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National and International Nuclear Material Monitoring

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The status of nuclear materials in both the U.S. and Former Soviet Union is changing based upon the execution of agreements relative to weapons materials production and weapon dismantlement. The result of these activities is that a considerably different emphasis is being placed on how nuclear materials are viewed and utilized. Even though much effort is being expended on the final disposition of these materials, the interim need for storage and security of the material is increasing. Both safety and security requirements exist to govern activities when these materials are placed in storage. These requirements are intended to provide confidence that the material is not being misused and that the storage operations are conducted safely. Both of these goals can be significantly enhanced if technological monitoring of the material is performed. This paper will briefly discuss the traditional manual methods of U.S. and international material monitoring and then present approaches and technology that are available to achieve the same goals under the evolving environment.

Traditional Methods

Traditional monitoring methods are mostly manual and thus manpower intensive. The methods used are a combination of inventories supported by observation. Both international and domestic inventories are conducted via personnel accessing the material locations and visually reading identification numbers. This process is usually accompanied by nuclear material measurements on a selected sample of the containers. The data gathered during these inventories is compared within an accounting system to verify material integrity. One primary drawback of this approach is the radiation exposure incurred by personnel. Frequent exposure of material to personnel also creates potential security problems. The observation aspects of monitoring the material differ between international and domestic applications. In the domestic application, access to the material is closely controlled and unauthorized access is detected, visually observed on real time video and responded to in real time as appropriate. In the international application, observation occurs through the use of stored images which are reviewed during inspector visits and anomalous conditions responded to through international organizations.

Technological Approaches and Methods

Technological approaches are beginning to be used to accomplish these functions. Most of the systems in use as well as those being developed are summarized below. In general, all of these systems electronically collect data from the material and forward it to collection locations which are used for the monitoring centers.

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Technological Approaches and Methods

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VSIS - The Vault Safety and Inventory System (VSIS) has monitored approximately 6900 nuclear storage canisters for several years at the Hanford Plutonium Storage Facility. This system consists of canister monitor units (CMUs) which provide data to a central computer over hard wires. The CMUs gather label identification, canister bulge, canister temperature, canister presence, and ambient air temperature data. A minicomputer functions as the control computer for the VSIS. It allows the operator to issue commands and to print reports. It also receives inventory and alarm data for the CMUs from four microcomputers hardwired to the CMUs. One of the vault areas which is monitored by the VSIS is also under IAEA safeguards. The IAEA is not using the data from VSIS but continues to rely on the manual inspection and measurement methods described above. The facility is considering an upgrade to VSIS and has no intention of returning to a manual system because of the advantages to the operation that have accrued in the past .

SAMMS - The Idaho Chemical Processing Plant uses the Security Alarm and Material Monitoring System (SAMMS) to monitor stored SNM. The SAMMS consists of a series of steel tubes welded into a matrix and set in concrete below the level of the storage area floor. The floor contains circular openings above each steel tube. A steel cap or lid seals each opening in the floor. Suspended from the top of the tube is a rack holding a number of SNM containers. When a rack is placed in the storage tube a load cell monitors the weight of the rack and the containers. The SAMMS uses a data acquisition system to continuously monitor the load cells' output. Weight tolerance limits are software selectable. The SAMMS generates an alarm when the data acquisition system detects that the weight of the rack exceeds either the upper or lower limit. Statistical analysis of the weight data is performed to assure system information quality.

Personnel and Material Tracking (PAMTRAK) System - This system provides a capability to monitor materials as well as the personnel activities associated with material movements. This modular PC-based system provides a comprehensive set of security rules which are site selectable. The personnel tracking capability allows a site to monitor and restrict personnel movements and enforce the two-person rule. The material tracking portion of the system has five material monitoring subsystems available for use and three prototype subsystems that would require more development before being ready to use. The Wireless Alarm Transmission of Container Handling (WATCH) subsystem employs motion sensors packaged together with radio-frequency (RF) transmitters to report attempts to move material. The AIMS has been integrated as a subsystem. A polled RF sensor subsystem called Versatag developed by RandTec Corp. overcomes some of the drawbacks of the WATCH and AIMS subsystems by sequentially polling the transmitters in order to minimize transmission collisions. This subsystem supports material attribute-measuring sensors (weight, temperature, radiation) as well as actively monitoring seals. The system also offers three video motion detection (VMD) subsystems. The first is a Sandia-designed VMD called the Material Monitoring Image Processing System (MMIPS). The second, Monitor, was designed by Los Alamos National Laboratories. The third is a commercial VMD, the TSI 20/20 by Tech. Services International. Although they have different features, they all work by using video cameras to detect and report movement within predefined regions of interest. The system can also interface with two prototype canister monitoring subsystems designed to measure physical attributes of material such as weight and temperature. However, both subsystems need further development before being ready for deployment in a real-world environment.

Monitor - The Monitor System is a Los Alamos National Laboratory image-based system which provides timely information on the state of nuclear materials in storage or process. Using video cameras the Monitor acquires baseline image data throughout a monitored area. A host computer digitizes this data and stores it. The system then gathers subsequent image data. The host computer then analyzes this data against the baseline data to detect visually observable changes that occur within the monitored area. The host analyzes these detected events for safeguards significance, archives them for review, and if necessary, triggers an alarm to inform site personnel that an event has occurred.

