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INMM
INSTITUTE OF NUCLEAR MATERIALS MANAGEMENT

New Appointments and Activity Overview

It is my pleasure to report that Rich Strittmatter has been appointed to fill an open member-at-large position on the INMM Executive Committee. Strittmatter had been the Materials Control & Accountability (MC&A) Division chair for several years and brings a good deal of institutional experience to his new position.

I am equally pleased to report that Dennis Brandt is the new MC&A Division chair. I, and the rest of the Executive Committee, look forward to working with both members in their new positions.

To follow up on the remarks about communications I made in the February 1997 journal, I would like to provide a brief overview of the Institute's workshops, seminars, and meetings held recently or planned during the next couple of months. Because workshops and seminars, are designed to share timely information and require minimal lead time to organize, it is likely there will be additional activities scheduled. INMM members will receive updated information via *JNMM* or individual fliers.

INMM's 38th Annual Meeting, scheduled for July 20-24, 1997, in Phoenix, is the Institute's premier technical meeting. The Annual Meeting addresses a broad range of topics contained in a number of concurrent sessions (see story, page 11). INMM Vice President Debbie Dickman has overall responsibility for the meeting. With the outstanding assistance of the Technical Program Committee, chaired by Charles E. Pietri, an excellent program has been assembled for this year's meeting.

In January 1997, the Waste Management Division, chaired by Ed Johnson, held a Spent Fuel Management Workshop in Washington, D.C. As the series indicates, this meeting has a long history and continues to attract a large number of attendees (150 this year). The Waste Management Division also is organizing a European Low-Level Waste Seminar, in Spain, for October 1997.

The Institute works closely with other organizations to co-sponsor international meetings that attract large numbers of attendees. In October 1996, INMM and ESARDA jointly sponsored the Science and Modern Technology for Safeguards Workshop in Arona, Italy. Cecil Sonnier, International Safeguards Division chair, and Gotthard Stein from ESARDA co-chaired this popular workshop. The two organizations are planning a similar workshop to be held in the United States in 1998.

The Institute, along with the American Nuclear Society, Ministry of Atomic Energy of Russian federation, and the U.S. Department of Energy cosponsored the Russian International Conference on Nuclear Material Protection, Control, and Accounting, which was held in Obninsk, Russia, in March 1997. Mike Ehinger was the INMM liaison for this activity. Another collaborative effort under way is with the International Atomic Energy Agency for an International Safeguards Symposium in October 1997.

The MC&A, International Safeguards, and Nonproliferation and Arms Control Divisions recently combined forces to conduct the International Inspection of Excess Fissile Material Workshop (see summaries, page 17). Ronald Cherry chaired this workshop held in Washington, D.C., in February 1997. A special one-day Nonproliferation and Arms Control Seminar, chaired by C. Ruth Kempf, followed the workshop.

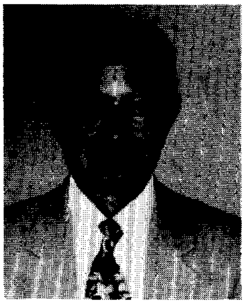
In addition to these internationally attended activities, the individual chapters of INMM hold a variety of local meetings. These events feature relevant technical presentations that contribute to the communications effort of the Institute.

This listing of recent and upcoming technical meetings illustrates INMM's broad range of activities designed to facilitate communication of items of interest to the nuclear materials management community. I thank all of the organizers and participants who make INMM activities a success. The significant amount of personal time and energy devoted to organizing and hosting these events ensures successful exchanges of information and professional experiences among our members and other interested individuals. Without these efforts, INMM would be unable to fulfill this very important aspect of outreach and communications.

Should you have any suggestions, comments, or questions, please call me at (509) 372-4663.

Obie P. Amacker Jr., INMM President
Pacific Northwest National Laboratory
Richland, Washington, U.S.A.

Some Things Never Change



In my previous column, I talked about how many things have changed since I began my career in safeguards. Recently, however, I found something that makes me think some things never change. It's rather trivial, but you might find it amusing.

We are all aware of the largely fear-based reactions of much of the public to nuclear power. I suspect it basically reflects a lack of understanding of science. Such reaction has, perhaps, always existed. The following was taken from the Congressional Record of 1875.

"A new source of power, which burns a distillate of kerosene called gasoline, has been produced by a Boston engineer.* Instead of burning the fuel under a boiler, it is exploded inside the cylinder of an engine. This so-called internal-combustion engine ... begins a new era in the history of civilization. Never in history has society been confronted with a power so full of potential danger and at the same time so full of promise for the future of man and for the peace of the world.

"The dangers are obvious. Stores of gasoline in the hands of people interested primarily in profit would constitute a fire and explosive hazard of the first rank. Horseless carriages propelled by gasoline engines might attain speeds of 14 or even 20 miles per hour. The menace to our people of vehicles of this type hurtling through our streets and along our roads and poisoning the atmosphere would call for prompt legislative action even if the military and economic implications were not so overwhelming."

This issue of *JNMM* contains three technical papers. The first has 18 co-authors, perhaps a record, all from the Oak Ridge National Laboratory; the lead author is J.T. Mihalczo. The paper, "NWIS Signatures for Confirmatory Measurements With B33 Trainers," describes the successful use of nuclear weapons identification system (NWIS) signatures to confirm that B33 trainer parts, shipped from military bases to the Oak Ridge Y-12 Plant, were as declared by the shipper to be nonenriched uranium. Verification was accomplished by comparing signatures for the trainer parts with signatures for mock-ups made with depleted uranium.

The second paper describes nearly 16 months of experience with a remote-monitoring system installed at the Embalse Nuclear Power Station in Embalse, Argentina. The system monitors the status of four typical Candu spent-fuel dry-storage silos. The monitoring equipment consists of electronic fiber-optic seals and sensors for measuring temperature, gamma radiation, and motion. The paper is titled "The International Remote-Monitoring Project: Results of the First Year of Operation at Embalse Nuclear Power Station in Argentina." The authors are Aníbal Bonino, Luis Pizarro, and Zulema Higa of the National Board of Nuclear Regulation in Buenos Aires, Argentina, and Stephen A. Dupree and J. Lee Schoeneman of the Sandia National Laboratories in Albuquerque, New Mexico.

"Technology Diffusion of a Different Nature: Applications of Nuclear Safeguards Technology to the Chemical Weapons Verification Regime" focuses on the issue of arms-control implementation from the standpoint of technology and technical assistance. Although not dealing with nuclear materials management per se, the paper analyzes the similarities between the nuclear and chemical weapons nonproliferation verification regimes and suggests that technologies, procedures, and programs used by the nuclear safeguards community might provide a template for the Organization for the Prohibition of Chemical Weapons. The authors of the paper are Steven P. Kadner, Ann Reisman, and Elizabeth Turpen.

Darryl Smith
Los Alamos, New Mexico, U.S.A.

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* The Boston engineer was, almost certainly, George B. Brayton, who took out a patent in 1872 on a two-cycle internal-combustion engine.

Plutonium Management

The November 1996 issue of the *Journal* contained an article titled "Technical Considerations and Policy Requirements for Plutonium Management." The article states, "Of particular concern, is the fact that the American Nuclear Society (ANS) Special Panel on Protection and Management of Plutonium reported that spent nuclear fuel is a continuing proliferation risk, that burial of spent nuclear fuel is not adequate to protect it from proliferation, and ..." As the subject matter of the *JNMM* article is plutonium in its various forms and locations specifically in the United States, the implication is that the ANS report advises that spent U.S. nuclear fuel is a continuing proliferation risk and that burial of spent U.S. nuclear fuel is not adequate to protect it from proliferation.

The prestigious authorship of the ANS report makes it influential. It is, therefore, important to ensure that characterizations of it are accurate; however the necessary accuracy does not appear to have been achieved in this instance.

The scope of the ANS report is global, and, although the report advises (1) that the growing accumulation of spent fuel in many countries entails a long-term risk* that must be dealt with, and (2) recognizes a question as to whether, from a nonproliferation perspective, it is responsible to assume that plutonium is safe and unrecoverable if it remains stored in the form of spent fuel, the report does not conclude that a specific part of the answer to this global question is that spent U.S. nuclear fuel is a continuing proliferation risk and that burial of spent U.S. nuclear fuel is not adequate to protect it from proliferation.

With regard to the particular question of the adequacy of burial, the ANS report advises (1) that, because placement of spent fuel in geologic repositories does not wholly eliminate the risk of national proliferation, it is important that we develop a better understanding of the costs and difficulties of the retrievability of spent fuel from closed repositories, and (2) that the U.S. mandatory period of intentional retrievability will enable a fuller understanding of these costs and difficulties. This does not come close to constituting a conclusion that burial of spent U.S. nuclear fuel is not adequate to protect it from proliferation. Nor does the report's preference for a global nuclear power system in which spent fuel accumulation is capped and eventually reversed by recycle, "if economically feasible." A preference, qualified by economic feasibility, does not equate to a conclusion that burial of spent U.S. nuclear fuel is not adequate.

Rather, the ANS report sees benefit in diversity among countries in the choice between the three spent fuel disposition options identified (permanent disposal, interim storage, and processing). In the event of such diversity, one might ask where, from considerations of the safety of U.S. citizens, would the permanent disposal option be more secure than in the United States, and also from considerations of global security, because the United States, being already a nuclear weapons state, has no motivation to retrieve spent fuel for the purpose of national proliferation.

The essence of the these comments is that the ANS report recognizes a global question and identifies a path to reaching an answer, but does not come to an answer, nor even implies that the answer is likely to include the U.S.-specific conclusion indicated by the *JNMM* article's characterization of the ANS report.

Ed Rodwell, manager
Electric Power Research Institute
Palo Alto, California, U.S.A.

Author's Response

I find the comments by Ed Roswell concerning the *ANS Special Panel Report on the Protection and Management of Plutonium* to be totally correct and accurate, but feel that he has not fully addressed the point of its contribution to the article "Technical Considerations and Policy Requirements for Plutonium Management," which appears in the November 1996 issue of *JNMM*. The article focuses on the management of separated plutonium that is excess to the U.S. National Defense Inventory. It makes the case that chemical separation and stabilization of that material is necessary. Despite the fact that there is clear guidance concerning the need to safeguard the excess materials and to avoid environmental insult resulting from processing and disposal, the limits of processing are not clear and consistent across the U.S. Department of Energy complex. In view of the fact that the inventory of plutonium in spent nuclear fuel (SNF) dwarfs that in separated and excess national defense inventories, it is prudent to look to the decision concerning the management of SNF for guidance. From the safeguards standpoint, it is consistent to process and separate plutonium residues to the point that they are no more attractive than SNF. This allows for the appli-

Continued on page 11

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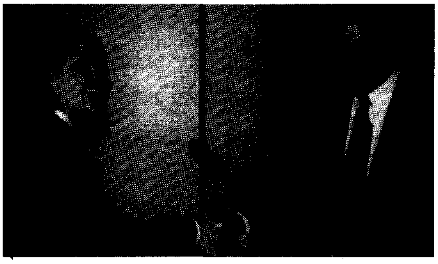
* The ANS report's discussion keeps even this global risk in perspective by the following mitigating observations: 1) that diversion of materials from the safeguarded civil nuclear fuel cycle is an improbable means of acquiring material for nuclear explosive purposes; 2) that, although spent fuel involves a continuing risk of national proliferation, the spent fuel standard is effective against subnational threats; and 3) that the controls of the international proliferation regime, including International Atomic Energy Agency safeguards, provide a high degree of assurance that the material committed to peaceful use, including spent fuel, will not be diverted to nuclear explosive use.

Chapter News

INMM Vienna Chapter



Vienna Chapter Chair Jill Cooley presents chapter member Tom Shea with a plaque to recognize his acceptance as a Fellow of INMM.

In 1996, members of the INMM Vienna Chapter held elections to select new officers and approve revisions to the chapter constitution and bylaws, which bring chapter practices into agreement with the international organization. Chapter Executive Committee members for 1996-97 are:

- Chair, Jill Cooley;
- Vice president, Mark Killinger;
- Secretary, Susan Pepper;
- Treasurer, Michio Hosoya;
- Past president, Martha Williams;
- Members-at-large, David Sinden, Fredy Franssen (symposium chair), and Maribeth Hunt; and
- Special event chair, Ed Kerr.

The chapter also held two luncheon meetings in late 1996. In September, Hiroyoshi Kurihara, senior executive director of the Nuclear Material Control Center in Tokyo, discussed moving "Toward Better Management of Nuclear Materials in Japan and Asia." In November, Nic von Wielligh, senior manager of nuclear nonproliferation at the Atomic Energy Corp. in South Africa and the South African representative to SAGSI, addressed "The Completeness Exercise in South Africa: Relevance to Programme 93+2."

During the latter luncheon, Tom Shea of the Vienna Chapter received a plaque for being named a Fellow of INMM. Shea was recognized as a Fellow during the 1996 Annual Meeting in Naples, Florida, but was unable to personally accept the award at the meeting.

The annual Vienna Chapter social was held in November at the Nussdorfer Brauerei. A tour of the local microbrewery was provided after dinner.

In March 1997, the Vienna Chapter held its annual safeguards symposium. The keynote speaker was Garry Dillon, deputy leader of the International Atomic Energy Agency's UNSC 687 Action Team, which is responsible for monitoring and verification activities in Iraq. One paper from the symposium was selected by the IAEA Safeguards Department to be presented at the INMM Annual Meeting in July 1997.

The chapter also is providing financial and organizational support for the 1997 International Science Fair to be held in Vienna, Austria, in the spring.

Jill Cooley, chair
INMM Vienna Chapter
International Atomic Energy Agency
Vienna, Austria

INMM Japan Chapter

Members of the INMM Japan Chapter announce the group's 18th annual meeting will be held November 27-28, 1997, in Tokyo. The Chapter's executive committee appointed Keisuke Kaieda as chair of the Program Committee. More information will appear in future issues of JNMM. *From left, are Tohru Haginoya, Japan Chapter chair; John Puckett, U.S. Department of Energy (Los Alamos National Laboratory); Tsuyoshi Mishima, 1996 program chair; Shoko Iso, Nuclear Material Control Center, Tokyo; and Michael Ross, Sandia National Laboratories.*

INMM Pacific Northwest Chapter Report

The Pacific Northwest Chapter officers for 1997 are:

- Chair, D.E. Six,
- Vice chair, B.W. Smith,
- Secretary/treasurer, D.L. Osowski,
- Executive committee, T.L. Welsh, and
- Executive committee, D.D. Scott.

Chapter members who remain on the Executive Committee are J.P. Andre and S.W. Gority, immediate past president.

During the election, chapter members approved revisions to the chapter constitution and bylaws. The changes create a better definition of membership requirements for the Pacific Northwest Chapter and a closer alignment with INMM's international constitution and bylaws.

Bob Ferguson of Technical Resources International in Richland, Wash., was guest speaker at a chapter dinner meeting in February 1997. He discussed "The Hanford Role in Plutonium Disposition."

The chapter's other activities include sponsoring a presentation about radiation fundamentals and uses during the Columbia River Exhibition of History, Science, and Technology. Andre, in conjunction with Pacific National Northwest Laboratory Radiation Training, will provide fourth- to sixth-grade pupils with a basic understanding of radiation and its uses within and outside the nuclear industry. The students will participate in hands-on activities, such as using portable radiation monitors to detect the presence of radiation in everyday objects.

Deanna Osowski, secretary/treasurer
INMM Pacific Northwest Chapter
Westinghouse Hanford Co.
Richland, Washington, U.S.A.

N14 - Packaging and Transportation of Radioactive and Non-Nuclear Hazardous Materials

The N14 Technical Standards Committee issues the following update, listed by document number.

- N14.1-1990 — Packaging of Uranium Hexaflouride for Transport, R.I. Reynolds, chair. This standard provides criteria for packaging of uranium hexaflouride for transport. Committee members are working to update and maintain ANSI Standard N14.1-1995, which was approved in December 1995 and has since been published. Copies of the new standard are available from ANSI for $60 per copy, plus a shipping-and-handling charge.
- N14.2 — Tiedowns for Transport of Fissile and Radioactive Containers Greater Than One-Ton Truck Transport, R.E. Glass, chair. This standard prescribes general requirements for securing packages of radioactive materials so they do not dislodge in high-impact, nonaccident events during highway transportation. In accidents, packages secured as prescribed in this standard may dislodge from the vehicle. Developers completed a draft of the standard and sent it to the writing group for consensus. The draft was sent to the N14 Management Committee in mid-July 1996 for review and comment, and should go to ballot within N14 in mid-1997. Committee members expect the standard to be complete in 1997.
- N14.5-1987 — Leakage Tests on Packages for Shipment, L.E. Fischer, chair. This standard specifies methods for demonstrating that Type B packages comply with the package containment requirements of Title 10 of the Code of Regulations, Part 71, September 1983, as amended, or of the International Atomic Energy Agency (IAEA) Regulations for the Safe Transport of Radioactive Materials, Safety Series No. 6, 1985, or verification, and periodic verification. The N14.5 writing group approved a draft of the standard and submitted it to the N14 chair for ballot. Committee members expect to resolve comments by summer 1997 and complete the standard in autumn 1997.
- N14.6-1993 — Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4,500 kg) or More for Nuclear Materials, George Townes, chair. This standard sets forth requirements for the design, fabrication, testing, maintenance, and quality-assurance programs for special lifting devices for radioactive-materials containers that weigh 10,000 pounds (4,500 kg) or more. A revision of N14.6-1986, approved in June 1993, has since been published and is for sale. Committee members expect to review the standard in 1997.
- N14.7 — Guide to the Design and Use of Shipping Packages for Type A Quantities of Radioactive Materials, R.B. Pope, chair. This standard provides guidance for industry participants responsible for activities that involve the packaging of radioactive materials in Type A quantities. Comments about the initial draft are being evaluated and incorporated. While there is currently no activity on this draft standard, funding should be available in 1997. Developers expect the standard to be ready for ballot by the end of fiscal year 1997.
- N14.8 — Fabricating, Testing, and Inspection of Shielded Shipping Casks for Irradiated Reactor Fuel Elements, D. Dawson, chair. This activity will use the peer-panel review process to determine standards that should be developed. The group will become active when members receive documents for standards consideration. Completion dates will be set for each document received.
- N14.23 — Design Basis for Resistance to Shock and Vibration of Radioactive Material Packages Greater Than One Ton in Truck Transport, Ken Gwinn, chair. This standard specifies minimum design values for shock and vibration in highway transport, by truck or tractor-trailer combination, for radioactive materials when package weight exceeds one ton. Developers are preparing a final draft for N14.23 Committee approval and then will send it to N14 for balloting. All comments from the recent meeting have been incorporated, and the standards should be completed in 1997.
- N14.24-1985 (R1993) — Domestic Barge Transport for Highway Route Controlled Quantities of Radioactive Materials. This standard identifies the organizations, equipment, operations, and documentation that are involved in U.S. domestic barge shipments of highway-route controlled quantities of radioactive material on inland waterways and in coastwise and ocean service. Also, committee members are looking for a new writing group chair for the LSA Steam Generators Concern Reaffirmation, which was approved in June 1993. The NRC NuReg Document for LSA project has been abandoned, but LSA reactor components will be considered. The committee plans to appoint a writing group chair prepare a new scope by January 1, 1998.
- N14.25 — Tiedowns for Rail Transport of Fissile and Radioactive Material Containers, Bob Glass, chair. This standard applies to attachment or tiedown of containers of radioactive materials to railroad cars where the gross weight of the containers exceeds one ton. Glass has prepared a preliminary draft, which was sent to the N14 Management Committee for its review and comment. A Project

Initiation Notification System (PINS) will be prepared for submittal to ANSI. The scope will be sent to the N14 Committee for approval before the work goes to ANSI. Committee members expect the standard to be completed in 1998.

- N14.26 — Fabrication, Inspection, and Preventative Maintenance of Packaging for Radioactive Materials, Ray Hahn, chair. This standard provides packaging requirements to ensure that reusable Type A packages (nonfissile) are properly fabricated in accordance with appropriate specifications, properly maintained, properly inspected, and properly assembled for shipment. The committee has formed a writing group, and a first rough draft is complete. Developers now await for the United States to adopt the 1985 IAEA regulation before they distribute the draft for review.
- N14.27-1986 (R1993) — Carrier and Shipper Responsibilities and Emergency Response Procedures for Highway Transportation Accidents, Bill Pitchford and Mike Keane, co-chairs. The scope for this standard encompasses the preparation and execution by carriers and shippers of their emergency response program. It does not include the responsibilities of the first-on-the-scene response personnel, the actions of governmental authorities, or the specific responsibilities of the carrier or shipper during recovery operations. Reaffirmation was approved June 28, 1993. A writing group chair has been appointed, and developers will begin work on a new scope and an extensively revised standard in 1997. Group leaders need 20 new volunteers: 10 from government agencies and 10 from the industry. The project should be completed in 1999.
- N14.29-1988 — Guide for Writing Operating Manuals for Packaging, Dennis McCall and Mike Burnside, co-chairs. This guide describes the preparation and distribution of operating manuals for the use, maintenance, and inspection of packages for shipping radioactive material. It prescribes the contents of such a manual and their arrangement and contains a sample manual that can be used as a model. The group will review a draft internally before sending it to the writing group for review. The estimated completion date is 1997.
- N14.30-1992 — Design, Fabrication, and Maintenance of Semi-Trailers Employed in the Transport of Weight-Concentrated Radioactive Loads, Ralph Best, chair. This standard established the design fabrication and maintenance requirements for the highway transport of weight-concentrated radioactive loads. A weight-concentrated load is any payload that exceeds 1,000 pounds per lineal foot in any portion on a tractor-trailer. In addition, the standard provides detailed procedures for in-service inspections, testing, and quality assurance. Revision of this standard will start in 1997. Best of SAIC has agreed to be the new writing group chair, replacing Dan Huffman. The standard should be completed in 1999.
- N14.31 — Standard Tiedowns on Legal Weight Transport System (80,000 pounds) for Packages Containing Hazardous Materials and Weighing Greater Than 500 Pounds, Larry Shappert, chair. This standard provides a method for defining an appropriate tiedown system through the use of the Tiedown Stress Calculation Program. The standard describes general requirements for securing hazardous materials packages to conventional trailers. The packages have a suitable base plat (pallet or skid) or flat base, and appropriate size arrangement of tiedown assemblies for packages that are within weight and dimensional limits of the equipment. The group has received comments from the writing group and will revise the text and computer model. The draft modification also will take into account issues that emerged during a recent IAEA committee meeting to discuss package securement. It appears that funding may be available in 1997 for the review, revision, resubmittal, and completion of the standard.
- N14.32 — Gas Generation in Packages Used for the Storage or Transport of Radioactive Materials, L.E. Fischer and Phillip Gregory, co-chairs. The scope of this standard is gas generation in packages used for the transport or storage of radioactive materials. It includes, but is not limited to, the following gas generation mechanisms: radiolysis, chemical reactions, thermal expansion, and biological degradation. The standard would provide a consistent approach to testing, analysis, and mitigation of gases that could cause a pressure building up or a potentially flammable mixture in a package containing radioactive materials. Group members have prepared a PINS form, and N14 balloting of title and scope began in winter 1997. Committee members are forming a writing group and expect to complete the standard in 1999.

John Arendt, chair
INMM N14 Technical Standards Committee
John Arendt Associates Inc.
Oak Ridge, Tennessee, U.S.A.

N15 Technical Standards Committee

The N15 Technical Standards Committee is pursuing the development and maintenance of standards in support of U.S. and international nuclear material protection control and accountability. The N15 Committee is composed of the chair, vice-chair, secretary, Management Committee, Balloting Committee, subcommittee chairs, and the technical standard writing groups (listed in ascending order of importance).

The N15 committee is divided into five subcommittees in line with the principal components of a safeguards program: INMM-1 Safeguards Systems, James Crabtree, chair; INMM-2 Physical Protection, Charles Gaskin, chair; INMM-3 Material Control, Joe Rivers, chair; INMM-4 Audits, Records, and Recordkeeping, Garland Proco, chair; and INMM-5 Measurement Control, Yvonne Ferris, chair.

The subcommittees and the standards within each subcommittee are arranged in a hierarchical order. The first subcommittee and the first standard developed by each subcommittee provides an overview of the subject and defines the content of the following subcommittees or standards.

Thus, INMM-1 will define criteria for an effective material protection, control, and accountability program and identify those components of an effective program. These components will be addressed the other subcommittees or INMM-1 if the component has general applicability across the subcommittees. The first technical standard of INMM-5, titled INMM 5.0 — Guide to Nuclear Facility Measurement Control, defines an effective measurement-control system and establishes the format and content for the subsidiary standards.

The standards existing, under development, or under consideration by the subcommittees are as follows.

- INMM-1: MPC&A Systems, Management Structure and Controls, Qualification and Certification of Personnel, and System Quality Assurance;
- INMM-2: Physical Protection Systems, System Testing and Preventive Maintenance, Assessment Programs, and Physical Protection of Material in Transit;
- INMM-3: Material Control Systems, Tamper-Indicating Device Programs, Access Control, and Remote Monitoring;
- INMM-4: Audits, Records, and Recordkeeping Systems, Classification of Uranium Scrap, Classification of Plutonium Scrap, Inventory Audits, and Accounting Records; and
- INMM-5: Measurement Control Systems, Control Program for Analytical Chemistry Laboratories, Control and Calibration of Mass Measurement Devices, Control and Calibration of Mass Spectrometry Systems, Control and Calibration of Radiometric Calorimeters, Control and Calibration of Volumetric Measurements, and Control and Calibration of Nondestructive Assay Measurements.

Committee members are forming writing groups for preparation, evaluation, and maintenance of most of these standards. Members encourage industry participants with technical expertise in areas covered by the standards to become involved with the development process.

Writing groups are composed of about 10 people and do most of their work through communication channels such as telephone, fax, Internet, and postal mail. Writing group meetings are held annually at the INMM Annual Meeting or as required to resolve specific issues. Anyone who wishes to contribute to the N15 technical standards development process should contact the appropriate subcommittee chair or Bruce Moran, committee chair, at (301) 415-7871; fax, (301) 415-5390; e-mail: bwm@nrc.gov.

N15 and N14 standards committee members hope to offer a training course about the standards development process during the INMM Annual Meeting this summer in Phoenix.

Bruce W. Moran, chair
INMM N15 Technical Standards Committee
U.S. Nuclear Regulatory Commission
Washington, D.C., U.S.A.

Don't Miss Out on *JNMM*

The *JNMM* staff urges members who work in an integrated-management environment to keep addresses current. To ensure prompt delivery of *JNMM*, please send updated contact information, either a work or home address, to INMM headquarters, (847) 480-9573, fax, (847) 480-9282; e-mail, bscott@inmm.com.

INMM 38th Annual Meeting Tackles Technical Topics ... and More

The Technical Program Committee recently held its review meeting and the technical sessions at the 38th Annual Meeting look outstanding. There were a number of papers submitted with a range of topics addressed. The INMM technical programs have historically been very strong and this year is no exception. Therefore, it is my pleasure to invite you to attend the 38th Annual Meeting of the Institute of Nuclear Materials Management, July 20-24 1997, at the Pointe Hilton at Squaw Peak in Phoenix. The INMM Annual Meeting will again be the focus of important issues in nuclear materials management.

As the international political climate continues to change, this is a particularly important time for the exchange of technical information internationally. The INMM Technical Program Committee, chaired by Charles E. Pietri, worked closely with the Institute's six technical divisions to arrange a program that will appeal to a broad range of nuclear materials management professionals interested in materials control and accountability, physical protection, international safeguards, nonproliferation and arms control, packaging and transportation, and waste management. Domestic and international issues will be addressed by the international array of presenters.

While the technical sessions are the focus of the meeting, there are many additional activities occurring simultaneously. Topics of immediate interest to the technical and policy communities will be discussed not only in formal presentations, but also during informal associations of the attendees. The INMM Annual Meeting also provides the opportunity to conduct business efficiently and cost-effectively. One trip to Arizona will bring you in contact with people you need to see from across the United States and around the world.

Each of the INMM technical divisions — materials control and accountability, physical protection, international safeguards, nonproliferation and arms control, packaging and transportation, and waste management — will conduct meetings July 20. There will also be the usual special interest meetings conducted before and after the technical program.

In addition, the U.S. Department of Energy Central Training Academy will be conducting a course at the hotel the week prior to the meeting. These meetings are open to all and you are invited to attend those of interest. I encourage you to stay for the duration of the program to take advantage of the government liaison session on Thursday morning, which features invited speakers.

This year the Institute's annual business meeting will again be held just prior to the Tuesday evening banquet. The business meeting agenda will include member-recognition activities and will provide the opportunity to learn more about INMM. Please review the preliminary program carefully to take advantage of all the available activities.

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Letter to the Editor

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than SNF. This allows for the application of the same level of safeguards to SNF and processing waste. Aggressively processing residues beyond this point is inconsistent with current safeguards actions, while stopping short would require that significant additional safeguards provisions be employed. Of course, the application of the current technology, in many cases, will result in waste materials with plutonium concentrations that are less attractive than SNF. With regard to environmental protection, we know the most about the long-term stability of relatively pure plutonium oxide and metal. The storage of plutonium in all other forms, such as residues, has resulted in container degradation and/or the loss of containment within relatively short periods of time. Experience clearly indicates that we cannot assure that relatively high concentrations of plutonium, in processing residues, can be contained in repository containers. Therefore, the protection of the environment can be best assured if separation of plutonium from residues is accomplished. Again, processing, such that the plutonium concentrations are significantly below that existing within SNF is illogical in view of the relatively small volume compared to that of SNF. The policies and approach being used to make decisions for SNF will drive those needed for plutonium residues.

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International Verification of U.S. and Russian Materials Released for Storage and Disposition

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The following article is a speech presented at the INMM Workshop on International Inspection of Excess Fissile Material, January 20–21, 1997, in Washington, D.C.

The United States and Russia have taken steps to establish international verification of fissile materials released from weapons programs. The steps taken so far are of a preliminary nature. To make progress, Russia and the United States have much to discuss and agree upon. Yet, the declarations of Presidents Bill Clinton and Boris Yeltsin open new vistas in the evolving area of nuclear disarmament.

The international community — in particular the International Atomic Energy Agency (IAEA) — will need to find ways to meet the challenge of a verification assignment that goes beyond the experience accumulated in the area of nonproliferation.

With the superpower nuclear arms race consigned to history, Russia and the United States have agreed to substantial reductions in their respective arsenals. There is great hope that the United States and Russia will continue with further reductions and that other nuclear weapon states ultimately will engage in similar reductions.

The Nuclear Non-Proliferation Treaty, which Russia and the United States have agreed to follow, embodies the international will for nuclear disarmament. While the complete elimination of nuclear weapons remains a distant goal, hope spurred by the treaty provides a beacon to guide the incremental steps toward that ultimate goal.

The process of nuclear disarmament will pose challenges to domestic, regional, and international security, to economic growth and environmental protection. Even the early steps taken in the United States and Russia are not without problems.

Dismantling tens of thousands of warheads is creating a surplus of hundreds of tons of plutonium and highly enriched uranium (HEU). That plutonium and HEU demands protection and prudent disposal. Concerns remain that those materials could be stolen through force or guile, or that relations between the United States and Russia could sour, and today's surplus materials would be used to jump-start a resurgent nuclear arms race.

If the storage and disposition of those fissile materials is carried out in a prudent and effective manner, Russia and the United States may agree to additional arms reductions, other nuclear weapon states may begin to reduce their arsenals, and the international community could be more effective in efforts to prevent further proliferation of nuclear weapons.

Verification May Parallel Nonproliferation Safeguards

IAEA's involvement in the verification of nuclear disarmament has long been anticipated — as early as 1955 when the IAEA statutes were written. Russian, U.S. and IAEA experts are beginning to outline a verification system for nuclear disarmament that ultimately may parallel the nonproliferation IAEA safeguards system.

In September 1994, IAEA accepted for the first time defense materials for verification. The United States submitted plutonium and HEU for verification through an exchange of letters under its existing Voluntary Offer Safeguards Agreement with IAEA.

The United States government declared its intent to keep that plutonium and HEU under IAEA safeguard on an indefinite basis, with a proviso that those materials could be withdrawn for nonexplosive military applications if needed. The letters also stated that the United States will meet the financial burden that IAEA incurs in carrying out the verification activities. In public statements, the United States has indicated that more than 200 tons of plutonium and HEU could be removed from defense programs. Approximately 12 tons now are subject to IAEA safeguards.

While Clinton's initiative started this effort, Yeltsin included the following statement in an April 1996 address to the Russian Security Council:

> "Nuclear materials are becoming available as a result of the dismantling of nuclear weapons. These should be used in peaceful activities for the benefit of all mankind.
>
> We are engaged in the construction of reliable storage facilities for them. We are erecting a storage

> facility for such materials in Russia on the territory of the Mayak production association, with U.S. participation. We regard this as a positive example of cooperation and believe that this experience could be extended to other countries.
>
> The storage facility will house around 40 percent of Russia's stocks of weapons-grade plutonium. After completion of construction, we propose to place it under IAEA control."

In addition to Russia and the United States, other major countries — especially members of the P8 Group — believe Cold War legacies demand urgent attention. During the 1996 Moscow Summit, the group pledged "support for efforts to ensure that all sensitive nuclear material (separated plutonium and highly enriched uranium) designated as not intended for use in meeting defense requirements is safely stored, protected and placed under IAEA safeguards (in nuclear weapon states, under the relevant Voluntary Offer IAEA Safeguards Agreement) as soon as it is practicable to do so."

In the follow-up to the Moscow Summit, on Sept. 17, 1996, IAEA Director General Hans Blix invited U.S. Energy Secretary Hazel O'Leary and Russian Minister Viktor Mikhailov to initiate trilateral consultations discussing the nature, scope, and objective of international verification arrangements for fissile materials of weapon origin. The trilateral understanding reached during the meeting constitutes the basis for current and future activities.

Possible Tenets of a Trilateral Verification Agreement

It is still too early to report about specific aspects or the outcome of the trilateral initiative. Nevertheless, IAEA has ventured to put forth some thoughts about the possible nature of the international verification arrangements. These thoughts are meant to encourage discussion about issues such as:

- IAEA believes that any verification activities would be best carried out in the context of international verification of nuclear disarmament. The results and conclusions of the verification measures would assure that fissile materials from weapon programs submitted for verification are not used for nuclear explosive purposes. Thus, the objective should relate to nuclear disarmament rather than nonproliferation. Hence, the choice of the word: verification — not safeguards, which in our world applies specifically to the prevention of proliferation.
- Any verification activities would apply to specific fissile materials that the United States or Russia, as a result of their voluntary decisions, would submit to such verification. IAEA envisions that Russia and the United States will determine independently which forms and amounts of fissile material they will submit for verification and the timing of those submissions. The respective amounts and kinds of materials released could be decided in bilateral agreements.
- Once submitted, verification would continue to assure the world that the fissile materials are not used for nuclear explosive purposes. In line with P8 recommendations, IAEA expects that verification would continue on an irrevocable basis from storage through conversion to peaceful use or disposal as waste.
- This undertaking should not necessarily lead toward the universal application of IAEA safeguards on civil materials in the United States and Russia. This would remain a separate issue. The verification arrangements for weapons materials would apply only as long as such fissile materials meet certain technical conditions. Verification might end with irradiation of MOX fuel up to a specified burnup, or with the downblending of HEU to low-enrichment levels.
- IAEA anticipates that most of the fissile materials submitted for verification will be stored for extended periods until final arrangements are made and implemented for conversion and peaceful use or disposal as waste. The verification methods applied must take such long-term requirements into consideration.
- To meet the need of international verification and national security concerns in the United States and Russia, the verification system will need to be flexible, yet consistent and uniform enough to meet international objectives of nondiscrimination. Furthermore, in addition to fissile and materials of weapon origin, the arrangement will need to accommodate other kinds of surplus fissile materials.
- Much of the fissile materials expected to be submitted for verification will be protected to prevent revealing classified information that might relate to the composition, shape or manufacturing of nuclear warhead components. Accordingly, verification measures applied to fissile materials in sensitive forms should provide credible assurance — no less, and no more — that only bona fide items are placed under verified storage or that such items are indeed being processed into nuclear fuel or waste. The verification measures must proceed without exposing sensitive information that would contribute to nuclear weapons proliferation.

IAEA Inspectors Must Not Access Too Much Information

The sensitive materials to be provided likely will include nuclear warhead components loaded in containers that have been designed for storage for extended periods. The verification of those containers must be carried out in ways that prevent IAEA inspectors from gaining information about the composition, shape, or manufacturing methods of the components.

That restriction is fundamental to this undertaking. Finding acceptable combinations of measurements that respect those restrictions but still allow IAEA inspectors to derive credible assurance will demand innovative concepts and very different arrangements than those IAEA has established for nonproliferation purposes.

In IAEA's nonproliferation safeguards activities, agency officials verify fissile materials used in peaceful nuclear programs in a number of states. IAEA requires that the state provide officials declarations of the location of all such materials; their exact chemical, physical and isotopic composition; dates of measurements; and derived estimates of measurement uncertainties. IAEA's verification activities are intended to confirm the completeness and correctness of those declarations.

IAEA inspectors sample materials for laboratory analysis at the IAEA Safeguards Analytical Laboratory near Vienna, and scientists have developed verification equipment for in-plant measurement of the amounts of nuclear material. Through the years, IAEA has made significant strides in improving the accuracy of those measurements and integrating measurement systems with containment and surveillance devices to provide unattended verification.

Verifying sensitive fissile materials of weapon origins means that no comparable declarations will be given, no visual examinations of the items will be permitted, no samples can be taken, and no quantitative nondestructive assay measurements can be made that could reveal the total mass, plutonium fraction or isotope fractions. Perhaps the current classification requirements will be relaxed in future years, but for the moment IAEA must consider only verification schemes that stay within the limitations stipulated by the United States and Russia.

For storage, IAEA scientists have come up with various concepts for the verification of such sensitive materials. One of them is called template verification. In this concept, high-accuracy measurements of classified parameters would be made and compared to templates established for each warhead component model. Inspectors would see on a computer screen whether a given container either compares successfully to an established template.

The state would control access to the computer to ensure that inspectors could not obtain classified measurement data. Inspectors would control the computer to prevent the state from manipulating the hardware and software in such a manner as to draw into question the ability of the system to function as intended.

There are several ways to establish the templates. Russian experts could establish templates for use in the United States, for example, and vice versa. Or selected and screened agency staff might be allowed to make the templates under controlled-access arrangements.

As previously noted, IAEA already verifies fissile materials in storage in the United States and in several non-nuclear weapon states. This experience will help to establish the containment and surveillance measures that will make it possible for stringent verification goals to be maintained in a cost-effective manner. IAEA will need to establish the required technical parameters for the verification system, addressing detection sensitivity, timeliness and the detection probability values to be applied for inspection planning and evaluation in storage facilities.

What About Disposition?

