brenner has 38 years of experience in developing and managing "peaceful uses" and "military uses" international nuclear cooperation and sensitive information control programs. He has actively participated in development of U.S. policies that led to establishment of the nuclear safeguards and security roles of the International Atomic Energy Agency (IAEA), and in formulating U.S. interagency and DOE intra-agency programs for carrying out National Non-proliferation objectives. Brenner served as a Special Assistant to the Atomic Energy Commission (AEC) Director of Military Applications for 10 years, which involved assignments in all aspects of nuclear weapons program development, production, testing, transportation, and security protection. Brenner is a graduate of the Industrial College of the Armed Forces, with a degree in electrical engineering and of a one-year Science Fellowship at the Department of Commerce. He served a one-year tour of duty with the IAEA in Vienna, Austria to initiate a program to standardize nuclear safeguards activities in facilities of countries that are not parties to the Nuclear Non-Proliferation Treaty. His extensive experience has made him particularly skilled at interfacing with senior officials in DOE, National Laboratories, other agencies, military organizations, and foreign governments.

David M. Gordon

David M. Gordon received B.S. and M.S. degrees in physics from the Ohio State University in 1963 and 1965, respectively. He then received a Ph.D. in nuclear physics from the California Institute of Technology in 1972. After engaging in nuclear physics research during two postdoctoral research associateships at Rutgers University and at the State University of New York at Stony Brook, he joined the staff of the Technical Support Organization at Brookhaven National Laboratory in 1976. There his primary work has been development of domestic and international safeguards for uranium enrichment processes, including gaseous diffusion, gas centrifuge, and the Atomic Vapor Laser Isotope Separation processes. In 1986, he became Group Leader for Safeguards, Security and POTAS Projects.

Glenn A. Hammond

Glenn A. Hammond is Director, Division of Safeguards, Office of Safeguards and Security (Defense Programs), at the Department of Energy. He served over 30 years in various technical positions at both field facilities and Headquarters in nuclear materials production, quality assurance, and management; and in safeguards and security programs involving policy, procedures, standards, and

R&D for both domestic and international safeguards. He has been a member of the INMM for the last 20 years with primary involvement in the technical program and long-range planning committees, presentations, as a voting representative of INMM-sponsored ANSI standards, and was Executive Committee Member-At-Large during 1982-83. He is a Senior Member of the Institute and was elected Fellow in 1985 by the Executive Committee.

William A. Higinbotham

William (Willy) Higinbotham is currently a consultant to Brookhaven National Laboratory. From 1968 to 1985 he was a Senior Physicist at BNL and for two of these years was the Division Head of TSO. Prior to his work in safeguards, Willy headed up the BNL Instrumentation Division. Willy also worked at the MIT Radiation Laboratory from 1941-43 and he was a physicist on the Manhattan Engineering District Project from 1943-45. He holds a B.S. in physics and a Ph.D. in science from Williams College. Willy is a world renowned expert on safeguards, and it can truly be said that he was there at the beginning.

Joseph P. Indusi

Joseph Indusi received a B.S. in electrical engineering in 1965 from the University of Bridgeport and an M.S. and Ph.D. in applied mathematics in 1969 and 1971 respectively from the State University of New York at Stony Brook. He worked as a system consultant for an electrical equipment manufacturer and then joined the staff of Brookhaven National Laboratory in 1973. In 1984 he was appointed Deputy Division Head of the Technical Support Organization and in 1986 was appointed Division Head of TSO. His interests in safeguards and security concern the design and modelling of safeguards systems, vulnerability and consequence analysis, and vital area analysis. He was instrumental in initiating new programs in TSO in the areas of security evaluations, classification technical support, nuclear weapons security systems, and arms control.

Jon Jennekens

Jon Jennekens holds a BS in mechanical engineering from Queens University, Kingston. He has been employed in the Canadian nuclear energy program since 1951 and in the safeguards program since 1962. He served as Chairman of the Board, President, and Chief Executive Officer of the Atomic Energy Control Board since 1978. Presently he is the deputy Director General, Department of Safeguards, of the IAEA in Vienna.

