Conf-930913--2

LA-UR- 93-1818

Title: NUCLEAR MATERIALS CONTROL TECHNOLOGY IN THE POST-COLD WAR: RADIATION-BASED METHODS AND INFORMATION MANAGEMENT SYSTEMS

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Submitted to: Global '93 Conference to be held in Seattle, Washington September 12-16, 1993.

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NUCLEAR MATERIALS CONTROL TECHNOLOGY IN THE POST-COLD WAR WORLD: RADIATION-BASED METHODS AND INFORMATION MANAGEMENT SYSTEMS

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ABSTRACT

The end of the cold war is providing both opportunities and requirements for improving the control of nuclear materials around the world. The dismantlement of nuclear weapons and the growth of nuclear power, including the use of plutonium in light water reactors and breeder reactor programs, coupled with enhanced proliferation concerns, drive the need for improved nuclear materials control. We describe nuclear materials control and the role of technology in making controls more effective and efficient. The current use and anticipated developments in selected radiation-based methods and related information management systems are described briefly.

INTRODUCTION

During the super-power nuclear arms race that exemplified the cold war, the control of nuclear materials for domestic safeguards and to prevent the proliferation of new nuclear weapons states was viewed as an important but clearly secondary concern compared to weapons production and deployment. The end of the cold war and the breakup of the former Soviet Union, coupled with the revelations about Iraq and concerns about other proliferant states such as North Korea, have increased international concerns about the control of nuclear materials. At the same time, the world's energy needs must be met with environmentally sound electrical generation, and nuclear power remains the only quad-level supply option that does not produce greenhouse gases.

Nuclear materials control comprises all aspects of policies, procedures, and technical measures to ensure that nuclear materials are used only for their intended purposes, are handled safely, and are protected from unintended release to the environment. Control includes nuclear materials safeguards designed to prevent the proliferation of nuclear weapons by terrorist groups or nations. The concept of controlling nuclear materials through a system of safeguards has been a cornerstone of US nonproliferation policy since the Baruch Plan of 1947. Nuclear materials controls also include measures designed to protect nuclear workers from unnecessary exposure to these radioactive materials and procedures and technical approaches to support nuclear waste management and environmental control.

The breakup of the former Soviet Union and the strategic nuclear arms reduction agreements, START I and II, when fully implemented, will result in significant reduction and dismantlement of nuclear weapons. These events will result in notable increases of stored nuclear materials requiring the utmost control and care for the indefinite future. Some of these materials, in addition to existing wastes and residues, may need further processing. Also, the use of nuclear power continues to grow worldwide, and some countries, notably Japan, are making a commitment to a plutonium fuel cycle. At the same time, the revelation of Iraq's nuclear weapons program following the UN/IAEA inspections has made it clear that nuclear weapons proliferation is a real and urgent threat to the US and its allies. The control of nuclear materials through safeguards is one of only a few effective barriers to proliferation.

Health, safety, and environmental concerns regarding the handling and storage of nuclear materials have grown significantly over the past 50 years. The environmental cleanup and waste management legacy of the cold war nuclear weapons production in all the nuclear weapons states, but especially the US and the former USSR, is a high-priority, high-cost problem. Worldwide public opinion insists on minimizing the environmental impact of electric power generation, including the nuclear option.

Thus, world events, public opinion, and the continuing need to generate electricity with nuclear power plants make the importance of effective and efficient nuclear materials controls essential to our security, safety, and economic well-being.

NUCLEAR MATERIALS CONTROL TECHNOLOGY

Improved technology is the key to cost-effective control of nuclear materials. To provide assurance that these materials are still where they are supposed to be and have not been stolen or unintentionally released to the environment, they must be measured and inventoried, pathways to the environment must be monitored, and records must be maintained. Timely detection of unwanted actions requires the continuous monitoring of processes and personnel in nuclear facilities. Waste containers destined for permanent disposal must be monitored for nuclear materials content for good waste management practice and to detect diversion of nuclear materials. The nuclear facility's external environment must also be monitored to detect any failures of plant controls.