Eventually, nuclear warhead components will, hopefully, be processed into nonsensitive forms. The fissile materials recovered from these components will, thus, be used as fuel in nuclear power plants or disposed of in an immobilized form in geological repositories. When nuclear warhead components are taken from storage for processing, verification should continue to be applied to ensure the nuclear warhead components are in fact destroyed, and that the plutonium and HEU recovered from those warhead components are maintained under appropriate verification arrangements.

A perimeter verification system with managed access could be the basis for verifying the conversion of plutonium and HEU from nuclear warhead components to nonsensitive forms, without disclosing the amounts of plutonium or HEU present in the nuclear warhead components. Under this approach, nuclear warhead components selected for conversion could be verified a last time at the storage facility. The containers would then be shipped to a designated conversion facility under seals or continuous inspector observation to maintain continuity of knowledge of the verified results.

The perimeter-control system could incorporate physical structures and barriers to isolate the conversion operation, as well as monitoring systems like those commonly used in physical-protection applications.

Upon arrival at the conversion facility, the seals would be checked and the containers would pass through a perimeter-control system that envelops the conversion facility. Recovered nuclear materials would be verified quantitatively as they are transferred out of the conversion facility. No nuclear warhead component would ever leave the facility.

Throughout the process, the state could take steps to make it impossible for IAEA inspectors to determine the amounts of plutonium and HEU contained in the warheads. For example, other defense plutonium and uranium — not in the form of nuclear warhead components — could be introduced into the conversion facility without being measured by IAEA inspectors. That plutonium or uranium (including depleted or natural uranium) could then be mixed with the plutonium or HEU from warhead components in varying amounts not revealed to the inspectors.

Periodically, the conversion facility could be cleaned out and IAEA inspectors could be allowed in to examine all areas within the perimeter to establish that no warhead components remain within the conversion facility. Based on the perimeter monitoring and the periodic inspections of the conversion area, IAEA experts believe it would be reasonable to conclude that the warhead components received at the facility had been destroyed.

The next steps become easier. The released materials — ready for fabrication of MOX fuel or for incorporation in glass or other inert matrix — have by then essentially lost their explicit association with weapons. IAEA verification would then move into familiar territory.

Fissile materials submitted for verification under arrangements that are not sensitive in nature and fissile materials converted to nonsensitive forms could be verified through methods and procedures similar to or identical with IAEA safeguards methods and procedures applied to fissile materials in nonnuclear weapon states. The verification goal amounts, verification timeliness requirements, and detection probabilities used in planning and evaluating the verification activities for nonsensitive fissile materials could nevertheless differ from those applied for nonproliferation purposes, reflecting the nuclear-disarmament related objective.

IAEA anticipates that verification under this regime could eventually extend to a variety of facilities, such as:

- Facilities for blending HEU down to low-enrichment levels,
- Plutonium and HEU fuel manufacturing plants,
- Nuclear power reactors and research reactors of critical assemblies,
- Vitrification facilities, and
- Waste repositories.

IAEA experts have considered how the verification activities might be carried out at each of these facilities, but substantial work remains, and verification activities will need to be tailored to cope with facility-specific features. IAEA also has identified different rationales for establishing verification goal amounts to be used.

One thought is to base the verification goal for a state on the amount of fissile material remaining in the defense stockpile. Such a scheme would allow the verification goals to relate to progress toward disarmament and allow the verification arrangements to converge with those used for nonproliferation purposes when nuclear weapons are ultimately eliminated.

What to say about the termination of verification under such agreements dealing with released materials? The determination of the end-points applicable to the various disposition options should be pragmatic and review practical considerations, such as complexity of implementation, costs and objective matching.

In a nutshell, does it make sense to verify downblended uranium in a weapon state in which hundreds of tons of low-enriched uranium remain outside safeguards? The same kind of question applies to spent fuel containing MOX elements irradiated beyond an appropriate level (e.g. the Spent Fuel Standard). The immobilization option has its own dimensions. Here, the early design decision of the maximum concentration of plutonium in the waste matrix would inevitably affect the determination of a verification end-point preceding geological disposal. Currently, IAEA terminates safeguards below a concentration of 2.5 kilograms per cubic meter. Such a low concentration of economic no-return — set for nonproliferation purposes — may have an unjustifiable negative impact on the outlook for the immobilization option for the disposition of released materials.

Does it make sense in a weapon state where plutonium is still readily available to worry about a possible recovery from waste in geological repositories? Here, the concentration of economic no-return could reasonably be much higher. In any case, it is important to keep in mind the potential costs of verification when considering fabrication options and their related costs.

The Bottom Line

Suitable legal and institutional arrangements for the verification of materials released from weapons programs could be established in a variety of ways. Perhaps the ideal way would be to establish a new type of IAEA agreement for the international verification of nuclear disarmament: the storage and disposition of nuclear materials from weapon programs and possible future controls related to the production of fissile materials for defense purposes.

A new type of IAEA agreement would provide an unencumbered framework that does not impose the restrictions or irrelevant provision of the existing Voluntary Offer Safeguards Agreements, which were clearly not intended as vehicles for nuclear disarmament. The Voluntary Offer Safeguards Agreements — as they are part of the nonproliferation system — are probably too demanding in terms of verification activities. Moreover, they are not acceptable to the international community because they allow the state to withdraw nuclear materials and facilities at any time. These agreements are indeed voluntary, and such a basis is simply not consistent with the perceived need for international verification of nuclear disarmament.

There is, of course, great concern about the costs of verification and the means through which those costs will be borne. The actual costs will depend on the scope of the system, the verification requirements, and measures that IAEA might employ to reduce staff costs. Remote monitoring is one method that could be used to limit staff costs; regional offices and resident inspector basing is another. Several financing options have been considered, but it is too early to gauge how this issue will be resolved.

To repeat, these are preliminary thoughts at IAEA about how an international verification system might be structured for released fissile materials in Russia and the United States.

Beyond these trilateral discussions, looming on the horizon is the negotiation in Geneva of a treaty to ban the production of fissile materials for use in nuclear explosives. Together, the verification of fissile materials from weapon programs and verification of a production cut-off would represent substantial progress on the international disarmament agenda. Both will force IAEA to think ahead and adapt to these new missions.

An Introduction to the Workshop on International Inspection of Excess Fissile Material

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The Clinton administration's nonproliferation policy, announced in 1993, called for a comprehensive approach to deal with the problems of fissile materials, including the increasing quantities of materials from dismantled nuclear weapons. As part of this approach, the United States has been engaged in an initiative to submit fissile materials no longer needed for deterrent purposes, or excess fissile material, for inspection by the International Atomic Energy Agency (IAEA).

The Workshop on International Inspection of Excess Fissile Material provided an opportunity to share the United States' experience and future plans in this initiative. In the following pages are summaries of presentations delivered during the workshop's four sessions.

The first session focused on the U.S. fissile-materials policy but also included a presentation from IAEA about inspections it has carried out in the United States. The second session discussed lessons learned from the process and included speakers involved with the U.S. Department of Energy facilities where IAEA inspections are under way or being planned. The third session covered new developments in safeguards technology that resulted from IAEA's inspections of excess materials in the United States. The final session examined emerging issues and included presentations about fissile materials disposition plans, advancements in safeguards technology, and U.S. plans to submit additional excess materials for IAEA inspection.

By all accounts, the workshop was an outstanding success. More than 120 people, representing government and private industry, attended from across the United States and abroad. In these meetings, INMM clearly demonstrated the value of its role as a forum for the exchange of ideas. Speakers addressed provocative topics and were, in turn, challenged by the questions and viewpoints expressed by the audience. In the end, everyone gained from the exchange.

The workshop was the result of a collaboration by three divisions of INMM: Materials Control and Accountability Division, International Safeguards Division, and Nonproliferation and Arms Control Division. This event would not have taken place without their support. Special thanks go to Amy Whitworth, Nancy Jo Nicholas, and Robert Whitesel for their work in organizing and chairing sessions. Whitworth also was a central contributor in scheduling and organizing the workshop. Finally, Barb Scott from INMM headquarters and Beth Perry of Perry Management deserve recognition for their work in planning and making administrative arrangements, as well as handling registration and the myriad details that enabled the meeting to run smoothly.

The Clinton Administration's International Fissile Material Control Policy

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The end of the Cold War raised awareness in the international community about the threat posed by large, global stockpiles of weapons-usable nuclear material. The Clinton administration has taken a leadership role in constructing a comprehensive, mutually reinforcing agenda to control existing stockpiles of fissile material and constrain future production and use. The agenda has four basic policy prescriptions:

- Secure existing stockpiles of weapons-usable nuclear material,
- Limit the production and use of fissile materials,
- Eliminate nuclear warheads as part of a new arms control regime, and
- Strengthen international cooperation and regimes to prevent the spread of nuclear weapons.

These policy elements have a number of component parts, and the implementation of these programs and activities have met with varying degrees of success.

Secure Existing Fissile Material Stockpiles

The major activity in this area has been the creation of a comprehensive program to improve the security of fissile material at all locations where it is known to be stored in the former Soviet Union. The size of this stockpile is quite large, with some estimates placing the Soviet-produced highly enriched uranium (HEU) holdings at 1,200 metric tons and the weapon-grade plutonium figure at 150–200 metric tons. Officials know this material is in Russia, the Baltic States and other nations in the commonwealth of Independent States.

From 1994 to 1996, the partners in this cooperation to improve fissile-material security began to make improvements at about 40 locations, nearly 100 percent of the locations that possess fissile material. This work is scheduled to expand to the remaining locations in 1997. Significant improvements made during this period provide greater security for tens of tons of fissile material. In addition, work has begun with the Russian nuclear regulatory agency, called Gosatomnadzor; the nuclear transportation sector; and the facilities focused on nuclear-powered ships.

Limit Fissile Material Production and Use

While it is essential to secure the existing stockpiles of fissile material, it also is necessary to move forward on the global agenda of limiting the production and use of these materials. One key initiative in this area is the Clinton administration's proposal to eliminate the production of fissile material for weapons purposes outside international safeguards. This effort has met with resistance.

As a first step in this area, however, the United States and Russia agreed to cease production of weapons-grade plutonium. The United States stopped producing the material, while Russia continues to produce weapons-grade plutonium in its three remaining plutonium production reactors at Tomsk-7 and Krasnoyarsk-26 because the heat and electricity generated by the reactors is used in the surrounding towns.

While the original intent was to shut down these reactors by 2000, the effort has changed its focus to converting the nuclear cores of the reactors by that date so that no additional weapon-grade plutonium will be produced. Progress in this area is being made, but it is slow. For example, the formal agreement to cooperate has been bogged down for more than two years.

An ancillary program the United States initiated with Russia focuses on converting the cores of the Russian research and test reactors that currently use HEU. This effort had been slowed by a debate about intellectual property rights but is now moving forward. This program is the latest step in a decades-long U.S. effort to convert all HEU research reactors to nonweapon-usable low-enriched uranium.

To date, reactors have been converted in 13 countries, three additional countries are in the process of converting, and China has signed a letter of intent to work with the United States in this area. Unfortunately, some other countries, including Germany, continue to insist on the use of HEU in research reactors.

Eliminate Nuclear Warheads

The first two agenda items focused on preventing the use of fissile materials in nuclear weapons. The flip side of the policy is the dismantlement of nuclear warheads and the disposition of the materials removed from them.

A major initiative in the area of cooperative nuclear warhead dismantlement was outlined by presidents Clinton and Yeltsin during a May 1995 summit. They agreed to work together on a new arms-control regime focused on the transparency and irreversibility of the nuclear-disarmament process. Both countries dismantle thousands of nuclear warheads a year, but little concrete progress has been made in the development of a cooperative regime.

While cooperative warhead dismantlement lags, progress has been made in the fissile-material disposition arena. One area that has been working is the U.S.-Russian agreement to blend-down and purchase 500 metric tons of HEU derived from dismantled Russian nuclear weapons. Numerous shipments of blended-down HEU have arrived in the United States, and a five-year agreement has been reached on the amount to be purchased per year and the SWU price.

The future disposition of weapon-grade plutonium also is showing promise, though the results are less concrete than the HEU agreement. In this case, the United States and Russia agreed to dispose of surplus plutonium, but questions remain about the exact method by which the plutonium should be eliminated.

The United States has made a decision to pursue 2 methods: utilization in existing reactors, immobilization, or a combination of both. Most industrialized nations agree that these are the most feasible options. However, all methods of disposition are expensive and the reactor-based methods are very controversial, so much work remains in this area.

Strengthening International Cooperation and Regimes

The Clinton administration's policy recognizes that the ability to accomplish its fissile material control goals rests on the established international nuclear nonproliferation regime. It has sought to strengthen the elements of this regime and improve international participation and cooperation in them. The most notable instance in this effort was the struggle to indefinitely extend the Nuclear Nonproliferation Treaty (NPT).

To make the case for an indefinite NPT, the Clinton administration instituted a number of initiatives. The most forward-reaching was the president's decision to declare 200 tons of fissile material excess to U.S. national-security needs, never again to be used for weapons. To date, 12 tons of this material has been placed under International Atomic Energy Agency (IAEA) safeguards.

Plans are in place to address the safeguarding of the remaining material. This effort also has been extended to include Russia under a trilateral initiative. Little progress has been made between the three parties, but a report on the next steps is due in June 1997.

In addition to extending safeguards to fissile material produced for weapons purposes, the Clinton administration is committed to improving IAEA safeguards worldwide. It has strongly supported Programme 93+2, continues to work with IAEA in monitoring Iraqi compliance with relevant U.N. resolutions, and is working daily to eliminate the nuclear program of North Korea.

The work in North Korea deserves a special note, because for the past 18 months, experts from the U.S. Department of Energy and its national laboratories have labored to place the spent fuel from the North Korean nuclear program in cans, so it can be safeguarded effectively and ultimately shipped out of the country. So far, half of the 8,000 fuel rods in North Korea have been canned.

Summary

The Clinton administration has constructed a comprehensive fissile-material control regime. It is more complete and forward-reaching than the policy initiatives put forth by previous administrations, recognizes the changed nature of the nuclear danger in the 1990s, and focuses on addressing the challenge.

The administration has achieved success in some areas, particularly cooperative efforts to improve the security of fissile material in the FSU, the blend-down and purchase of HEU from Russia, and the canning of North Korea's spent nuclear fuel. However, progress is required in a number of other areas and the agenda can and should be expanded in the future.

Implementation of IAEA Programme 93+2 in the United States

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With the end of the Cold War, many people, who focused mainly on the U.S.-Russian relationship, assumed that the security threat posed by nuclear weapons had ended. Unfortunately, events in Iraq and the North Korea demonstrated that the threat of nuclear weapons remains real and efforts to ensure their nonproliferation are needed.

At the end of the Persian Gulf War in 1992, the world learned that Iraq was pursuing a secret, active, and advanced program to develop nuclear weapons. Even Iraq's adherence to the Nuclear Nonproliferation Treaty (NPT) and international inspection of its declared civil nuclear program by the International Atomic Energy Agency (IAEA) were no guarantee. Had it not been for the Persian Gulf War, Iraq might have secretly acquired nuclear weapons, which would have posed an enormous threat to security in the Middle East and beyond. The devastation and the enormous human suffering that could have resulted are incalculable.

Many governments and IAEA concluded that the world could not afford another surprise like that of Iraq's clandestine nuclear-weapons program. If it could happen once, it could clearly happen again. In response, governments and IAEA agreed that IAEA's international safeguards system needed to be strengthened, specifically to give the safeguards system a credible capability to detect undeclared nuclear-weapons programs. This led to the IAEA's Programme 93+2, which is designed to strengthen the effectiveness and improve the efficiency of the safeguards system. Programme 93+2 consists of two parts.

Programme 93+2, Part 1

Part 1 is composed of measures that can be implemented under the authority contained in existing safeguards agreements. It includes some increases in the information about a state's current and planned nuclear activities; use of environmental sampling at locations where IAEA already is inspecting; enhanced analysis of the increasing information becoming available to IAEA; increased use of non-notice inspections; the continuing introduction of advances in safeguards technology, such as unattended measurement and surveillance equipment; and increased cooperation with states, which in the case of the United States, means the Nuclear Regulatory Commission and the Department of Energy.

IAEA's plan to implement these measures was acknowledged by the IAEA board of governors in June 1995, and IAEA has begun the process of consultations and planning leading to their full implementation. IAEA has given priority to commencing implementation in non-nuclear weapons states.

As progress is made, the United States should expect to see IAEA proposals for implementation of some or all of these measures at U.S. facilities eligible for safeguards under the U.S. Voluntary Offer Safeguards Agreement (INFCIRC/288). It is important to remember that any implementation in the United States will continue to be governed by the U.S. right, embodied in our safeguards agreement, to exclude facilities associated with activities of direct national security significance to the United States.

Programme 93+2, Part 2

Part 2 is generally considered the crucial part of a strengthened safeguards system to detect undeclared nuclear materials and activities. It consists of a substantial increase in the scope of information a state will provide to IAEA about its nuclear and nuclear-related activities and inspector access to the locations of these activities, including research and development and manufacturing activities that do not directly involve nuclear materials. For this reason, IAEA needs additional authority to carry out Part 2, and this additional authority is to be provided by a new protocol to safeguards agreements.

Because of the access provisions, states have taken a keen interest in the model protocol, which an IAEA committee has nearly completed. This committee scheduled its last meeting for April 1997, at which time the committee was to recommend a model protocol to the board for approval. Following board approval of the model, IAEA will begin the arduous task of negotiating individual protocols with non-nuclear weapons states with comprehensive safeguards agreements.

As the details of the model protocol emerged, many non-nuclear weapons states, including key U.S. allies, took an increasing interest in the willingness of the United States and other nuclear weapon states to accept some of the protocol measures. In response, President Clinton announced in September 1996 that the United States is ready to apply the new measures as fully as possible, consistent with U.S. obligations under NPT.

The model protocol was drafted to be a protocol to an existing safeguards agreement. In the case of the United States, this would be INFCIRC/288, a key provision of which is the exclusion associated with activities of direct national-security significance to the United States. Clearly, this exclusion will continue to apply under a new U.S. protocol and to its provisions.

IAEA Safeguards on U.S. Excess Fissile Materials

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Historical Data

U.S. sites that use International Atomic Energy Agency (IAEA) safeguards to handle nuclear materials released from the weapons program are:

- Oak Ridge, Y-12: Highly enriched uranium (HEU) storage vault;
- Hanford: Plutonium storage facility; and
- Rocky Flats: Plutonium storage facility.

IAEA safeguards also are applied at an HEU downblending facility at the Babcock & Wilcox Naval Fuel Plant at Lynchburg, Virginia, for materials reportedly received from Kazakstan.

A U.S. offer to apply IAEA safeguards to HEU materials being downblended at a facility of the Gaseous Diffusion Plant at Portsmouth, Ohio, also is under consideration.

Focal Points

The features of facility-specific safeguards are:

- Never before was more HEU material verified in such a short time (within a week) with such high precision and confidence than it was at Oak Ridge. A remote monitoring system and a Gemini TV system are installed and tested at this facility under the US-SP.
- At the Hanford plutonium storage facility, the diverse chemical composition and the heterogeneous physical form of the inventory attributed to destructive assay (DA) sampling and analysis difficulties. Particular containment and surveillance measures were considered because of specific material-storage arrangements conditioned by the operator's real-time monitoring system.
- A relatively large DA sample size and the development of appropriate nondestructive assay (NDA) instrumentation are the main characteristics of the safeguards activities at Rocky Flats. Gemini tests are carried out under the US-SP.
- At B&W, a project-type safeguards implementation was developed to cover HEU downblending of Sapphire material. Two complementary unattended process-monitoring systems were appropriately developed and applied. However, repeated operational problems in the unique downblending process caused project delays, which have exhausted project funds. This project is financed separately.
- The U.S. voluntary offer to IAEA for a verification experiment on the HEU being downblended in the Gaseous Diffusion Plant is being considered with respect to a pertinent verification scheme, resource assessment, cost estimates, and funding.

Lessons Learned

The experience acquired so far dictates a series of issues for consideration in the application of IAEA inspections of nuclear materials released from weapon programs. These issues are:

- Stabilization and repackaging of plutonium to meet long or medium-term storage requirements;
- High radiation dose environments and their impact on the required inspection resources;
- DA sampling, transportation licensing, and container availability;
- Reporting requirements, transit matching, and quality control system; and
- Predicting the verification cost.

Finally, a number of topics bring into question the need for a new legal basis other than the current Voluntary Offer Safeguards Agreement (INFCIRC/288). These topics are:

- Verification objective,
- Irreversibility and nonwithdrawal,
- Volume and amounts of material to be subject to verification, and
- Funding and budget planning.

In addition, the verification and monitoring of material in classified forms must be addressed in the near future.

The Interagency Process and Program Planning for Excess Fissile Materials Inspections

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The International Atomic Energy Agency (IAEA) is conducting inspections of excess fissile materials in the United States pursuant to the Voluntary Offer Safeguards Agreement between the United States and IAEA. The U.S. government oversees implementation of the U.S.-IAEA safeguards agreement, in force since 1980, through an interagency process that involves the active participation of several federal agencies.

Since 1993, this interagency process has served as the principal mechanism for developing the policies and plans to make available for IAEA inspection fissile materials declared excess to U.S. national-security requirements. This paper will review the interagency process and some key decisions for excess fissile material inspections.

Background

On September 27, 1993, President Clinton announced that the United States would submit its excess fissile material to IAEA inspection. The president declared in March 1995 that some 200 metric tons of fissile material would be declared excess to U.S. defense requirements. Information about the quantities and locations of excess material was released to the public in February 1996.

The inventory of excess material includes approximately 174 metric tons of highly enriched uranium (HEU) and 38 metric tons of weapons-grade plutonium. An additional 14 metric tons of reactor- and fuel-grade plutonium is being treated as excess to U.S. defense requirements. At present, IAEA is applying safeguards to about 12 metric tons of HEU and plutonium at three sites: the Oak Ridge Y-12 Plant, Hanford, and the Rocky Flats Environmental Technology Site.

The Interagency Process

The U.S. government mechanism for coordinating policy and resolving disputes related to the implementation of safeguards under the U.S.-IAEA agreement is the interagency IAEA Steering Committee, which is generally concerned with IAEA policy matters. The Steering Committee established a Subcommittee on International Safeguards and Monitoring (SISM). In turn, the Subgroup on IAEA Safeguards in the United States (SISUS) was organized under SISM.

SISUS has responsibility for monitoring implementation of the U.S.-IAEA safeguards agreement. It is composed of representatives from the Nuclear Regulatory Commission (NRC), the U.S. Department of State, Arms Control and Disarmament Agency, and the Department of Energy (DOE). NRC appoints the chair of the subgroup. Within the subgroup, NRC is the agency responsible for facilities licensed or certified by the commission, and DOE is responsible for DOE license-exempt facilities.

SISUS has a broad range of responsibilities for overseeing implementation of the U.S.-IAEA safeguards agreement. Official communications through the State Department with IAEA about issues relating to the U.S.-IAEA agreement are coordinated by SISUS member agencies. The subgroup also coordinates the transfer to IAEA of material accounting reports required by the agreement. In turn, IAEA provides reports about its inspection activities. These are reviewed by SISUS to determine whether or not any corrective action is needed.

From time to time, IAEA may propose to designate one or more inspectors to serve in the United States. All such proposals must be considered by SISUS before an agency inspector can take part in safeguards activities at a U.S. facility. When IAEA schedules an inspection or other visit to a U.S. facility, SISUS, and particularly the member agency that is responsible for the facility, must ensure that the appropriate advance notification is provided for the activity.

Under the terms of the agreement, the United States must notify IAEA of all facilities with source or special nuclear material not associated with activities with direct national-security significance. SISUS is responsible for reviewing and, as necessary, updating the list of facilities that are eligible for IAEA safeguards. When IAEA selects an eligible facility for the application of safeguards, SISUS member agencies then make up the U.S. negotiating team for the facility attachment that defines procedures for routine agency inspections at that facility.

Program Planning for IAEA Inspections

In view of its responsibilities for the U.S.-IAEA agreement, SISUS is the focal point for carrying out Clinton's 1993 commitment to submit U.S. excess fissile material for IAEA inspection. A key aspect of this work is the determination of which materials can be made available for inspection.

The president's March 1995 announcement did not explicitly address how much U.S. excess material could be made available for IAEA inspection or when that might occur. Rather, the DOE was asked to develop recommendations that would be reviewed through the interagency process. The National Security Council approved the DOE's recommendations in September 1996. On that basis, Secretary of Energy Hazel O'Leary announced later that month that 26 metric tons would be made available during the next three years, in addition to the 12 metric tons already under IAEA safeguards.

SISUS is the principal interagency mechanism for the development of U.S. plans to make available further amounts of excess fissile materials available for IAEA inspection. The DOE continues to evaluate the excess material inventory to identify additional quantities that may be made available.

As part of this process, it also is necessary to ensure that the facilities containing these materials either are or can be made eligible for IAEA safeguards under the U.S.-IAEA agreement. SISUS is working to coordinate the development of these plans with IAEA to ensure that the agency has adequate resources to carry out inspections on the materials that the United States declares to be excess.

Conclusion

When the U.S.-IAEA safeguards agreement entered into force in 1980, it was never envisioned that its provisions would one day apply to materials removed from defense programs. Clinton's September 1993 excess fissile materials initiative brought significant changes in the issues that would have to be considered for implementation of the agreement. The existence of a well-defined interagency process for the U.S.-IAEA agreement has facilitated the resolution of those issues and provided an effective mechanism for future planning.

Lessons Learned From Implementing IAEA Safeguards for U.S. Excess Fissile Material at Oak Ridge Y-12 Plant

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Highly enriched uranium (HEU) at the Oak Ridge Y-12 plant was the initial U.S. excess fissile material to be placed under International Atomic Energy Agency (IAEA) safeguards. This paper describes the setting in which the U.S. offer was made and five lessons learned from that experience.

Several significant obstacles had to be overcome by the U.S. Department of Energy (DOE) to make the offering a reality:

1. Neither specific materials nor specific facilities were identified when President Clinton announced on September 27, 1993, that the United States would make HEU and plutonium no longer needed for U.S. weapons subject to IAEA safeguards.
2. The initial allotment of excess HEU at the Y-12 plant was comingled with nonexcess materials, and the material-handling activities required to separate the two had not been envisioned, much less budgeted for or prioritized.
3. The Y-12 plant has a national defense mission and many site activities and operations are of direct national-security significance. Thus, a facility to store the excess HEU had to be identified and isolated from the rest of plant operations.
4. Nearly a decade had elapsed since IAEA had selected a DOE facility for the application of IAEA safeguards. During this time period, the DOE was reorganized, the U.S. interagency process changed, IAEA began to strengthen the implementation of international safeguards following the Gulf War, and most of the individuals involved in the implementation process in the mid-1980s had assumed different responsibilities.

Lesson 1: Things May Happen Quickly

Within two months of the presidential announcement, the DOE identified specific material and a facility at the Oak Ridge Y-12 plant, and site representatives gave IAEA officials a familiarization briefing and orientation tour. The DOE authorized Y-12 to proceed with preparations in April 1994, and the State Department notified Congress in July 1994 of its intent to add a Y-12 storage facility to the list of U.S. facilities eligible for IAEA safeguards. The United States notified IAEA that the facility was eligible on September 5, 1994.

IAEA selected the facility three days later, and verification of the design information and initial inventory were completed by September 16, 1994. Thus, less than a year after conception, the initial offering of U.S. excess fissile material successfully became subject to IAEA safeguards.

Lesson 2: Facility Must Comply with IAEA Needs

Providing for the needs of IAEA to conduct its inspection activities at Y-12 posed significant logistical difficulties because the eligible facility was located in the heart of a plant with a national defense mission. The site had to develop a strategy for protecting sensitive U.S. information while providing IAEA access to the excess HEU.

For IAEA to independently verify the inventory, nondestructive assay measurement stations and a glove box had to be installed in an adjacent supporting area. Finally, provisions were necessary for IAEA to apply independent containment and surveillance measures to provide them with continuity of knowledge between inspections.

Lesson 3: Familiarize Site Personnel with Safeguards

Initially, few site personnel were knowledgeable of international safeguards. Safeguards tutorials should be conducted to familiarize personnel with the structure and mission of IAEA and describe the safeguards implementation process.

Working groups composed of representatives of each potentially affected discipline should be established. The site also should conduct mock inspections or table-top exercises to identify all regulatory requirements (badging, training, etc.) and methods for expediting the process.

Lesson 4: Prepare for the Initial Inventory Verification

The initial inventory is a time-consuming and labor-intensive activity. A number of specific activities should be completed as early as possible to prevent lengthy and costly delays.

Equipment and instrumentation provided by IAEA must be received and processed into the area. Calibration standards provided by the plant should be identified, fabricated, and certified well in advance of the verification. Site escorts and support personnel must be identified and undergo extensive training. If possible, the measurement capabilities of specific IAEA instruments should be established before the start of the physical inventory. This may reduce the number of items that must be handled during the verification.

Lesson 5: Prepare for Inspections

Many separate site functions are required to support inspections: badging, operations, nuclear-material control and accountability, physical protection, health physics, safety, etc. Anticipated schedules should be prepared and distributed to ensure that all site functions can respond when needed. A few golden rules that apply to all situations are:

- Don't assume anything,
- Put it in writing,
- Maintain continuous dialogue, and
- Allow extra time.

Making the initial portion of U.S. excess fissile material available for IAEA safeguards was a significant accomplishment for the DOE. The actions taken by the Y-12 plant to prepare for inspection activities ensured timely and successful implementation of international safeguards for excess HEU at the site. IAEA has stated that "never before had so much material of such high strategic significance been verified so fast with such a high degree of confidence."

Lessons Learned From the Implementation of IAEA Standards at the Hanford Facility

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The Hanford Plutonium Finishing Plant was committed to making excess fissile materials available for International Atomic Energy Agency (IAEA) safeguards, but the time frame for preparatory activities, while somewhat longer than that of the Oak Ridge Y-12 plant, required detailed planning to accomplish implementation objectives.

The planning effort was designed to meet specified objectives in a cost-effective manner, which ensured health and safety requirements were upheld and classified information was not compromised. A great deal of effort went into the preparatory activities associated with Hanford's implementation and there were a number of valuable lessons learned.

As the application of IAEA safeguards at additional facilities and quantities of fissile material is pursued, many of the same issues faced during the initial phase at Hanford will be encountered. The lessons learned during the implementation at Hanford were evaluated and documented to assist in minimizing implementation impacts at other sites.

The most obvious conclusion drawn from the experience is that failing to plan is, clearly, planning to fail.

Defining Activities

When Hanford was originally identified as a candidate for IAEA safeguards implementation, the first order of business was to develop a flow chart or decision tree addressing all the anticipated steps to be completed before the initial physical inventory verification (IPIV). Evaluation of the experiences at other sites, such as Oak Ridge, was a critical step in the development process.

To validate the accuracy of the chart/tree, a multidisciplinary team was developed that included staff from safeguards and security, facility operations, radiation protection, transportation, foreign visits and assignments, and nuclear-materials measurement organizations. Focus groups were formed with representation from each of these organizations to address specific actions resulting from evaluation of the chart/tree.

The action list was continually updated to reflect new items identified by focus groups or those resulting from technical discussions with IAEA. In general, the preparatory activities and safeguards implementation was accomplished in a positive manner.

The major activities from a cost and personnel-exposure perspective included: (1) the material movements required to load the vault room with the initial inventory of material and (2) the fabrication and installation of the sealing bars used as part of the IAEA containment and surveillance scheme. Although Hanford implemented a detailed planning process and focus groups to resolve issues early in the process, these activities continued to be impediments through the IPIV.

Lessons Learned

The implementation of IAEA safeguards at Hanford presented several challenges and clearly provided a valuable learning experience. Specific lessons learned within the general categories are detailed in the following descriptions.

1. Management commitment and support is essential. Management at all levels must be committed to supporting the implementation of IAEA safeguards from the initial identification of a facility to be placed on the eligible facility list. If a facility should be selected by IAEA for the application of safeguards, the need for management support is even more critical. Dedicated resources, labor, and funds are required to accomplish the activities associated with implementation. Without the ability to commit, schedule, and expend resources, the completion of necessary activities will not occur.

2. A dedicated multidisciplinary implementation team is essential. An early start to planning between a facility's multiple disciplines, the U.S. Department of Energy (DOE) and IAEA is critical to success. Each of the participating disciplines brings a different perspective to issues, helps to ensure that all bases are covered, and supports sitewide communication and coordination. Planning and action tracking should be lead by one organization through a clearly identified individual. The experience at Hanford supports the identification of safeguards as the lead organization.

3. Maximizing the value of technical discussions is critical. The contributions of former IAEA staff and inspectors throughout the planning and implementation process are invaluable. The knowledge that staff or contractors with IAEA experience can provide greatly enhances the value derived from technical discussions with IAEA. Asking the right questions and then pushing for a satisfactory answer, along with the ability to postulate a potential safeguards approach, are examples of the value added by those with IAEA experience.

A specific example would include the discussion of measurement methods and any effects packaging may have on measurement techniques. Continuous and open exchange of technical information is critical to successful preparation. To facilitate the information exchange, communications agreements need to be clearly defined and implemented between the operator, DOE, and IAEA. Such agreements help ensure that critical technical information can easily be transferred and that policy issues are formally addressed with all applicable parties. The early identification of any facility modifications required is essential for timely completion and to minimize the impacts on operations. Maximizing depth and breadth of technical discussions will aid the identification process.

4. Effective sitewide communication and coordination is critical. The greatest impacts of IAEA safeguards planning and implementation are on facility operations. Involving the operations staff in the planning process and with focus groups helps minimize the impacts through the identification and resolution of issues that may be apparent only from their perspective. Sitewide communication and coordination is critical to not only the preparation process, but also the implementation and ongoing activities.

The most explicit example involves the relatively simple activity of getting inspectors on site. Many organizations are involved and coordination is critical. Some of these are security-planning organization, protective-force operations, badging, radiation protection, facility operations (escorts), etc. Another example is the identification and development of sampling methodology necessary to ensure procedures and ancillary needs are identified. Multiple disciplines are involved in addressing all aspects of sample-taking and packaging.

5. Understanding the magnitude and scope of logistics issues is essential. Developing an understanding of the full spectrum of logistical issues is critical to effective preparation and implementation. A classic example is the multitude of issues associated with shipping samples. The operator needs to first secure the means for taking samples and then obtain early approvals for the shipment of samples for destructive analysis and the use of shipping containers. The use of shipping containers not only addresses the identification of approved containers, but also the location and availability of the required number of containers.

International shipping and customs requirements also must be understood with procedures in place to accommodate international activity. The operator needs to closely follow IAEA-equipment shipments from the point of origin through U.S. customs to receipt at the facility. Numerous problems can occur relative to equipment transfers. Material movements associated with facility loading and movement through measurement stations during IPIVs also create scheduling conflicts and operational impacts that must be addressed.

6. Addressing accountability system reporting formats and specifications early is critical. Site accountability system reporting formats and specifications need to be evaluated early to ensure the system can meet the requirements and needs of Nuclear Materials Management and Safeguards System (NMMSS), IAEA, and facility operations. While operator systems have been designed to meet the needs of operations and DOE reporting requirements through NMMSS, they are not necessarily compatible with all of the IAEA reporting requirements. Modifications often are quite time-intensive and, thus, require early identification.

Implementation of IAEA Safeguards at Rocky Flats Environmental Technology Site

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On December 4, 1995, the International Atomic Energy Agency (IAEA) began its initial physical inventory verification (IPIV) at the Rocky Flats Environmental Technology Site (RFETS). The United States made 288 10-gallon drums of weapons-grade plutonium oxide in vault-like Room 3331 of Building 371 available for international safeguards, and the commencement of the IPIV capped a two-year period of preparation by Rocky Flats, IAEA, and the U.S. Department of Energy (DOE). The purpose of this paper is to share much of the experience that was gained during the course of implementation of international safeguards at Rocky Flats.

Implementation Experiences

The costs for implementing IAEA safeguards at Rocky Flats were substantially higher than at Oak Ridge or Hanford. The primary reason was the purchase of a neutron-multiplicity counter for nondestructive assay and the extensive vault modifications performed in the eleventh hour, mostly on overtime. Had the facility's upper management committed earlier to providing adequate support, both in preparation for and during the initial physical-inventory verification, much of the work could have been completed in a more cost-efficient and resource-effective manner.

The material offered at Rocky Flats is impure (greater than 80 percent) plutonium oxide. IAEA's earlier experience at the Hanford site involved inhomogeneous residue materials that were of Rocky Flats origin. IAEA made the assumption that the RFETS offering was similarly inhomogeneous, so it requested five-gram samples and assigned multiple strata to the population, requiring a larger number of destructive assay (DA) measurements to establish the bias defect.

The presence of lead liners for radiation shielding inside some of the 10-gallon storage containers was not discussed with IAEA during technical exchanges before the IPIV. This information also was omitted from the design information provided to IAEA. IAEA's gamma spectroscopy measurements, used for gross-and partial-defect detection, did not use the higher energy regions of the plutonium spectra, but instead concentrated on the 100 - 200 keV region. The lead liners presented a problem for this technique because the lead effectively blocked most of the peak energies used. After the problem was discovered, Los Alamos National Laboratory and RFETS personnel worked with IAEA to modify its isotopics codes and authenticate the changes for use at RFETS.

IAEA uses the Plutonium-Air Transport-2 (PAT-2) container for shipments of samples to its Sibersdorf Analytical Laboratory (SAL) for destructive assay. These containers originally were produced by the United States Atomic Energy Commission; however, there are only 12 certified PAT-2s in existence. The large DA sampling population at Rocky Flats put severe strain on the allocation of these containers across the DOE complex. In addition, the 15-gram plutonium limit was not communicated until after the first several PAT-2s were packed.

Traditionally, there has been a prohibition against export of special nuclear materials to a foreign organization. In 1984, an exemption was written into the Code of Federal Regulations to allow for export of IAEA safeguards samples (10 CFR 110.11). However, this exemption provides for an annual limit of 100-gram total of plutonium, uranium-233, and uranium-235 in shipments. The large DA measurement requirement in IAEA's sampling plan caused Rocky Flats to quickly reach the 100-g limit. The DOE attempted several different methods for obtaining a license to ship these samples, until finally settling on a directed transfer as authorized by the Atomic Energy Act of 1953 (as amended).

A subset of the plutonium oxide placed under international safeguards contained highly enriched uranium (HEU). This had been discussed with IAEA, and an informal agreement was reached to treat the HEU as a trace contaminate. As such, no mention was made in the design information provided to IAEA. However, the physical-inventory listing generated for IAEA by the Nuclear Materials Management and Safeguards System (NMMSS) included the HEU.