G. Robert Keepin

G. Robert Keepin joined the Los Alamos staff in 1952. From 1963 to 1965 he was with the Headquarters Staff of the International Atomic Energy Agency in Vienna. Following his return to the United States in 1965, Mr. Keepin established and directed the Nuclear Safeguards research

Technical Support Organization
Twentieth Anniversary Symposium
September 25-27, 1988
Revised Agenda

Sunday, September 25, 1988
3:00 p.m. Registration
6:00 p.m Cocktail Hour
7:00 p.m. Buffet Dinner
- Welcome and Opening remarks by Herbert J.C. Kouts, Former Chairman, Department of Nuclear Energy, BNL

Monday, September 26, 1988
Session I 9:00 a.m.-12:00 noon
- Introduction to Session by N.P. Samios, Director, BNL
- William A. Higinbotham, Consultant, TSO—*Early AEC Safeguards and TSO Beginnings*
- S. McDowell, Meridian Corporation—*AEC Safeguards History and Evolution of Safeguards R&D Program*

10:15 a.m. Coffee
10:30 a.m.
- J. Jacobs, Sandia National Laboratories—*Physical Protection—A History and Overview*
- G. Robert Keepin, Los Alamos National Laboratory—*LANL Safeguards Program Overview and NDA in Safeguards*

12:00 noon Lunch

Session II 1:00 p.m.-5:00 p.m.
- Introduction to Session by W.Y. Kato, Chairman, Department of Nuclear Energy, BNL
- E. Ten Eyck, Director, DOE Office of Safeguards and Security—*Defense Programs Perspective of the Safeguards and Security, and Classification Programs in the DOE*
- G. Hammond, DOE Office of Safeguards and Security—*Current OSS Safeguards R&D Program and TSO Role*

3:15 Coffee
- J. Torres, Director, Office of Planning and Project Management, Defense Programs, U.S. DOE—*The Role of Security Evaluations*
- W. Barry, Project Engineer, Nuclear Systems Surety Division, Air Force Weapons Laboratory—*Role of Air Force Weapons Laboratory in Nuclear Security*

6:30 p.m. Cocktail Hour (Compliments of AUI)
7:30 p.m. Banquet—Banquet Speaker, General Edward Giller (to be introduced by Herbert Kouts)

Tuesday, September 27, 1988
Session III 9:00 a.m.-2:00 p.m.
- Introduction to Session by L. Green, Head of the International Safeguards Project Office, BNL
- J.C. Kessler, U.S. State Department—*State Department Perspective of IAEA Safeguards*
- R. Bello, Director of Safeguards Operations B, IAEA—*Recent and Future IAEA Directions*

10:15 a.m. Coffee
- D.M. Gordon, TSO/BNL—*TSO Efforts in Support of IAEA Safeguards*
- J.P. Indusi, Division Head, TSO/BNL—*Recent and Future TSO Directions*

12:00 noon Lunch
1:00 p.m. Open Discussion

and development program at Los Alamos National Laboratory. From 1983-1985 he returned to Vienna to serve as senior advisor and consultant to the IAEA Department of Safeguards. Keepin is a Fellow of the American Physical Society, the American Nuclear Society and the Institute of Nuclear Materials Management. He is a past National Chairman of the INMM. 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, non-proliferation and inspection/verification technology. Mr. Keepin was appointed a Fellow of the Los Alamos National Laboratory in 1985.

J. Christian Kessler

J. Christian Kessler is a senior officer in the State Department's Office of Nuclear Technology and Safeguards, where he is responsible for international safeguards, nuclear safety cooperation, technical assistance, and physical protection issues. He is chairman of interagency groups responsible for the U.S. Program of Technical Assistance to IAEA Safeguards (POTAS) and for implementation of IAEA safeguards in the U.S. Prior to joining the State Department, Mr. Kessler worked for the U.S. Nuclear Regulatory Commission's Office of International Programs, and for several companies involved in policy related research and consulting. He was a staff assistant to Congressman Mike McCormack.

Samuel C.T. McDowell

Samuel C.T. McDowell is currently a Nuclear Safeguards Consultant conducting surveys of major DOE nuclear reactor and processing facilities and serves as Director of Safeguards for a contractor supporting DOE safeguards programs. He has 30 years experience in nuclear safeguards and security with emphasis on domestic and international nuclear material control and accountability and allied research and development. He served as the Director, Division of Safeguards, Office of Safeguards and Security, DOE. Mr. McDowell has a background in commercial chemical industry experience in conducting plant operations, research and analytical chemistry.