Nuclear materials control technology has been employed since the beginning of the nuclear age. In the past 25 years much of the emphasis has been on developing methods to detect the presence of and to measure nuclear materials (primarily uranium and plutonium) rapidly and nondestructively. Technology development, most of it funded by the Department of Energy (DOE) in support of safeguards, has resulted in vastly improved systems to control and account for nuclear materials in DOE nuclear facilities and Nuclear Regulatory Commission (NRC) licensed plants. Similar technology developed for use by International Atomic

[a]Operated for the US Department of Energy by the University of California under Contract W-7405-ENG-36. Work supported by the US Department of Energy's Office of Safeguards and Security.

Energy Agency (IAEA) inspectors has permitted effective and efficient inspection of nuclear facilities around the world. This development effort, whose products (instruments, procedures, and computer software) are transferred to the private sector, DOE/NRC nuclear facilities, and international organizations via training and formal technology transfer programs, has made a significant impact on US security by improving the control over these strategic materials.

Nuclear materials control technologies span a broad range of instrumentation and systems that includes portable equipment carried by inspectors; on-site instrumentation for use by plant operators; continuous, unattended monitoring and assay equipment for on-site inspection; containment and surveillance measures;[1,2] and remote monitoring concepts for environmental and proliferation detection applications.[3] This paper will focus on radiation-based methods for detecting and assaying special nuclear materials (SNM) and supporting information management systems. Other technologies for measuring nuclear materials, such as chemical methods[4] and calorimetry,[5] and non-nuclear methods for protecting and tracking nuclear materials[6,7] will not be covered here.

Radiation-based measurements of nuclear material are based on nondestructive assay (NDA) techniques wherever feasible. The techniques measure induced or emitted radiation without altering the chemical or physical state of the material. NDA obviates the need for sampling, reduces operator exposure, and is fast enough to permit near-real-time accountability of nuclear materials in process or storage. NDA measurements are applied in fuel cycle facilities for materials accounting and control, process monitoring, waste screening, and criticality control. For example, passive/active neutron coincidence counters[8] are being used for passive assay of plutonium materials and for the active assay of uranium materials. Applications include safeguards instrumentation, verification of unmeasured facility inventories, international safeguards inspections, verification of weapons dismantlement, and monitoring of weapons materials being received for storage. Figure 1 illustrates another passive/active system for waste assay and screening.

Pedestrian and vehicle SNM monitors, which detect the passage of small quantities of these materials at the boundaries of processing or storage areas, are examples of technologies that strive for sensitivity of detection rather than quantitative assay results.[9,10]

Detection and assay of SNM are useful only if the information acquired by the instrumentation is organized, analyzed, and displayed in a way that can be used by human decision-makers who must provide assurance that nuclear materials have in fact remained under control. Thus, information management technologies are an integral part of nuclear materials control systems. Since the mid-1970s there has been a steady progression of computerized accounting systems for nuclear materials.[11]

THE FUTURE OF NUCLEAR MATERIALS CONTROL TECHNOLOGY

Although some of the existing technology for nuclear materials control can be utilized to meet the demands of today's problems, new technology is urgently needed to control nuclear materials during weapons dismantlement, during transfers between defense and civilian sectors, and for materials in US and Russian storage vaults. New technology is also needed to provide better tools to

Figure 1 - This figure shows several different waste containers ready to be moved by a conveyor into a passive/active californium shuffler that uses neutron coincidence counting for passive assay and delayed neutron counting for active assay. This shuffler will be placed on a material access area boundary and will provide both materials control capability and waste assay.