Several other problems arose during reporting of inventory data including timeliness of report submittal to IAEA, accuracy of data submitted (dates and inventory data), and inability of the United States to correct inaccurate data. The United States has attempted to address this issue by inviting IAEA to provide the "IAEA Workshop on Nuclear Material Accounting and Reporting," which was attended by DOE field and operations offices, facilities, and NMMSS personnel, and provided the basis for IAEA reporting requirements and the structure and format of required reports.

Conclusions

We believe the root cause for many of the issues that arose at Rocky Flats during the implementation of IAEA safeguards was inadequate communication between the RFETS, IAEA, and DOE. If time had been taken to ensure effective communication among the parties, if more time had been spent communicating the design information earlier to IAEA, and if there had been a more concerted effort to learn from the experiences at Oak Ridge and Hanford, most of the issues discussed in this paper could have been prevented.

IAEA Lessons Learned at Portsmouth Gaseous Diffusion Plant

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The Portsmouth Gaseous Diffusion Plant is located on a 4,000-acre federal reservation in southern Ohio. Uranium enrichment activities at the site are currently managed by the United States Enrichment Corp. (USEC), with Lockheed Martin Utility Services Inc. supporting the operation of the gaseous diffusion plant under contract to USEC. The Department of Energy (DOE) activities at the Portsmouth site are limited to environmental restoration and waste-management activities and include the disposition of historically produced highly enriched uranium (HEU) materials at the site.

Lockheed Martin Energy Systems provides contract support for DOE activities at the Portsmouth site. Although HEU materials are being shipped from the Portsmouth site to other domestic locations for storage or processing, a considerable quantity of HEU in the form of uranium hexafluoride (UF_6) will remain at the site to be downblended for use as a commercial product.

Currently, two facilities at the Portsmouth site have been designated by the United States as eligible for the application of International Atomic Energy Agency (IAEA) safeguards: the Portsmouth Gaseous Diffusion Plant for Uranium Enrichment and the Portsmouth Gaseous Diffusion Plant for Enriched and Depleted Uranium Storage. This designation supports verification of the downblending of 13 metric tons of excess HEU materials, and it is this material that has been the primary focus of IAEA activities at the site.

Following a declaration of eligibility, two IAEA-related activities have occurred at the Portsmouth site. Initially, a technical exchange meeting, including site- and process-familiarization activities, was conducted in April 1996. In addition, a technical experiment related to the evaluation of monitoring capabilities for the downblending operation was conducted by personnel from the Pacific Northwest National Laboratory and Brookhaven National Laboratory in December 1996. These activities provide the basis for the lessons presented in this paper.

Technical Exchange Meeting

The initial Portsmouth-IAEA technical exchange meeting included the participation of representatives from site operators, site contractors, supporting government agencies, and IAEA. The format of the site visit included familiarization briefings of site and operating processes, a limited tour of the HEU downblending facility, and technical discussions related to the application of safeguards to the HEU downblending process.

In preparation for the site meeting, several unique challenges were identified. Initially, the safeguards would be applied to a dynamic production process rather than to a static storage operation. The process involves a continuous flow of materials that cannot easily be tracked or monitored because of the existence of complex piping configurations contained within enclosed housings. Several security issues also required resolution through planning.

The need for a detailed, well-defined, and formally approved security plan was recognized early in the planning process. The development and implementation of the plan are seen as elements that contributed to the overall success of the meeting. The need to address any issues well in advance of the planned activity will help to eliminate the potential for delayed approval of security and operating plans.

A significant level of effort was directed toward learning as much as possible from other sites' experiences. Benchmarking visits to other sites were beneficial, as was participation in DOE-sponsored IAEA workshops. The lessons learned from these activities were implemented and evaluated during a mock visit before the actual meeting date, permitting the fine tuning of planned site activities.

A team approach was applied to the planning and preparatory activities at the Portsmouth site. Senior management representatives were assigned to oversee and coordinate IAEA activities, with a field coordinator assigned to ensure implementation of all planning measures.

Dedicated support was provided for the visit by representatives from nearly all site-support organizations, working in concert to ensure the activities were conducted as planned. Team meetings supported the overall process and experience identified the need for a full team walkdown of all elements of the visit during the planning stages to ensure that all supporting personnel fully understood the coordination and required levels of support to be provided.

Although efforts were taken to minimize impacts on site operations, some compensatory security-related activities were required. Multiple walkdowns of the projected tour access area were performed by the security group up to the time of building entry to ensure that no unforeseen conditions developed as a result of changing facility conditions.

Specialized visit training was conducted for assigned protective force personnel, including documentation requirements and special inspection processes to be followed. Escorts were assigned in advance, based upon the completion of training specified in the security plan and site expertise. The utilization of properly trained and experienced escorts provided a necessary information resource to IAEA visitors while ensuring compliance to the provisions of the security plan.

Routine site-access processes were modified to support the visit by IAEA representatives. Special authorization and sign-in sheets were used and an independent site-access portal was activated to support entry and exit processing. These modifications reduced the delays that would have been encountered by processing the visitors at the entry. Immediately following site entry, IAEA representatives participated in required briefings and training, including a hands-on training session addressing the use of contamination-monitoring equipment.

The tour group was kept as small as possible, composed of only IAEA representatives, government agency representatives, and a core group of site personnel necessary to support the visit. Routine ingress and egress measures at the security area boundaries were modified somewhat to accommodate the visit to the facility; however, routine metal and radiation monitoring processes were followed for all visitors. Minimal site impact was realized through this modified operation.

A number of logistical lessons were identified as a result of the site's experience. The benefit of providing drawings and photographs for use by the visitors in conveying necessary site-specific information was recognized. The benefit of assigning a recorder to document discussion points and topics for later reference also was noted. The provision of required protective clothing and appropriate change facilities and restroom access should be included as a preparatory action supporting the visit, and consideration should be made to any special needs of the visitors. Finally, management details, including funding sources, should be resolved well in advance of the site activity.

Technical Monitoring Experiment

An evaluation of monitoring capabilities for the in-process blending of HEU materials in the diffusion cascade also was conducted at the site, requiring a lower level of support in planning and implementation. Nonetheless, a number of lessons were learned in supporting this activity at the site.

The need to ensure that all safety and operational reviews are completed and approved in advance of the projected timeline for the activity was a significant lesson learned. Detailed reviews and approvals are necessary for all site activities, particularly those that could impact operations or site safety. The absence of advance approval was found to cause significant delays in the conduct of the planned activity. In addition, special operating needs for the activity should be addressed in advance of the projected activity timeline. Special power requirements, lighting requirements, source-storage requirements and any other site support needs all should be considered.

The equipment used in the technical monitoring experiment was subject to prior inspection, documentation, and entry approvals. To support the ultimate removal of the equipment, the Portsmouth site used tamper-indicating devices on equipment that could not be disassembled for exit inspections. Should IAEA monitoring processes be implemented for this or a similar monitoring process, the levels of security applied for the monitoring experiment would be appropriate for application to any IAEA equipment introduced into the facility.

For both site activities, the maintenance of a flexible response capability and an expect-the-unexpected attitude yielded the successful completion of the efforts.

Lessons Learned in Implementing IAEA Safeguards at the High Flux Isotope Reactor

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The International Atomic Energy Agency (IAEA) is considering the application of safeguards to a limited quantity of highly enriched uranium (HEU) irradiated fuel at the High Flux Isotope Reactor (HFIR) facility. The HFIR HEU irradiated fuel is intended as substitute material for South American HEU irradiated fuel returning to a U.S. facility currently not eligible for IAEA safeguards to satisfy requirements of the IAEA-Chilean safeguards agreement. A brief summary of IAEA-related activities at HFIR follows.

September 1996: Safeguards Tutorial at HFIR

The U.S. Department of Energy (DOE) International Safeguards Division (ISD), in coordination with the DOE Office of Nuclear Energy, Science and Technology, conducted a tutorial about IAEA safeguards at the HFIR facility. During the tutorial, representatives from the Oak Ridge Y-12 Plant National Security Program Office (NSPO) and other safeguarded U.S. facilities gave presentations that focused on the function and operation of IAEA, a description of safeguards methodologies and lessons learned in implementing safeguards at other U.S. facilities. A tour of the HFIR facility was followed by a discussion of the initial effort required to generate a design-information questionnaire for HFIR.

October 1996: First IAEA Technical Meeting at HFIR

The first U.S.-IAEA technical meeting at HFIR was sponsored by the facility, with substantial support provided by ISD through NSPO. The meeting aimed to provide sufficient technical information about the HFIR facility to IAEA to facilitate the determination of a cost-effective safeguards approach that would minimize operational impact. Additionally, IAEA toured the reactor building, including the reactor bay, and presented detailed information about the path fuel follows at HFIR.

December 1996: IAEA Accounting and Reporting Workshop in Atlanta

ISD sponsored IAEA to conduct a workshop about reporting requirements in December 1996. Topics discussed at this workshop included an overview of safeguards, accounting concepts, Code 10 reporting requirements, quality assurance of state reports, and exercises of item- and bulk-facility accounting. The IAEA workshop discussed methods the United States uses to provide inventory information to IAEA from the Nuclear Materials Management and Safeguards System (NMMSS).

The process of transmitting inventory information from DOE facilities to NMMSS was not addressed during this workshop but will be the topic of a future training course.

February 1997: Second IAEA Technical Meeting at HFIR

The second U.S.-IAEA technical meeting at HFIR also was sponsored by the facility and focused on IAEA's development of a safeguards approach for the HFIR facility. IAEA tested an improved Cerenkov viewing device in the reactor bay and discussed test results and thoughts about a safeguards approach. Follow-up actions were developed to determine the applicability of different options for a potential safeguards approach.

April 1997: Third IAEA Technical Meeting at HFIR

A third technical meeting at the HFIR facility, focused on specific issues including amounts, schedules, containment and surveillance systems, and design information.

As depicted by the timeline presented, the HFIR experience with IAEA has been brief. Although HFIR has not yet been selected for the application of safeguards, the technical-information-exchange process is continuing. This process has been significantly eased through domestic support provided by the ISD, NSPO, and interactions with representatives from other safeguarded U.S. facilities. The tutorial and IAEA workshop in Atlanta provided excellent opportunities to understand the philosophy and operation of IAEA as related to U.S. facilities.

It is anticipated that future technical-information exchanges between the United States and IAEA about the HFIR facility will result in the development and implementation of a cost-effective safeguards approach that will minimize operational impact and satisfy IAEA and U.S. mutual goals of nonproliferation.

Present and Future Nondestructive Assay Methods for IAEA Verification of Excess Fissile Materials

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The U.S. Nonproliferation and Export Control Policy, announced by President Clinton before the U.N. General Assembly in September 1993, commits the United States to placing under International Atomic Energy Agency safeguards nuclear materials no longer needed as nuclear deterrents.

As of January 1, 1997, IAEA had completed initial physical inventory verifications (IPIVs) at three storage facilities: a vault in the Oak Ridge Y-12 plant that contains highly enriched uranium (HEU) metal, a vault in the Hanford Plutonium Finishing Plant (PFP) that contains plutonium oxide and plutonium-bearing residues, and a vault at Rocky Flats Environmental Technology Site that contains pure and impure plutonium oxides. This paper focuses on the results of nondestructive assay (NDA) verification methods used by IAEA at Oak Ridge and Hanford.[1,2] A companion paper focuses on NDA verification methods required by IAEA at Rocky Flats.

Table 1 displays the routinely used NDA instruments for IAEA inspections of uranium and plutonium storage facilities. IAEA successfully used these standard NDA methods, along with other methods, for the IPIVs at Y-12, Hanford, and Rocky Flats. Some of the other methods IAEA used are described later in this paper.

Conventional neutron-coincidence counting is one of the routinely applied IAEA NDA methods for verification of uranium and plutonium. However, at all three facilities, neutron NDA equipment needed to be modified or developed for specific facility needs, such as the type and configuration of material placed under safeguards.

Techniques at Y-12, Hanford, and Rocky Flats

At Y-12, the size and mass of items to be verified required modification of the Active Well Coincidence Counter (AWCC).[3,4] The facility prepared a set of calibration standards representative of the items to be measured. IAEA certified these standards by destructive analysis (DA). Compared with operator declarations for ^{235}U mass (weighing and isotopic analysis), IAEA AWCC measurement values agreed to within 0.5 percent for randomly selected items. These AWCC results qualified them as

Table 1. Standard IAEA NDA Instruments Used at Storage Facilities

Measurement	Method	Instrument (acronym)
U, Pu radiation	Low-resolution gamma spectrometry	Portable MCA - NaI (PMCN)
^{235}U mass	Active neutron-coincidence counting	Active Well Coincidence Counter (AWCC)
^{235}U enrichment	Low-resolution gamma spectrometry High-resolution gamma spectrometry	Portable MCA - NaI (PMCN) Portable MCA - HPGe (PMCG)
^{240}Pu-effective mass	Passive neutron-coincidence counting	High-Level Neutron-Coincidence Counter (HLNC)
^{240}Pu-effective fraction	High-resolution gamma spectrometry	Medium Count Rate System (MCRS)

bias-defect measurements, thus eliminating the need for DA, except for standards.

At Hanford, IAEA used the standard high-level neutron-coincidence counter (HLNC)[5] for verification of pure PuO_2. For verification of plutonium material containing unknown impurity concentrations, IAEA used a three-ring multiplicity counter (3RMC) provided by Los Alamos National Laboratory. The 3RMC gave better results for the impure material than could have been achieved using HLNC.

The 3RMC also showed an improvement in measurement performance for pure PuO_2 because of higher efficiency compared with HLNC. IAEA has since procured and installed a plutonium scrap multiplicity counter (PSMC)[6] at Hanford. The PSMC has yielded better performance than the 3RMC.

Inspectors at Rocky Flats used a large neutron-multiplicity counter designed for multiple-can plutonium-oxide containers for the IPIV.[7] This enabled measurement of multiple-can items and reduced radiation exposure to plant personnel and inspectors. This counter has been used for facility- and IAEA-verification purposes for a variety of nuclear materials.

Some items at Rocky Flats also contained lead shielding, which prevented the use of the IAEA-standard medium count rate system (MCRS). The standard MCRS analyzes the 100-keV region, which is greatly shielded by the lead. IAEA, with support from Los Alamos and Lawrence Livermore National Laboratory, modified the plutonium-analysis algorithms, concentrating on higher-energy gamma rays for assay. This approach was successful for the lead-lined drums.

Future Inspections Will Bring New Challenges

Additional U.S. offers of excess nuclear weapons materials for international inspection will bring new challenges. For material stabilization, plutonium items at Hanford and Rock Flats will need to be temporarily removed from static storage. For direct verification of classified components, new approaches will be required that do not divulge sensitive information. For conversion of classified components to unclassified forms, the requirements of international inspections must be included early in the facility-design process. For future storage and warehouse facilities, NDA systems will need to be automated and integrated. Also, joint use of these systems will require new approaches by the United States and IAEA for protection of sensitive information and authentication.

References

1. J.E. Stewart, M.S. Krick, T.D. Reilly, D.G. Langner (LANL), W. Theis, R. Lemaire and J. Xiao (IAEA), "Implementation of Neutron Counting Techniques at U.S. Facilities for IAEA Verification of Excess Materials from Nuclear Weapons Production," *Proceedings of the Institute of Nuclear Materials Management 36th Annual Meeting*, pp. 548-554 (1996).
2. J.E. Stewart and M.S. Krick, "Assay of Scrap Plutonium Oxide by Thermal Neutron Multiplicity Counting for IAEA Verification of Excess Materials from Nuclear Weapons Production," presented at the Institute of Nuclear Materials Management 37th Annual Meeting, Naples, Fla., July 28-31, 1996.
3. H.O. Menlove, "Description and Operation Manual for the Active Well Coincidence Counter," Los Alamos National Laboratory report LA-7823-M (May 1979).
4. H.O. Menlove and J.E. Stewart, "A New Method of Calibration and Normalization for Neutron Detector Families," Los Alamos National Laboratory report LA-11229-MS (April 1988).
5. H.O. Menlove and J.E. Swansen, "A High-Performance Neutron Time-Correlation Counter," *Nucl. Technol.* 71, 97-505 (1985).
6. H.O. Menlove, J. Baca, M.S. Krick, K.E. Kroncke, and D.G. Langner, "Plutonium Scrap Multiplicity Counter Operation Manual," Los Alamos National Laboratory report LA-12479-M (January 1993).
7. D.G. Langner, M.S. Krick, and K.E. Kroncke, "A Large Multiplicity Counter for the Measurement of Bulk Plutonium," *Proceedings of the Institute of Nuclear Materials Management 34th Annual Meeting*, Naples, Fla., July 17-20, 1994, 474-47.

Thermal Neutron-Multiplicity Counting at Rocky Flats Environmental Technology Site

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Approximately one metric ton of excess weapons plutonium at Rocky Flats Environmental Technology Site (RFETS) is now under International Atomic Energy Agency (IAEA) safeguards. To date, the initial physical inventory Verification (IPIV) and the first annual Physical Inventory Verification (PIV) have been performed.

The material under safeguards at RFETS is plutonium oxide of varying purity stored in 10-gallon drums. In each drum there are two cans of oxide, each containing up to 2 Kg of Pu. The cans are stacked and centered in the drum by a metal tube or spider. All of the cans in the inventory contain at least 70 percent plutonium.

The oxide materials come from several sources and vary from extremely pure oxide to oxide containing moderate to large impurities. Pure oxide materials can be assayed rapidly and with good accuracy using a standard neutron-coincidence counting technique, the usual technique employed by IAEA in other countries to verify plutonium oxide.

Neutron Counting

In standard neutron-coincidence counting, two measured quantities, the total neutron rate and the rate of coincident neutrons, are combined with knowledge of a sample's isotopic ratios to deduce an assay. For materials like those in the RFETS inventory, however, standard neutron-coincidence assays can be greatly biased by neutrons produced from (alpha,n) reactions with light element impurities such as fluorine or beryllium. These elements are common impurities in the RFETS material.

For this reason and because of the failure of the standard coincidence technique at the Hanford IPIV, IAEA specified that the new neutron-multiplicity counting technique would be needed to verify the RFETS inventory. In multiplicity counting, a third measured quantity, the rate of coincident triples, is obtained by using a highly efficient detector and special counting electronics. The three measured quantities are then used to deduce the neutron-emission rates from the three processes that cause the neutron emissions in an impure plutonium sample: spontaneous fission rate, induced fission rate (multiplication), and (alpha,n) neutron rate. Finally, the isotopic ratios for the sample are used to convert the spontaneous fission rate to the sample plutonium mass.

Packaging

The packaging of the oxide at RFETS provided a challenge to meeting IAEA's specification because the only commercially available multiplicity counter, a unit that IAEA has had experience with in Japan, had too small a sample well to accommodate a 10-gallon drum. Because Los Alamos National Laboratory had just completed a prototype design of a multiplicity counter that could measure components in 30-gallon drums, and because there was insufficient time to design a new instrument specifically for the RFETS inspection, the 30-gallon drum neutron-multiplicity counter was fabricated for RFETS. This instrument has an efficiency of 42 percent and was designed to provide a measurement precision of between 1 percent and 3 percent in a 30-minute count time for materials having small to moderate impurities.

The instrument was characterized at Los Alamos with

Cf-252 sources and shipped to RFETS. Once the instrument was installed, the characterization was verified using a RFETS source. The instrument was authenticated at each inspection with Cf-252 sources owned by IAEA. Because multiplicity counting is a curveless technique, no plutonium calibration was needed before IAEA's inspections. During the IPIV, IAEA, however, chose three drums from the inventory to characterize using destructive analysis and to be used in subsequent inspections as working standards.

For the population of measurements made with the 30-gallon drum counter during both the IPIV and PIV, the average measurement precision for the instrument was 2.6 percent for a 30-minute count time. The average agreement between verification measurements and site-declared mass values was 4.2 percent. This overall agreement is consistent with the measurement precision of the multiplicity counter and the estimated average precision of the site-declared isotopic values.

All but one sample in the inventory was successfully verified with the multiplicity counter. This sample had a measured total neutron rate in excess of 2.7×10^6, a rate too high for the multiplicity electronics to process. Both cans in this drum were sampled for destructive analysis to investigate the cause of the unusually high neutron emissions.

Multiplicity Results Prompt Software Development

A comparison of the multiplicity results with the results that would have been obtained with standard coincidence counting shows that more than 50 percent of the inventory is unverifiable by the standard technique. A statistical analysis of the measurement precision obtained for the population of drums measured so far indicates that a small fraction of the drums need to be measured for count times greater than 30 minutes. However, many of the drums can be counted for less than 30 minutes and be successfully verified.

During the PIV, a new software option was successfully tested that allows a sample to be counted until a specified precision is reached. This work is supported by the U.S.

Shared Use of Calorimeters at the Hanford Plutonium Storage Facility

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Since December 1994, three physical-inventory verifications have been performed by the International Atomic Energy Agency (IAEA) at the U.S. Department of Energy's Hanford Plutonium Storage Facility. The inventory consists of plutonium that was determined to be excess for U.S. defense requirements. The excess materials were submitted to IAEA safeguards in two separate offers (December 1994 and August 1995). The materials represent relatively pure to impure and heterogeneous plutonium-oxide powders.

To verify nuclear material quantities placed under international safeguards, the IAEA safeguards department performs material measurements at three levels of increasing sensitivity. The first level is a qualitative identification of a nuclear-material property such as gamma spectrum or emission of coincident neutrons. The second level is quantitative measurement of nuclear material by nondestructive assay (NDA) techniques.

Such measurement generally must attain a combined relative random and systematic error of less than 6.25 percent (1 σ). For plutonium, coincident-neutron NDA combined with gamma spectrometry are accepted methods. These two levels of verification are performed onsite during inspection visits.

In accordance with IAEA safeguards-verification requirements for bulk-material inventory items, item weighing, sampling, and destructive analysis (DA) of the samples are used for the most precise plutonium measurements. The DA is performed at the IAEA's Safeguards Analytical Laboratory (SAL) in Austria by electrometric titration chemical techniques. Verification, thus, is not complete until samples are shipped to SAL and analyzed.

In contrast, plant operators at the Hanford site generally reserve chemical analyses for product-quality materials and use combined calorimetry and gamma-nondestructive techniques for most plutonium-accountability measurements. The operators found that NDA measurements offer lower variability (particularly for heterogeneous materials) and decreased personnel exposure, cost, waste, intrusiveness, and material handling compared with weighing, sampling, transporting, and destructive analysis of samples.

Calorimeters an Attractive Alternative to DA

An extensively designed set of measurements of materials entering and already under IAEA safeguards was performed and documented by IAEA and plant personnel to compare various DA and NDA measurement techniques. The relative sampling and measurement variabilities of weighing and DA of selected inventory items were determined and compared with NDA of the same items by gamma and calorimetric techniques. The calorimeter-based NDA method was found to give measurement variabilities equal or superior to those found by weighing and DA for the tested safeguarded materials.

IAEA and the operator thus recognized that IAEA use of operator calorimeters, combined with existing IAEA gamma NDA, could be an attractive replacement to part of the required IAEA DA requirement. However, use of plant-operator equipment, such as the calorimeters, by the IAEA needed to be balanced by the requirement that IAEA verifications be independent. Therefore, to authorize the calorimeters for routine IAEA use, independent testing of operator calorimetry and development of authentication features and confidence-building measures were necessary. The authentication features help ensure genuine results while confidence-building measures reduce the potential risks of equipment tampering.

Development of Authentication and Confidence-Building Measures

Possible authentication measures were created and described under support of the Program of Technical Assistance to Agency Safeguards. The merits, weaknesses, costs, and practicality of the proposed techniques then were scrutinized and evaluated by plant and IAEA personnel. Based on these discussions, a set of authentication and confidence-building measures ultimately were selected which, in combination, are pragmatic and technically strong.

The authentication and confidence-building measures involve:

- Provision of IAEA validated and controlled calorimeter-operating hardware and software,
- Calorimeter measurement of certified IAEA standards,
- Sealing of calorimeter and pre-equilibration bath chambers, and
- Limited destructive analyses of IAEA-selected items following calorimeter verification.

Monitoring of calorimeter function during verification measurements also provides a level of assurance to IAEA.

The implemention of shared IAEA use of operator calorimetry is proceeding. Calorimeter control hardware and software (including software documentation) for the operator and IAEA are designed and completed. Calorimeter and pre-equilibration bath sealing accommodations have been made. Acceptance testing at the Hanford site will occur soon after the software validation by IAEA is complete.

Blendpoint Monitoring Experiments at Portsmouth Gaseous Diffusion Plant

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In December 1996, experiments were conducted at the Portsmouth Gaseous Diffusion Plant to test two neutron-based methods for monitoring the downblending of highly enriched uranium (HEU). The goal of the experiments was to test and evaluate the neutron-based methods under realistic plant operating conditions, including cell-operating temperatures from 140°F to 180°F. The equipment for the experiments was set up on two pipes carrying UF_6 gas being blended as part of the program to reduce the inventory of excess U.S. HEU.

Results of the initial experiments showed that gas (on-off) could be detected, but that additional tests and data are needed to quantify the flow velocity and ^{235}U content. Future work also must accommodate the dynamic operating conditions in the plant and reduce the neutron-background counts rate.

The experiments at Portsmouth Gaseous Diffusion Plant used a ^{252}Cf neutron source to induce fission in a small fraction of the ^{235}U contained in the UF_6 gas. The first method measured the attenuation of neutrons passing through the low-pressure (5 mm Hg) UF_6 gas in the 3-inch-diameter HEU feed pipe. The concept was based on the fact that some of the thermal neutrons are absorbed by ^{235}U, changing the observed count rate.

Experimental results showed changes in the count rate as HEU gas was repeatedly removed from the pipe by valving off the supply of HEU being blended. However, the changes observed were larger than expected, indicating that more than just the small amount of HEU gas in the pipe was changing during the experiment. Possibly, the effect also was a result of decomposition of uranium deposits on the walls of the pipe changing.

The second method, which used a modulated neutron flux to induce fission in the ^{235}U, was tested on an 8-inch-diameter low enriched uranium pipe with higher gas pressure (57 mm Hg). Modulation was achieved by moving a neutron source near the pipe and then away.

The resultant fission products drifted downstream with the gas flow, and some of them emitted delayed neutrons near a detector located about three meters downstream. The detected signal's amplitude is proportional to the ^{235}U content, and the phase shift, relative to the source modulation, gives the flow velocity. Results of the test indicated that better neutron shielding was needed to isolate the neutron source from the detector. The background counts in the detectors were too high to allow the expected small signal to be observed.

Additional work will be required to validate the methods for monitoring HEU blending. The next steps include additional data analysis, consultation with Portsmouth on the experimental results and dynamics of the enrichment cascade, computer simulations of enhanced neutron shielding, and possible collection of additional experimental data.

Lessons Learned

- Operating parameters at Portsmouth are dynamic and can introduce significant uncontrolled variables into the measurements.
- Support and cooperation of the site personnel is essential for early success.
- Plant operating parameters may vary over short periods (15 minutes), making calibration difficult; long runs to reduce statistical variations may not be practical.
- Robust equipment was demonstrated that would work for extended periods of unattended operation.
- Neutron background from the source needs to be reduced to allow the delayed-radiation signal to be detected.

Current Applications of Remote Monitoring

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A remote monitoring system provides three functions: unattended monitoring, local and global communication, and information management. Remote monitoring systems and technology can be applied to the safeguarding and inspection of nuclear materials. To be widely accepted and applied, remote monitoring must provide beneficial solutions to a wide variety of nuclear-materials monitoring scenarios. These monitoring needs exist for different materials, including plutonium, highly enriched uranium (HEU), metals, oxides, classified parts, and unclassified bulk material. These monitoring needs exist for the full lifecycle of storage, transportation, and processing.

Benefits of remote monitoring are expected to be realized by all involved parties. The inspection agencies should have lower costs with fewer onsite inspections and improved efficiency. The facility operators should have reduced intrusiveness and decreased costs. There should be reduced radiation exposure for workers and inspectors. Remote monitoring should promote increased openness and transparency and build international confidence.

Field Experience with Remote Monitoring Systems

Remote monitoring is not yet approved for routine use in International Atomic Energy Agency (IAEA) safeguards. However, there is a joint U.S.-IAEA field trial of remote monitoring with U.S. excess fissile material at the Oak Ridge HEU storage vault that is under IAEA safeguards. The objectives of this field trial are to identify the optimal sensor set, evaluate telephone vs. satellite data transmission, evaluate sensor-triggered video recording, define end-to-end data authentication, and obtain IAEA assessment of system acceptability for routine inspection use. This field trial with IAEA participation is especially valuable because it is providing hands-on experience for inspectors and direct user feedback for system providers.

The Oak Ridge physical configuration is HEU metal ingots inside stainless-steel cans placed in tray positions in long drawers inserted in horizontal tubes inside a wall-containment structure. The sensor set under evaluation includes fiber-optic seals on the drawer closure mechanism, item motion sensors on the front and rear of each drawer, electronic tags on each can, and gamma-radiation detectors adjacent to each can. Two video systems provide sensor-triggered and time-interval recordings. The field trial began in October 1996 and concludes in June 1997.

Expectations Related to Excess Fissile Materials

Most of the international remote monitoring experiments have been conducted at facilities for static temporary or long-term storage. These field trials have demonstrated that there is technology available for the remote monitoring of the containment and surveillance of some nuclear materials in storage.

Remote monitoring of material transportation activities continues to be demonstrated and evaluated. This category can be divided into two types: material movement within a closed site and material transportation on a national or global scale. The least amount of field experience is with nuclear material processing activities. This includes the HEU downblending and plutonium stabilization processes that are expected to be major activities for excess fissile materials prior to interim storage and as part of final disposition.

All international remote-monitoring experiments have been conducted using nonsensitive enriched-uranium materials. A major issue related to the monitoring of plutonium materials is the potential release and proliferation of nuclear-weapons design information. Possible technical solutions to this policy barrier to international safeguarding of sensitive materials include limiting the spectral resolution of the radiation instrument, processing the material to remove the sensitive information before placing the material under safeguards, and defining an alternative set of measurements that are acceptable for safeguards use.

Further Development in Remote Monitoring Technologies

The ongoing field trials and new applications have identified some gaps in and the need for further development of remote monitoring system technologies. For sensors, the optimization of packaging, power, sensitivity, size, and weight is needed; in video, improved image compression and image processing will be useful; and new radiation detectors, chemical microsensors, and microelectromechanical devices should be valuable for remote monitoring.

In local communications, new products for radio-frequency and fiber-optic networks will be useful, and improved network management tools are needed. In global communications, an Internet solution with adequate data security should be a future option. For information management, higher level data-analysis packages are needed for safeguards applications, and efficient central monitoring stations will be essential for remote monitoring implementation. Improved unclassified, exportable information surety and security systems will help gain approval for offsite data transmission.

Summary

Experiments have demonstrated that remote monitoring is a useful tool for safeguarding fissile materials. Significant work remains to fill some technology gaps, optimize its effectiveness and efficiency for safeguards use, resolve methods for sensitive materials, and modify and adopt criteria for remote monitoring. Remote monitoring implementation for routine use will begin soon, and is here to stay.

Nonintrusive Monitoring Technologies

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The materials declared excess to defense needs in the United States include classified and unclassified materials, and the United States has endorsed inspections of these materials by the International Atomic Energy Agency (IAEA). The most challenging and difficult problems to enable IAEA inspections involve approaches to verification of classified nuclear components or materials.

The protection of classified information is an essential requirement for international inspections. Yet, virtually all currently available measurements reveal classified information if used on weapons or components. New, nonintrusive verification technologies and monitoring approaches will be necessary to resolve this problem. To date, such technologies and approaches have not been developed and the impacts on national security have not been assessed.

Excess Materials and IAEA Safeguards

Traditional IAEA safeguards are based on materials accounting; when the material is placed into safeguards, this includes measuring the item's mass and taking samples for destructive analysis. The key issue for placing classified materials under IAEA monitoring is the conflict between traditional IAEA materials accounting procedures and U.S. classification laws and nonproliferation commitments that require mass and other weapons-design information be protected. As a consequence, traditional IAEA safeguards must be precluded as a viable option for classified materials.

Nonintrusive Monitoring Approach

To date, the scope and objectives of nonintrusive IAEA monitoring have not been defined. Nor have the attributes been specified that would provide the required confidence in verification. The technical challenge is to create a credible inspection approach acceptable to IAEA, where classified components can be nonintrusively monitored by IAEA without revealing classified information. The application of inspections based on nonintrusive monitoring of specified attributes that are selected to limit information because of classification will present a number of issues, such as:

- Verifying items with an acceptable level of confidence,
- Addressing a detected anomaly,
- Demonstrating transparency, and
- Obtaining acceptance from the international community.

Three possible approaches to implement nonintrusive IAEA monitoring of classified materials are:

1. IAEA item accountancy, with no verification, followed by containment and surveillance (C/S) to track containers of classified materials. This approach minimizes the delay in submitting classified material to international inspections, assuming IAEA accepts the approach. This approach provides no confidence that items are as declared, resulting in limited transparency; it is significantly limited relative to traditional safeguards applied to civilian material in non-nuclear weapons states (NNWSs); and raises the issue of acceptance by the international community.
2. Allowing IAEA to perform nonquantitative attribute measurements to verify and provide acceptable confidence that items contain weapons-component materials, followed by item accountancy and C/S. Attribute measurements, if approved, have the potential to provide assurance that the material is as declared, without releasing design information.
3. Allowing approved inspectors from Russia or other nuclear weapons states (NWSs), to certify the initial inventory using agreed-upon verification techniques on weapons components and classified materials, followed by IAEA item accountancy and C/S. To allow bilateral certification of classified items requires that all the legal mechanisms are in place to allow sensitive information exchanges between the United States and selected NWSs. Cooperation agreements between each of the selected NWSs would need to be established and would require congressional action in each of the countries. In addition, sharing sensitive weapons-design information with other NWSs could proliferate advanced design information to arguably less advanced NWSs. IAEA would be required to accept, without verification, that items are as declared.

These approaches must be balanced with the ultimate objectives and goals for international inspections without adversely affecting U.S. national security. Specific concerns with each approach may include potential claims of complicity between NWSs and claims of limited international transparency brought by the NNWSs.

Establishing a credible chain-of-custody for classified material, based on nonintrusive monitoring and C/S, will be critical to achieve the goal of transparency and irreversibility. As processing facilities become operative and classified items are processed to unclassified forms, the material can transition from nonintrusive IAEA monitoring to traditional safeguards inspections.

Nonintrusive Monitoring Technologies

The prospects for monitoring depend upon developing key technologies that provide nonintrusive verification of selected attributes. At present, a number of technologies have been proposed but remain unproved and will need a detailed review for classification issues and impacts to national security.

One technology, for example, is based on a single-channel energy-range measurement using low-resolution gamma-ray spectroscopy. This technology was incorporated in the NAVI-2 instrument and is designed to limit the information attainable by inspectors. The NAVI-2 was developed to specifically address U.S. classification guidance with respect to measurements of weapons. This technology has not been proven, but the NAVI-2 has passed a U.S. Department of Energy classification review for its "yes/no" mode of operation for detecting plutonium using the 400-keV complex.

In particular, the acceptability of using the NAVI-2 to measure an isolated component in a storage container has not been addressed. The caveats are that classified information must not be revealed by the measurement, and the gamma-ray energy region chosen must be less than 300 keV. Desirable choices for the single-channel energy range is the region containing the 186-keV ^{235}U line for uranium and the 400-keV complex for plutonium (which is above 300 keV). Difficulties exist using this technique in trying to protect sensitive information about uranium components because of the prominence of the 186-keV ^{235}U line. Plutonium is easier because of the abundance of gamma-ray lines, which are not resolved in low-resolution spectroscopy.

Conclusion

The materials declared excess to defense needs in the United States include classified and unclassified materials; the most challenging and difficult problems involve approaches to inspections of classified materials. Traditional IAEA safeguards must be precluded as a viable approach for inspections of classified materials.

The scope and objectives of nonintrusive IAEA monitoring have not been defined, nor have the attributes for verification been specified. Key technologies must be developed that provide nonintrusive verification of selected attributes without revealing classified or sensitive information. The context in which these technologies might be used will need a detailed classification review. If technologies are proven, it may be possible to place classified weapons-component materials, such as pits and secondaries, under a nonintrusive IAEA monitoring approach.

Advanced Nonintrusive Containment and Surveillance Technologies

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In the application of normal safeguards, the International Atomic Energy Agency (IAEA) uses material accountancy as a safeguards measure of fundamental importance, with containment and surveillance (C/S) as important complementary measures. C/S is a technology area that provides continuity of knowledge during periods of inspector absence for materials under safeguards. C/S provides information to verify declared operations by the facility operator, as well as information relating to undeclared operations. C/S uses facility features for containment and includes the use of seals, cameras, detectors, and other technologies to acquire data. Techniques to provide tamper protection for equipment and data are important elements of C/S.

C/S technologies vary. There are systems that are basically static and provide passive data, such as a seal system; systems that collect and store data on sight, such as a video-surveillance system; and systems that can transfer data off site, such as is accomplished with remote monitoring. The IAEA possesses and applies C/S technologies as appropriate to material in storage, transportation, and processing.

Generally, IAEA will install its own C/S equipment at a facility. However, it is not uncommon for IAEA to use operator-supplied equipment, provided that IAEA can be assured that the data used from such systems is authentic and can be trusted. In some cases, operator-supplied equipment has more than one purpose. It might be used to provide information for IAEA C/S purposes, as well as information useful for secure facility operations.

In the previously mentioned context of C/S in normal IAEA safeguards, the purpose of C/S in a verification regime for excess fissile materials is the same. C/S technologies will provide continuity of knowledge during periods of inspector absence. Such knowledge could reflect facility operations or could provide information about an item or a process.

The initial emphasis for the international inspection of excess fissile materials will be for materials in storage, because the disposition of such materials is not expected to begin for several years. Some of the materials could be classified, such as pits from dismantled weapons; other materials could be nonsensitive, such as plutonium-oxide product from the stabilization processes.

With such an emphasis, C/S can provide, with confidence, item monitoring and accountancy of storage containers. It is not normally envisioned as providing information that can be used to verify the contents of a container.

Nonintrusiveness

Nonintrusiveness has different meanings, and likewise exhibits different degrees. For C/S equipment, it can enjoy the label of nonintrusiveness if several things are considered. First, the impact on facility operations has to be considered. If, after the C/S system is installed, the facility operator can perform functions in a normal way without interference, nonintrusiveness is accomplished. Nonintrusiveness also is accomplished if the installed C/S system reduces the frequency of facility visits required by the inspector.

Finally, nonintrusiveness is realized if the installed C/S system can provide information that can be used for purposes other than C/S, such as safety and security.

A Systems Approach

The availability of today's technologies, coupled with the rapid advances in the fields of sensor development, information management, and information dissemination, allows for a comprehensive systems approach for the safe, secure, and international accountability of excess fissile materials in storage. This systems approach also can be considered in future stages such as the transportation of material from storage facilities to and through the stages of disposition. This systems approach is shown in Figure 1.