Mr. McDowell obtained a B.S. in chemical engineering from the University of West Virginia in 1941; B.S. equivalent in meteorology (1943), Combat and Photo Intelligence School (1943), and Radar Intelligence School (1945) from the U.S. Army Corps; M.S. and Ph.D. in physical chemistry (1950 and 1954, respectively) from the University of Delaware.

James de Montmollin

James de Montmollin is a graduate of Georgia Institute of Technology with a degree in electrical engineering. He joined the staff of Sandia National Laboratories in 1953. From that time until the mid 1960s he worked on nuclear weapon design, full-scale atmospheric testing, and weapons deployment and effects studies. Following that, he participated in a variety of non-nuclear defense-related projects. He has been involved in safeguards work since 1973, first in connection with physical protection of DOE facilities and the commercial fuel cycle. Since 1979 his work has centered on international safeguards, in the areas of analysis and concept development. In 1983 he received recognition from Sandia as a Distinguished Member of the Technical Staff, with a citation noting his contributions in the safeguards area as well as previous work.

William C. Myre

After graduating from Texas A&M with a degree in electrical engineering in 1950, William Myre took a position with Sandia National Laboratories in Albuquerque. He worked in various programs including the Vela satellite project before joining nuclear safeguards in 1976. Since 1977 he has served as Director of Nuclear Security Systems.

Elizabeth Q. Ten Eyck

Elizabeth Q. Ten Eyck joined the U.S. Department of Energy as the Director of the Office of Safeguards and Security in August 1988. In this position she serves as the single focal point for all DOE safeguards and security related matters and as such is responsible for the development of measures to assure adequate protection, control and accountability of special nuclear materials; nuclear weapons and weapon components; facilities; and classified information against theft and sabotage. She is responsible for the security clearance process in the Department.

Prior to joining the Department of Energy, Mrs. Ten Eyck served as Deputy Director, Division of Safeguards and Transportation, U.S. Nuclear Regulatory Commission, having assumed this position in July 1985. During her 10 year tenure with NRC she held progressively more responsible management positions with emphasis on safeguards effectiveness evaluation and threat assessment.

Mrs. Ten Eyck was a security engineer for the U.S. Secret Service for eight years, developing sophisticated security systems and law enforcement investigative equipment. Immediately after graduation from the University of Maryland, in 1968, as an electrical engineer, she worked in private industry developing electronic countermeasures systems for defense applications.

Julio L. Torres

Dr. Julio L. Torres was born in Santurce, Puerto Rico, where he graduated from Central High School in 1951. In addition to completing premedical studies at the University of Puerto Rico in 1953 and earning a bachelor of science degree at the U.S. Naval Academy in 1957, Dr. Torres earned masters and professional engineer's degrees in electrical engineering at Stanford University in 1961, and a Ph.D. in electrical engineering and applied physics at Stanford University in 1966. Dr. Torres is also a 1983 graduate of the U.S. Naval War College (with highest distinction) and a 1984 outstanding graduate of the Industrial College of the Armed Forces.

Dr. Torres is currently Director, Office of Planning and Project Management, U.S. Department of Energy (DOE). For the previous 12 years, Dr. Torres has served as the Director, Office of International Security Affairs, and as the Director, Office of Security Evaluations, both in DOE. From 1970-1976, prior to entering DOE, he was Director of the Washington Research Office of the Riverside Research Institute (previously the Electronics Research Laboratory of Columbia University). From 1957 to 1970, he held many positions of increasing responsibility as a regular officer in the U.S. Air Force (e.g., Chief, Sensor Branch Space Track Program Office; Program Manager, Strategic Technology, Advanced Research Projects Agency, etc.). He left the Air Force in February 1970 as Major and is currently a Brigadier General in the Air Force Reserve serving as the Individual Mobilization Assistant to Commander, AF Communications Command at Scott AFB, Illinois.

Posts Vacant in the IAEA

The Department of State, the U.S. Arms Control and Disarmament Agency and the Department of Energy have initiated a program to improve recruitment of U.S. nationals for employment in the IAEA.

In an effort to support this program, *JNMM* will publish IAEA vacancies.