inspectors and agents charged with detecting or deterring proliferation around the world; to improve nuclear emergency detection, search, and analysis methods; and to support management and control of materials in the nuclear-power-reactor fuel cycle. Nuclear technology is not stagnant, and nuclear materials control technologies must keep up. Instrumentation to detect and assay a wide variety of nuclear materials can be made to provide more timely results, be more portable, operate continuously in harsh environments, and be less expensive. Information management, the key to effective nuclear materials control, is based on the revolution in computer and communications technology. Hardware and software developments for improved processing of materials inventories and transfer information have the potential to alert nuclear materials managers or inspectors to problems where human analysis would be impossible or not timely. Finally, the integration of nuclear materials control subsystems for safeguards and security, health and safety, and environmental protection is required for the nuclear facilities of the future. Technology development is the key to continuous improvement of nuclear materials management in the US and around the world.

Measurement technology developed for DOE weapons production facilities is finding equally important applications in weapons dismantlement facilities, weapons component storage facilities, and waste-stream monitoring and characterization activities associated with the cleanup of the weapons complex. Integration of NDA instruments with robotics for automated sample handling will be important to meet the twin goals of near-real-time accountability and reduced radiation exposure for operators. Figure 2 is an example of such a robot-operated system. For international inspection activities, there will be increased emphasis on more compact, rugged equipment with internal data analysis and diagnostic capabilities. For monitoring of compliance with the Nuclear Nonproliferation Treaty, there will be an increased use of fixed NDA equipment in remote, unattended operations. Measurement technology is also evolving to become part of integrated data collection and review systems that will provide continuous monitoring and anomaly detection for complete facilities.

As an example of advances in portable equipment made possible by advances in electronics, the miniature modular multichannel analyzer (MMMCA) package has been developed to meet facility holdup measurement and international field inspection needs. The modular unit includes four circuit boards: amplifier, analog-to-digital converter, high-voltage power supply, and microprocessor for control and interface functions. The unit also has self-contained battery power and nonvolatile memory to automatically set up the hardware and conditions for data acquisition. The new MCA can be interfaced to a pocket-size programmable controller, data-logger, or computer. Los Alamos also is developing a segmented gamma-ray scanner with tomographic capability for the assay of 55-gallon drums. The first-generation prototype tomographic scanner will simultaneously acquire transmission and emission projection data. The scanner is expected to provide more accurate assays of drums with inhomogeneous matrices and to provide a capability for detecting shielded nuclear material.

Recent DOE Complex reconfiguration activities involving the design of the proposed plutonium storage facility have highlighted the need for additional technology development activities in the area of receipts confirmation measurements and periodic inventory verification measurements. Incoming receipts will require a gamma-ray/neutron fingerprint measurement of the

Figure 2 - This figure shows a robot-operated uranium solution assay system that automatically assays an array of solution vials to provide near-real-time accountability without operator handling or exposure. Uranium concentration, uranium enrichment, and sample ID are determined using x-ray fluorescence, transmission-corrected passive gamma-ray counting, and a laser bar-code reader.

shipping container that precedes more accurate accountability measurements. After items are stored in the facility, automated confirmatory measurement systems, neutron and image zone monitor systems, and/or individual item radiation monitoring systems will be needed to reduce the frequency of human inventory activities. Many of these concepts are being explored for implementation in the Russian nuclear materials storage facility as well.[12]

Information management for nuclear materials control is benefiting from the revolution in computer hardware and software. Recent advances in technology coupled with reductions in cost make it possible to consider local area networks (LANs) for nuclear materials control and accounting applications.[13] Software tools for data analysis and anomaly detection[14] also provide promise for aiding human analysts in detecting the loss, either through process upset, theft, or diversion, of significant quantities of nuclear material in a timely manner.

CONCLUSION

The end of the cold war and the super-power arms race provides many opportunities to develop and apply nuclear materials control technologies to counter proliferation, control arms, and safeguard the power reactor nuclear fuel cycle. Many of these technologies carry over to environmental monitoring and restoration and waste management applications. The continued development and application of these technologies will be an integral part of providing assurance to the public that nuclear activities, be they weapons dismantlement and storage or commercial nuclear power, are conducted safely and securely around the world.