Shown in this concept is a multipurpose monitoring system with the dissemination of information on a need-to-know basis to different end users. Likewise, implicit in this systems approach is the ability to monitor material for purposes of safety, security and international accountability. This is true whether the material is in storage, transportation, or processing. For our purposes, processing covers the various possibilities of the disposition alternatives.

Figure 1. Comprehensive systems approach

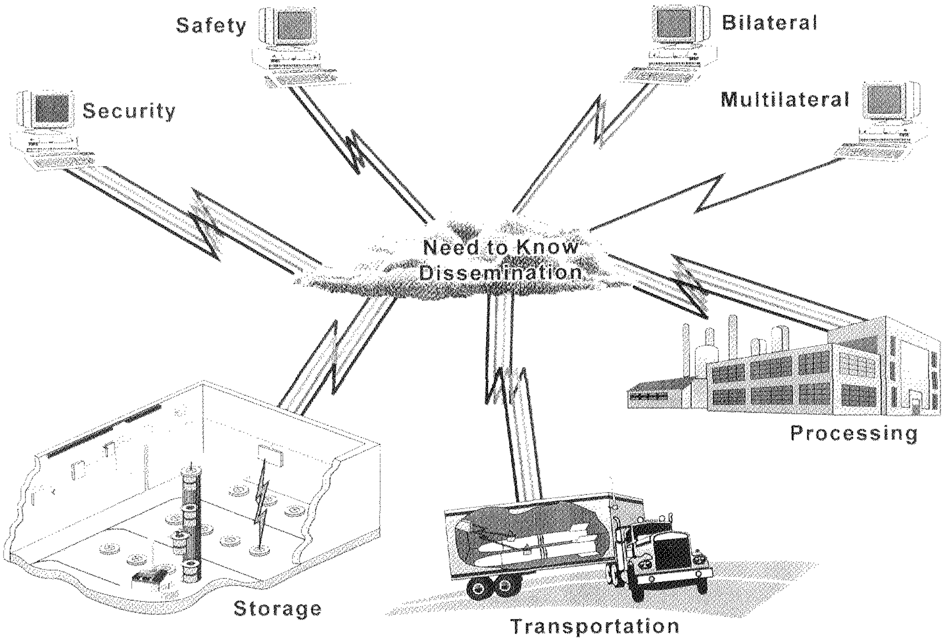
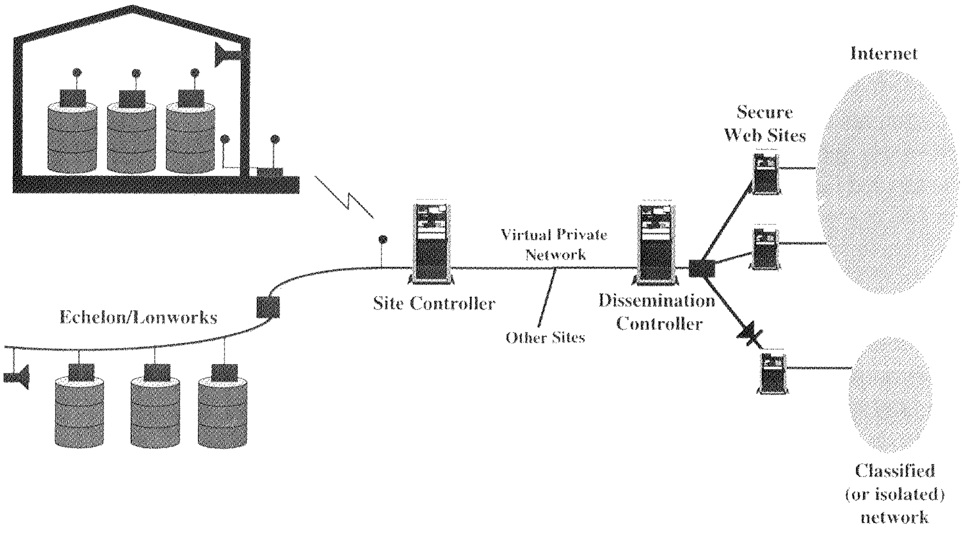


Figure 2. A modular, flexible storage monitoring system



Modularity and Flexibility

An excellent example for the need for modularity and flexibility in a C/S system envisioned to support the international inspections of excess fissile materials is the availability of electrical power to support the monitoring system. Although it is assumed that power will be available on site, some storage areas have no power. Shown in Figure 2 is a concept that allows for the integrated use of technologies, some of which require power and some that use batteries.

Details of this concept are shown in Figure 3. The data and information collected by the sensor subsystems can be disseminated on the World Wide Web to different end users on a need-to-know basis, as depicted in Figure 4. Plans are under way to demonstrate, at an operational storage site, the modular, flexible system in fiscal year 1998.

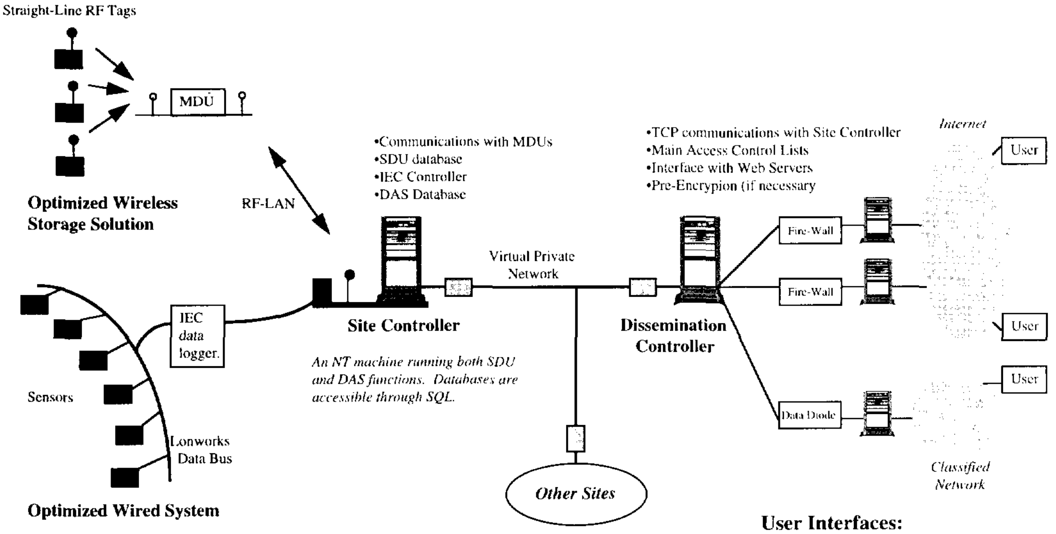
Research and Development Challenges

The major thrust in research and development associated with this comprehensive system approach is to reduce cost and enhance maintainability of the system. Sensor technology is being pursued to reduce the size and cost by using microelectronic technology. This approach is referred to as "developing sensors on a chip." Modularity allows prototypic sensors to be evaluated, as well as to exercise the system architecture. Improvements made in sensor technologies can be added and evaluated. For battery-operated components or subsystems, advances in power management also are needed to prolong battery life.

Summary

There exist technologies, and there is research and development under way, that will allow for the implementation of a comprehensive, nonintrusive C/S system to support, in a cost-effective manner, the international inspection of excess fissile materials. The details of the system will obviously be dependent upon what is negotiated under the auspices of the U.S.-Russian-IAEA trilateral initiative.

Figure 3. Details of a modular, flexible storage monitoring system



An NT machine running both SDU and DAS functions. Databases are accessible through SQL.

INuMM & 2-Way RF

To effectively communicate with the INuMM hardware, a new MDU or IEC data logger will be needed. This new device may need the MDU's ability to operate via solar power. It will also incorporate the IEC's ability for bi-directional sensor communication

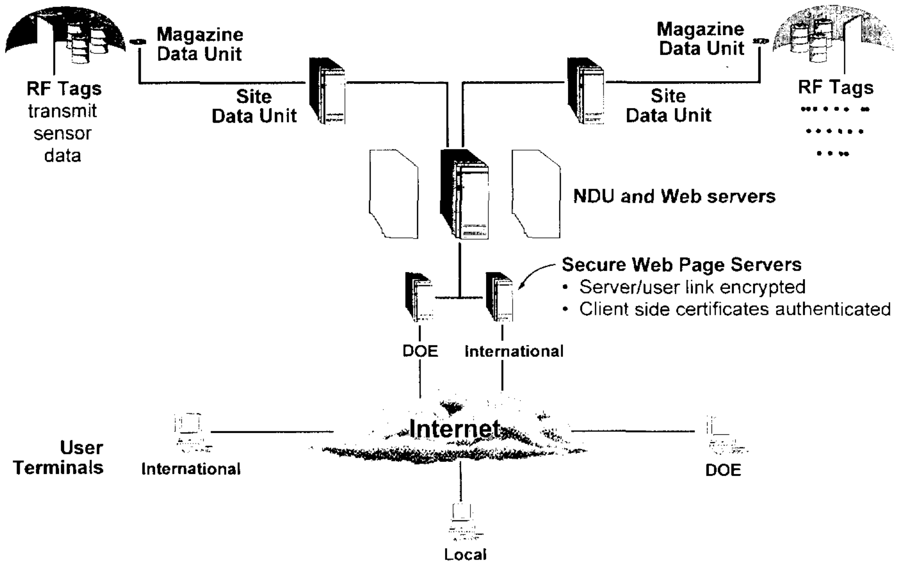
The system can be used for single or multiple sites. For single sites, the dissemination controller and site controller can be in the same room, or perhaps the same computer.

User Interfaces:

For "Real-Time" data, the dynamic Straight-Line web page is used.

For reviewing data, the user will use a web page to download the latest data file. A special file extension will be assigned to this data file, and will cause the browser to call a special helper application (the current review software)

Figure 4. Need-to-know information dissemination



ARIES Fully Integrated and Automated Nuclear Material Assay System

■

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The Advanced Retirement and Integrated Extraction System (ARIES) mission involves the demonstration of advanced technologies for the integrated dismantlement of surplus nuclear-weapon components (pits) and the packaging of the recovered plutonium into long-term storage containers. The unclassified plutonium product is suitable for traditional international safeguards, as well as other potential inspection regimes.

As indicated in the recent secretary of energy's record of decision (ROD), this unclassified excess material is anticipated to be offered for international safeguards under the U.S. Voluntary Offer Safeguards Agreements (INFCIRC/288) performed by the International Atomic Energy Agency (IAEA).

The ARIES nondestructive assay (NDA) suite offers state-of-the-art capabilities that provide highly accurate, precise material assay meeting IAEA bias-defect measurement levels. Because of these levels of performance, the requirement of destructive analysis is largely removed.

The unique combination of automation and high accuracy suggests the possibility of dual-use, operator-owned, IAEA-authenticated instrumentation. The concept of continuous unattended monitoring for international safeguards applications with the ARIES NDA suite is intriguing and may encourage additional deployments of similar NDA systems elsewhere within the U.S. Department of Energy (DOE) complex.

ARIES Process and Disposition

The ARIES system, supported by the DOE Office of Fissile Material Disposition, is designed to integrate disassembly and conversion of surplus pits (those excess to defense needs) into a stable unclassified form. The ARIES system consists of a number of subsystems: pit bisection, plutonium removal via a hydride-dehydride process resulting in a metal ingot, casting of the plutonium into a nominal mass, and possible conversion to oxide. At this point, the material is effectively unclassified with a nominal mass and form.

The final product is then packaged and placed into a long-term storage container that meets the 3013 storage standard and is decontaminated before NDA assay. Following the ARIES NDA suite assay, the container is ready for interim storage and ultimate disposition, both of which are anticipated to be under international safeguards. The disposition options announced by the secretary of energy's January 1997 ROD include reactor burning and immobilization, with final placement into an underground repository.

According to various presidential announcements and directives, U.S. policy is to place excess fissile materials under international safeguards subject to classification limitations and national security needs. Hence, the plutonium output from the ARIES process is anticipated to be offered for international safeguards.

ARIES NDA Suite

The ARIES NDA consists of four computer-based NDA instruments integrated with a host computer and a robotic handling system. The integrated ARIES NDA suite is designed to measure all ARIES products and wastes contained in the specialized 3,013 contamination-free, stainless-steel containers.

The NDA assay instrumentation consists of a gamma spectrometer for determining the plutonium isotopics, a segmented gamma scanner for waste assay, a neutron counter for waste and product assay, and a calorimeter for high-precision assay. A key component of the system is the extensive use of automation and robotics for sample handling. These features are anticipated to increase throughput and reduce radiation exposure, while maintaining the highest standards of material accounting and control. The system capabilities and designed features are indicated in Table 1.

The gamma-isotopic measurement combined with calorimetry or neutron-counting data provides the total plutonium mass of a container. Together, the techniques offer complementary assay with high assurance. The ARIES neutron counter can measure products and wastes, primarily through passive modes through coincidence counting or multiplicity analysis to correct from matrix effects.

Active interrogation can be used for measurements of uranium or where contamination is problematic. Calorimetry measures the heat produced by alpha decay and is proportional to the mass. Calorimetric assay is the most precise and accurate for the plutonium product (greater than 100 grams).

The ARIES NDA suite is strongly leveraged on existing

Table 1. Materials Measurement Methods

		Measurement Method				
					Neutron	
Item Measured	Amount of SNM	SGS	Cal	Pu Iso	Passive	Active
Pu-metal product	>100 g Pu		X	X	X	
Pu-contaminated w/Be	<10 g Pu	X		X	X	
Pu-contaminated high-density waste	<50 g Pu			X	X	
Pu-contaminated low-density waste	<50 g Pu	X		X	X	
Uranium	>0.5 kg U				X	X
U-contaminated low-density waste	<50 g U	X				

Table 2. ARIES NDA Suite: Precision and Bias

	Calorimetry — Pu Iso		Neutron — Pu Iso	
Instrument	Precision (%)	Bias (%)	Precision (%)	Bias (%)
Calorimeter	0.25	0.08		
Gamma spec P_{eff}	0.25	0.11		
Neutron counts			0.25	0.10
Gamma spec - ${}^{240}Pu_{eff}$			2.00	0.14
Overall precision and bias	0.35	0.20	2.00	0.25

technology and extensive measurement experience. All instruments are of proven NDA designs largely developed at Los Alamos National Laboratory and in use throughout the world, both internationally by IAEA and at the DOE complex.

Inventory Differences

Experience with multiple processes at the Los Alamos Plutonium Facility indicates that inventory differences (IDs) are largely driven by NDA measurement biases. For comparison purposes, the Los Alamos plutonium casting process is similar to ARIES, i.e., high throughput and low wastes.

The IDs for casting are small, on the order of a few tenths of a percent. Hence, the anticipated IDs for the ARIES process should be comparable to those observed for the casting process. Any biases will become apparent as measurements are compared to external audits or other facilities. A standards-based measurement program also serves to minimize IDs and allow continuous assessment of process IDs. Table 2 summarizes the expected measurement uncertainties for the ARIES NDA suite.

Conclusion

The ARIES process converts classified nuclear-weapon components to unclassified plutonium forms in standard containers. The forms and containers potentially could be offered to IAEA for international safeguards in alignment with current U.S. policy.

The ARIES instrumentation suite offers true standardized state-of-the-art NDA assay capabilities to minimize inventory differences for the ARIES process. The ARIES NDA suite enables high-quality materials accountancy where high accuracy significantly reduces needs for destructive analysis. Importantly, the material assay precision is such that it meets the IAEA bias defect measurement criterion.

Record of Decision and the U.S. Program for Plutonium Disposition

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Surplus of Weapons-Usable Fissile Material

Within the U.S. Department of Energy (DOE), the Office of Fissile Materials Disposition administers a key national-security program focused on implementing a path forward for the verifiable storage and disposition of U.S. weapons-grade fissile materials and providing technical support for administration efforts to attain reciprocal actions for the disposition of surplus Russian plutonium.

In the aftermath of the Cold War, significant quantities of weapons-usable fissile materials, primarily plutonium and highly enriched uranium (HEU), have become surplus to defense needs in the United States and Russia. President Clinton announced in 1995 that approximately 200 metric tons of U.S. weapons-grade fissile materials had been declared surplus to U.S. defense needs.

Less than a year later, the secretary of energy's Openness Initiative announcement of February 6, 1996, stated that the United States has more than 213 metric tons of surplus fissile materials, of which approximately 174 metric tons are HEU and approximately 38 metric tons are weapons-grade plutonium. In anticipation that additional quantities of plutonium may be declared surplus, the DOE has assumed that a nominal amount of 50 metric tons of plutonium will require disposition.

Record of Decision

In January 1997, the DOE issued a record of decision (ROD) that outlines the storage and disposition of weapons-usable fissile materials. The storage decision calls for reducing from seven to three the number of sites where surplus nuclear weapons materials are stored. The disposition decision also calls for pursuing immobilization of surplus plutonium in glass or ceramic forms and burning some of the surplus plutonium as mixed oxide (MOX) fuel in existing reactors.

Initial efforts to implement the storage decision will involve upgrading and expanding existing facilities and constructing new facilities at the Pantex plant and Savannah River site, and continuing the storage of weapons-usable HEU at the Oak Ridge Y-12 plant in upgraded and consolidated facilities. The pits at Rocky Flats Environmental Technology Site (RFETS) will be shipped to the Pantex plant starting in 1997.

After certain conditions are met, the nonpit plutonium now stored at the RFETS will be moved to Pantex and Savannah River. Plutonium currently stored at the Hanford site, Idaho National Engineering and Environmental Laboratory, and Los Alamos National Laboratory will remain at those sites pending disposition.

In deciding upon disposition approaches, it was important that plutonium be converted to forms that meet the spent-fuel standard, as set forth by the National Academy of Sciences, which requires that plutonium should be made as inaccessible and unattractive for use in nuclear weapons as the residual plutonium in commercial spent fuel. Both of the disposition approaches identified in the ROD will convert weapons-usable plutonium into disposition forms that will meet the spent-fuel standard.

At least eight metric tons of surplus plutonium will be immobilized because it is not suitable for use in MOX fuel without costly and extensive purification. For the remaining surplus plutonium, the timing and extent to which the immobilization approach or a combination of both approaches is ultimately deployed will depend on follow-up work to resolve technical, institutional, cost and international issues.

The ROD did not identify specific sites that would host disposition activities. Supporting actions and subsequent site-specific National Environmental Policy Act analyses are required to select the sites for implementation of disposition technologies.

Surplus plutonium exists in a variety of forms and must be converted to an oxide form for either disposition approach. The DOE is developing and testing a prototype integrated system — Advanced Recovery and Integrated Extraction System (ARIES) — that disassembles plutonium-weapons components and converts the plutonium to stable, inspectable oxides or metals.

Nonpit plutonium forms will be converted to oxides using predominantly dry-processing approaches and with minimal removal of impurities. This front-end processing for converting the variety of surplus plutonium forms to an oxide suitable as feed to the disposition technologies contributes to a significant portion of resources required for the overall disposition effort.

Cooperative Efforts

In addition to domestic-based activities, the Clinton administration is committed to working cooperatively with Russia on programs to facilitate the elimination of fissile materials suitable for use in nuclear weapons. Efforts will build on the recently completed Joint U.S.-Russian Plutonium Disposition Study and include a series of analyses and small-scale tests and demonstrations of disposition technologies.

The United States also proposes to jointly develop a plutonium pit disassembly and conversion and nondestructive assay pilot plant in Russia. The objective is to have the United States and Russia demilitarizing and converting surplus plutonium from pits on a pilot scale, and placing the resulting material under an international safeguards regime within a few years.

Nonproliferation and Arms-Control Assessment of Weapons-Usable Fissile Materials Storage and Excess Plutonium Disposition

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The U.S. Department of Energy (DOE) published a Nonproliferation and Arms-Control Assessment of disposition alternatives for excess plutonium in January 1997 to support the Record of Decision on the Storage and Disposition of Weapons-Usable Fissile Materials PEIS, which was issued by Secretary of Energy Hazel O'Leary on January 14, 1997.

The assessment's primary focus is on the potential benefits and vulnerabilities associated with the alternatives under consideration for excess plutonium disposition and possible steps to maximize the benefits and minimize the vulnerabilities. A brief description of program objectives and factors for analysis are included in this paper.

Plutonium Disposition Background and Objectives

Plutonium and highly enriched uranium (HEU) are the essential ingredients of nuclear weapons. Several kilograms of plutonium, or several times the amount of HEU, is enough to make a nuclear bomb. With access to sufficient quantities of these materials, most nations and even some subnational groups would be technically capable of producing a nuclear weapon. Therefore, controls on access to these materials are the primary technical barrier to nuclear proliferation in the world.

Yet, since the collapse of the Soviet Union, international authorities have confirmed several cases of theft of weapons-usable nuclear materials, leading the director of central intelligence to warn that these materials are more available than ever before in history. The United States and Russia each have hundreds of tons of excess material.

Disposition of excess plutonium poses more complex challenges than disposition of excess HEU. HEU can be blended with non-chain-reacting U-238 to produce low-enriched uranium (LEU), which is a valuable commercial fuel for nuclear power reactors and cannot be used to make nuclear weapons without complex and technologically demanding re-enrichment. The United States has agreed to purchase LEU blended from 500 tons of Russian excess HEU, for sale on the commercial market, through the next 20 years, and has announced similar plans to blend down its own excess HEU.

It is assumed that excess and nonexcess HEU will have been relocated to the Oak Ridge Reservation before any action is taken under PEIS. All of the actions taken with respect to HEU will be accomplished according to strict DOE security and safeguards procedures.

Because nearly all isotopes of plutonium can be used in nuclear weapons, weapons plutonium cannot simply be blended with other plutonium to make it unusable in nuclear weapons. Separating plutonium from other elements mixed with it or from irradiated reactor fuel containing plutonium requires only well-understood chemical processing techniques, which are within the capability of many states and even subnational groups.

Moreover, plutonium's toxicity and the need for stringent security and safeguards during handling makes it more expensive to fabricate reactor fuel from plutonium than to buy uranium fuel on the commercial market, even if the plutonium itself is "free" (i.e., from excess weapons stockpiles). Hence, disposition of plutonium will cost the government hundreds of millions or even billions of dollars, whether it is used as reactor fuel or disposed as waste.

The United States does not encourage civilians to use plutonium and does not itself engage in reprocessing for the purposes of either nuclear explosives or nuclear-power generation. Disposition of excess plutonium, regardless of the specific option chosen, will not change this basic fuel-cycle policy.

Any option chosen for plutonium disposition will be used only for the specific mission of addressing the security risks posed by the stockpiles of excess plutonium that already exist in the DOE inventory. No reprocessing or recycling of this material or of other civilian spent fuel is implied or contemplated. The licenses and approvals that will be sought for the facilities necessary for plutonium disposition will be limited specifically to that mission and will not authorize any broader civilian plutonium use.

Factors for Analysis

This assessment of the nonproliferation and arms-reduction implications of the storage and disposition alternatives under consideration is based on technical and policy factors.

Technical factors include:

- How rapidly the option could be implemented (time to start and time to finish), which determines how soon the benefits of plutonium disposition could be achieved. Time to start is particularly important in gaining domestic and international credibility and confidence in the disposition process.
- The degree to which the option could ensure that plutonium could not be stolen or diverted during the process by a host or subnational group, coming as close as possible to the degree of protection afforded for intact nuclear weapons.
- The degree to which the option would permit international monitoring to confirm U.S. commitments that excess fissile material will never again be used in weapons.
- The degree to which the option would result in a form that is as unattractive and inaccessible for the host government or a subnational group for use in weapons as plutonium in spent power reactor fuel, meeting the spent-fuel standard.

Policy factors include:

- The impact on Russian programs for disposing of surplus plutonium, which is a major motivation for U.S. action.
- The effect on nuclear-arms reduction efforts, including the extent to which U.S. decisions ensure the irreversibility of the arms-reduction process.
- The impact on nonproliferation efforts, such as demonstrating the U.S. commitment to its obligations to nuclear arms reduction under the Treaty on the Nonproliferation of Nuclear Weapons.
- The impact on fuel-cycle policy and choices by other nations, because the United States does not encourage civilian use of plutonium but seeks to eliminate excess stockpiles of HEU and plutonium.
- The political implementability of each alternative, because selecting an option with low chances for achieving success in a timely manner will affect all other policy factors.

Each of these technical and policy factors must be balanced in judging the relative nonproliferation and arms-reduction merits of each disposition alternative. Policy-makers must judge for themselves the relative importance of these differing criteria.

Near-Term Activities for Additional Excess Material

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In 1993, President Clinton committed to submit fissile material declared to be excess to national security needs to inspection by the International Atomic Energy Agency (IAEA). Building upon this commitment, in March 1995, President Clinton assigned the U.S. Department of Energy (DOE) with developing recommendations to maximize the amount of excess material under IAEA safeguards. These recommendations were approved by the National Security Council in September 1996. During the September 1996 IAEA General Conference in Vienna, Austria, Secretary of Energy Hazel O'Leary announced one of the recommendations: 26 metric tons would be made available during the next three years, in addition to the 12 metric tons already under IAEA safeguards.

The DOE International Safeguards Division is responsible for coordinating the implementation of these recommendations. Near-term implementation activities include updating the list of facilities eligible for the application of international safeguards to reflect the portion of the 200 metric tons of excess material in unclassified forms and coordinating efforts for the implementation of IAEA safeguards for highly enriched uranium (HEU) disposition activities.

Evaluation and Update Process

The evaluation and update of the list of facilities eligible for the application of international safeguards was a two-step process. The first step was to determine how much excess material was in facilities that were currently eligible. This determination was accomplished with the assistance of officials from the DOE Office of Defense Programs, who identified the nuclear-materials inventory listed under the reporting identification symbols (RIS) contained in the Nuclear Materials Management and Safeguards System (NMMSS) database for the facilities on the eligible- facility list.

These inventory listings then were provided by the International Safeguards Division to the DOE operations offices so that they could, in turn, work with DOE operating contractors to correlate the inventory listing to the facilities on the eligible list. When the data returned from the operations office, reviewers identified approximately 15 metric tons of excess materials, in addition to the 12 metric tons currently under safeguards, in facilities eligible for the application of international safeguards.

The second step of the evaluation-and-update process involved obtaining an inventory listing of the 200 metric tons of excess material and identifying the locations where the materials were stored. In November 1996, the DOE Office of Defense Programs provided to the International Safeguards Division an inventory list, derived from NMMSS data, of the 200 metric tons of excess material. This master inventory list was provided to DOE operations offices in December 1996 with instructions to work with DOE operating contractors to identify the storage location to the lowest level possible (i.e., vault, vault-type room), provide information on other materials stored in the same location that were not part of the 200 metric ton listing, and determine if access to these areas would result in the release of restricted data.

This information was due back to the International Safeguards Division in February 1997. The data will be used to update the eligible-facility list in coordination with the DOE program offices and the interagency Subgroup on the Implementation of IAEA Safeguards in the United States (SISUS), whose members include representatives from the Department of State, Arms Control and Disarmament Agency, Nuclear Regulatory Commission, and DOE.

As stated previously, O'Leary committed to making an additional 26 metric tons available for international safeguards in the next three years. The 26 metric tons of excess material include 13 metric tons of uranium hexafluoride at the Portsmouth plant, seven metric tons of HEU oxide at the Portsmouth plant, and six metric tons of HEU metal at the Y-12 plant. The facility at the Portsmouth plant, where the downblending of the 13 metric tons of uranium hexafluoride is taking place, is eligible for IAEA safeguards. U.S. officials added this facility to the eligible-facility list in April 1996.

Verification Experiment

In April 1996, the United States also proposed that IAEA engage in a verification experiment of the downblending operations; the United States would cover, at a minimum, the incremental costs of the experiment. As a result, a team from IAEA came to the United States for a technical meeting at the Portsmouth plant, April 25 - 26, 1996. Since that time, U.S. officials continue to work on preparations for the verification experiment in anticipation of IAEA participation.

DOE has identified a subject-matter expert to serve as a dedicated consultant to IAEA on Portsmouth and continued efforts to develop a downblending verification technology. DOE also is in the process of adding the uranium hexafluoride storage vault to the list of eligible facilities. Currently, only 10 metric tons of HEU remain, while downblending operations at Portsmouth continue with an increased rate because of additional refeed stations.

Schedule of Downblending Operations

The anticipated completion date for the downblending operations is August 1998. The storage facilities for the seven metric tons of HEU oxides at Portsmouth and six metric tons of HEU metal at the Y-12 plant are currently not eligible for IAEA safeguards. This material is part of the 50-metric-ton United States Enrichment Corp. (USEC) Memorandum of Agreement (MOA), which means that once the MOA is signed, the material will be downblended within 18 months of receipt at a commercial downblending facility.

Although it is anticipated that these materials will be stored in an eligible DOE facility before shipment, the application of IAEA safeguards to these materials at DOE facilities are not preferable for many reasons, including the lack of adequate sampling capability. Because the commercial downblending facility that receives the material will be required to perform measurements and sampling, it may be optimal to involve IAEA in these activities to minimize operational impact.

Other materials scheduled for downblending in the near term include 8.8 metric tons of HEU solution at the Savannah River site and 25 metric tons of HEU metal buttons and uranium-aluminum alloys at the Savannah River site and Y-12 plant. These materials are part of a memorandum of understanding between the DOE and the Tennessee Valley Authority to manufacture "off-spec" fuel for commercial power-reactor use. Downblending activities are anticipated to begin this year.

In conclusion, officials from several organizations are proceeding with activities on more than 60 metric tons of excess material. The DOE International Safeguards Division, as part of SISUS, is working with IAEA to focus on transparency during irreversibility (i.e., safeguards on the downblending process) through the next three years. The anticipated outcome is that a potential U.S.-IAEA effort on additional excess material could lead to the development of new verification measures for excess materials.

The Application of Remote Monitoring to Excess Fissile Materials

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The International Atomic Energy Agency (IAEA) is faced with the challenge of safeguarding an ever-increasing quantity of nuclear material with a zero-real-growth budget. At the same time, U.S. Department of Energy (DOE) officials are being asked to provide increased assurances that nuclear weapon states (NWSs) are not conducting undeclared nuclear activities. They also are initiating safeguards at a number of excess fissile material sites in the United States and potentially in other NWSs.

Remote monitoring provides a reliable and timely way of safeguarding declared material while reducing the number of IAEA routine onsite inspection resources. For the purposes of this paper, remote monitoring is defined as the transmission of sensor and other safeguards-relevant data from a nuclear facility to a location off site. The DOE is committed to the use of remote monitoring as an accepted IAEA safeguards measure.

Potential Advantages

Introduction of remote monitoring of excess fissile material in an NWS at facilities such as Oak Ridge, Hanford, Rocky Flats, and other sites offers the opportunity for an entirely new regime of safeguards. The new safeguards would be applied to material for which there is no precedence in international safeguards. They could involve highly classified material (until it is processed into an unclassified form) and be conducted in an open and cooperative atmosphere.

Thus, the decades-old safeguards concerns and measures may not be appropriate or necessary. There would be minimum concern about diversion by an NWS. The benefits of remote-monitoring systems include:

- Increased monitoring confidence through the provision of data to the inspectorate more frequently (on call vs. at intervals of a month or more) and randomly (anytime vs. fixed schedule);
- Reduced worker radiation exposure and reduced impact on facility operations; and
- Potential cost savings for the facility and inspectors through the reduction of onsite inspector presence, inspection activities requiring access to the materials, and reduced travel expenses.

Policy and Technical Issues

Adoption of remote monitoring by international agencies responsible for monitoring sites for nonproliferation purposes could not occur rapidly because of many technical and policy issues. Experience with these systems is essential before the stakeholders in international safeguards — NWS regulatory organizations, international monitoring organizations, inspectors, facility operators, and developers of the technology — can provide the technical data and policy guidance necessary for its routine acceptance.

To gain this experience, the DOE and its international partners initiated the International Remote Monitoring Project (IRMP) in 1993 to install demonstration systems in various nuclear facilities and conduct field trials of the technology. The project promotes the exchange of monitoring, data handling, and communication technology; installation and testing of such technology in various types of nuclear facilities; and collection and assessment of data obtained from the fielded systems.

In September 1995, the U.S. secretary of energy conducted a remote-monitoring demonstration for the IAEA General Conference in Vienna, Austria. By 1995, the demonstrations had successfully shown that remote monitoring offered a viable solution to improving monitoring confidence at a lower operating cost than onsite inspections.

Despite this progress, there still are policy and technical problems that need to be resolved, and cooperative and eager partners are willing to assist in progressing into an operational prototype phase. This is being accomplished through field trials of safeguards operational systems at the Y-12 facility; planned upgrades at the Embalse facility in Argentina, the Russian Federation, and other sites; and installations in South Africa and other sites.

It is DOE's expectation that fully operational remote-monitoring systems will be implemented by 1998, with acceptance of a variety of openness and transparency measures. Openness and transparency, including some form of short-notice inspections, are prerequisites to the implementation of remote monitoring in any NWS.

Because of the long-standing requirements for domestic safeguards and physical protection, the general construction of the storage sites with very secure vault construction will form the basis for an extremely simple remote-monitoring system. Monitoring all penetrations would seem to be the basic requirement at all of these facilities. This usually can be accomplished with inexpensive motion detectors, monitorable seals and, where necessary, optical surveillance.

In general, if the storage sites are declared to be inactive — or active only in the presence of an inspector — then the system configuration could become even simpler, while still maintaining all safeguards objectives. In considering remote monitoring of excess fissile material facilities, and its interface with domestic safeguards requirements, the potential exists to introduce a wide variety of physical protection heretofore not used in international safeguards, such as motion detectors, door switches, etc. Inclusion of several of these detectors in the networks used in the IRMP were introduced several years ago.

When considering the use of remote monitoring, it is necessary to evaluate a number of nontechnical: policy-related issues. There are critical elements of physical protection, classified information, and proprietary information that must be protected. The data to be transmitted does not include real-time, onsite classical verification data determined through measurements, although the results of these data likely will be entered into the remote-monitoring data bank to be used later for periodic comparisons. Virtually all elements of physical protection, directed at the protection of facilities from outside as well as inside threats, are considered very sensitive.

With remote monitoring, there now exists the possibility to have all of the data available to IAEA, regional authorities, NWS authorities, and facility operators. Because they all will have equal access to the data, it will be possible to easily resolve many of the anomalies by telephone or other real-time communications. Importance must be placed on achieving a very high level of data authentication, making certain, to the highest degree practical, that the data has not been altered.

Labor-union restrictions must be examined on a case-by-case basis. There are expected to be a wide range of situations that have an impact on the use of remote monitoring. The use of optical surveillance and the transmission of this data off site may be considered very sensitive.

Finally, it is not likely that remote monitoring can be used without significant cooperation from facility operators. This is particularly important in the areas of equipment installation and checkout, monitoring of the data, and resolution of anomalies.

Summary

In summary, a number of excess fissile material sites in the United States have been offered to be placed under IAEA safeguards. Remote monitoring provides a reliable and timely means of safeguarding declared material while reducing IAEA routine onsite inspection resources.

The DOE is committed to the use of remote monitoring as an accepted IAEA safeguards measure. Through the efforts of the DOE and its international partners, the viability of remote monitoring has been amply demonstrated in a number of facilities around the world. The stage has been set for moving into an operational prototype phase, with expectation of full implementation by 1998.

A key factor of such implementation will be the acceptance of various elements of openness and transparency, with some form of short-notice inspections. The introduction of remote monitoring to excess fissile material offers the opportunity for an entirely new regime of safeguards. In this regime, decades-old safeguards concerns and measures may not be appropriate or necessary.

Perspective and Review of Current Nonproliferation and Arms-Control Topics

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The 1990s have seen a tremendous transformation in the nonproliferation and arms-control landscape. The end of the Cold War meant the beginning of a new series of challenges relating to the security of nuclear weapons, fissile materials, chemical and biological agents, and related technologies. The break-up of the Soviet Union resulted in the de facto distribution of nuclear weapons and fissile materials in multiple, independent states as opposed to one. The emerging terrorist threat has been made more frightening by the possibility of terrorist acquisition of information, materials, and technology to make nuclear, chemical, and biological weapons. The bombing of the federal building in Oklahoma City, Oklahoma, and the Tokyo subway sarin incident showed that advanced countries were vulnerable to "home-grown" terrorist attack. The acceptance of the international safeguards regime, which had operated for nearly two decades, was challenged by the findings after the Persian Gulf War of nuclear, chemical, and biological warfare programs in Iraq, a country under International Atomic Energy Agency safeguards.

The responses to this evolving environment have been many: the Chemical Weapons Convention (CWC) and Comprehensive Test Ban have been completed, the Biological Weapons Convention is the subject of negotiations for improved compliance assurance, and the Nuclear Nonproliferation Treaty (NPT) has been indefinitely extended. At the same time that traditional, government-level instruments have received increased attention, there has evolved a need for faster, responsive, flexible, grass-roots types of nonproliferation programs. A case in point would be the joint international (U.S.-Russian) programs to address the security and safety of Russian fissile materials and nuclear plants. We can expect similar programs to be needed in any State where fundamental governmental controls and infrastructure are either threatened, compromised, or, worst-case, nonexistent.

These and additional nonproliferation and arms-control topics were discussed at a one-day INMM Special Session held February 21, 1997, in Washington, D.C. The session was well-attended and stimulated interesting discussions. I hope it served as a vehicle to provide interested and responsible parties with useful technical information, assumptions, and context. Below are summaries I have prepared for each presentation given. The session structure was such that administration and congressional nonproliferation and arms-control priorities were first described, followed by increasingly detailed specific topics and initiatives.

Clinton Administration Nonproliferation and Arms Control Priorities

John Holum
Director, Arms Control and Disarmament Agency

Holum summarized what President Clinton calls "the most ambitious agenda to dismantle and fight the spread of weapons of mass destruction since the atom was split."

START II cannot complete the two-thirds reduction in nuclear arsenals and eliminate the last of SS-18 missiles until it is ratified in Russia. Without START II, the United States is legally obligated to maintain START I force levels of 6,000 accountable weapons, i.e., about 8,500 warheads under the counting rules. To match that level would be prohibitively costly for Russia. With START II, however, Russia will have parity with the United States at 3,000 to 3,500 warheads; it is in Russia's interest to ratify. START II is the only door to START III.

One of the most urgent issues relating to nuclear arms control is the "loose nukes" problem, i.e., the potential for movement out of Russia of weapons program technologies, materials, and brainpower. The United States must "use all the diplomatic, technical, law enforcement, and other resources needed to make sure that brainpower is otherwise occupied and that materials are safeguarded until thay can be used up or rendered useless."

The NPT, our main tool against the spread of nuclear weapons, has been made permanent and its safeguards regime is being strengthened via IAEA's 93+2 Programme to make sure that nuclear weapons programs aren't concealed from inspectors. Further, Clinton has directed intensified efforts to negotiate a cutoff in production of fissile materials for weapons, our best hope of capping the nuclear weapon potential of countries outside the NPT and an arms-control measure to formally limit the nuclear weapon states.