Department of Research and Isotopes

Division: IAEA Laboratories Seibersdorf *Section:* Argriculture Laboratory *Position:* Head, Animal Production Unit *Grade:* P-4 *Vacancy* #89/031 *Opened:* 23 May 1989 *Closing:* 22 September 1989

Division: Physical and Chemical Sciences *Section:* Nuclear Data *Position:* Nuclear Physicist *Grade:* P-3 *Vacancy* #89/029 *Opened:* 23 May 1989 *Closing:* 22 Sept 1989

Division: Physical and Chemical Sciences *Section:* Physics *Position:* Head of Physics Section *Grade:* P-5 *Vacancy* #89/022 *Opened:* 21 March 1989 *Closing:* 21 July 1989

Department of Safeguards

Division: Safeguards Information Treatment *Section:* Data Processing Development *Position:* Unit Leader *Grade:* P-5 *Vacancy* #89/030 *Opened:* 23 May 1989 *Closing:* 22 Sept 1989

Division: Safeguards Information Treatment *Section:* Data Processing Development *Position:* Systems Analyst—Documentation *Grade:* P-4 *Vacancy* #89/025 *Opened:* 25 April 1989 *Closing:* 25 August 1989

Division: Operations *Posistion:* Nuclear Safeguards Inspector *Grade:* P-3 (several positions) *Vacancy* #89/SGO-3 *Opened:* 25 April 1989 *Closing:* Continuous recruitment until 31 Dec 1989.

Divisions: Operations *Position:* Nuclear Safeguards Inspector *Grade:* P-4 (several positions) *Vacancy* #89/SGO-4 *Opened:* 25 April 1989 *Closing:* Continuous recruitment until 31 Dec 1989

Division: Standardization, Training and Administrative Support *Section:* Standardization *Position:* Technical Standards Specialist *Grade:* P-5 *Vacancy* #89/021 *Opened:* 14 March 1989 *Closing:* 14 July 1989

Department of Technical Co-operation

Division: Technical Assistance and Co-operation *Section:* Fellowships and Training *Position:* Fellowship Officer *Grade:* P-4 *Vacancy* #89/024 *Opened:* 28 March 1989 *Closing:* 28 July 1989

Division: Technical Assistance and Cooperation *Section:* Middle East & Europe *Position:* Area Officer *Grade:* P-4 *Vacancy* #89/020 *Opened:* 14 March 1989 *Closing:* 14 July 1989

How to Apply

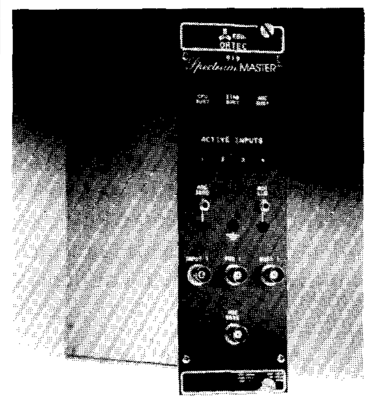
Applications must include a vacancy notice number, and should be mailed to the United States Mission to the International Atomic Energy Agency, Kundmanngasse 21, 1030 Vienna, Austria (Attention Ronald Bartell). After U.S. Government endorsement is given, the Mission will forward the application to the Division of Personnel at the IAEA.

U.S. Candidates must also send a photocopy of the original application to: (for positions in the Department of Safeguards) P.O. Box 650, Brookhaven National Laboratory, Upton, NY 11973, (for all other positions) IO/T/SCT, Rm. 5336, Department of State, Washington, D.C. 20520.

For more information contact Mr. W. Porter, Department of Energy, (202) 586-8253, FTS 586-8253. Potential applicants should leave their name, address, and position in which they are interested. DOE will then forward a package of information on the IAEA and the position for which they applied.

Gamma Analysis Software

The 919 SPECTRUM MASTER is the latest addition to EG&G ORTEC's line of multichannel analyzer (MCA) products.



The Model 919 incorporates a 16K-channel ADC, four-input multiplexer-router, digital stabilizer, and 64K channels of non-volatile data memory. It may be configured for four inputs at low-to-moderate count-rates, each with its own conversion gain, presets, and start/stop control. Alternatively, the 919 may be configured as a single-input, digitally-stabilized MCA that can handle from low to ultra-high count-rates.

For information and a free data sheet call, 800/251-9750, or a local EG&G ORTEC representative.