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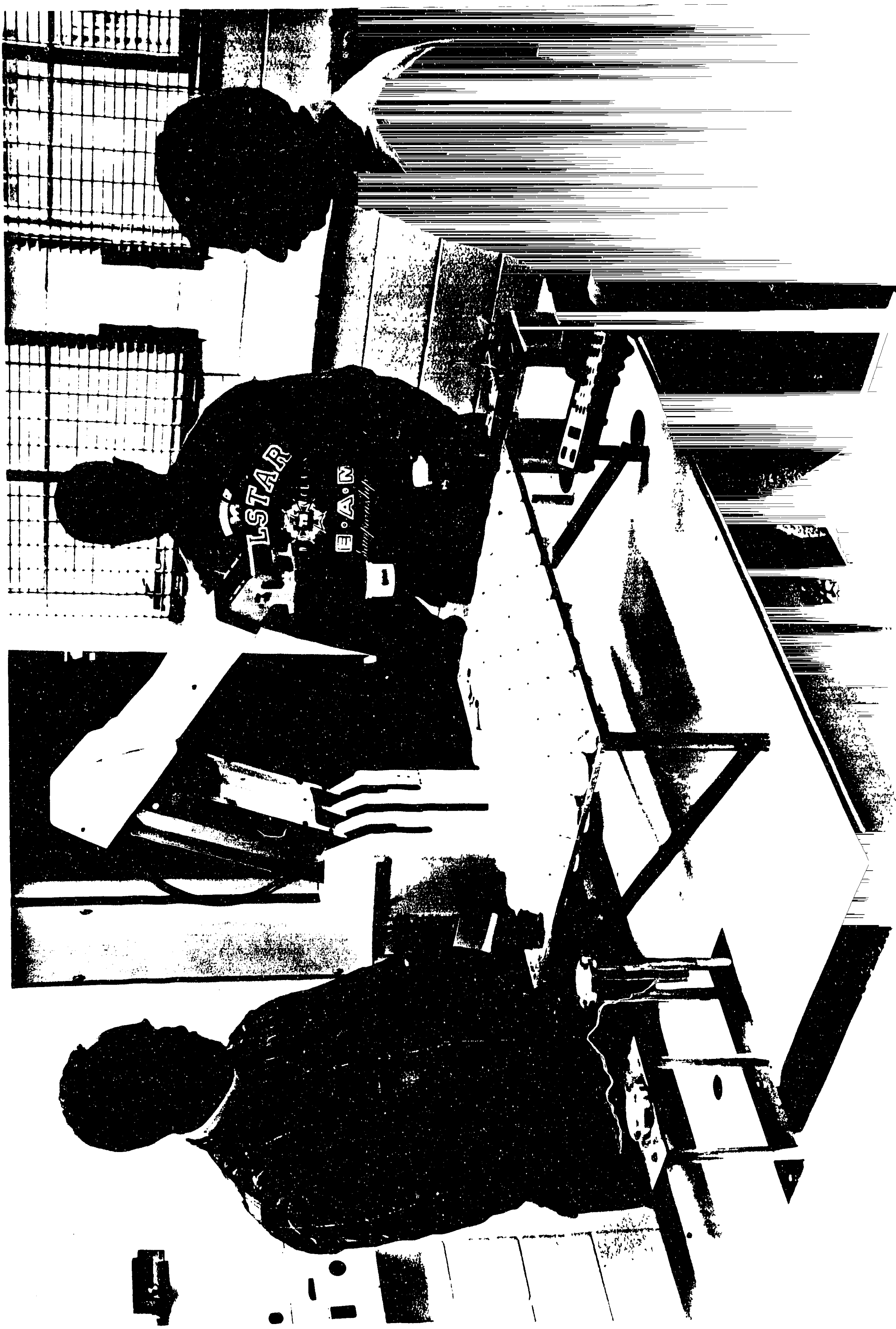
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