The CWC is awaiting a vote by the U.S. Senate. Missing the

April 29, 1997, deadline for entry into force would send a strong negative message to the world and limit our role in implementation. The Biological Weapons Convention, which seriously needs strengthened compliance provisions, is the subject of negotiations in Geneva to exploit advances in technology that could make this treaty a much more effective instrument.

And, because they do so much damage every day, we cannot neglect conventional weapons such as antipersonnel landmines. Clinton is calling for negotiations to ban their use, stockpiling, production, and transfer — and we are dedicated to pursuing a global solution.

U.S. Congressional Nonproliferation and Arms Control Priorities

Zachary Davis
Congressional Research Service

In a presentation which was enlightening and entertaining, Davis described the structural, institutional, and political factors that make the Clinton administration's nonproliferation and arms control agenda a tough one for Congress. He first pointed out the overwhelming number of items Congress faces: the CWC, followed closely by the Comprehensive Test Ban Treaty, Conventional Forces in Europe and START, to which are added Nuclear Weapons Free Zones, China, North Korea, Iran, Iraq, Export Control, 93+2, etc. Even the experts cannot follow all of these carefully. In Congress, in the best of circumstances, members are overburdened with multiple memberships in committees and subcommittees. Members' and staff time is limited and no one can spend full time on nonproliferation and arms-control issues (even though they are dear to this community's heart).

Historically, Sens. Sam Nunn, John Glenn, and Richard Lugar had staff devoted to this area, but Nunn has recently retired, Glenn will follow this year, and Lugar will be hard-pressed to carry on effectively without help. Davis believes that the pressure to progress on these items must come through the "education, care, and feeding" of congressional members and staff by the executive branch and interested nongovernmental organizations.

Many members of Congress, including Lugar and Nunn, have reportedly come to believe that the agenda is too "cross-cutting and turf-cutting" to be handled effectively by the existing structure in the executive branch. Lugar is pushing for a nonproliferation and arms control "czar" at the National Security Council, someone who would be aware of and coordinate all the issues, including terrorism. The "old structures and old boundaries" don't fit the problem; especially when the "traditionally international" outlook runs up against efforts to address domestic threats.

The Cooperative Threat Reduction program (START implementation, MPC&A, HEU Purchase, etc.) has been fully funded by Congress and is seen as logical and persuasive, particularly because the linkage of expenditure to U.S. national security can be clearly made. Other items are not so easy for Congress to understand, e.g., warhead dismantlement transparency, irreversibility, core conversion, Mayak storage, two-track plutonium disposition decision, etc. Members become confused about the benefits for U.S. security when the community mixes "concepts with programs and facilities," e.g., irreversibility is a concept, while Mayak is a place/facility. Given limited time, appreciation for these items is hard to get without visible, tangible evidence of progress. Davis gave an example of photographs showing the U.S. secretary of defense standing over a destroyed missile silo as effective communication. Congress can't see irreversibility, so there is a big job ahead for the nonproliferation and arms control community to get its message through, particularly if it wants to "maintain substance and not be overrun by show."

Follow-up to Indefinite Extension of the Nuclear Nonproliferation Treaty

Lawrence Scheinman
Arms Control and Disarmament Agency

Scheinman presented a synopsis of activities and commitments consequent to the indefinite extension of the NPT. Two major items were discussed: strengthening the review process, which is institutionalized to take place every five years and decisions on principles, which are recommendations to promote full implementation of the treaty. There will be several preparatory commissions (strengthening the review process) to develop the procedural and organizational framework, as well as deal with substantive issues for the review in the year 2000. The first such commission will be in New York City, New York, in April 1997.

From the U.S. point of view, the focus of the review process must be the treaty itself rather than the agreed principles and objectives, which are an important reference point for that review. There were about 20 principles and objectives recommendations, of which Scheinman discussed five:

1. *Completion of a Comprehensive Test Ban Treaty by 1996.* This is a step in achieving Article VI of the NPT.
2. *Universal adherence to the NPT.* NPT nonparties Cuba and Brazil have signed the Treaty of Tlatelolco, leaving India, Pakistan, and Israel outside the NPT regime.
3. *Support for Nuclear Weapons Free Zones.* There are seven criteria for establishment of such zones, including requirements that the process be initiated within the region, that all affected states participate, and that the establishment of the zone not disturb existing security arrangements.
4. *Strengthening IAEA safeguards in the context of the NPT.* A main purpose of this is to increase confidence that NPT parties have about their neighbors. The United States is to set forth, by May 1997, what we will be able to do in this regard, particularly relating to comprehensive export/import measures.
5. *Disarmament.* The United States will continue its engagement in irreversible disarmament. This does not mean zero, yet, but it does mean movement in one direction only.

Scheinman elaborated on the last point to say that the United States awaits Russian ratification of START II and, thereafter, as Clinton and President Boris Yeltsin agreed in earlier summit meetings, will discuss further cuts and make deep reductions irreversible. However, disarmament cannot be achieved on demand or in a vacuum because the historical nuclear deterrent/umbrella represents a security structure that cannot be suddenly removed without supporting or substituting institutions in place. Hence, disarmament affects all NPT states and becomes a responsibility of all NPT states.

Russian Plutonium Production Reactor Conversion

Mike Stafford
U.S. State Department

Stafford gave a timely review of the latest U.S.- Russian Plutonium Production Reactor Shutdown/Conversion negotiations, from which he had returned at the end of January 1997. Before detailing the agreed provisions, he stressed the point that everything was subject to Russian review because, opposite U.S. practice, individual Russian negotiators may agree to text without having full government backing or commitment.

The purpose of the agreement being sought is to stop U.S. and Russian production of nuclear-weapons-grade plutonium by banning the restart of the production reactors that have been shut down and modifying the three reactors in Russia that are still operating so they no longer produce such plutonium. A "bonus" may be possible which prohibits the use in nuclear weapons of that plutonium produced in Russia after entry-into-force and before the full reactor conversion is complete.

Key elements of the pending agreement are: (1) shutdown reactors in the United States and Russia will never be restarted; (2) by the year 2000, the three operating production reactors at Tomsk and Krasnoyarsk will be modified so they no longer produce weapons-grade plutonium (defined within the text of the agreement); (3) modified reactors will shut down at the end of their normal lifetime, consistent with safety (approximately in 2006 or 2007); (4) plutonium produced after entry-into-force will not be used in nuclear weapons; (5) a Joint Implementation and Compliance Commission will be established to discuss additional measures or issues identified by either side; (6) shutdown reactors would be subject to monitoring by use of seals and devices to detect attempts to restart; and (7) modified reactors would be monitored to assure consistency with specifications of fresh fuel composition and spent fuel discharge schedules, to ensure that weapons-grade plutonium is not being produced.

Mutual Reciprocal Inspections

Guy Lunsford
U.S. Department of Defense

Progress in developing means to perform mutual reciprocal inspections (MRI) of U.S. and Russian excess nuclear weapons was summarized by Lunsford. This program had its start in March 1994 with agreements between the Russian Ministry of Atomic Energy (Minister Mikhailov) and the U.S. Department of Energy (Secretary O'Leary) and between Clinton and Yeltsin. The purpose is to "build confidence on both sides that excess material in a container came from dismantled nuclear weapons." During 1994, reciprocal visits at Seversk and Rocky Flats took place, as did some early U.S. and Russian inspection equipment tests on plutonium point source, disk, rod, and oxide samples.

Both plutonium and highly enriched uranium (HEU) are involved in MRI. A two-page nonpaper on HEU MRI was submitted to the Russians in June 1995, but the Russians have not provided a formal response. Every attempt is being made to keep the HEU part unclassified.

A draft MRI demonstration agreement has been developed to allow the application of proposed confirmation technologies to classified forms. At this time, the two sides are considering three technical measurements: (1) the Pu-239/240 ratio, (2) plutonium mass, and (3) component shape. Both sides are satisfied with annexes 1 and 2, but there is continuing discussion on "shape" measurement techniques. The Russians proposed neutron measurements and the U.S. proposed gamma-ray scans. Some believe it may be necessary to share classified information as part of the MRI process; this would require an agreement for cooperation, which could be embedded within the MRI agreement. If such an agreement is required, it would need to be approved by the president and Congress.

U.S.–Russian HEU Purchase Agreement Transparency

Andrew Bieniawski
U.S. Department of Energy

Bieniawski provided a presentation on the history and progress of transparency negotiations associated with the U.S. purchase of 500 metric tons of HEU from Russian dismantled nuclear weapons. The 500 metric tons will be in the form of approximately 15,000 metric tons of low-enriched uranium (LEU), blended down from dismantled Russian nuclear weapons material, over 20 years, for a purchase price of about $12 billion. According to the signed agreements, transparency measures are required to provide confidence that:

- the HEU recovered from dismantled Russian nuclear weapons is being converted and blended to LEU that is shipped to the United States, and
- the LEU that is shipped to the United States from Russia is converted to fuel for use in commercial nuclear power reactors.

Negotiations on the purchase agreement began in late 1992, with transparency following a track parallel to the commercial aspects of the contract. The HEU Purchase Contract was signed in January 1994 and the Protocol on HEU Transparency Arrangements was signed in March 1994. The protocol identified specific facilities involved, both in Russia and United States; established the Transparency Review Committee responsible for completion of detailed transparency procedures to be contained in implementing annexes to the protocol; and allowed deliveries of uranium and payments to begin.

The flow of uranium through the process can be summarized as follows:

- The Siberian Chemical Enterprise in Seversk (formerly Tomsk-7) receives HEU weapons components from Russian dismantlement facilities and converts the HEU metal to oxide and then ships the HEU oxide to the two Russian blending facilities at the Ural Electrochemical Integrated Enterprise (UEIE) and the Krasnoyarsk Electrochemical Plant (ECP).
- Both UEIE and ECP convert the HEU oxide to hexafluoride, which is then downblended to LEU hexafluoride and shipped to St. Petersburg, Florida.
- The Portsmouth Gaseous Diffusion Plant in Piketon, Ohio, receives the LEU hexafluoride from St. Petersburg, alters the enrichment if required to meet customer needs, and ships the LEU to U.S. fuel fabricators.

Specific transparency activities include special monitoring visits, which can take place six times per year at any of the relevant facilities in the United States or Russia. Permanent presence monitors are located at UEIE and will be located at Portsmouth in April 1997 to perform transparency activities on a continuing basis. Transparency measures include observation of tags and seals on uranium containers; review of material accounting and control-relevant data; and nondestructive assay measurements to confirm the enrichment of HEU weapons components, HEU metal shavings, HEU oxide, and uranium hexafluoride in sealed containers. In the near future, transparency measures will include the continuous monitoring of the enrichment and flow of HEU and LEU at the blend points at ECP and UEIE. The United States and Russia will conduct a series of special monitoring visits to each other's facilities during 1997.

Chemical Weapons Convention Impacts

Mary Elizabeth Hoinkes
Arms Control and Disarmament Agency

An overview of the background and impacts of the CWC was given by Hoinkes. She outlined the early debate about whether or not the CWC should prohibit chemical weapons production. The predecessor to the CWC, the 1925 Geneva Protocol, banned the wait time use of chemical weapons between members. The protocol scope was, in effect, reduced by 50 percent when many ratifications were conditional on the exclusion of retaliation with chemical weapons. Thus, the 1925 protocol has become essentially a ban on first use of chemical weapons.

Thereafter, the question that arose in the arms-control community, was should we do anything more? (i.e., should we attempt to ban production of chemical weapons?) Would such an undertaking be possible to enforce? Concern over the standard of verification made it clear that the days of agreements six to seven pages long had ended. We were now talking about documents hundreds of pages long because of the extensive, detailed provisions on verification.

Two factors supported the idea that we could effectively monitor compliance with a ban on chemical weapons production: (1) the information about participant states' activities would not be limited to that provided through declarations which would be part of a formal CWC regime; the United States would have access to intelligence information through "national technical means;" and (2) the United States was willing to pursue a more "intrusive" verification regime in a CWC, i.e., was willing to accept such intrusiveness itself and thereby gain futher access to other participant states' activities.

Besides our willingness to ban production, we wanted to eliminate existing chemical weapons arsenals. The U.S. defense establishment decided years ago that chemical weapons were not effective as military offensive weapons. As a consequence, the United States has discontinued chemical weapons production and committed to destroy existing stocks. This chemical weapons stock destruction program is a $20 billion-plus program. The estimate for CWC implementation is $20 million annually. The United States can, thus, only gain by pursuing an international agreement requiring destruction of chemical weapons stocks by other states, something the United States is already internally committed to do.

The CWC requires destruction of stockpiles and bans not only the use, but the production or transfer of chemical weapons. Its affiliated monitoring regime is to be operated by the international Organization for the Prohibition of Chemical Weapons, located in the Hague, with a staff of inspectors who will perform routine inspections (verifying declarations) as well as challenge inspections (very short notice, negotiated but unproscribed access).

The latter inspection, by its nature, raises domestic constitutional questions relating to the U.S. constitutional protection against "unreasonable searches and siezures." If there were a conflict between a treaty's requirement and our constitution, the United States would of necessity need to violate the treaty. Thus, the United States steered the CWC challenge inspection provisions to include on-the-spot negotiations with the inspected party (weakening the charge of unreasonable). Further, U.S. implementing legislation will include a regime for administrative warrants, which can be issued for administrative probable cause, as could be the case in a challenge inspection situation.

The CWC has already served as a good precedent for verification provisions in the Comprehensive Test Ban Treaty (CTBT) that was just completed and represents fulfillment of a commitment related to the NPT. Further, the CWC will serve as a model for BWC provisions under negotiation in Geneva. The April 29, 1997, deadline for U.S. CWC ratification is approaching quickly. Should ratification fail, U.S. nonparticipation in the CWC could result in decreased support thereafter for other, hard-won treaties and agreements.

Review of the Comprehensive Test Ban Treaty and its Verification Aspects

Lisa Evanson
U.S. Department of Energy

Evanson presented a synopsis of the key provisions of the recently completed CTBT and outlined the role being played by the DOE. A CTBT has been a long-term goal of the international arms-control community. Allusions to this go back as far as the 1958 U.S.-U.K.-U.S.S.R trilateral talks. A major incentive was the commitment made as part of the indefinite extension of the NPT.

In September 1996, the U.N. General Assembly endorsed the CTBT by a vote of 158 to 3. The treaty opened for signature on September 24, 1996, and Clinton was the first world leader to sign. Since that time, 140 countires have signed, including all five weapons states, Israel, and Iran. Forty-one of 44 "required" states have signed (required states are defined as those nuclear-capable nations in Table 1 of the 1996 IAEA edition of *World Nuclear Power and Research Reactors* and having membership in the Conference on Disarmament). India, Pakistan, and North Korea have not yet signed. A two- to three-year Preparatory Commission effort will develop the details of the verification system.

The treaty contains the basic obligation that participants will not test for themselves nor ask other states to do so. A new organization, to be located at the Vienna International Center, will monitor the treaty. There are four global monitoring regimes: (1) seismic, with 50 primary stations and 120 auxiliary stations; (2) radionuclide monitoring (particulates and noble gases), with 80 stations monitoring particulates and 40 stations monitoring gases (to be extended to 80 in the future); (3) hydroacoustic (monitoring for sound waves caused by a nuclear explosion in the ocean), with 11 stations; and (4) infrasound (monitoring for very low-frequency sound waves in the atmosphere that could be caused by a nuclear explosion), with 60 stations.

On-site inspections (OSI) can be carried out under the CTBT; their objective is to determine whether or not a suspected nuclear test (detected by the monitoring stations) actually occurred. OSI can have three phases: (1) overflight/visual observation, photography, radioactivity measurement, environmental sampling, and passive seismic monitoring for aftershocks; (2) active seismic surveys to locate underground anomalies plus magnetic and gravitational field mapping, ground penetrating radar surveys, and electrical conductivity measurements; and (3) drilling to obtain radioactive samples.

The DOE has provided technical expertise during the CTBT negotiations and expects to continue through the Preparatory Commission and into treaty implementation. DOE contributions to verification technology research and development have focussed on prototype sensors for monitoring stations, data authentication, particulate and xenon samplers, and on-site inspection support. In a policy role, DOE works to develop treaty article-by-article technical analysis to contribute to the ratification process. Finally, the DOE hosts a CTBT research and development Web site at http://www.ctbt.rnd.doe.gov.

U.S. Nuclear Transfer/Export Control — the U.S. DOE Role

Cynthia Gritton
U.S. Department of Energy

DOE efforts to improve nuclear export controls in the Former Soviet Union were described by Gritton. The U.S. export control system is a complex arrangement of law and regulations involving four different government departments and agencies. This system has worked well for the United States but is not a model we would propose for adoption by other nations. Our objective is not to duplicate the U.S. system in other countries but rather to help other suppliers build effective nuclear export control systems.

The United States and Soviet Union were well aligned in regard to nuclear export controls throughout the Cold War. Both were members of the NPT Exporters' Committee (Zangger Committee) and the Nuclear Suppliers Group (the London Club). Between the inception of the Zangger Committee in the early 1970s and the end of the Soviet Union in 1991, all Eastern European countries of the Warsaw Pact were sponsored for membership in the Zangger Committee and had also adhered to the nuclear suppliers guidelines.

After the breakup of the Soviet Union, Russia assumed the role of the U.S. counterpart in export control bilaterals, as well as the role of succeeding member of the Nuclear Suppliers Group. Concerns arose at this time, however, about illicit trafficking in nuclear materials and equipment brought about by the lack of strong protection, control, and accounting, as well as lax export controls in the Newly Independent States.

The DOE has focussed on dealing with the establishment of effective nuclear export control systems in the Newly Independent States (including Russia). Four areas have been identified for attention: (1) establishment of legal and organizational framework for nuclear export controls; (2) identification of and technical support to responsible and accountable officials in the export control system; (3) provision of technical and policy expertise to licensing officials and technical advisers; and (4) outreach activities to establish cooperative relationships between government and industry in each country, ensuring that exporters are aware of their responsibilities in trading with foreign customers.

The DOE publishes a handbook of detailed information about all the nuclear-related dual-use items controlled by the Nuclear Suppliers Group; a resource for everyone involved in the nuclear export control process, from licensing officials to border guards. In addition, the DOE recently established a cooperative arrangement with the U.S. Customs Agency to help in the detection and enforcement aspects of export control.

Six DOE-FSU laboratory-to-laboratory (L-t-L) programs have been established to identify and train technical experts who can provide licensing review support to the governmental export control authorities. L-t-L agreements are in place with Russia (3), Ukraine (2), and Kazakhstan (1). In each case, we are providing technical expertise via workshops and ongoing collaboration to improve nuclear export control practices.

The DOE sponsors a competitive graduate student program, which provides intensive training in Washington, D.C., and at the national laboratories to students who are then placed in export control organizations in the Newly Independent States. Thus far, three students have been placed at the Russian Center for Export Controls, one has been placed at the Kazakhstan Atomic Energy Agency, and one at the Ukraine Institute for Nuclear Research.

Efforts to Improve International Border Security

J. Terry Conway

U.S. Customs Service, Department of the Treasury

Conway described ongoing U.S. Customs Agency activities to help improve security at international borders, both for the United States and the republics of the Former Soviet Union. Of particular concern is the ever-increasing traffic in dual-use technologies and illicit materials.

A three-phase program called Project Amber has been instituted to improve inspection and border security for the Former Soviet Union republics. The phases are (1) assessment of country border enforcement capabilities, (2) provision of technical assistance in detection of nuclear and other materials, and (3) training. Conway and his team have completed the first phase and are beginning the second and third phases.

The U.S. Customs Service maintains close cooperation with many foreign law enforcement counterparts. Through these connections, Project Amber has been able to provide training to Estonia, Latvia, Lithuania, Slovakia, Czech Republic, Hungary, Poland, Belarus, Ukraine, and Kazakhstan. Fundamental needs such as warm clothing, flashlights, and even direct salaries exist in many places; it is difficult to maintain any level of inspection sophistication (or effectiveness) when basic infrastructure is lacking.

In the second and third phases of Project Amber, specific foreign customs officials are brought to the United States and given on-the-job training in U.S. methods, as well as in the use of recently developed, advanced technologies such as the material identification system, which uses eddy-current detection to identify and distinguish between metals; or the ultrasonic pulse echo, which can confirm contents of closed metal containers.

Conway sees the increased international collaboration resulting from increased traffic as a long-term challenge, but he views the technology developments to address the problem as greatly advancing the state of the art in customs inspections.

NWIS Signatures for Confirmatory Measurements With B33 Trainers

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Abstract

Nuclear weapons identification system (NWIS) signatures have been used successfully to confirm that B33 trainer parts, shipped from military bases to the Oak Ridge Y-12 Plant, were, as declared by the shipper, nonenriched uranium. The B33 was a gun-assembled weapon consisting of two components. Verification was accomplished by comparing signatures for B33 trainer parts with signatures for mock-ups made with depleted uranium packaged at the Y-12 Plant in M102 containers. Measurements with a normal production war reserve (WR) Component 2 part and calculations for a normal WR Component 1 part showed the very high sensitivity of the frequency-domain signatures to the presence of enriched uranium. Some measured frequency-domain signatures were greater than a factor of 100 different for the WR units. These verifications alleviated the criticality safety and safeguard concerns for material returned to the Y-12 Plant for dismantlement. This work in 1993 was part of the weapons dismantlement program at the Y-12 Plant, with hardware partially funded by the U.S. Department of Energy (DOE) Office of Arms Control and Non-Proliferation through the National Security Program Office of the Y-12 Plant. The weapons dismantlement program dismantles nuclear weapons components and trainers, safely stores fissile materials, and disposes of the wide variety of materials in an environmentally acceptable manner, meeting all applicable DOE, state, and federal regulations.

These verifications were conducted in a timely, reliable manner and produced no false positives for the 512 verifications (263 containers with Component 1 parts and 249 containers with Component 2 parts). Measurement times were 10 min each for time- and frequency-analyzer verifications. As many as 32 verifications were performed in one day (normal eight-hour shift) and 111 in one week.

Some of the signatures were different from those of the reference units, but not sufficiently different to be those for enriched uranium components. All of the anomalous signatures (those that differed significantly from the reference) were explained once the M102 containers were opened and the parts removed. The verification measurements revealed that the weights of eight Component 1 parts were not as declared by the shipper. These deviations resulted in the Y-12 Plant receiving more Component 1 parts than declared by the shipper. The Y-12 Plant, through the DOE, Oak Ridge Operations Office (DOE-ORO), resolved these differences with the Albuquerque Operations Office and related shipping personnel. For one Component 1 part and one Component 2 part, the uranium was not in the usual location in the container. The Component 2 part was not at the bottom of the container, and the Component 1 part, which normally had an aluminum spacer under the part at the bottom of the container, was itself at the bottom of the container. The measurements also showed that alternative fixtures were used in the M102 containers for the Component 2 parts. Ten Component 2 parts showed anomalously high values of the coherence between the source and detectors, identifying increased transmission of particles through the parts and suggesting less nonenriched uranium in the containers. This finding was confirmed when the containers were opened and it was found that many holes had been drilled partway into each part, removing 4.5% of the mass of uranium.

These verifications demonstrated the use of NWIS signatures for identification of nuclear weapons mock-up parts. The sensitivity of some of the signatures to small changes in packaging and others to mass of uranium inside the container was also demonstrated. Signatures for mock-up units usually require more measurement time than normal WR units because there is no significant fission-induced part of the signal and because only directly transmitted, scattered, and secondary particles reach the detectors. Thus, measurement and identification of normal production weapons components would be easier for NWIS.

This was the first use of NWIS in a nonresearch environment and indicated the desirability of automated operation. NWIS signatures have been demonstrated to be adequate for shipper-to-shipper confirmatory measurement within DOE and between the U.S. Department of Defense (DOD) and DOE. A nonintrusive

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use of NWIS signatures was demonstrated, which would allow the use of this method by foreign nationals at DOE or DOD facilities. A field-deployable system, supported by the DOE Office of On-Site Systems within the Office of Research and Development (NN-20) and the Y-12 Plant, is briefly discussed.

Introduction

Under the support of the U.S. Department of Energy (DOE) Office of On-Site Systems within the Office of Research and Development (NN-20) and the Oak Ridge Y-12 Plant, the feasibility of a nuclear weapons identification system (NWIS) that is a verification technology for arms-control treaties and special nuclear materials (SNM) management was under investigation from 1987 to 1992.[1] Work on such an identification system has been supported by the Y-12 Plant since 1984. These investigations included measurements by the californium isotope (^{252}Cf) source-driven noise method using time- and frequency-analysis techniques with pits, fully assembled systems at the Pantex Plant of Mason and Hanger-Silas Mason Company Inc., and components manufactured at the Y-12 Plant. The measurements were performed on small and large components. Measurements for some systems were made in and out of shipping containers and with mock-ups, as well as with secondaries in a fully assembled weapons system and separated. This previous work consisted of demonstrating the feasibility of the method and included the assembly and testing of a measurement system, which was the required step before development of a field-deployable prototype.

Continuing work to develop a field-deployable system was supported partially by NN-20 and now is supported by the Y-12 Plant. One design for a workstation data processing system is briefly described in Appendix A and is now operational. A laptop-based system is under development. A nonintrusive scenario for use of this system is also under development and is presented in this paper. This work in 1993 was part of the weapons dismantlement program at the Y-12 Plant, with hardware partially funded through the National Security Program Office also of the Y-12 Plant. The weapons dismantlement program dismantles nuclear weapons components and trainers, safely stores fissile materials, and disposes of the wide variety of other materials in an environmentally acceptable manner, meeting all applicable DOE, state, and federal regulations.

Although many tests were performed in the time domain, particular emphasis was placed on development of the frequency-analysis method of nuclear weapons verification because it provides many additional signatures and advantages. The method employs a process for exciting an assembly of materials with neutrons, averaging the resulting signals from the emission of neutrons and/or gamma rays to reduce statistical uncertainty, and processing the signals so as to obtain a set of values that constitute a signature of a particular assembly configuration. The frequency content of the signal is used as a signature of a nuclear weapon or component in much the same way that voice signatures are used to identify persons or acoustic signatures are used to identify ships. Both the time- and frequency-domain data compose the total signature.

The method also has application where detailed identification of nuclear weapons, subassemblies, or parts is desired or required. Alternatively, the system can be used to verify assay, quantity, and material type without opening containers of SNM. The method could be used by DOE contractors to verify, without opening the shipping container, that shipments received are as declared by the shipper and that the particular item shipped is complete (such as the B33 parts verification described in this paper). This system may be configured and implemented to confirm or deny in a nondesign-revealing (nonintrusive) manner the existence of particular types of nuclear weapons in shipping containers, at storage facilities, and on delivery vehicles. The method has unique advantages for identification of pits and secondaries in a dismantlement scenario where pits or secondaries are stored in some type of generic container in a controlled, secured, and monitored facility. One advantage is high sensitivity and another is that for some frequency-domain signatures the background averages to zero. The latter is an advantage for practical application to storage facilities and for the first stage of dismantlement. NWIS is applicable to all types of nuclear weapon systems and components.

The demonstrated capabilities of the method, based on both time- and frequency-analyzer processing of the data from measurements for 17 weapon systems or component parts in approximately 40 configurations, are as follows:

1. Nuclear weapons and components both in and out of their shipping containers can be identified by their unique signatures.
2. Nuclear weapons and components can be distinguished from mock-ups that contain depleted uranium (D-38) or other materials in place of fissile material.
3. Mock-ups for one weapon system are distinguishable from mock-ups for another weapon system.
4. Omission of as little as 4% of the uranium mass from weapons or components can be detected in shipping containers.
5. Omission of other parts from components in shipping containers can also be detected.
6. Changes in internal configurations of parts can be detected.
7. The method can track secondaries through the first stage of dismantlement because some of the signatures are not affected by the presence of the plutonium bearing primary.
8. Intervening materials, such as plastic or iron in some cases, do not significantly affect some of the time or frequency dependence of the signatures but in other cases affect only the magnitudes.
9. Nondesign-revealing implementation is possible through the use of a controlled intrusiveness verification technology (CIVET).[2]
10. Because it is an active method, it does not suffer from the shielding problems of passive gamma-ray spectrometry, in which ^{235}U could be shielded by ^{238}U.
11. The sensitivity of the method, as shown with weapons components and in other measurements, is such that modification of reactor fuel for covert tritium or plutonium production, not allowed by some future treaty, would be detectable.

The sensitivity of the method to changes in the variables of a configuration, in many cases, is much higher than direct measurement of the variables themselves.[3-5]

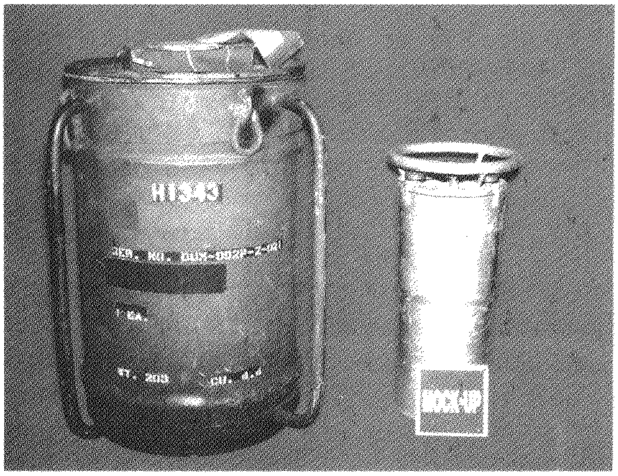
The B33 was a gun-assembled weapon consisting of two components. Signatures from NWIS were used to verify that B33 training unit parts shipped from the military to the Y-12 Plant were, as declared by the shipper, to be of nonenriched uranium. These verifications were performed with the parts in their M102 protective containers.[6,7] Both time- and frequency-domain signatures were used in this verification for redundancy. The reference signatures that this verification process was based on were obtained from Component 1 and 2 mock-ups of D-38 in M102 containers. Both of these mock-ups were assembled by the Y-12 Plant. These time- and frequency-domain signatures were the basis for the verification process that involved comparing signatures with the trainer components to the reference signatures.

In addition, signatures were obtained for a normal war reserve (WR) Component 2 part of highly enriched uranium (HEU) in its M102 container. The deviation of this latter signature from the mock-up is a measure of the sensitivity of this process to the presence of HEU. Because no Component 1 HEU parts existed, the signature for the HEU Component 1 part was obtained from Monte Carlo neutron transport theory calculations. This paper describes the measurement methods, and verification process and presents ratios of the signature for each container to the reference signature, as well as some conclusions. Also, a method for nonintrusive implementation of NWIS is presented.

Configuration of B33 Trainer Components

The B33 was a gun-assembled weapon and consisted of two components designated as Component 1 and Component 2. Each of these components was packaged in an M102 container. The M102 container surrounded by Celotex fits inside the H-1343 shipping container (Figure 1). For these confirmations, the M102 containers were placed on 122- × 152- × 0.64-cm-thick steel tables with each steel table top 91 cm above the floor.

Figure 1. Photograph of the M102 and H-1343 containers



In these returns to the Y-12 Plant, the containers with Component 1 had varying masses designated as low, intermediate, and high, with the mass changes at the lower portion of the container. The Component 1 reference mock-up unit was of intermediate mass. In a few cases, abnormal materials such as wood were in the containers.

In the M102 containers for the Component 2 parts, a special fixture was used. For some of the Component 2 training parts, the special fixture was not as in the reference mock-up unit, but an alternative material was used. The verifications could have been performed from outside the H-1343 shipping containers but would have required a slightly larger neutron source for a 10-min measurement time. Because the M102 container could be removed from the H-1343 container in much less than 5 min, this could be done during the verification of the previous unit and thus not impact the verification time.

Measurement Concept and Advantages

The NWIS employs a unique method of exciting a fissile assembly or other assembly with neutrons from a combination source and counter, which initiates the fission chain multiplication process if fissile material is present. NWIS processes and averages the resultant signals from the source counter and a pair of detectors sensitive to neutrons and/or gamma rays emitted from the assembly. NWIS measures a set of values that constitute a signature of a particular assembly configuration. A conceptual sketch of NWIS is shown in Figure 2 adjacent to a container. The components of the system that detect the emitted particles are two detectors sensitive to neutrons and gamma rays and a pulse-mode ionization chamber containing less than a few micrograms of the spontaneously fissioning isotope ^{252}Cf (614,000 spontaneous fissions per second per microgram). Each fission of ^{252}Cf produces an electrical pulse in the ^{252}Cf source chamber, which signals the time of emission of ~3.8 neutrons, along with gamma rays, that can enter the assembly. If the assembly contains little or no fissile material, some neutrons and gammas will pass through the assembly to the detector(s), some will reach the detector after being scattered, and some

Figure 2. Conceptual sketch a laptop-based nuclear weapons identification system

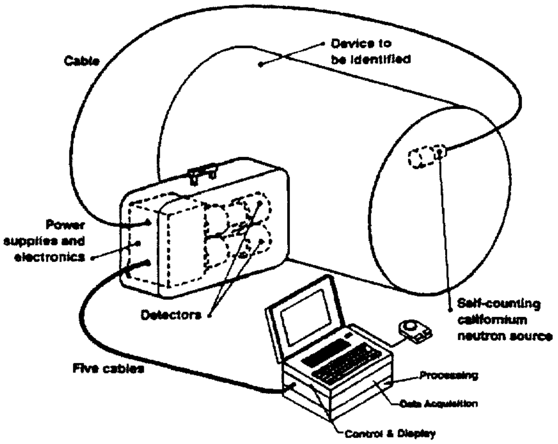
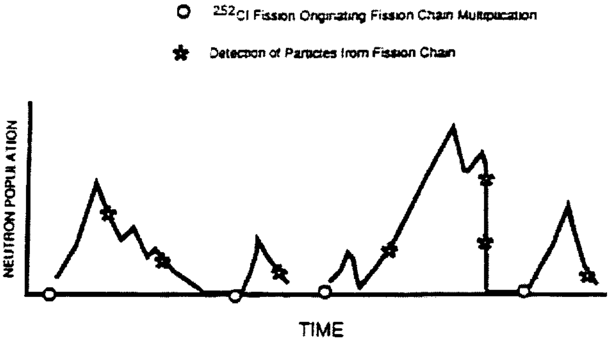


Figure 3. Sketch of typical successive fission chain buildup and decay



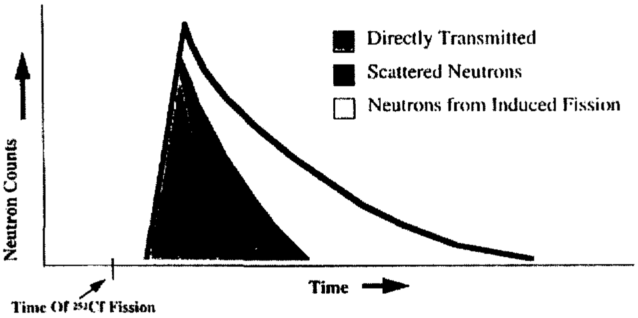
gammas will be created by neutron reactions in the assembly. If the assembly contains fissile material, some of the neutrons will initiate fission chain multiplication processes. These processes always die out because the assembly is subcritical, but they can release many additional neutrons and gamma rays. A sketch of typical successive fission chain buildup and decay is shown in Figure 3, which illustrates the statistical nature of the fission chain multiplication process. Each chain is initiated by a spontaneous fission of ^{252}Cf, which also generates a timing pulse that defines $t = 0$ for the fission chain. Thus, the detected particles are of three types: directly transmitted from source, scattered, and secondary particles from fission or other reactions of the source particles. For nonenriched uranium, the induced fission part of the signal is small. Time- and frequency-domain processing are performed, and there is a unique transformation between them. Time delay in signals in the time domain will correspond to differences in phase in the frequency domain.

Frequency-domain measurements usually have required less measurement time because there is no equivalent of the fast Fourier transform (FFT) in the time domain. They also have an additional advantage in that, in the cross-power spectral densities (CPSDs) between detectors, the background or uncorrelated information averages to zero after many samples of data. As a result, meaningful measurements can be made with fractions of correlated information in two signals at frequency $\omega(\omega \neq 0)$ as low as 10^{-6}. Larger sources can also be used. Time differences between signals can be measured more accurately in the frequency domain because a phase shift of a few degrees is measurable and a time shift of one digitizing interval produces a 180-degree phase shift at the maximum frequency. Thus, for 1-GHz digitizers, a 3-degree phase shift, representing a time of 1.7×10^{-11} s, could easily be measured. Certain frequency-domain signatures are independent of detection efficiency or type of detector as long as particles from fission are detected. They are also independent of source size for certain materials. These two features, as well as a field calibration of detection efficiency, allow for easy and reliable detector replacement. There has been a demonstrated high sensitivity of frequency analysis measurements with weapons components to small changes in the system under interrogation and also for other fissile systems. Nearby material emitting neutrons and/or gamma rays is usually not a problem because the correlated information comes from the region between the source and detectors. This latter advantage simplifies the use of NWIS in warehouse or storage configurations. In these verifications, hundreds of units were stacked in and close to the verification area (as are shown later in Figures 7 and 8).

Time-Domain Processing

For time-domain measurements, the time distribution of detected particles is measured with respect to the time of emission of ^{252}Cf neutrons. For this type of measurement, the source intensity must be sufficiently low so that the fission chains do not overlap, thereby allowing their buildup and decay to be measured (illustrated in Figure 3). The instrumentation and processing system for these two time-domain signatures was located in the verification area. This time distribution was obtained with a conventional time-to-amplitude converter (TAC)-pulse height analyzer (PHA) system, where the signal from the ^{252}Cf ionization chamber starts the TAC, a detector pulse stops the TAC, and the time between each pulse is stored in the PHA. For this type of measurement hardware, it was sometimes advantageous to start on the detector pulse and stop on the delayed signal from the ^{252}Cf ionization chamber (this method was used in the B33 trainer verification program). Systems of this type can have time-channel widths as short as 0.1 ns. For proton recoil scintillators with pulse shape discrimination, two signals result: one for neutrons and the other for gamma rays. Because these discrimination methods are not perfect, some gamma rays will be in the neutron signal and vice versa. The time distribution of detector pulses after ^{252}Cf fission contains directly transmitted, scattered, and secondary neutrons and gamma rays from interactions other than fission, as well as fission-multiplied components for the gamma ray and neutron portions of the signal as illustrated in Figure 4. The fission-mul-

Figure 4. Sketch of time distribution of counts after ^{252}Cf fission showing the transmitted, scattered, and fission multiplied components

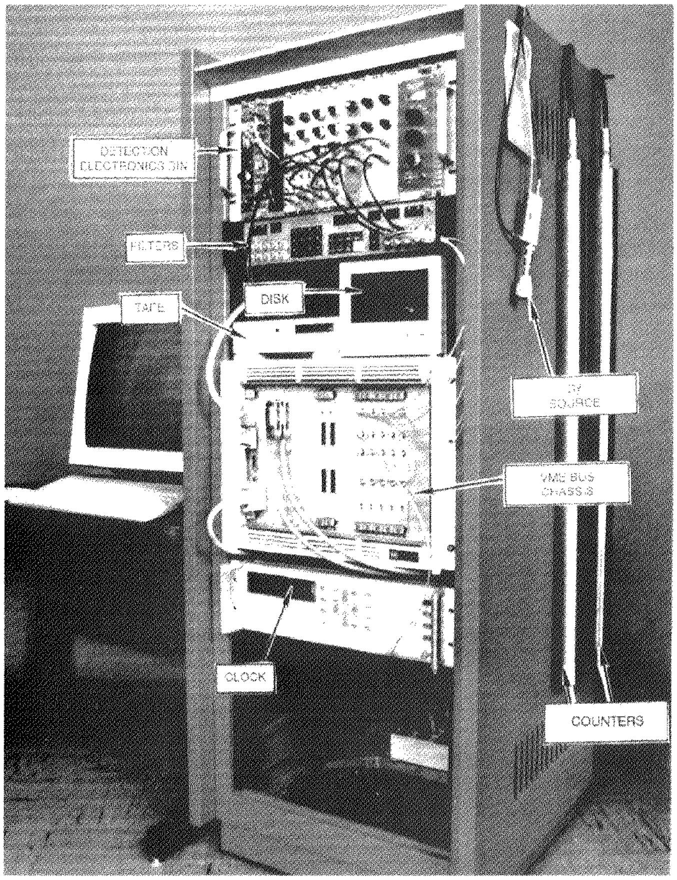


tiplied component of the gamma-ray signal is from neutron-induced fission. In addition, the gamma signal contains an uncorrelated background associated with the natural gamma ray emissions from uranium decay. For this application with mock-ups of nonenriched uranium metal, the induced fission component is small.