Gamma Spectroscopy Newsletter

Spectrum PEAKS a free newsletter from EG&G ORTEC describes the latest developments in the field of nuclear instruments for gamma spectroscopy. Products discussed include members of the SPECTRUM MASTER Family of PC-based multichannel analyzer workstations and plug-in cards. Also described are disks for two new software products: MAESTRO II MCA emulation and MINIGAM II gamma-ray analysis.

Call 800/251-9750, or a local EG&G ORTEC representative to receive a free newsletter.

Switcher Package

Javelin Electronics, has introduced its SuperSwitcher(TM) Plus microprocessor-controlled switcher system.

The System (model JO101SSC) is composed of a master control, a video gathering panel, and a power supply. It is a basic switching package that permits sequencing and call up of ten video cameras—expandable to 100 camera inputs with additional video gathering panels.

SuperSwitcher Plus is capable of manual, looping, sequential, auto alarming, bridging and remote switching functions. A digital display on the master control informs the operator which camera is being displayed on which monitor. The video gathering panel and power supply can be installed in a closet or other out-of-the-way place.

For more information contact Javelin Electronics at 213/327-7440.

Alpha Spectroscopy Package

Canberra Industries announces the Alpha Spectroscopy Software Package: ASP. The package runs under Microsoft Windows on AT- and PS/2-compatible personal computers.

Using sample set-ups and calibration files, the package will automatically locate nuclides in a sample spectrum, set up regions of interests (ROIs), and output the results to disk, printer or both. The user is given the opportunity to interact with the results to ensure their correctiveness before printing an analysis report.

File formats from other manufacturers (including Ortec, The Nucleus, and Nuclear Data) as well as other Canberra file formats (Spectran-AT, Gamma-AT, MicroSampo and PC Toolkit) can all be analyzed by the ASP program.

For more information, contact Canberra Industries, Inc., One State St., Meriden, CT 06450, 203/238-2351.

CALENDAR

July 9-12, 1989
30th Annual Meeting of the Institute of Nuclear Materials Management, Stouffer Orlando Hotel, Orlando, Fla. USA *Sponsor:* Institute of Nuclear Materials Management *Contact:* Barbara Scott, INMM Headquarters, 60 Revere Dr., Suite 500, Northbrook IL 60062 USA, (312) 480-9573.

July 10-14, 1989
Management & Disposal of Radioactive Wastes *Sponsor:* Harvard School of Public Health *Contact:* Sharon E. Block, Office of Continuing Education, Harvard School of Public Health, 667 Huntington Ave., L-23, Boston MA 02115 USA, (617) 732-1171.

August 21-24, 1989
American Glovebox Society Third Annual Conference and Equipment Display, Denver, CO, USA *Sponsor:* American Glovebox Society *Contact:* Richard T. Burns, (803) 557-4294.

September 11-14, 1989
35th Annual Seminar and Exhibitor of the American Society for Industrial Security, Nashville, TN, *Contact:* ASIS, 1655, N. Fort Myer Dr., Suite 1200, Arlington, VA 22209 USA, (703) 522-5800.

October 1-5, 1989
Second International Conference on CANDU Fuel, Chalk River, Ontario, Canada *Sponsor:* Canadian Nuclear Society *Contact:* CNA, 111 Elizabeth St., 11th Floor, Toronto, Ont., Canada M5G1P7,(416) 977-6152.

October 23-28, 1989
1989 Joint International Waste Management Conference, Kyoto, Japan *Sponsor:* ASME, JSME, AESJ *Contact:* To submit papers on high-level waste contact S.C. Slate, (509) 376-1867, Battelle, P.O. Box 999, Richland, WA 99352; to submit papers on low-level waste contact F. Fiezollahi, (415) 768-1234, Bechtel National, 50 Beale St., P.O. Box 3965, San Francisco, CA 94119 USA

November 26-30, 1989
ANS Winter Meeting, San Francisco, CA, USA *Sponsor:* American Nuclear Society *Contact:* General Chair Bertram Wolfe, General Electric Co., 175 Curtner Ave., MC/803, San Jose, CA USA 95125, (408) 925-6900.

June 4-7, 1990
Emerging Technololgies For Hazardous Waste Treatment, Atlantic City, NJ USA *Sponsor:* American Chemical Society *Contact:* Dr. D. William Tedder (404) 894-2856.

The events listed in this calendar were provided by Institute members or taken from widely available public listings. We urge INMM members, especially those from countries outside the United States, to send notices of other meetings, workshops or courses to INMM headquarters.

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