Frequency-Domain Analysis

The particle scattering and the fission chain multiplication processes are statistically fluctuating phenomena and thus have frequency content determined by the type, amount, and configuration of material. The frequency content of the signal is used as the signature of a nuclear weapon or component in much the same way that voice signatures are used for personnel identification and acoustic signatures are used for ship identification. A special-purpose commercial Fourier analyzer (Figure 5) located in a trailer adjacent to the building provided the frequency analysis of the signals from the ^{252}Cf source and the detectors. This Fourier processor, operational in 1990, was replaced in 1996 by the system described in Appendix A, which performs time and frequency analyses. The system shown in Figure 5 differs from that used for these verifications in that two ^{3}He proportional counters are used rather than the two scintillators described in the detectors section of this paper. The signals were transmitted over 183 m of cable to the trailer from the verification area. A small, special-purpose computer system in the VME bus chassis has three functions: (1) it converts the three signals (one signal from the ^{252}Cf in an ion chamber and one signal from each of the two detectors) to digital form by sampling them by amplitude digitization into time bins forming data blocks of 512 points, (2) it calculates the Fourier transforms of each data block, and (3) it generates averaged auto power spectral densities (APSDs) by complex self-multiplication and CPSDs by complex multiplication of two channels that are functions of frequency and which represent the correlations between the various detection channels. This is done for many data blocks and the results averaged. Algorithms adapted from the highly developed discipline of digital signal processing are then used to calculate the frequency-domain signatures.

Figure 5. Photograph of Fourier processor with ^{252}Cf source and two ^{3}He proportional counters



Some simple physical definitions are now given for those not familiar with frequency analysis. The real part of the CPSD between two band-pass filtered signals is the product of the two instantaneous values of the signals divided by the bandwidth of the filter; the imaginary part of the CPSD is the product, with one of the signals phase-shifted 90-degrees, divided by the bandwidth. The coherence (definition follows) is the fraction of the signals in two detection channels that is common to both channels and has a real value between 0 and 1. Measurements have been performed with coherence values as low as 10^{-6}. This means that, with correlated signal-to-uncorrelated background ratios of less than 10^{-3} in each of two channels, the correlated part of the signal that provides the signature can be measured. The ratio of spectral densities (definition follows) is approximately proportional to the ratio of the neutron fluctuations in the output of the ^{252}Cf source to the neutron fluctuations in the fissile assembly. Its value is thus related to the neutron multiplication of the assembly, the fissile content, the configuration, and the location of the ^{252}Cf source.

The quantities that can be used as signatures for the three channels used in these measurements are:

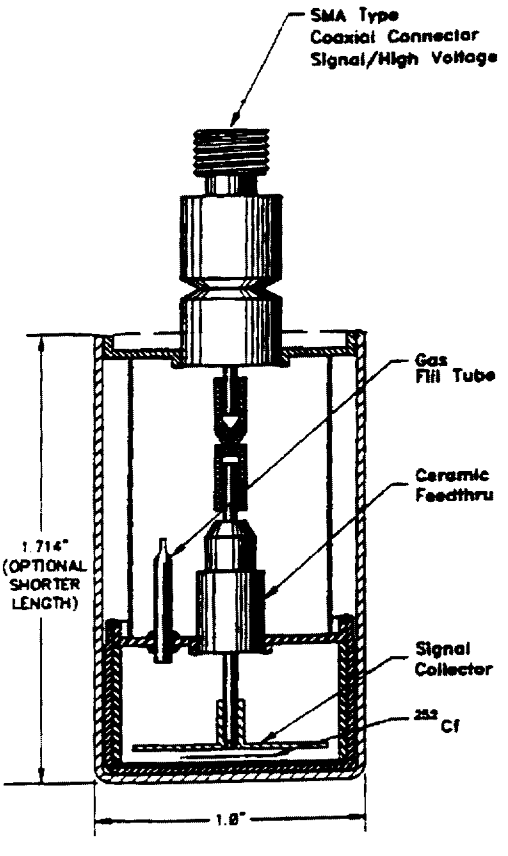
1. two auto power spectral densities, $G_{ii}(\omega)$, (i = 2&3), which are real and related to signal levels of the detection channels 2 and 3;
2. two CPSDs (which have real and imaginary parts) between the source (Detector 1) and the two detectors, $G_{1j}(\omega)$, (j = 2&3);
3. the CPSDs between the two detection channels, $G_{23}(\omega)$, which has real and imaginary parts;
4. a ratio of spectral densities ($G_{12}^* \, G_{13}/G_{11} \, G_{23}$, where * means complex conjugate), which has a real and an imaginary part; and
5. three coherence values, ($\gamma_{ij}^2 = |G_{ij}^2/G_{ii}G_{jj}$ (i = 1 and 2, $j > i$ but < 4).

In all, this comprises a set of 13 functions of frequency, which constitute the frequency-domain signature. For measurements like those reported in this paper that do not include the full frequency bandwidth of the signal, the numbers of functions reduce to nine because the imaginary parts of the CPSDs and the imaginary part of the ratio of spectral densities will be zero. These nine signatures, plus the two from time-domain measurements, comprised the set of 11 signatures used for the B33 verification.

Neutron Sources

Although ^{252}Cf sources were used in the measurements reported in this paper, alternative sources can be used as long as the time of emission of the neutrons can be identified. The ^{252}Cf fission counting system consists of a 25.4-mm diameter and 33.5-mm long parallel plate ionization chamber[8] containing the ^{252}Cf, a 200-V power supply, a current pulse amplifier, and a discriminator. The discriminator output pulses are input to either the time- or frequency-domain processing systems. The ^{252}Cf is electroplated on one side of a platinum foil (0.25 mm thick and 21.6 mm diameter) with an 8-mm spot ^{252}Cf spot in the center. The platinum foil is placed in a welded double-contained 304 stainless-steel chamber shown in Figure 6. The chamber is evacuated and filled with an Ar-CO_2 mixture to a pressure of 760 mm Hg (absolute). For the time-domain measurements, the chamber contained 0.18 µg of ^{252}Cf (approximately 100,000 spontaneous fissions per second) and was initially fabricated in 1981. For each spontaneous fission, one fission fragment enters the chamber gas between the plates and produces an electrical pulse. Electrical pulses from the chamber are such that greater than/more than 99% of the spontaneous fissions of the ^{252}Cf are detected, with essentially none of the alpha decay particles detected. The ^{252}Cf source for the frequency-domain measurements contained 0.83 µg (approximately 500,000 fissions per second) and has been in continuous operation since 1983. Both sources have been operated reliably for more than 10 years since fabrication without any failures or maintenance.

Figure 6. Sketch of ^{252}Cf source ionization chamber



The sources were located adjacent to the outside of the M102 containers at a vertical location corresponding to the vertical center of the uranium in the containers.

Detectors

Proton recoil scintillation detectors with pulse-shape discrimination, plastic scintillators, lithium glass scintillators, and composite scintillators have been used for past measurements. Detector sizes have been as small as a few centimeters and as large as 60 × 30 × 10 cm. Larger detectors result in loss of spatial detail in the signal. A proton recoil scintillator with pulse-shape discrimination of the neutrons and gamma rays was used for the time-domain measurements. The overall time resolution of the detection system involves the detection of two events: (1) the spontaneous fission of the ^{252}Cf and (2) the detection of a particle in the detector on the opposite side of the container under test. This time resolution is determined by measuring (after the neutron/gamma-ray discrimination system has identified each detection event as having resulted from either a neutron or a gamma-ray) the time dispersion of gamma rays arriving at a detector placed in air some distance from the ^{252}Cf source. Because all gamma rays travel at the same velocity, the time resolution of the measurement system can be obtained from the time dispersion of the gamma-ray peak. Such data, with knowledge of the number of ^{252}Cf source fissions (107,000/s) and the solid angle subtended by the detector, permit determination of the efficiency for detecting ^{252}Cf fission neutrons as a function of energy or the total efficiency for gamma rays.

The detector for the time-domain measurements was located such that the axis of the cylindrical scintillator was horizontal and located at the vertical center of the region where the uranium was in the containers for the reference mock-up configuration. This is the most sensitive location for determining the presence of HEU. These locations assured that the particles reaching the detector passed through or originated in the uranium. For the Component 1 parts, the location of the detector for time-domain measurements was such that it was insensitive to the contents of the bottom of the M102 container where uranium, steel, and/or aluminum were located.

The two detectors for the frequency-domain measurements were composite lithium glass/plastic organic scintillators, sensitive to gamma rays by interaction in both scintillator materials, to fast neutrons by proton recoil interactions in the organic scintillator, and to slow neutrons by interaction with ^{6}Li. These detectors did not use pulse-shape discrimination and thus detected neutrons and gamma rays without distinction. The detecors were located one above the other on the table 180-degrees from the source. The lower detector adjacent to the table was frequency analysis Channel 2, while the one above it was Channel 3. The two detectors were located symmetrically about the vertical center of the parts so that the lines of sight from the source to the detectors passed through all of the region expected to contain the uranium of the parts.

Neutron Detection Efficiency as a Function of Energy

The time-of-flight (TOF) distribution of the neutrons detected subsequent to ^{252}Cf fission at a detector spaced 1 meter from the source in air can be used to obtain the neutron-detection efficiency from 0.5 to 6 MeV. From this TOF data, the measured ^{252}Cf fission rate (approximately 107,000/s), the known neutron emission spectrum for ^{252}Cf, the detector diameter, the distance between the source and the detector, and the detection efficiency as a function of neutron energy can be obtained. By integrating the gamma ray counts in the transmitted peak, the efficiency for detection of gamma rays from ^{252}Cf fission can also be obtained.

The stability of the detection system can be verified routinely at any time by this type of TOF measurement in air. These field calibrations of the detection-system can be made routinely. In the event of a detection system failure that would require a detector replacement, this simple test would allow the replacement detector to be adjusted to have the same efficiency as a function of neutron energy. This simple test could also be used to verify the time resolution of the detection system. This ensures long-term reproducibility of the measurements.

Periodically during the B33 trainer verification process, the detection efficiency was measured as a function of energy. This technique was used to precisely match the detection efficiency as a function of energy for the time-domain detection system after the one detector component failure during these verifications.

Neutron/Gamma-Ray Discrimination

The effectiveness of neutron/gamma-ray discrimination was assessed in two ways. Using the TOF distribution, the ratio of gamma signals with and without discrimination can be obtained by examining the relative areas of the two gamma-ray peaks. The discrimination of gamma rays from ^{252}Cf fission for the detection system was typically a factor of around 1,200.

Looking at the ratio of the areas under the prompt gamma peaks in a measurement with the Component 2 mock-up placed between the source and the detector, one finds that the neutron/gamma-ray discrimination reduces the prompt gamma-ray peak by a factor of 320. Because some of the pileup gamma-ray pulses have the shape of neutron pulses, the experiments with neutrons will include a small number of gamma rays misidentified as neutrons, and the gamma signal will include a small number of neutrons misidentified as gamma rays. The small number of misidentified gamma rays in the neutron channel are used to determine the time of ^{252}Cf fission.

Reference Signatures

Reference signatures were obtained from measurements in the time and frequency domains using mock-ups of D-38 of Component 1 and 2 parts in M102 containers and a normal production WR Component 2 part in its M102 container. Because no normal production Component 1 part was available, Monte Carlo neutron transport calculations were used to calculate these signatures for the Component 1 part. Normal production parts contain HEU at approximately 93 wt % ^{235}U.

Time Domain Signatures

Measured Time-Domain Signatures

The efficiency of the time-domain data collection was increased by starting the TAC with the detector signal and stopping on the delayed signal from the ^{252}Cf ionization chamber. Both the neutron and gamma-ray data have a directly transmitted gamma-ray peak, followed by scattered and secondary neutrons and gamma rays from scattering and induced fission. Because of the effectiveness of the gamma/neutron discrimination, no significant transmitted gamma peak appears in the neutron data. The time distributions of time-correlated neutrons and gamma rays after ^{252}Cf fission were measured for each of the reference mock-up components with the source and detectors 180-degree apart, each adjacent to the M102 container. The reference signatures from measurements with these Component 1 and Component 2 mock-ups of D-38 were used as a standard to which all units returned from the military were compared.

The same source-detector-M102 configuration was used for a normal production WR Component 2 part of HEU in a material access area, and the time distribution of neutrons and gamma rays was measured. This WR unit was also packaged in the M102 container. The signals from the WR Component 2 part persisted for much longer times because of the fission chain multiplication process in the HEU metal, which produces neutrons and gamma rays that leak out of the system to the detector.

Calculated Time-Domain Signatures

Because of the lack of a WR Component 1 part, Monte Carlo neutron transport theory calculations were performed to obtain an estimate of the time-domain signature for the WR Component 1 part. Again, the time-domain signature for the HEU Component 1 part persists for a much longer time, indicative of the fission in the HEU. Calculations also showed that these measurements had the sensitivity to easily detect the presence of small amounts of HEU. These calculations used a variation of the Monte Carlo neutron transport theory code KENO Va[9] with the ENDF-B IV cross sections.[10]

Frequency-Domain Signature

Frequency-Domain Calibration Signatures

Because the full frequency content of the signal could not be measured with the existing Fourier processor, a sampling rate of 5 MHz was chosen for these measurements. The signals from the detection system were then sampled only once every 200 ns. Thus, the details of the time-domain signatures could not be sampled. As a result, this sampling rate is somewhat nonintrusive in that much of the detailed time history of the signal is lost. The highest measurable frequency (one-half sampling rate) in these measurements was 2.5 MHz. Except for the frequency response of the antialiasing filters, the APSDs and CPSDs are flat with frequency. The frequency response of the total measurement system (including the antialiasing filters) is obtained by placing the source adjacent to and equidistant between both detectors. Because the source is random, the input to the processing system is constant with frequency. Any nonflatness of the APSDs and CPSDs will be due to the frequency response of the measurement system. The results of this calibration can be divided into the measured frequency response with the B33 trainer parts present in the M102 containers to remove the frequency response of the measurement system. Similarly, this can also be done for measurements with the WR Component 2 part in the M102 containers. The reproducibility of this calibration measurement is a verification of the performance of the total frequency analysis measuring system, including the three detection systems, and is a useful field test of the system.

Components 1 and 2 Reference Measurements

The reference measurements with the Components 1 and 2 mock-up parts in M102 containers were obtained at several times prior to and during the verification process to confirm the performance of the Fourier processing system, as well as to have a reference file for comparing the trainer measurements. These measurements were also performed with the normal production Component 2 WR unit in an M102 container. There were significant differences between the frequency-measured parameters for the mock-up and the WR Component 2 in its container, some much larger than a factor of 100. This illustrates the high sensitivity of some frequency-analysis parameters to small changes in configuration and composition of fissile material that has been observed experimentally in many previous measurements.

This sensitivity is consistent with previous measurements where small changes in fissile assemblies produced large changes in measured frequency-analysis parameters. These differences are largest for coherences. The large differences suggest that comparison of these quantities would be a good indicator of differences in units. A plot of the square root of the product of Coherence 12 and Coherence 13 vs. Coherence 23 is a useful way of distinguishing between different units.

Verification Procedure

This section presents an overview of the verification procedure. The use of both the time- and frequency-domain measurements in the verification is described. Both types of measurements were performed with totally independent measurement systems: the time-domain analysis in the verification area and the frequency-domain processing in a trailer adjacent to the building. This redundancy improved the reliability of the verification, and signatures from both processing systems were used in the verification analysis. Photographs of the verification area are shown in Figures 7 and 8. Figure 7 shows a distant view of the verification area with approximately 100 shipping containers with B33 trainer parts nearby. Figure 8 shows the two measurement tables and the close proximity of pallets of unverified units in H-1343 containers. Two 122 × 122 cm, 0.64-cm-thick steel tables, each steel top 91 cm off the floor, were used for these verifications. One table was for time-domain and the other for frequency-analysis measurements. Unverified units in H-1343 containers were moved on pallets (5 per pallet) to the floor adjacent to the tables (within 3 m, see Figure 8); normally, four pallets were present. Once verification was completed, pallets were stacked in a nearby array, as shown (approximately 6 m from the verification tables). This array usually contained more than 20 pallets stacked two high.

Each unit was tested at separate stations by both a time analyzer and a frequency analyzer. At each station, the unit in its M102 container was placed on a table with a neutron source/counter on one side and one or two lead-shielded radiation detectors on the other. Each table had two measurement positions, one for each type of unit. In Figure 7, the time ana-

Figure 7. Photograph of the verification area showing proximity of already verified units in their H-1343 shipping containers stacked two high

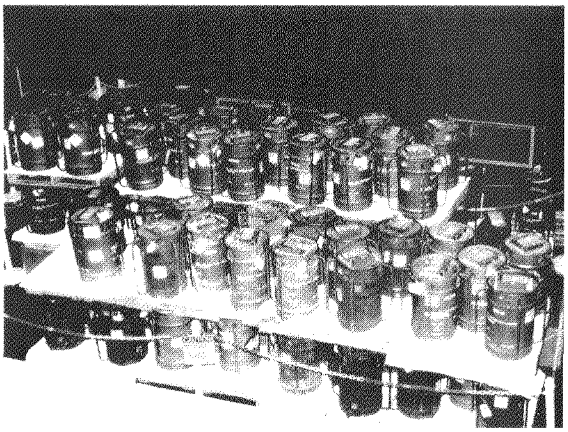


Figure 8. Photograph of the verification area showing the measurements tables and nearby unverified units stacked one high on pallets

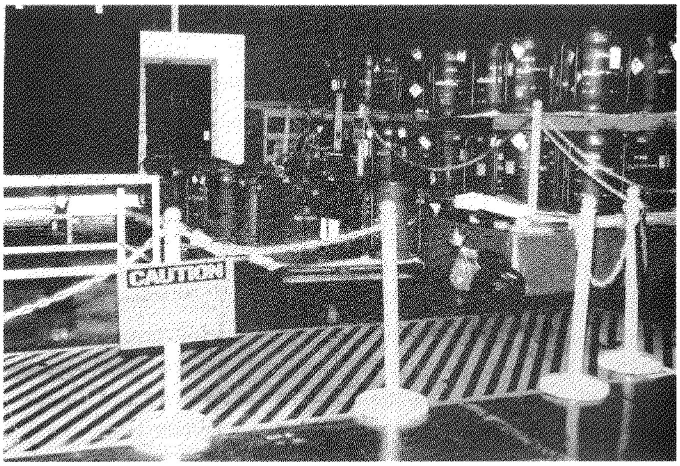


Table 1. Ratio of Signatures of a Component 1 Part to Those for the Reference Mock-up Unit for Nonintrusive Applications

Time and Frequency Analysis Parameters	Average Values of Ratio
Time Analysis[*]	
Correlated neutron counts	1.0244
Correlated gamma-ray counts	1.0302
Frequency Analysis	
APSD 11	1.0003
APSD 22	0.9767
APSD 33	0.9729
CPSD 12	0.9734
CPSD 13	0.9806
CPSD 23	0.9656
Coherence 12	0.9704
Coherence 13	0.9843
Coherence 23	0.9962
Ratio of spectral densities[†]	1.0040

[*] Integral of correlated counts for the Component 1 part divided by the same integral for the reference mock-up.

[†] Independent of detection, and thus, not affected by drifts in the detector system electronics.

lyzer table is shown on the left and the frequency analyzer table is on the right, whereas in Figure 8 they are in the foreground and background, respectively. The three signals from the frequency-analysis detectors (the source ionization chamber and the two plastic scintillators) were transmitted over 183 m of cable to the trailer outside the building for analysis. The measurements were directed by a technical supervisor who, along with a time-analyzer operator, worked in the verification area; two frequency-analyzer operators worked in the trailer. These four people constituted the standard team of verification personnel. In the future, more automated systems would require many fewer personnel. Operating personnel were also available to handle the units.

Both analyzers contained a data acquisition system controlled by a host computer. The data acquisition systems run autonomously so that the host computers are available to do processing and plotting while data acquisition is in progress. The data acquisition process took 10 min for each analyzer, and the two analyzers normally ran simultaneously, with the time analyzer testing a previously untested unit and the frequency analyzer testing the unit that had just been tested by the time analyzer. The testing sequence was as follows, starting at the completion of a data acquisition:

1. The source for frequency analysis was removed (approximately 1.5 m), and the M102 container on the frequency-analyzer table was returned to its H-1343 shipping container.
2. The source for time analysis was removed (approximately 1.5 m), and the M102 container on the time analyzer table was moved to the frequency analyzer table and set in position next to the detectors. Then the frequency analyzer source was set in place and the frequency analyzer was started, via a telephone call to the frequency analyzer trailer.
3. An untested M102 container, which had been removed from its H-1343 shipping container during the previous measurement, was placed on the time analyzer table next to the detector. Then the time analyzer source was set in place, and the time analyzer was started.
4. The run names, unit identifications, and other parameters were entered into log books and data sheets, as appropriate.
5. The next M102 to be tested was removed from its H-1343 shipping container and held ready to be placed in the time-analysis position.
6. During data acquisition, the computers of both analyzers were used to process and plot the data acquired in the previous data acquisition cycle. The time analyzer's data were processed by subtracting the uncorrelated background and converting the data to units of correlated counts per californium fission per nanosecond, as a function of time. To provide a visual comparison, this signature was plotted on the same graph with the corresponding signature of a reference mock-up unit known to be nonfissile. The plots and comparisons were done for the neutron data and the gamma data. In the frequency analyzer computer, the nine frequency-spectrum signatures (two APSDs, three CPSDs, three coherences, and the ratio of spectral densities) were plotted and averaged over frequency. The plots were printed and the average values entered into data sheets and the logbook. The pattern of average values was compared with that of the reference unit to determine whether or not the unit tested was nonfissile.
7. The technical supervisor evaluated the time analyzer comparison plot and telephoned the frequency analyzer operators to obtain a description of the comparison of the pattern of average spectrum values with the pattern for the reference unit. If all comparisons were satisfactory, he signed a certification in the log book that the unit was nonfissile[*] and also signed two nonfissile tags and gave them to the operating personnel to attach to the unit's H-1343 container. If any of the signatures were found to be anomalous, ambiguous, or inconsistent, the verification operations stopped while the technical supervisor and the appropriate operator(s) repeated the measurement or performed such validation tests as they deemed necessary on one or both analyzers. If the signatures for a container had indicated the presence of enriched uranium, the plant shift superintendent and the Nuclear Criticality Safety Department would have been informed. Operations personnel would have repackaged the unit into the appropriate H-1343 shipping container and secured it in preparation for taking it to the MAA for further evaluation, according to Y-12 procedures.

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[*] Nonfissile in this context means nonenriched uranium.

Figure 9. Nonintrusive comparison of time distribution of correlated neutrons after ^{252}Cf fission for 600 s of data accumulation for a trainer Component 1 part with the reference signature

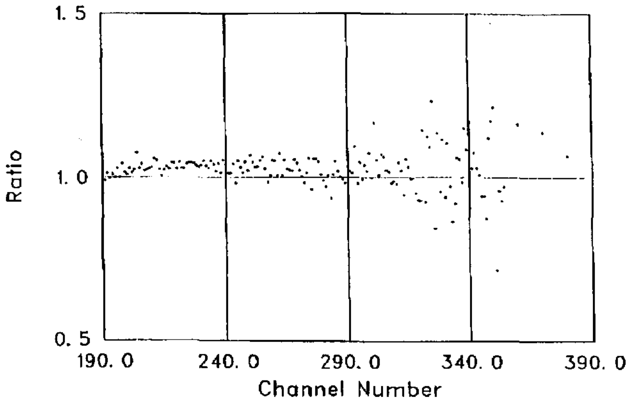


Figure 10. Nonintrusive comparison of time distribution of correlated gamma rays after ^{252}Cf fission for 600 s of data accumulation for a trainer Component 1 part with the reference signature

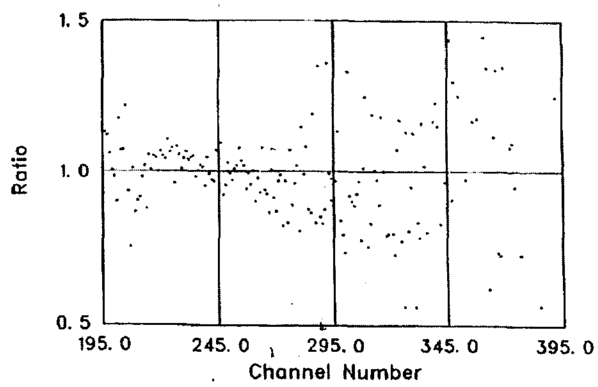


Figure 11. Nonintrusive ratio of APSD 33 to that for the reference mock-up unit as a function of frequency for a Component 1 part

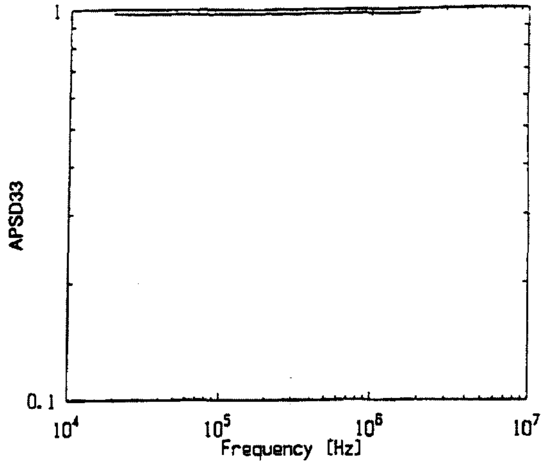
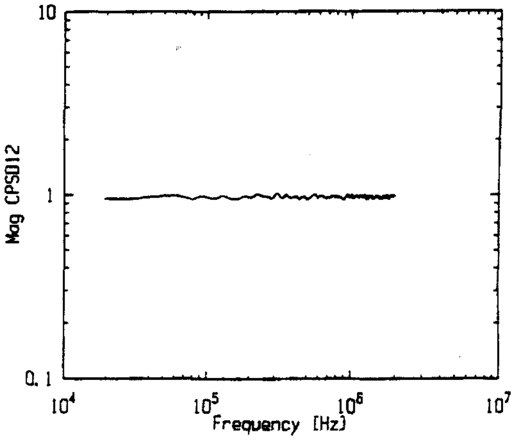


Figure 12. Nonintrusive ratio of CPSD 12 to that for the reference mock-up unit as a function of frequency for a Component 1 part



Nonintrusive NWIS Signatures

The use of CIVET^2 to make the use of NWIS nonintrusive could be implemented in a variety of ways. One way would be to let the host country operate the data acquisition system but operate on the data in such a way as to make the display unclassified. Once the reference data signature is obtained, methods of manipulating the data may be devised to obtain a nonintrusive verification instead of visually comparing the signatures from a given item with the reference. One way is to divide the signature by the reference signature (template). Within statistical fluctuations, the resultant signature should be unity at all frequencies and at all times. Another way would be to avoid displaying the actual signatures at all and let the software with pattern recognition methods make all the decisions about the quality of the match of signatures with the reference. The ratio of signatures approach was used with the verification data from Component 1 and 2 parts and the signatures obtained from the reference mock-up units in order to present the results in this paper. For the frequency analysis signatures, the average values over frequency were also compared. The data for the Component 1 or 2 parts were accumulated for 600 seconds. The time distribution of correlated neutron and gamma-ray counts after ^{252}Cf fission per ^{252}Cf fission for one unit divided by similar data for the reference mock-up unit is shown in Figures 9 and 10 over the channels where the data are statistically significant. These data are statistically distributed near unity, which indicates good agreement with the reference unit.

The time-domain data can be compared with the reference data in another way, as follows. The time-correlated counts could be integrated over time and the total time-correlated counts obtained. These integrals for each unit could then be divided by the integral of the total correlated counts for the reference unit. In this integration, some information is lost (i.e., the detailed functional dependence on time). Typical values are listed in Table 1.

Figure 13. Nonintrusive ratio of CPSD 13 to that for the reference mock-up unit as a function of frequency for a Component 1 part

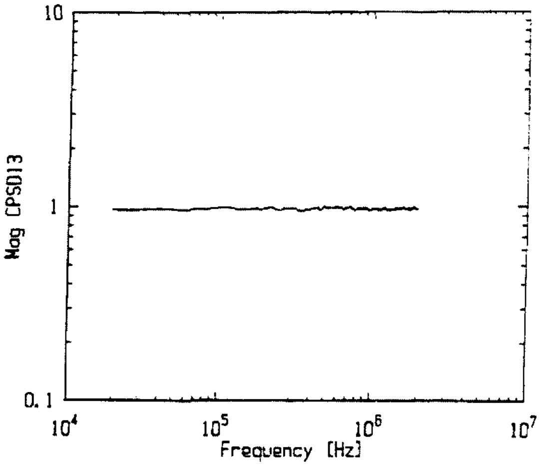
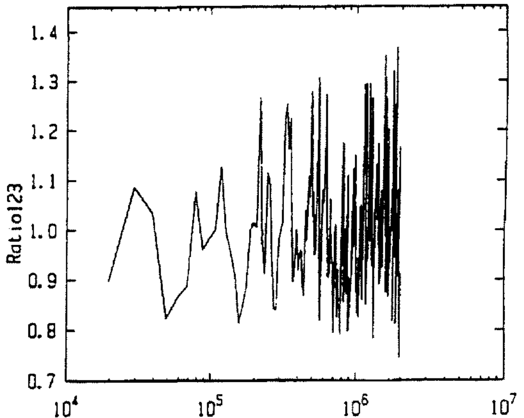


Figure 14. Nonintrusive ratio of the spectral densities to that for the reference mock-up unit as a function of frequency for a Component 1 part



The data for the frequency-analysis measurements can also be displayed as ratios of the measured frequency function (APSD, CPSD, etc.) at each frequency point to the value for the reference mock-up unit at the same frequency point. Typical plots of some of these ratios as a function of frequency are shown in Figures 11 through 14. These values are constant with frequency and thus can be represented by a single value, averaged over frequency. The averaged values over frequency or time of the ratios to the reference mock-up unit are given in Table 1. The divided data were constant over the frequency or time range and deviated only slightly (at most, 3.5%) from unity. This is caused by the slight differences in the packaging of the reference mock-up unit and the units from the military, as well as the statistics of the measurement process.

Verfication Measurements

In this section, the verification measurements in both the time and frequency domain for both the Component 1 and Component 2 trainer parts returned from the military are described. In all, measurements on 512 M102 containers were performed. The source-detection systems were arranged adjacent to the M102 containers not only to ascertain that the component parts of the B33 were nonfissile (no enriched uranium), but also to verify the mass of the Component 1 parts, which varied, in the M102 containers. These verifications were performed in four campaigns: one starting in May 1993 with Component 1 trainer parts; one with Component 2 trainer parts starting in June 1993; one with Component 1 trainer parts starting in August 1993; and the last starting in September 1993 with Component 2 trainer parts. During this verification program, the temperature varied from 60°F to 92°F and may have produced small changes in detection systems. The measurements were performed in a normal eight-hour-day shift. The days the verification measurements were performed depended on the availability of trained operations personnel. The maximum number of verifications in any day was 32, and the maximum number in any week was 111. The number of verifications per day could be increased by further automation of the measurement process. The displays of comparisons to the reference mock-up given in this paper will be nonintrusive ratios, as described in the previous section. Data on all 11 signatures for both components are not presented; only a limited amount of data is given to avoid being too cumbersome.

Time-Domain Measurements for the Trainer Parts

Normally Packaged Component 1 Parts

In all these measurements, the source and detector were located symmetrically about the expected half height of the intermediate mass Component 1 parts in the M102 container because the reference mock-up unit was of intermediate mass. Thus, if more or less mass was in the container, the source and detector were not at the half height of these masses. The time-domain signatures, which were the time distributions of both correlated neutrons and gamma rays after ^{252}Cf fission for each of the trainer units, were compared to the reference signatures. The normal measurement time was 600 s. The ratios of signatures to the reference were shown in Figures 9 and 10. The data from the neutron signature for 600 s of data accumulation are indistinguishable from the reference mock-up signature. This is also true for the gamma-ray data shown in Figure 11, although the gamma ray data have higher statistical uncertainty. The agreement between the trainer signatures and the reference signatures is excellent and confirms that the trainers do not contain enriched uranium. This precise agreement was typically observed for correctly declared trainer units.

In addition to the use of the time distribution of correlated counts, the integral of the correlated counts can be used for comparison. The values of these integrated counts were divided by those for the reference mock-up component. Plots of the distribution of these ratios of correlated counts for all the neutron and gamma-ray signatures obtained are given in Figures 15 and

Figure 15. Nonintrusive normalized distribution for measurements of the neutron total correlated counts from time-analysis signatures for Component 1 parts in M102 containers

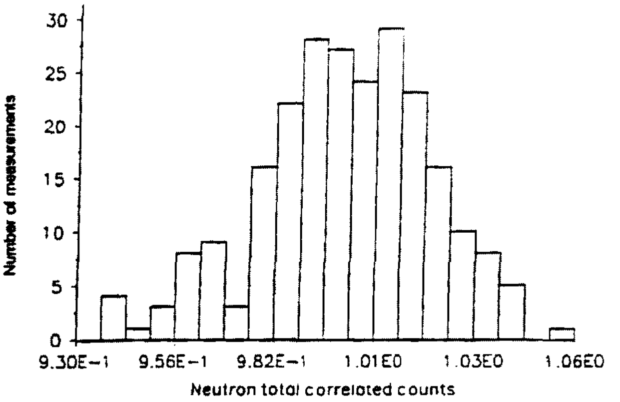
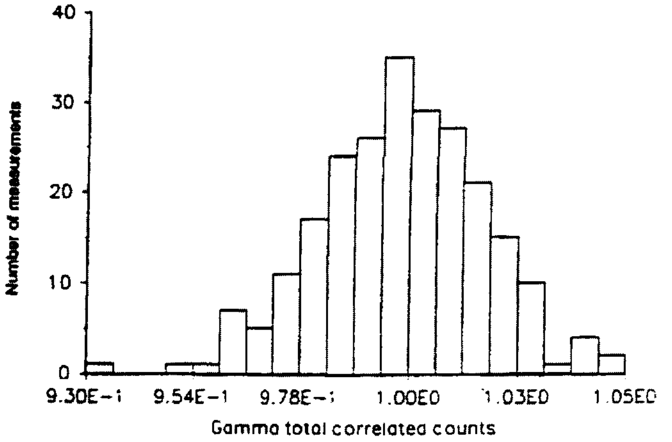


Figure 16. Nonintrusive normalized distribution for measurements of the gamma total correlated counts from time-analysis signatures for Component 1 parts in M102 containers



16. This type of plot gives the number of measurements (ordinate) within a specific range of values indicated on the abscissa by the boundaries defined by the vertical lines. The narrowness of these distributions indicates the excellent quality of these signatures and the general reliability of the total measurement system. All distributions of this type in this paper are the individual measurement divided by the average values for the reference type units. Thus, they show the total variation in the signatures. The variations in the measurement result from the statistics of the measurements, uncertainties introduced by placements of the source and detectors, variations from measurement system drifts, and variations introduced by variations in the parts themselves. If individual unit signatures were divided by the latest reference measurement rather than those at the beginning of the verification program, any variations-caused measurement system drifts could be reduced.

The time-domain signatures for Component 1 parts in M102 containers were not sensitive to the mass of uranium in the bottom of the container because neutrons from the source reaching this part of the container had almost zero probability of reaching the detector. Thus, the time-domain signatures were essentially the same for various masses of uranium in Component 1 containers. This was not the case for the frequency-analysis signatures, where the detectors (one at the bottom) was used to detect variations in the mass of uranium in the M102 container.

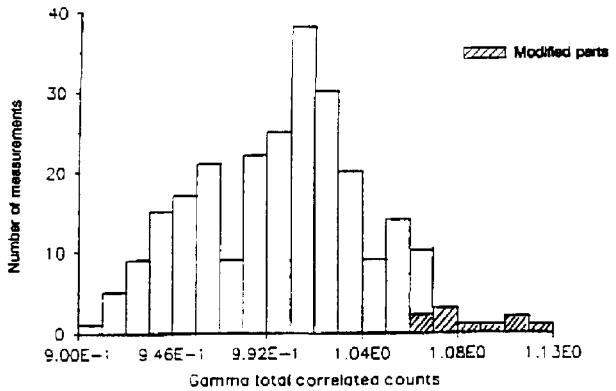
Normally Packaged Component 2 Parts

For the time-domain measurements for the Component 2 parts, the source and detector were located adjacent to opposite sides of M102 containers at the half height of the part. The time-domain signatures were compared to the reference signatures of the D-38 mock-up. The normal measurement time was again 600 s. For many of the Component 2 trainer parts, the signal and thus the ratio to the reference was slightly reduced because of the use of another insert material in the container that was different from the reference mock-up component. The use of an alternative insert of higher density was revealed later in the verification program by those familiar with the packaging by the military before the containers were opened. The decreased value of the ratio to the reference mock-up unit indicates an insert different from the normal insert of the reference mock-up. These differences were used to determine the type of material of the insert. The presence of this alternative material around the Component 2 parts was confirmed after the verification program when the M102 containers were opened for all containers with these differences.

The integral of the correlated counts was obtained for each verification and the value was divided by the corresponding value for the reference mock-up unit. Plots of the distribution of measurements of ratios of integrated gamma-ray correlated counts per ^{252}Cf fission are shown in Figure 17. The effects of the attenuation of signal by the inserts in the containers is most clearly evident in the distribution of total correlated gamma rays. There are really two normal distributions that overlap. The one for units with alternative insert material is on the left. As with the Component 1 comparison, only reference mock-up signatures used for comparison were obtained at the beginning of each verification campaign. Agreement with the reference mock-up signature would have also been better if the reference mock-up signatures obtained periodically during the verification were used.

Several of the Component 2 parts were altered by or for the military by having various holes drilled in the uranium. The normal Component 2 parts mass was reduced 4.5% by the presence of holes. The deficiency of material in these parts resulted in a higher transmission of neutrons and gamma rays from the source to the detectors, which resulted in slightly higher correlated neutron and gamma ray counts in the time-domain signatures when compared to the reference mock-up unit. The shaded measurements shown on the right of these distributions (Figure 17) are those for the 10 modified Component 2 parts.

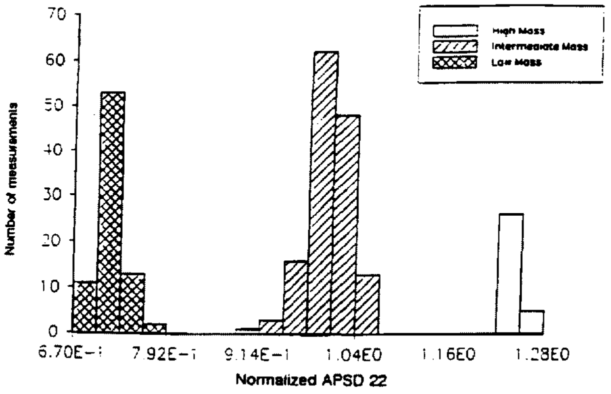
Figure 17. Nonintrusive normalized distribution for measurements of the gamma total correlated counts from time-analysis signatures for Component 2 parts in M102 containers



Frequency-Analysis Measurements for the Trainer Parts

The frequency-analysis verification for the trainer parts used a variety of measured signatures. Because these detectors were sensitive to both gamma rays and neutrons with no distinction between the types of particles, each of the two detectors (designated by the subscripts 2 and 3) provided one signal to the Fourier processing hardware, in addition to that provided by the ^{252}Cf source ionization chamber (subscript 1). The frequency-analysis signatures were APSD 22, APSD 33, CPSD 12, CPSD 13, CPSD 23, Coherence 12, Coherence 13, Coherence 23, and the ratio of spectral densities. The reproducibility of APSD 11 verifies the proper operation of the source and its ionization chamber. The imaginary parts of the CPSDs contained no additional information because the frequency response of the measurement system was much less than the frequency content of the verification signals. If the full frequency content of the signals were measured, four additional signatures would have been provided: the imaginary part of the three CPSDs and the roll-off of the signatures with frequency at high frequency, which is related to the time decay of the fission chains. The arrangements of source and detectors for these verifications were such that the material of the parts in the M102 container were between the source and the detectors. This was accomplished by using a pair of adjacent detectors whose height was greater than that of the parts. The frequency-analysis verification accumulated 500,000 data blocks of 512 samples per block in 600 s at 5 MHz sampling rate and approximately 0.6 MHz processing rate. Because of this slow processing speed, data were sampled only approximately 10% of the time. These data were not as precise because of the data processing limitations of the present processor. An improved processor operational in 1996 would have increased the data-accumulation rates by a factor greater than 100 and operated at a digitizing rate consistent with the high-frequency content of mock-up part signatures (Appendix A).

Figure 18. Distribution of the nonintrusive normalized average APSD 22 from frequency-analysis signatures for measurements with Component 1 parts in M102 containers

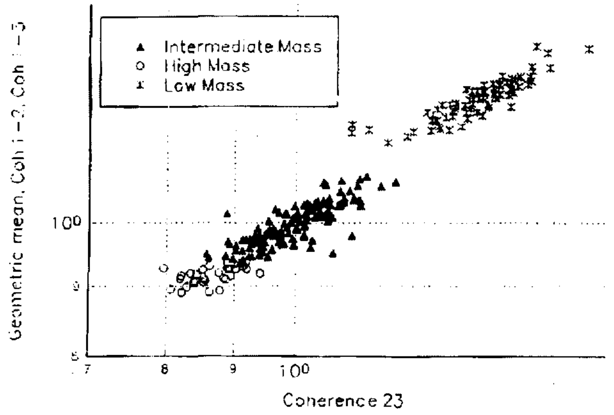


Normally Packaged Component 1 Parts

Some of the measured nine signatures from frequency analysis will be discussed. Because these parameters were constant with frequency over the limited range of frequency measured, only the average values will be presented. A set of data as a function of frequency for one trainer part divided by the values for the reference mock-up unit has been plotted previously in Figures 11-14. The distribution of the average values of the ratios of the APSDs for detector 2 is shown in Figure 18. This type of plot gives the number of measurements (ordinate) within a specific range of values indicated on the abscissa by the boundaries defined by the vertical lines. For example, the extreme left shaded area of the APSD 22 distribution means that there were 11 values of the ratio of APSD 22 within 6.7E-1 and 7.0E-1. The values of the APSD 22 (2 designates frequency analysis detection channel for the detector adjacent to the lower portion of the M102 container) fall generally into three groups, depending on the amount of uranium at the bottom of the container. Each of the groups looks normally distributed. The configuration of materials at the bottom of the container affects the APSD of the detector viewing the lower portion of the container. The lower ratios of APSDs are for the container loadings with lower mass than the reference, the intermediate values of the APSDs are for the containers with intermediate mass like the reference mock-up unit, and the higher values are for containers with more mass than the reference mock-up unit. The dependencies of some of these frequency-measured parameters on the mass of uranium in the containers were used to determine deviations from masses declared by the shipper, as discussed in the next section.

A useful plot that shows the high-discrimination capability of frequency-analysis measurements is a plot of the square root of the product of Coherence 12 and Coherence 13 vs. Coherence 23. This plot is given in Figure 19 for normally packaged Component 1 parts. This plot shows the data grouped into three groups corresponding to the mass of uranium in the M102 container. The group with the highest mass of uranium

Figure 19. Distribution of nonintrusive normalized geometric mean of Coherences 12 and 13 vs. Coherence 23 for mock-up Component 1 parts in M102 containers



has the lowest coherence because the coherence is reduced by the background counts from the natural activity of the uranium. The coherence plots of these data show the distinction between the containers with the three different uranium masses. These distinctions are not as significant as those of Figure 18 because Detector 3 was located so as not to be sensitive to mass in the containers.

The location of one of the detectors at the bottom of the M102 containers made it sensitive to the contents of the lower part of the containers with Component 1 parts. If the uranium more or less than that for the reference Component 1 mock-up unit was in the container, the contents of the lower part varied. The frequency-analysis signatures involving the detector at the bottom of the container (which was identified as frequency analysis Channel 2) such as APSD 22, CPSD 12, CPSD 23, Coherence 12, Coherence 23, and the ratio of spectral densities depend on the mass in the container. For three containers anomalous signatures were obtained associated with the material at the bottom of the container. After the containers were opened, it was found that the support material for these three Component 1 parts was wood.

Deviations from Declared Weight of Component 1 Parts

Eight verifications showed that the measurements indicated a weight of uranium different from the weight declared by the shipper. Unpacking of the container after all the verifications were completed revealed the actual contents and confirmed the results of the verification measurements and thus the errors of the declared shipping masses. These deviations are summarized in Table 2. Thus, the Y-12 Plant received uranium parts above what was declared by the shipper for the Component 1 parts. The Y-12 Plant, through DOE-ORO, resolved these differences with the Albuquerque Operations Office and related shipping personnel.

Normally Packaged Component 2 Parts

As with the data from measurements with the Component 1 parts, only average values of ratios over frequency are presented. The distributions of the measured APSD 33 are given in Figure 20. The distribution is clearly divided into two groups. In every case, these differences agreed with the slight differences measured in the time-domain analysis. This was caused by the presence of container inserts different from that of the reference mock-up unit. The areas on the left in the distributions of measured values are for the units with the alternative inserts, as indicated by the time-domain measurements. These alternative inserts reduce the signal from the material in the container and result in lower APSDs. The use of the alternative inserts was confirmed after the verifications were all completed, when the containers were opened.

The distributions of the CPSD 12, CPSD 13, and CPSD 23 also showed distributions relating to two types of insert materials. The distributions of the measured coherence ratios are more

Figure 20. Distribution of nonintrusive normalized average APSD 33 from frequency-analysis signatures for measurements with Component 2 parts in M102 containers

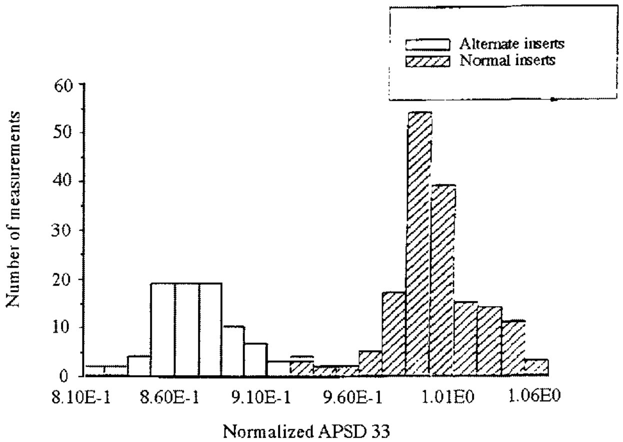


Figure 21. Distribution of nonintrusive normalized geometric mean of Coherences 12 and 13 vs. Coherence 23 for mock-up Component 2 parts in M102 containers

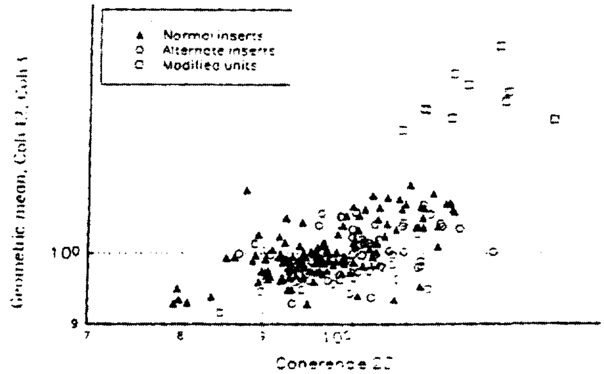


Table 2. Deviations from Shipper Weights for Component 1 Parts

Deviation No.	Shipper Declared Weight	Weight from Verification Measurements	Actual Weights
1	Low	Intermediate	Intermediate
2	Very low*	Intermediate	Intermediate
3	Intermediate	Low	Low
4	Low	Intermediate	Intermediate
5	Intermediate	Low	Low
6	Low	Intermediate	Intermediate
7	Low	Intermediate	Intermediate
8	Low	Intermediate	Intermediate

*Shipper indicated weight was much lower than that designated as low.

normally distributed because the effects of two groups of inserts on the APSD and CPSD cancel in the calculation of the coherence because Coherence 12 = $|\text{CPSD } 12|^2/\text{APSD } 11, \text{APSD } 22$. This is also true for the ratios of spectral densities. A plot of the square root of Coherence 12 and Coherence 13 vs. Coherence 23 is shown in Figure 21. Except for the points on the upper right, which will be discussed in the next section, part of this scatter is statistical but, in any case, not sufficient to identify the units as containing enriched uranium.

Altered Component 2 Parts

The parts with the 10 anomalous signatures on the upper right of Figure 21 were noted and reported to those opening the containers after the verification. Removing the contents of the containers revealed that all 10 parts had been modified by drilling holes in the uranium, reducing the mass 4.5%. For the frequency-domain signatures with the altered (by drilled holes) Component 2 parts, the increased transmission increased the CPSDs and the coherence between the detectors and the source, Coherences 12 and 13, by as much as 25% each. The plot of the square root of the product of Coherence 12 and Coherence 13 vs. Coherence 23 (Figure 21) clearly shows how these measured values (points on the upper right) differ from the other Component 2 parts. The variation in the measured parameters for these altered parts results from the orientation of the holes with respect to the path of particles from the source to the detectors. The APSDs are not significantly different because they are count-rate dependent. Much of the count rate in these detectors is from the natural gamma-ray activity of the uranium, which comes mainly from the surface, and the presence of holes does not affect it significantly. The CPSDs and coherences changed significantly because they depend primarily on particles from the source reaching the detectors.

Conclusions

NWIS signatures have been used successfully to confirm that B33 trainer parts in their containers, shipped from military bases to the Y-12 Plant, were as declared by the shipper to be of nonenriched uranium. This verification was done by comparing signatures for B33 trainer parts in their M102 containers with signatures for known mock-ups of D-38 packaged in M102 containers. Measurement with a normal production WR Component 2 part and calculations for a normal WR Component 1 part showed the very high sensitivity of the frequency-domain signatures to uranium enrichment. Some frequency-domain signatures were greater than a factor of 100 different for the WR units.

These verifications were conducted in a timely, reliable manner and produced no false positives for the 512 verifications (263 containers with Component 2 parts and 249 containers with Component 1 parts). Measurement times were 10 min each for time- and frequency-domain verifications, which occurred simultaneously. As many as 32 verifications were performed in one day (normal eight-hour shift) and 111 in one week. These verification measurements produced a variety of anomalous signatures that differed significantly from the references but were not sufficiently different to indicate the presence of HEU. These deviations were all later confirmed when the parts were eventually removed from the M102 containers.

The verification measurements showed that eight Component 1 parts had different masses in the M102 container than declared by the shipper. These deviations resulted in the Y-12 Plant receiving more Component 1 parts than declared by the shipper. The Y-12 Plant, through DOE-ORO, resolved these differences with the Albuquerque Operations Office and related shipping personnel.

For one Component 1 part and one Component 2 part, the uranium was not in the usual location in the container. The Component 1 part was at the bottom of the container instead of having an aluminum spacer below the uranium. The Component 2 part was not in the usual location at the bottom of the container. The measurements also showed that alternative inserts were used in the M102 containers for many of the Component 1 parts. For one Component 1 part, the high values of the frequency measured parameters (coherences and CPSD involving the detector at the bottom of the container) indicated a lack of material below the uranium (i.e., lower density than aluminum). For another Component 1 part, it indicated too much material under the part. These were later confirmed when the containers were opened, and the material on the bottom was found to be varying amounts of wood. Ten Component 2 parts showed anomalously high values of the coherence between the source and detectors identifying increased transmission of particles through the parts, suggesting less nonenriched uranium in the container. This was also confirmed when the containers were opened and it was found that many holes had been drilled partway into each part, removing 4.5% of the mass of uranium.

These verifications demonstrated the use of NWIS signatures for identification of weapons mock-up parts. All anomalous signatures were explained when the containers were opened. Because signatures for mock-up units usually require more measurement time than normal WR units, measurements and identification of normal production weapons parts would be easier with NWIS. These verifications by use of a large set of signatures (11) provided by NWIS showed that this method would be difficult to defeat because some signatures depend on mass and others do not, and because some depend on packaging and others do not. The complexity of the total signatures is an advantage of this system. This was the first use of NWIS in a nonresearch environment and thus pointed out the potential usefulness of automated operation.

NWIS signatures have been demonstrated to be more than adequate for shipper-to-shipper confirmatory measurements within the DOE and between the DOE and DOD. A nonintrusive use of NWIS signatures was demonstrated and would allow the use of this method by foreign nationals at the DOE facilities or verifications at foreign facilities.

Appendix A. Field-Deployable System

Figure A1. Photograph of NWIS cart/portable system with detectors and source adjacent to a container with a weapons component

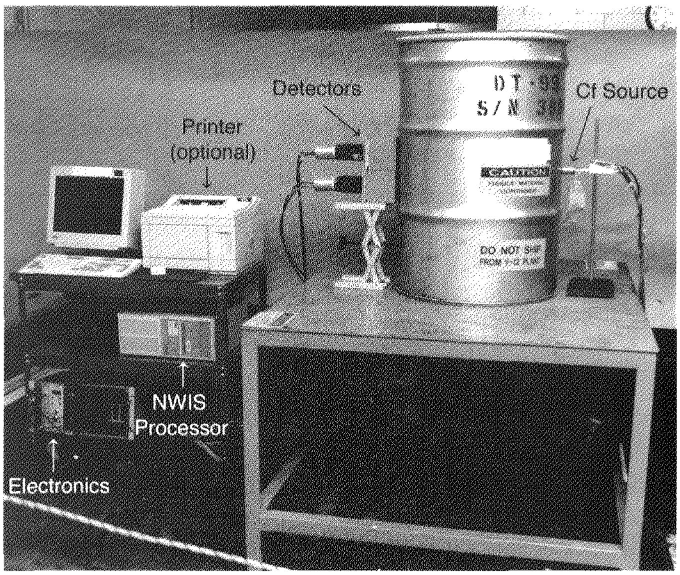


Table A1. Time- and Frequency-Domain Signatures for a 3-Channel System

Signatures for 3-Channel System	Number
Time distribution of counts after Cf fission, f(t)	2
Time distribution of counts in any one of two detection channels after a previous count in the same or any of the other detection channel, f(t)	3
Multiplicity arrays from two detection channels	2
APSDs of two detection signals, f(ω)	2
Real part of 3 CPSDs, f(ω)	3
Imaginary part of 10 CPSDs, f(ω)	3
Coherences between channels, f(ω)	3
Ratios of spectral densities, f(ω)	1
Total	19

Additional signatures such as the APSD of the source fission detection system, the multiplicity and the time distribution of spontaneous fission previous spontaneous fission in the source, all of which can be used to verify proper operation of the source detection channel.

A photograph of a field-deployable system operational in 1996 is given in Figure A1. It consists of a work station with two special processor cards that sample the signals and pass the data to the computer where the signatures are obtained and stored. This new system is capable of synchronously sampling the pulses from the californium source ionization chamber and the detectors at up to 1 GHz rates in all five channels. The detection system shown provides three signals to the data acquisition card, which samples the data and passes the data to the processor card and then to the memory, where the total NWIS signature is accumulated. The number of signatures for this system, which does both time and frequency analysis, consists of 17 functions of time and frequency for three channels of data input plus multiplicity arrays for two detection channels. The multiplicity arrays are the number of times 0, 1, 2, 3... pulses appear in a specified time. A list of signatures is given in Table A1 for three-channel operation. This totality of signatures is a very robust signature, which is difficult to defeat. These complicated signatures and the dependence of some of them on mass and packaging, as demonstrated by the B33 trainer parts verifications, are one of the advantages of this method. The other two main advantages of frequency analysis are the elimination of background from some of the signatures and the very high sensitivity of the frequency measured parameters to changes in the fissile system. Another advantage is that the ratio of spectral densities is independent of detection efficiency, and for uranium metal systems, it is also independent of source intensities and background gamma rays. This latter advantage has been demonstrated with HEU metal cylinders, where measurements nine years apart with different neutron sources and detectors yielded ratios of spectral densities within ±1%.[11]

References

1. J.T. Mihalczo and V.K. Paré. "Nuclear Weapons Identification System (NWIS)," Arms Control and Nonproliferation Technologies Report on Nuclear Warhead Dismantlement, Third Quarter 1994, DOE/AN/ACNT-94C.
2. C. Sastre, J.B. Sanborn, and J.P. Indusi. "CIVETCA Controlled Intrusiveness Verification Technology," Verification Technologies, DOE/DP/OAC/VT-91A, U.S. Department of Energy, March/April 1991, pp. 17-19.
3. T.E. Valentine and J.T. Mihalczo. "Sensitivity of Calculations of ^{252}Cf-Source-Driven Analysis Measurements to Cross Sections for Aqueous Fissile Solutions," 1993 Topical Meeting, American Nuclear Society, Nashville, Tenn., September 1993.
4. T. E. Valentine, J.T. Mihalczo, and J.W. Patten. "Sensitivity of Calculations of ^{252}Cf-Source-Driven Noise Analysis Measurements to Cross Sections for Aqueous Fissile Plutonium Solutions," 1994 Topical Meeting on Advances in Reactor Physics, Knoxville, Tenn., April 1994.
5. J.T. Mihalczo, A.W. Krass, and T.E. Valentine. "Validating Criticality Calculations for Spent Fuel with 252Cf-Source-Driven Noise Measurements," INMM 33rd Annual Meeting, Orlando, Fla., July 1992.
6. J.T. Mihalczo and V.K. Paré. "Nuclear Weapons Identification System Signatures for Verification of Trainers Returned to the Y-12 Plant," 1994 U.S. DOE Defense Programs Packaging Workshop, Knoxville, Tenn., May 16-20, 1994, Y/WR-145.
7. Video tape of presentation entitled "Nuclear Weapons Identification System Signatures for Verification of Trainers Returned to the Y-12 Plant," Knoxville, Tenn., May 16B20, 1994, Y/WR-151.
8. M.M. Chiles, J.T. Mihalczo, and C.E. Fowler. "Small, Annular, Double-Contained ^{252}Cf Fission Chamber for Source-Driven Subcriticality Measurements," *IEEE Trans. Nucl. Sci.* 40: 816 (1993).
9. E.P. Ficaro and D.K. Wehe. "Monte Carlo Simulations of the ^{252}Cf-Source-Driven Noise Analysis Measurements for Determining Subcriticality," *Proc. Int. Top. Meet. Adv. Math., Comput. React. Phys.*, 1, 5.22.1-10 (1991).
10. R. Kinsey, Ed., "ENDF-102, Data Formats and Procedures for the Evaluated Nuclear Data File," ENDF, BNL/NCS-50496 (ENDF 102), 2nd ed. (ENDF/B-B), Brookhaven National Laboratory, October 1979.
11. J.T. Mihalczo, W.T. King, and E.D. Blakeman. "Subcriticality Measurements for Coupled Uranium Metal Cylinders Using the ^{252}Cf-Source-Driven Neutron Noise Analysis Method," *Nucl. Sci. Eng.* 95, 1-13 (1987).

The International Remote-Monitoring Project: Results of the First Year of Operation at Embalse Nuclear Power Station in Argentina

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Abstract

As a part of the International Remote Monitoring Project, during March 1995, a remote monitoring system (RMS) was installed at the Embalse Nuclear Power Station in Embalse, Argentina. This system monitors the status of four typical Candu spent-fuel dry-storage silos. The monitoring equipment for each silo consists of: analog sensors for temperature and gamma-radiation measurement, digital sensors for motion detection, and electronic fiber-optic seals. The monitoring system for each silo is connected to a wireless authenticate item monitoring system (AIMS). This paper describes the operation of the RMS during the first year of the trial and presents the results of the signals reported by the system compared with the on-site inspections conducted by the regulatory bodies ABACC, International Atomic Energy Agency (IAEA), and National Board of Nuclear Regulation of Argentina (ENREN).

As an additional security feature, each sensor periodically transmits authenticated state-of-health (SOH) messages. This feature provides assurance that all sensors are operational and have not been tampered with. The details of the transmitted information and the incidents of loss of SOH, referred to as a missing SOH event (MSOHE), and the possible causes that produced the MSOHE are described.

The RMS at the Embalse facility uses gamma-radiation detectors in a strong radiation field of spent fuel dry-storage silos. The detectors are Geiger Muller (GM) tubes and silicon solid-state diodes. The study of the thermal drift of electronics in GM detectors and the possible radiation damage in silicon detectors is shown. Since the initial installation, the system has been successfully interrogated from Buenos Aires and Albuquerque. The experience gained and the small changes made in the hardware to improve the performance of the system are presented.

Introduction

ENREN and the U.S. Department of Energy (DOE) sponsored the installation of an RMS at the Embalse Nuclear Power Station, Cordoba, Argentina. The Embalse facility, which houses one power reactor and spent-fuel dry-storage silos, provides an excellent site to test the concept of front-end detection. This is because the major activity of safeguard's interest is the movement of spent fuel, which occurs during six months of every year at this plant.

The RMS field test in Argentina has been operational for almost 16 months. Motion and temperature sensors and the fiber-optic seals have performed fairly well. GM radiation sensors experienced some drift because of temperature changes, while the silicon radiation detectors showed radiation damage during the first year of operation.

Technical Description

A full technical description of the RMS installed in Argentina has been published.[1] Some changes have been made to the original system, which include the installation of an external modem to improve the telephone data link. In addition, a new version of the control software was installed.

Test Results

A proper analysis of all the components of the RMS can be carried out by grouping them in the following way:

- Data transmission by telephone lines,
- Hardware,
- Radiofrequency (RF) link,
- Motion sensors,
- Fiber-optic seals,
- Temperature sensors, and
- Radiation sensors.

Data Transmission by Telephone Lines

After analyzing several alternatives, a standard telephone line was chosen because of the ease and the rapidity of its installation in the site. This line is analog because only a fraction of the Argentinean telephone network is digitized. On the other hand, the final link between the telephone company and the nuclear power plant is done through a microwave system with a reduced bandwidth, which severely deteriorates the signal-to-noise ratio. Previous tests performed between the Ezeiza Atomic Center (CAE) and the Sandia National Laboratories (SNL) showed that the maximum transmission speed for a stable data link was 4800 baud. Later, communication trials carried out between SNL and the Embalse Nuclear Power Station demonstrated that the limit between both facilities was 1200 baud. Higher speeds produced loss-of-carrier effect, which interrupted the communication. Taking into account these results, it was decided to operate at 1200 baud.

Hardware

The hardware of the receiver processing unit (RPU) behaved properly; only the floppy disk drive of the computer had to be replaced. This demonstrates the adequacy of an industrial computer for this application. On the other hand, it was found that most failures occurred while establishing the communications were produced by the internal modem, which hung up the system. This was caused by the fact that several peripherals shared hardware interrupt, which sometimes provoked hardware malfunctions. This problem was solved by using an RS232 serial interface, which allowed full interrupt and input/output address selection. The RS232 serial interface was defined as Com-3; it was connected to an external modem. In this way, the communications were improved, and their evolution could be verified through the front panel LEDs.

RF Link

Each pair of detector-transmitters periodically emits a signal indicating its proper performance. This signal, received by the computer, not only indicates that the RF link is operative but also authenticates the message. During the first year of operation, this behavior was studied and the causes of some failures were determined. Figure 1 shows a report of missing SOH messages during a 100-day period.

A thorough analysis of the data clearly demonstrated that, most of the time, maintenance and inspection jobs on the silos or the operation of the bridge-crane over them, interfered the RF link. In those cases where a clear explanation could not be found, adverse meteorological conditions or signal collisions between transmitters were assumed to be responsible for the failures. In any case, each sensor emits about 8,600 SOH signals per month; only about five of these were reported by the RPU as missing, indicating the high reliability of the system.

Figure 1. RPU report on the missing SOH messages during a period of 100 days

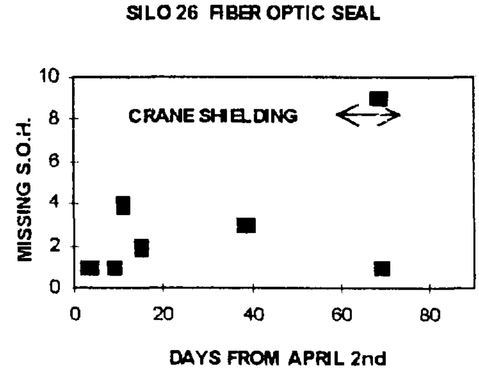
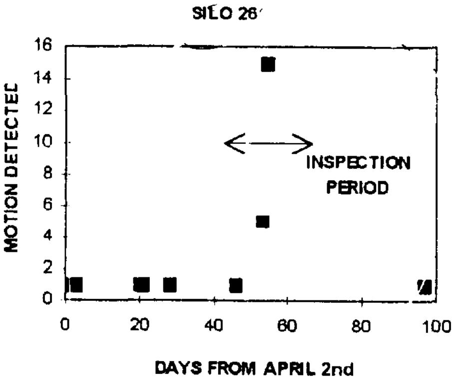


Figure 2. Data report of motion sensors



Motion Sensors

Motion sensors were placed on the silo instrumentation tubes to verify the positioning of the radiation detector and lid of the silo, which connects to the inner baskets. The data report of the motion sensors is shown in Figure 2.

Background signals prevailed during a period of about 50 days, and a marked increase of motion-detection signals, covering one or two days, appears after this period. This correlates fairly well with an inspection period. In cases when a less important rate of signals above the background was detected, a coincidence with different jobs performed on the silos sector, such as spent fuel transfers involving bridge crane operation, was found. Background signals may be attributed to the high sensitivity of the detector, which allows the detection of quite weak movements, such as those produced by rainfalls or the occurrence of birds on the silos. These spurious contributions can be eliminated by reducing the detector's sensitivity.

Figure 3. Dose rate at different times on one day

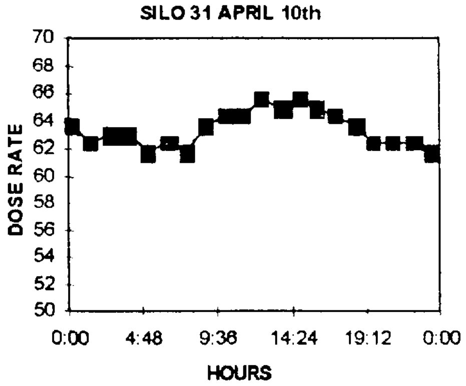
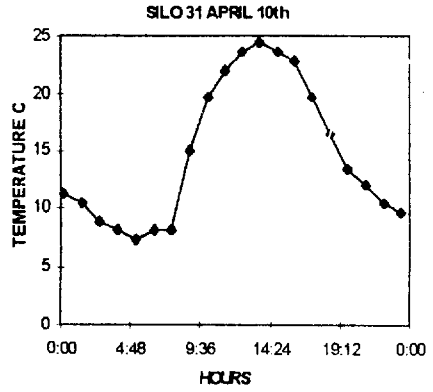


Figure 4. Temperature variation in one day corresponding to the electronic chain location



Radiation Sensors

The radiation sensors are based on GM detectors and solid-state semiconductor detectors (silicon diodes). The dose rate indicated by the GM detectors and their associated electronic chains (HV power supply, preamplifier, and amplifier) showed slight fluctuations around a mean value since the installation of the system. It was demonstrated that this effect was temperature dependent. Taking into account that the temperature at the detector's location stayed almost constant during the periods under consideration, it was assumed that the daily changes in the temperature affected only the electronic chains. As shown in Figure 3, the highest value of the dose rate is registered at noon.

Figure 4 shows the temperature variation during the same period (one day) corresponding to the electronic chain location. The correlation between the dose rate and the temperature can be visualized in Figure 5. The linealirity of this correlation allows the application of a temperature-correction factor to the dose rate measurement between 5°C and 50°C.

The dose rate measurements performed during 12 months, corrected for temperature, are represented in Figure 6. The values show a decreasing behavior, fairly coincident with the radioactive decay of a typical Candu burnt fuel element.

Regarding the semiconductor detectors, because the tungsten shielding had to be removed at the onset due to mechanical problems, the dose rate measurements did not represent the right values. This situation was corrected by applying a linear factor. It was demonstrated that the whole system, detectors plus electronic chains, were not affected by the daily temperature variations (Figure 7).

Figure 5. Dose rate vs. temperature

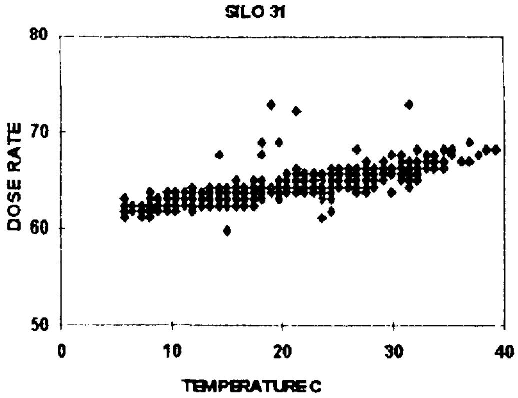


Figure 6. Dose rate measurements, corrected for temperature, during 12 months

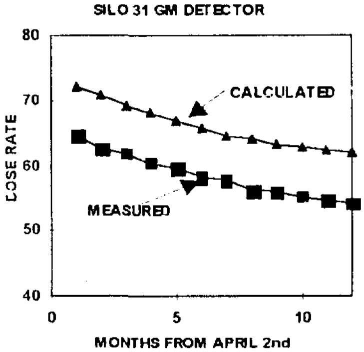
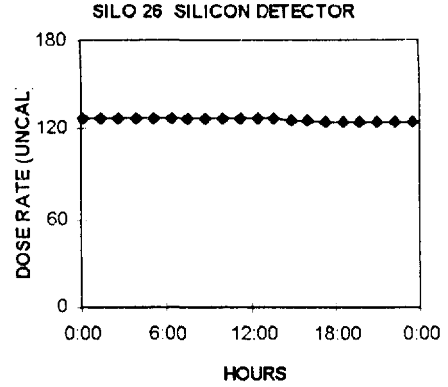


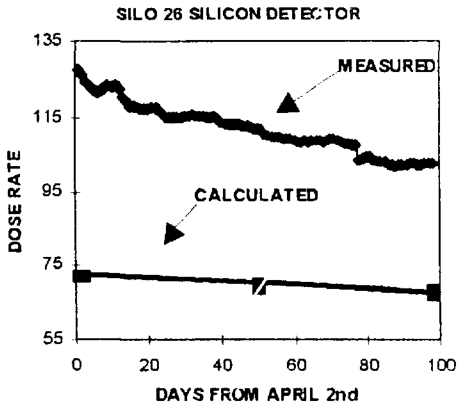
Figure 7. Dose rate of entire system



Over the long term, a decreasing tendency of the measured values can be seen. This tendency does not correlate to the radioactive decay process, and it can be explained by a decrease of the counting efficiency of the detectors, caused by radiation damage (Figure 8). To support this assumption, it should be taken into account that the semiconductor detectors receive a monthly dose of 360 Gy, which is high enough to produce severe radiation damage in this kind of detector.

To solve this problem, the detectors were replaced with ionization chambers in May 1996.

Figure 8. Decrese of counting efficiency of detectors



Fiber-Optic Seals

The performance of these devices was fully acceptable, without any indication of fiber-optic rupture. Only a few cases of missing SOHs were reported, most caused by interference, shielding of transmitters, or collisions among signals from similar remote-control devices. However, the lithium batteries were replaced with ones that have a higher capacity, because the lifetime of the originals was not satisfactory.

Temperature Sensors

These devices, connected to radiation and motion detectors, have shown proper behavior during the first year of operation.

Conclusions

The experience gained during the first year of operation of the system demonstrated its adequacy for safeguards purposes. The online remote operation and the possibility of its acceptance without interfering with the normal plant activities make this system an attractive alternative to routine "in situ" safeguards inspections. The use of authentication and a reliable RF transmission technique assure that the information has not been tampered with, allowing the use of this system in many high-security installations.

Acknowledgments

The cooperation of the Embalse Nuclear Power Station staff and the participation of Nestor Fruttero in the theoretical calculation of dose rates is greatly appreciated.

References

1. A. Bonino, L. Pizarro, A. Perez, J. Schoeneman, S. Dupree, R. Martinez, and C. Maxey. "The International Remote Monitoring Project First Results of the Argentina Nuclear Power Station Field Trial." *INMM 36th Annual Proceedings*, July 1995, Vol. XXIV.

Bibliography

J. Schoeneman, M. Baumann, L. Fox, C. Jenkins, and A. Perlinski. "Universal Authenticated Item Monitoring System, Second Generation Equipment." Sandia National Laboratories report SAND-922-643A.

J. Schoeneman, K. Insch, C. Jenkins, A. Perlinski, and C. Brusseau. "Authenticated Item Monitoring System, System Description and Operational Manual." Cooperative Monitoring Systems Department 9249. Sandia National Laboratories report VST-039, September 1995.

J. Schoeneman, K. Insch, C. Jenkins, A. Perlinski, and C. Brusseau. "Authenticated Item Monitoring System, System Objectives: History and Description Final Report." Cooperative Monitoring Systems Department 9249. Sandia National Laboratories report VST-065, September 1995.

Technology Diffusion of a Different Nature: Applications of Nuclear Safeguards Technology to the Chemical Weapons Verification Regime

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Abstract

The following discussion focuses on the issue of arms-control implementation from the standpoint of technology and technical assistance. Not only are the procedures and techniques for safeguarding nuclear materials undergoing substantial changes, but implementation of the Chemical Weapons Convention (CWC) and the Biological Weapons Convention will give rise to technical difficulties unprecedented in arms-control verification. Although these regimes present new challenges, an analysis of the similarities between the nuclear-and chemical-weapons nonproliferation verification regimes illustrates the overlap in organizational structures and technological solutions. Just as cost-effective and efficient technologies can solve the problems faced by the nuclear safeguards community, these same technologies offer solutions for the CWC verification regime. Experts at the Organization for the Prohibition of Chemical Weapons (OPCW), who are responsible for verification implementation, need to devise a CWC verification protocol that takes into account the technology already available. The functional similarity of International Atomic Energy Agency (IAEA) and the OPCW, in conjunction with the technical necessities of both verification regimes, should receive attention with respect to the establishment of the national authority and a technical assistance program. Moreover, the advanced status of the nuclear and chemical regime vis-à-vis the biological nonproliferation regime can inform our approach to implementation of confidence-building measures for biological weapons.

Introduction

Given the inherent threat of the proliferation of weapons of mass destruction, a prudent approach to policy formulation entails a thorough assessment of the technical aspects of verification. In this vein, there is much to be gained from looking at the technological overlap between nuclear and chemical nonproliferation verification procedures. Furthermore, the success of the existing nuclear nonproliferation infrastructure and its methodologies should inform our approach to implementation of chemical and biological nonproliferation regimes. What follows is a discussion of the provisions set forth by the Chemical Weapons Convention (CWC) and the technical and functional similarities of the nuclear and chemical nonproliferation regimes. The discussion will then be summarized in some basic policy prescriptions in the utilization of nuclear verification technologies to implement the CWC, as well as for technical assistance to the Organization for the Prohibition of Chemical Weapons (OPCW). Both the nuclear and chemical weapons nonproliferation regimes offer a solid blueprint for the formulation of comprehensive confidence-building measures and their implementation in the realm of biological weapons.

Chemical Weapons Convention

A regime to eliminate the threat of chemical weapons was foreseen in the negotiation of the CWC. Since the CWC opened in Paris in January 1993, more than 160 countries have signed and more than 58 states have deposited their instruments of ratification.[1] The CWC bans the production, stockpiling, and use of chemical weapons, and it includes strong verification provisions applicable to chemical weapons and to the production of industrial chemicals that could be used to make those weapons. These provisions include the following:

- international inspectors to implement a system of accounting and tracking of the weapons until they are destroyed safely,
- proper control of new kinds of chemical weapons,
- routine inspections in the industry to make sure that these chemical compounds are used only for commercial products, and
- challenge inspections at any place to investigate problem situations.[2]

The Preparatory Commission (PrepCom) for OPCW is working to ensure the organization's readiness to function when the convention becomes effective 180 days after ratification by 65 states. This trigger point was reached in November 1996 with Hungary's ratification,[3] and the treaty will take effect April 29, 1997. The OPCW and implementation of the CWC will be discussed in more detail later in this paper.

Implementation of the CWC

Verification and on-site inspection difficulties are likely to be a source of debate and continuing concern even after the CWC goes into effect. Despite the fact that 100 percent verification is not feasible, the effective application of reliable and comprehensive verification measures, backed by adequate responses in the event of a state's noncompliance, is essential to the viability of any nonproliferation regime. More specifically, the United States needs to look at its role in ensuring the eventual efficacy of the OPCW through the funding and establishment of its national authority and a technical assistance program to support the OPCW, now and in the years to come.

The system of international inspections provided for under the CWC will help address not only the safety of the dismantling process and ongoing verification in the United States and Russia, but proliferation threats of other states as well. The CWC represents unprecedented verification measures, including extensive declaration requirements by industry participants and information-gathering opportunities through the aforementioned activities. Chemical weapons differ from nuclear weapons in that their acquisition is not in and of itself significant; this difference is important in the implementation of a nonproliferation regime. Creating a chemical weapons arsenal of military significance includes the following steps: research, development, production, storage, munitions filling, and military training in their use. Because the CWC bans all of these activities and its verification measures are extensive, a sufficient web of deterrence and detection can be achieved via this regime.[4] Furthermore, the intrusive inspections regime in conjunction with extensive sharing of information between national authorities and the OPCW should allow for an increased capacity to detect terrorist activities, whether these are of military significance or not; such measures are to be included in domestic implementing legislation of any state party to the CWC regime.[5]

The Organization for the Prohibition of Chemical Weapons

The Organization for the Prohibition of Chemical Weapons now being established in The Hague is functionally equivalent for chemical weapons to the IAEA.[6] The PrepCom and the

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[1] *OPCW Synthesis: Newsletter of the Provisional Secretariat of the Preparatory Commission for the OPCW*, Issue No. 14 (March 22 1996), p. 1.

[2] *Convention on the Prohibition of the Development, Production, Stockpiling, and Use of Chemical Weapons and on their Destruction* (corrected version), Depository Notification C.N.246.1993. Treaties-5 (8 August 1994). For detailed information on inspections and chemical schedules, see *Chemical Weapons Update for Industry*, a publication of the Arms Control and Disarmament Agency (No. 5) (June 1995).

[3] The most notable exceptions to ratification are Russia and the United States, whose legislatures have yet to ratify the CWC. However, joint implementation of a bilateral agreement to destroy weapon stocks is under way. "Over the Impasse," *Chemical Weapons Convention Bulletin*, Issue No. 30: 1 (December 1995). The CWC has languished in the U.S. Senate for over three and a half years, despite having support of the Chemical Manufacturers Association and the current U.S. administration. U.S. failure to ratify could isolate American companies and hurt business. Despite existing concerns over verification and noncompliance by rogue states, the U.S. Senate should seize its opportunity to lead in implementing the CWC. A prepared statement before the House International Relations Committee, "Chinese Assistance to Iran's Weapons of Mass Destruction and Missile Programs," by Leonard S. Spector, director of the Nuclear Non-Proliferation Project at the Carnegie Endowment for International Peace, on September 12, 1996, clearly addresses the more immediate threat that chemical weapons pose to U.S. security. According to Spector, even in the case of nonsignatories, "the pact will impose new restrictions on all other parties prohibiting transfers to it of sensitive dual-use chemicals" and "broad acceptance of the prohibition against chemical armaments embodied in the treaty would … increasingly isolates Iran as a malefactor. U.S. ratification of the treaty is essential to its success."

[4] For a thorough description of the CWC's verifiability in light of these activities, see Michael Moodie's "Ratifying the Chemical Weapons Convention: Past Time for Action," *Arms Control Today*, 26 (No.1): 5-6 (February 1996).

[5] National implementation is an indispensable prerequisite for the CWC, because a country-specific approach will entail legislative provisions as to the legal requirements of the domestic chemical industry in that state. Article VII, Paragraph 1, of the Convention states: "Each State Party shall, in accordance with its constitutional processes, adopt the necessary measures to implement its obligations under this Convention. In particular, it shall prohibit natural and legal persons anywhere on its territory or in any other place under its jurisdiction … from undertaking any activity prohibited to a State Party under this Convention, including enacting penal legislation with respect to such activity." These measures will include the "information function" of the national authority and individual private chemical actors in meeting the declaration requirements and inspection preparations. See T. Stock, T. Kuzidem, P. Radler, and R. Sutherland, *CWC Implementation: Targeting the important groups and the role of NGOs — an overview*, Paper 9 in the series of the SIPRI-Saskatschewan-Frankfurt Group on National Implementation of the CWC (February 1995).

[6] The OPCW will consist of three organs: the Conference of States Parties (CSP), Executive Council (EC), and Technical Secretariat (TS). The CSP, which will meet 30 days after entry into force of the Convention and annually thereafter, is the principal organ of the Convention and is to oversee the activities of the EC and TS, as well as issue guidelines to both of those organs. (Article VIII, Para. 20). The EC is to perform a central fuction in supervision and implementation of the Convention. Some of its responsibilities include: supervising the work of the TS, concluding agreements with states and other international agencies, approving agreements and procedures in implementation of verification activities (facility agreements), and considering allegations in cases of noncompliance. The TS, currently referred to as the Provisional Technical Secretariat, is the organ that is responsible for carrying out the verification measures encompassed by the Convention and formulated in the facility agreements with individual states.

Provisional Technical Secretariat (PTS) have provided technical assistance in the creation of the OPCW during the initial stages. In recent months, the PTS has become increasingly occupied with responsibilities for recruitment, training, data handling, and other activities; this, in turn, implies that the PTS has diminished capacity to provide necessary technical services to PrepCom.[7] Currently, PrepCom's duties focus on three areas: verification; establishment of the implementing organization, i.e., the OPCW; and assistance in the establishment of national authorities to implement the CWC. Technical assistance from signatory states will become essential if the PrepCom is to meet treaty verification objectives. More technical assistance is necessary on a permanent basis to support planning and implementation activities of the PrepCom and the OPCW.

The assumption that the OPCW will require additional support is based on its similarities to the IAEA. The OPCW mirrors the IAEA in these specific areas: its infrastructure and managerial, procurement, and training tasks. Both agencies feature a multinational governing body responsible for determining resources, programs, and priorities. Upon reaching the benchmark of 65 ratifications, the OPCW then has 180 days to begin implementing extensive verification measures worldwide; in short, the OPCW must be able to cope immediately with a large obligation. That obligation appears formidable in light of its budgetary constraints unless sufficient "extra-budgetary" assistance is forthcoming from national programs.[8] As is true for the IAEA, moneys and capability for research and development of technologies for information-gathering and inspections will not be possible in-house. Lastly, the OPCW will require a staff with the necessary competence and expertise to accomplish its objectives; this will undoubtedly require assistance with training, as well as occasional specialists that can assist in finding solutions to technical problems.

Moreover, the actual verification activities of the OPCW are similar to those of the IAEA. In this regard, technical assistance would facilitate the formulation of the OPCW's preinspection, inspection, and postinspection activities. To carry out its verification mandate, the OPCW must define each of its verification approaches in detail, standardize its analysis and evaluation of inspection results, develop an information treatment infrastructure, provide for maintenance and shipping of equipment, make provisions for using experts in special cases, and train inspectors from a multinational pool of applicants. In all of these areas, technical assistance programs from signatories have allowed for the IAEA to fulfill its mandate. Thus, a similar program of technical assistance should be established for the OPCW.

The Technical Secretariat and National Authority

According to Article VIII, Paragraph 38 (e), the Technical Secretariat (TS) shall "provide technical assistance and technical evaluation to States Parties in the implementation of the provisions of this Convention ...." Although technical assistance in a narrow sense could be seen as including only analysis of chemicals, laboratory help, and the like, it might also be read to imply assistance in the establishment of national authorities of signatories, training, computer software, and standardization of procedures and declarations. While the TS appears to have extensive obligations in providing assistance to state parties, the CWC implies that state parties also are required to provide assistance. Under the provisions found in Articles I, III, IV, V, VI, and IX, each state party must establish a national authority, produce the requisite declarations, communicate and cooperate with the OPCW, assist the OPCW in international inspection of its facilities, cooperate and exchange information with other states parties, ensure confidentiality of all communications with the OPCW and other states parties, and enact penal legislation to prevent any activity prohibited to a state party.[9]

National implementation of the CWC will be set forth in so-called facility agreements between the OPCW and the respective national authority. Facility agreements will incorporate a complex array of responsibilities. States parties will need to accomplish vast reporting duties in a number of areas related to chemical production. Whereas reporting obligations with respect to chemical weapons in a state's territory should cause little difficulty, the gathering of information on scheduled chemicals from private facilities and protection of legitimate private interests, i.e., confidentiality, represent much more problematic tasks. Routine monitoring and access to scheduled facilities will need to be regulated; in addition, access for OPCW inspectors to facilities that are the object of challenge inspections must be included.[10] Lastly, the provisions of Article VII require each state party to control or prohibit several activities (research, production, and trade) and legislate penal sanctions to deter and/or punish violations to the CWC.

The facility agreements required by each state party that is a signatory to the CWC parallel the safeguards agreements that are negotiated between IAEA and the individual states that are parties to the Nuclear Nonproliferation Treaty (NPT); the national implementation measures of the CWC correspond to

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[7] *Chemical Weapons Convention Bulletin*, Publication of the Harvard Sussex Program: Cambridge, Massachusetts (No. 30): 1 (December 1995).

[8] Given its total budget of $35,800,000, more than half of this ($18,570,000) has been designated for verification and inspection acitivities. About $6.5 million is for inspector training; $1.8 million, inspection equipment; and $200,000 for laboratory supplies and equipment at the OPCW. See "Beyond VEREX: A Legally Binding Compliance Regime for the Biological and Toxin Weapons Convention," *The Federation of American Scientists* 4 (July 1994).

[9] See T. Stock, T. Kuzidem, and R. Sutherland, "Perspectives for entry into force of the CWC: Benefits of early ratification," *Series of the SIPRI-Saskatschewan-Frankfurt Group on National Implementation of the CWC* (No. 6): 5 (January 1995).

[10] In addition to initial declaration and annual declarations as codified in Articles III, IV, V, and VI of the CWC, provisions for escorting OPCW inspections (Articles IV, V, VI, IX, and X), accrediting OPCW inspectors and overseeing closure and destruction activities relating to chemical weapons and chemical weapons production facilities must be coordinated between the OPCW and the national authority. For more information on the national authority's obligations, see "The national authority: Some important issues to be addressed" by T. Kurzidem, P. Radler, T. Stock, and R. Sutherland, *Series of the SIPRI-Saskatschewan-Frankfurt Group on National Implementation of the CWC* (No. 10) (March 1995)

the State System of Accounting and Control in the IAEA context. Comprehensive safeguards agreements are negotiated between the IAEA and each NPT signatory to ensure timely verification of nuclear materials and provide for on-site verification activities by the IAEA.[11] As mentioned previously, the collection and exchange of information and coordination of inspection activities between the national authority and the OPCW must be set forth in facility agreements. For this reason, as well as other regulatory and functional similarities that will be discussed, many signatories to the CWC have opted to utilize existing structures and regulatory models in the establishment of their national authorities. Many states that have a large chemical industry have chosen to establish the head of the national authority in the Ministry of Foreign Affairs, then "to delegate the enforcement of the Convention to existing governmental agencies that have already acquired some experience in related fields."[12] For example, Germany divided responsibility for implementation and enforcement between two agencies: one for the civilian and one for the military component of chemical production. Australia, on the other hand, established its Chemical Weapons Convention Office within the existing Australian Safeguards Office.[13] The decisions regarding the structure of regulatory instances for national implementation are a function of several domestic factors, such as the size and distribution of the chemical industry and whether or not they have chemical weapons manufacturing capabilities or existing stockpiles.

Technical Assistance Against Chemical Weapons

Article X, "Assistance and Protection Against Chemical Weapons," codifies signatory states' obligations to provide information, technology, and expertise to the OPCW. Article X, Paragraph 1, defines *assistance* as the "coordination and delivery to States Parties of protection against chemical weapons, including, inter alia, the following: detection equipment and alarm systems; protective equipment ... and advice on any of these protective measures." Similarly, Paragraph 3 stipulates: "Each State Party undertakes to facilitate, and shall have the right to participate in, the fullest possible exchange of equipment, material, and scientific and technological information concerning means of protection against chemical weapons." In addition, Paragraphs 6 and 7 ensure the rights of any state party to provide assistance in the event of an emergency, as well as requiring each state party to provide assistance through a variety measures. No state party is excluded from an "obligation to provide assistance" in accordance with Article X, Paragraph 7, of the CWC.[14] While the final structure of the national authority will be a function of the nature and size of its chemical industry, among other things, it is generally assumed that the national authority will also be responsible for the coordination of a national technical assistance program as foreseen in Article X of the CWC.[15] Having outlined the CWC's provisions for reciprocal assistance between the national authorities and the OPCW, the discussion turns to the nuclear nonproliferation infrastructure and U.S. technical assistance in order to demonstrate its role in ensuring the success of the IAEA's objectives.

IAEA and OPCW: Functional Similarities, Technical Synergy

IAEA: Challenges and Changes

The experience of the IAEA indicates that a major challenge in the implementation of the nuclear nonproliferation regime has been balancing technical affectiveness against political acceptability. On the heels of incidences in Iraq and North Korea, the IAEA set out to make its safeguards program more effective and efficient, which is a difficult aim considering the financial constraints of the agency. "Effectiveness is measured by the extent to which IAEA verification and inspection activities achieve nonproliferation objectives; efficiency is determined by how well available resources ... are used to achieve IAEA objectives."[16] The IAEA "92+3" program was initiated with the general objective of eliminating the weaknesses in the policy and procedures that these incidents brought to light.[17] In addition, some changes in the policy and procedures of the IAEA needed to be forthcoming given the additional burden of providing safeguards to an increasing number of states while remaining

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[11] Rights and obligations of the state and the IAEA regarding safeguards are first established upon conclusion of a safeguards agreement between the IAEA and a particular state. Comprehensive safeguards agreements are modelled on INFCIRC/153 and cover all nuclear materials in all peaceful nuclear activities. For more information on INFCIRC/153 and comprehensive safeguards agreements, see *IAEA Safeguards: An Introduction*, Vienna: IAEA, p. 2 (1981).

[12] See T. Stock, T. Kurzidem, and R. Sutherland, Perspectives for entry into force of the CWC: Benefits of early ratification, (No. 6): 10.

[13] Germany located its head of the national authority within the department at the Ministry of Foreign Affairs that had been responsible for negotiation of the CWC. Actual implementation and enforcement has been relegated to two existing governmental agencies: the Verification Centre of the *Bundeswehr* in Geilenkirchen will oversee the military component and the Export Control Office, which is affiliated with the Ministry of Economics, is responsible for the civilian component. The Verification Centre acquired verification experience in the implementation of the Conventional Forces in Europe Treaty, and the Export Control Office already has experience in controlling exports of Chemical Weapons-related material. Sweden opted to follow a model similar to that of Germany. *Ibid.*

[14] Article X, Paragraph 7, states: Each State Party undertakes to provide assistance through the Organization and to this end to elect to take one or more of the following measures: (a) To contribute to the voluntary fund for assistance to be established by the Conference at its first session; (b) To conclude, if possible not later than 180 days after this Convention enters into force for it, agreements with the Organization concerning the procurement, upon demand, of assistance; (c) To declare, not later than 180 days after this Convention enters into force for it, the kind of assistance it might provide in response to an appeal by the Organization. If, however, a State Party subsequently is unable to provide the assistance envisaged in its declaration, it is still under the obligation to provide assistance in accordance with this paragraph.

[15] See *National Authority: Some Important Issues To Be Addressed*, p. 2.

[16] Hooper, Richard. "Strengthening IAEA Safeguards in an Era of Nuclear Cooperation," *Arms Control Today* 25 (No. 9): 14 (November 1995).

[17] The objectives of Program 92+3 included: increase the level of assurance against nondiversion; reduce implementation costs yet maintain or improve safeguards effectiveness; improve capabilities to detect clandestine activities at undeclared facilities; increase safeguards effectiveness or efficiency through greater cooperation with state systems of accounting and control; improve effectiveness and efficiency of the acquisition, processing, and analysis of safeguards-relevant information; and improve the capabilities of agency inspectors and safeguards staff for testing and implementation. See also Hooper, p. 15.

within their zero-growth budgetary constraints.[18] Funding shortfalls, in conjunction with increasing demands for safeguards, have forced the IAEA to scale back its safeguards programs. According to some sources in recent years, these financial difficulties have adversely affected the safeguards programs.[19] These limitations to resources, however, underscore the important role performed by national technical assistance programs to the IAEA. Similarly, technical assistance programs have been fundamental in the realization of the 92+3 program objectives.

POTAS/ISPO: Background and Update

Since 1977 the International Safeguards Project Office (ISPO) has provided technical project management of U.S. Program Office for Technical Support (POTAS) funding exceeding $90 million and is the primary mechanism to transfer technology from national laboratories and industry to IAEA safeguards. POTAS, through ISPO, provides a wide array of technical assistance, which includes identifying and contracting U.S. entities to provide equipment and instruments for verification procedures.[20] Another important need met by POTAS has been the provision of consultants, often called cost-free experts (CFEs), to provide expert advice and/or assistance on a well-defined, short-term problem.[21] The IAEA has relied heavily on programs like POTAS to arrange access to nuclear facilities, materials, or experts within the member state to provide inspectors with realistic training. Since its inception, POTAS has completed more than 600 tasks and provided more than 50 different types of equipment.[22]

Not only does the technical assistance program give IAEA access to more technology and expertise than would otherwise be feasible, it has proven a particularly effective means to develop and acquire those technologies that match facilities inspectors needs in the field. Simultaneously, ISPO's ongoing dialog with national laboratories and private-sector participants who provide the equipment and instrumentation results in the IAEA having access to the most reliable and efficient technology for the numerous tasks necessary for verification.[23] The establishment of this type of access to technology, along with capacities for equipment adaptation and/or development, procurement and maintenance, is critical to the CWC's success, and Article X obligates each state party to provide such assistance.

Technologies for Verification

Equipment, technical procedures, and concepts that are used in nuclear verification efforts can be adapted for CWC verification. Containment and surveillance techniques, design and evaluation of verification tasks, and statistical sampling techniques are some examples of verification procedures applicable to both regimes. Another example is found in the concept termed *managed access*, which will become a concept inherent in carrying out challenge inspections (also called no-notice inspections). As part of the 92+3 Programme, the IAEA has been taking measures to incorporate challenge inspections into its verification protocol. As previously mentioned, the CWC foresees challenge inspections as a key component of that regime as codified in Article IX of the CWC. And, the results of the VEREX process on confidence building measures to strengthen the Biological Weapons Convention indicate incorporating short-notice, on-site visits at undeclared facilities as well.[24] Inspections, whether routine or challenge, are a crucial element of any verification regime. To achieve either one of the these types of inspections in the context of nuclear, chemical, or biological weapons, managed-access capabilities will be necessary. In addition to this example, an analysis of the other tasks involved in implementation of these nonproliferation regimes indicate a great deal of technological similarity in the capabilities, instrumentation, and equipment required to achieve verification objectives.

Managed Access

Managed access refers not only to the facility agreements that incorporate restrictions on the inspectors' access to certain areas and information, but it also is used in reference to the technology necessary for on-site, intrusive inspections, especially short-notice (or no-notice) challenge inspections. Achieving challenge inspection objectives requires assembling, transporting, and implementing the equipment necessary to verify compliance at any facility that may be suspected of clandestine activities. Whereas instrumentation and equipment for routine and in-situ verification activities exists, a sufficiently lightweight, portable system that can handle the tasks of challenge inspections has yet to be designed. Given the specific provisions of current nonproliferation regimes to allow only minimal access in order to not endanger proprietary information, this

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[18] In real (inflation-adjusted) terms, the IAEA budgets, including "extrabudgetary" contributions, have remained flat since 1985. Kosiak, Stephen M. *Nonproliferation and Counter-proliferation: Investing for a Safer World?* Washington, D.C.: Defense Budget Project, p. 11 1995.

[19] *Ibid*, p. 15.

[20] ISPO, in communication with the contractor and IAEA inspectors, provides overall management of tasks — from the request process to the reporting and implementation (fielding) of new equipment. Such equipment includes the development and provision of authenticated video surveillance systems; in-situ verifiable seals; nondestructive and destructive measurement equipment, techniques, and procedures; personal computer-based software for use by inspectors in the field; training materials for inspectors; and preparation of system studies and computer models.

[21] These experts are supported by POTAS and are therefore "cost-free" to the IAEA. About 50% of the U.S. support program budget has been allocated to support between 20 and 25 experts at the IAEA headquarters in Vienna. CFEs generally remain in Vienna for two to five years to offer support in training, data processing, systems studies, and the like.

[22] Percentage allocations of POTAS funds since 1977 are as follows: equipment accounted for 41.2 percent; information treatment and evaluation, 18.2%; procedures, 14.4%; training, 14.3%; system studies, 10.9%; and 2% for orientation and recruitment purposes.

[23] Instrumentation supports both on-site, as well as remote, activities of measurement, monitoring, sealing, and containment. At present, approximately 100 different instruments are available to IAEA inspectors, and the IAEA's inventory consists of some 5,000 of these. See Pellaud, Bruno, "Safeguards in Transition: Status, Challenges, and Opportunities," *IAEA Bulletin* 26 (No. 3): 2 (September 1994).

[24] VEREX is an ad hoc group of experts established by the Third Review Conference on confidence-building measures to identify and examine the technical and scientific feasibility of potential verification measures. See "Beyond VEREX," p. 5.

system must attain "virtual presence," i.e., obtain the information requisite to satisfy verification of compliance but avoid unnecessary intrusiveness. Virtual presence is also requisite in ameliorating the threat of any breach of confidentiality in the inspection process that would be of detriment to the party involved.

The Managed Access by Controlled Sensing (MACS) system developed by the Safeguards, Safety, and Nonproliferation at Brookhaven afforded virtual presence while denying personal access. The MACS system also used as much commercially available technology as possible to limit the complications and costs of designing new components. The MACS demonstrated that portable, managed access is possible with the right combination of communication devices, video capability, position monitoring, and sensing equipment.[25] What is needed is a concerted effort by safeguards and verification technology experts to streamline and rationalize a MACS-type system, using commercial and specially designed equipment. Of course, the specific components and instrumentation for a viable managed-access system would have to be tailored to the material under scrutiny and the type of facility. However, this type of portable, self-contained unit offering virtual-presence capabilities will be needed for inspections in nuclear, chemical, and biological verification activities.

Remote Monitoring

Remote monitoring will provide a significant enhancement in international safeguards in the coming years. The term *remote monitoring* means "the transmission via telephone, Internet, satellite, or other communications links, of information from unattended sensors and cameras installed in nuclear facilities worldwide directly to an inspector's personal computer for verifying safeguards obligations."[26] Unattended surveillance allows for a reduction in the volume of data, which also decreases the effort required for review and evaluation. This capability significantly reduces inspection costs, increases reliability in the detection of intrusion, and enhances worker or inspector safety by limiting exposure. Remote monitoring systems are currently being fielded in a variety of facilities in the United States and abroad.[27]

While this technology is currently being introduced in the area of nuclear safeguards, its application extends to biological and chemical nonproliferation regimes. Even though permanent monitoring will be requisite at few sites, advances in the area of remote monitoring make comprehensive verification and compliance monitoring more cost-effective and reliable than ever before. The chemical and biological verification regimes can benefit substantially from these monitoring capabilities as well. To the extent that these regimes utilize on-site scrutiny, which all of them do, remote monitoring offers a means to reduce travel, decrease amounts of data, and increase safety of inspections for verification purposes.

Data Management

Related to, yet distinct from, remote monitoring is the issue of data management. The activities concerned with data collection, transmission, and analysis underpin almost every activity in the overall process of verification. Improvements in computational capacity, more reliable and cost-effective transmission capabilities, and enhanced analysis capabilities afford more efficient tools for verification tasks. Just as remote monitoring can reduce the amount of data collected at a particular facility, the transmission of that data is now feasible via a variety of media; in addition, the computational capacity exists to enhance most analysis techniques used in verification processes.

Again, the IAEA is trying to capitalize on these advances to meet increased demands and remain within budget. One primary area identified by the U.S. technical support program focused on the 92+3 Programme is "enhanced information acquisition and analysis" in the form of greater information security and integrity, use of satellite information, and information-management systems generally.[28] The OPCW and any agency created for biological weapons verification will rely on similar technologies.

Training

Unlike the previous examples, the recruitment and training of highly skilled, professional personnel from an international pool of applicants remains a difficult task; one that, for the most part, increases in complexity with advances in technology. For example, only highly qualified professionals are to be hired for chemical weapons inspections; these persons also receive additional training to ensure that inspections are performed efficiently and with minimum intrusion and compromise of confidential business information. Not surprisingly, the OPCW is currently experiencing a dearth of qualified candidates to staff its TS in certain categories. An anticipated cadre of 140 inspectors and technical inspector assistants will be necessary to proceed with implementation.[29] From the candidates interviewed so far, about one-third were found unsuitable. Individuals who would qualify appear reluctant to apply, as the salaries offered are not competitive, start dates are uncertain, and initial

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[25] J.A. Curtiss, and J.P. Indusi, "Managed Access by Controlled Sensing (MACS)" *Proceedings of the Institute of Nuclear Materials Management 35th Annual Meeting*, pp. 794-799 (July 1994).

[26] See Sheely, Kenneth B., "Remote Monitoring Safeguards for the 21st Century" in *JNMM*, Vol. XXIV (No. 11): pp. 15-18 (January 1996) for more information on existing remote monitoring capabilities and technologies.

[27] Through the International Remote Monitoring Project of DOE's International Safeguards Program remote monitoring systems have been installed in facilities in Australia, Sweden, United States, Japan, Argentina, and the European Union. More information is available in "Remote Monitoring in International Safeguards" by S.A. Dupree, C.S. Sonnier, and C.S. Johnson, *JNMM*, Vol. XXIV (No. 11): 19-30 (January 1996).

[28] A presentation made by Ira Goldman, "U.S. Technical Support to IAEA" July 29, 1996, at the *Institute of Nuclear Materials Management 37th Annual Meeting* addressed the changed focus of technical support in light of the 92+3 objectives. The primary areas of U.S. support, as offered by Goldman, were environmental monitoring, remote monitoring, and information acquisition and analysis.

[29] *The CBW Chronicle*, Henry L. Stimson Center, Vol. II (No. 1): 4 (January 1996).

employment is by short, fixed-term contract.[30]

Training of personnel in the procedures and use of instrumentation and equipment at international agencies has been an ongoing difficulty for the IAEA; already the OPCW is showing similar strains in its capacity to recruit and train a staff with the necessary skills to accomplish its objectives. As mentioned previously, one focus of the existing technical assistance program to IAEA is to recruit and train personnel for their role at IAEA. Upon EIF, in April 1997, a trained staff must be ready to effect implementation of the CWC's measures. The best route to facilitate the personnel requirements of these international agencies would be to offer support through a technical assistance program in conjunction with national support to increase incentives for industry experts to work for these agencies.

Budget Constraints and Research and Development

The financial means of an international secretariat whose main function is operational (e.g., verify compliance of parties to the treaty), such as that of the IAEA, require that "extrabudgetary assistance" in the form of programs like POTAS be established. The IAEA does not have the internal resources to develop improved verification technology or adapt commercial off-the-shelf (COTS) technology for international implementation. Thus, technical assistance programs to the IAEA are common among member states of the NPT, 13 of which were modeled after POTAS. Not only is POTAS the primary mechanism for the transfer of technology to facilitate the verification tasks required of IAEA inspectors, but technical assistance has proven the most effective means to protect U.S. interests and influence agency policies within the framework of the NPT. The OPCW mirrors the IAEA in its verification implementation and compliance monitoring of the CWC; the CWC will, undoubtedly, struggle with the same budgetary and in-house resource constraints faced by the IAEA. As such, a technical assistance program to the OPCW is not only a legal obligation but also a necessity.[31]

Policy Prescriptions

Technological Similarities

It is hoped that this cursory overview of technologies for verification illustrated the overlap in technical capacities required by nuclear, chemical, and biological regimes. Managed-access capabilities will be necessary, especially for challenge inspections. Remote monitoring will greatly enhance capabilities and lower costs for the IAEA. Remote monitoring to detect clandestine activities is also foreseen for chemical and biological nonproliferation. Efficient and cost-effective data collection, transmission, and analysis is essential in all areas, for both international and domestic agencies. Lastly, adequate training for international and domestic personnel is requisite to realizing verification objectives.[32] Technical means to achieve verification are prerequisite to implementation. Support for enhanced technological capabilities would not only promote the IAEA's nonproliferation objectives, but it would also offer technical solutions for implementation of regimes to deter chemical and biological weapons proliferation.

Technical Assistance

Support to the OPCW from government programs is foreseen in the following areas: operational requirements for inspection equipment, inspection procedures, planning for inspector training, declaration formats, and model facility agreements. Other areas of importance include development of confidentiality procedures and information management systems. Assistance is especially needed in the area of information systems, logistics planning, and program planning and management. After EIF, the focus of technical assistance programs should be verification-related support. As mentioned previously, these are similar technical and procedural support as is offered to IAEA through the POTAS/ISPO model.

Aside from the overriding concern about curbing the proliferation of chemical weapons, several other compelling reasons exist for a U.S. technical assistance program to the OPCW. The POTAS/ISPO program not only protects U.S. capabilities and interests, it ensures that U.S. capacity to operate within the IAEA is not diminished. Secondly, although some COTS technology is useful, a long-term research-and-development capacity is essential; in addition, even COTS equipment must be adapted for use by international secretariat and be maintainable. Lastly, technical assistance programs offer the international agency access to expertise, facilities, and technology far superior than what is possible within the administrative and operational budget available. Because the technologies and procedures for implementing the terms of the CWC are relatively similar to those used in nuclear nonproliferation verification and the two agencies are functionally similar, one approach might be to expand the existing IAEA technical assistance program to include the necessary additional expertise for support to the national authority and the OPCW. This would allow for synergy between the nuclear and chemical technical assistance programs and avoid the cost and inherent redundancy of establishing a separate agency.

Biological Weapons: Transparency and Confidence-Building Measures

Although the Biological Weapons Convention (BWC) entered into force in 1975, this particular regime does not have legally binding measures to assure compliance with its provisions.

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[30] *Ibid*, p. 5.

[31] Instrumentation supports both on-site, as well as remote, activities of measurement, monitoring, sealing, and containment. At present, approximately 100 different instruments are available to IAEA inspectors, and the IAEA's inventory consists of some 5,000 of these. See Pellaud, p. 2.

[32] Two differences in the CWC are worth noting. First, given the wide array of "dual use" chemical agents, material balance accounting will not be used as a measure of fundamental importance under the CWC. Secondly, the initial operational interpretation by the OPCW of the "Confidentiality Annex" could make the arrangements for the use of so-called cost-free experts much more difficult than for the IAEA.

Confidence-building measures were first adopted in 1986 by the Second Review Conference; the Third Review Conference not only improved and extended confidence-building measures, but it also established VEREX to examine possible verification measures for their scientific and technical feasibility.[33]

Although VEREX provided the foundation for moving forward on measures that are legally binding, the BWC is nascent relative to the nuclear and chemical nonproliferation regimes. An ad hoc group of states parties is now negotiating those measures outlined in the VEREX process; however, the details of enhanced compliance measures and institutional arrangements are yet to be determined. Support exists, for example, for the option of a free-standing BWC-related organization and of integrating such an organization with the OPCW. Regardless of the final form this nonproliferation regime takes, the lessons learned and blueprint offered by the nuclear and chemical regimes should inform the course for implementation of biological weapon verification protocol provisions. Similarly, the increases in efficiency and cost-effectiveness achieved through technological advances in the nuclear and chemical weapons verification regimes may also provide solutions for implementation the realm of biological weapons.

Conclusion

"Trust but verify" remains an appropriate motto in the realm of arms control, particularly in light of the increasing threat of weapons of mass destruction. The existing regimes, embodied in the NPT and CWC, will require ongoing support from national governments. In light of successes in the realm of nuclear nonproliferation, the experience accumulated in providing an international secretariat with sufficient means to meet its objectives suggests that technical assistance programs allow those agencies access to a worldwide pool of technologies, equipment, and technical expertise to successfully accomplish their mission. Almost 20 years of providing technical assistance to the IAEA has proven that targeted support furthers U.S. policy objectives, fosters effective and efficient international verification of treaty obligations, and increases the ability of the agency to respond to changing verification obligations. The core technologies that will underpin these regimes are providing more cost-effective and reliable means to accomplish verification objectives than ever before. Utilizing the technology and experience already implemented for nuclear nonproliferation purposes will facilitate progress in implementation of the CWC. Both of these regimes provide a backdrop for making technical decisions about biological weapons verification and designating a path for the BWC.

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Ann Reisman is head of the International Projects Division (IPD) of Brookhaven National Laboratory. The IPD supports U.S. policy objectives abroad by providing scientific, engineering, and policy expertise to improve the safety of nuclear and fossil energy systems across the international community and by supporting verification of nonproliferation treaty obligations. Since 1977, the International Safeguards Project Office (IPSO) of IPD has administered the U.S. Program of Technical Assistance to IAEA Safeguards, the primary source of technical assistance to the IAEA Department of Safeguards in Vienna, Austria.

Before assuming her present position, Reisman served as ISPO liaison officer to IAEA and was based at the U.S. Mission to the U.N. Organizations in Vienna. Reisman joined Brookhaven National Laboratory in 1974. She obtained her undergraduate degree from Cornell University and her graduate degree from the University of California at Los Angeles.

Elizabeth A. Turpen is a doctorial candidate at the Fletcher School of Law and Diplomacy. Turpen interned at Aquila Technologies in 1992, and she currently provides consulting services on safeguards and nuclear nonproliferation policy issues as they relate to Aquila's technological expertise in this area.

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[33] "Beyond Verex," p. 1.

IAEA Modifies Publishing Program

The International Atomic Energy Agency (IAEA) announced a change in its publishing program. Starting this year, two basic series of publications, the Safety Standards Series and the Safety Reports Series will take the place of the Safety Series.

The new publications will include information of a regulatory nature issued under the terms of Article III of the agency's statutes, which authorize the agency to establish standards of safety for protection against ionizing radiation. The series will comprise safety fundamentals, safety requirements, and safety guides, and will discuss issues such as radiation safety, transport safety, nuclear safety, waste safety, and general safety.

The Vienna, Austria-based agency will discontinue the previous series following the publication of *Safety Series No. 120: Radiation Protection and the Safety of Radiation Sources.*

Russian, Ukrainian Facilities Contain Radiation With Foam

Eurotech Ltd. signed an agreement with the Ukrainian State Construction Corp., the Chernobyl Nuclear Power Station Industrial Amalgamation, and the Ministry of Russian Federation on Atomic Energy to contain nuclear waste using the company's radiation-resistant, silicon-organic foam.

Chernobyl officials will apply the substance, called EKOR foam, at the damaged Reactor No. 4 to suppress airborne and waterborne transmission of radionuclides and prevent the structure's collapse. Accelerated life testing of the foam under simulated Chernobyl radiation conditions indicates the foam should remain effective for 200 years.

Russian Federation scientists will test EKOR technology for potential use in the decommissioning of nuclear facilities, containment of liquid radioactive waste stored in drums, and the suppression of radioactive dust in inactive mining and processing facilities. The initial project, to begin by summer 1997, will test how much foam is required to contain radioactive emissions in the decommissioning of a nuclear plant; preliminary estimates are 3,000 cubic meters.

The EKOR technology was developed by Eurotech and the I. V. Kurchatov Institute of General and Nuclear Physics in Moscow.

JAI Changes Address

JAI Corp., formerly E.R. Johnson Associates Inc., has moved to a new office. The company's new address is 4103 Chain Bridge Rd., Suite 200, Fairfax, VA 22030 U.S.A. Telephone and fax numbers remain the same: (703) 359-9355; fax, (703) 359-0842.

DeltaTRAK Releases New Temperature Recorder

DeltaTRAK Inc. unveils its ICON Data Logger, an electronic temperature recorder with an 8,000 data-memory capacity. The unit is designed with an internal or external sensor, a waterproof ABS plastic case, a two-year lithium battery, infrared data-transfer system, and a minimum/maximum temperature alarm light. It operates with Windows.

For more information, contact DeltaTRAK at (800) 962-6776 or (510) 467-5940; fax, (510) 467-5949; e-mail, salesinfo@deltatrak.com.

CALENDAR

June 9–10, 1997
Nuclear Waste Contamination Cleanup Conference: Containment Technologies at U.S. Department of Energy Sites, Washington National Airport Hilton, Arlington, Virginia. Sponsor: *The Energy Daily.* Contact: King Communications Group Inc., (202) 662-9710; fax, (202) 662-9719; e-mail, kingcomm@dgs.dgsys.com.

June 30–July 2, 1997
Meeting of the American Society for Testing and Materials Committee E-10 on Nuclear Technology and Applications, Marriott River Center, San Antonio, Texas. Sponsor: ASTM. Contact: Felicia Quinzi, ASTM; (610) 832-9738; e-mail, fquinzi@astm.org.

July 20–24, 1997
INMM's 38th Annual Meeting
The Pointe Hilton at Squaw Peak, Phoenix, Arizona. Contact: INMM headquarters, (847) 480-9573; fax, (847) 480-9282; e-mail, inmm@inmm.com.

July 27–31, 1997
Meeting of the ASTM Committee C-26 on Nuclear Fuel Cycle, Doubletree Hotel-Pentagon City, Arlington, Virginia. Sponsor: ASTM. Contact: Felicia Quinzi, ASTM; (610) 832-9738; e-mail, fquinzi@astm.org.

October 8–10, 1997
Low-Level Radioactive Waste Technical Seminar, Cordoba, Spain. Sponsor: INMM and ENRESA. Contact: Pierre Saverot, (703) 359-9355; fax, (703) 359-0842; e-mail, psaverot@jaicorp.com.

November 10–14, 1997
International Conference on Physical Protection of Nuclear Materials: Experience in Regulation, Implementation, and Operations, Vienna, Austria. Sponsor: International Atomic Energy Agency. Contact: Susan Melnicove, American Society for Industrial Security, 1655 N. Fort Myer Dr., Arlington, VA 22209-3198 U.S.A.; (703) 522-5800; fax, (703) 243-4954.

Author Submission Guidelines

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    2. F.T. Jones, *Title of Book*, New York: McMillan Publishing, 1976, pp. 112-118;
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