Continuous Automated Vault Inventory System (CAVIS) - CAVIS was developed to provide the Oak Ridge Y-12 Plant and other domestic and international facilities with an automated system for remotely performing special nuclear material (SNM) inventories of weapons grade uranium and plutonium in long-term (static) or short-term (dynamic) storage. The technologies developed for this system provide both enhanced security and accountability for all SNM within a facilities jurisdiction. CAVIS technologies provides near-continuous monitoring of all materials in these vaults. CAVIS technologies represent the state-of the-art in low cost technologies that are durable, highly reliable, and have either totally or virtually passive modes of operation. The sensors can and have been configured into direct wired or wireless automated monitoring systems. Usually, the systems are designed to provide individual item monitoring from all stored materials, but the system can also be configured for items stored in lots or groups. Sensors and automated monitoring systems have been developed for both static and dynamic (active) storage environments. Several types of the low-cost sensing devices have been built, each capable of monitoring one or more physical attributes from either enriched uranium or plutonium. The attributes that can be monitored include radiation (both gamma and neutron), weight, item identification tags, temperature, isotopic enrichment, item motion, and physical location.

SMARTSHELF™ - SmartShelf™ is an inexpensive method to monitor the inventory of containers in an active storage area. The system continuously maintains surveillance over items in its charge, thus reducing the time required to verify inventory from hours to minutes, and eliminating the need for manual searches. As an added feature, SmartShelf™ can record the identity of the personnel moving containers, and the time of day of the move. SmartShelf™ automates the who, what, when, and where associated with inventories. SmartShelf™ uses standard modular telephone wire and jacks to connect up to 128 electronic identifiers (one identifier affixed to each container) to a controller. The controller includes firmware to detect additions or removals of containers, recognize alarm conditions, perform self testing, and to communicate with a host computer over an RS-485 serial communication line. Up to 32 controllers can be connected to the RS-485 line, allowing a single host to account for 4096 containers. Hosts can, in turn, be networked so that an inventory containing many thousands of containers can be kept current.

Unattended Monitoring Systems - These technologies continue to evolve for the arena of international security, which includes arms control, nonproliferation, treaty verification, and international safeguards. The subsystem technologies are generally the same as for domestic security systems: sensors, communication, and information management. However, due to the nature of these international systems being unattended (by the monitoring party), there are some significant differences in requirements that result in important technical differences. To assure information surety a higher level of system security is employed. Normal international requirements include data authentication and a higher level of tamper protection than for domestic systems. Because most international monitoring applications do not include a real time physical response function, they have a lesser requirement for real time reporting than for physical security. A recent trend is "remote monitoring", which provides remote communication for data transfer and system control from off-site, often across national boundaries. Remote communication capability is provided by telephone, satellite, or the Internet.

On-site integrated sensor networks are connected using distributed communication and control technology. An example of this is LonWorks technology by the Echelon Corporation in Palo Alto, California.. Their original main line product is for industrial process and building control systems, but adapts well for international nuclear material monitoring systems. Each network node includes processing capability for communication with other nodes, control of the attached sensors, and pre-processing of the sensor data. Local communication media options include twisted pair, power line, optical fiber, and radio frequency.

The U.S. Department of Energy's Office of Nonproliferation and National Security (DOE/NN) currently has two complementary programs for the development and implementation of international nuclear monitoring systems. The Modular Integrated Monitoring System (MIMS) program provides for the development and integration of this technology and the International Remote Monitoring Program (IRMP) supports site and application specific field trials leading toward implementation. Both programs emphasize the integration of commercial hardware and software supplemented by unique national laboratory technology and system engineering. The MIMS emphasis is for "plug-and-play" capability for sensor options, network configuration, and data display.

An Authenticated Item Monitoring System (AIMS) was developed at Sandia a few years ago with funding from DOE/NN and the Defense Nuclear Agency (DNA). Its basis is a local radio frequency (RF) communication network that uses RF transmitters and receivers from Inovonics Corporation in Boulder, Colorado, and a data authentication algorithm and software developed by Sandia. Numerous commercial bi-level and analog sensors have been integrated into the AIMS network. Two custom AIMS sensors have been developed at Sandia: an item motion sensor (based on a set of mercury switches) and an active fiber optic seal. More recently the AIMS Receiver Processing Unit (RPU) has been integrated into a node on the Echelon network, enhancing the capability of both systems.

Sandia is currently finishing the development of the Authenticated Tracking and Monitoring System (ATMS) with original funding form DOE/NN and continuing funding from DNA. In a sense ATMS is just "AIMS-on-Wheels". ATMS is actually an unattended monitoring system for transportation applications. AIMS is used for the local on-board sensor network. The Global Positioning System (GPS) is used for tracking information. The International Maritime Satellite (INMARSAT) system is used for remote communications and control. Both capabilities are provided by an integrated Trimble (Sunnyvale, CA) GPS INMARSAT terminal. The reporting station can be either fixed or mobile. The tracking software is TracerLink by Miletus Associates (Albuquerque, NM) and the sensor status display software uses LabView by National Instruments (Austin, TX).

Straight-Line - This is a Sandia-developed pilot system to demonstrate comprehensive monitoring of nuclear material in storage. It is an integrated system of sensors providing information that will enhance the safety, security, and international accountability of stored nuclear material. The goals of this effort are to: 1) Provide the right sensor information to the right user in a timely manner. 2) Reduce the expenses, risks, and frequency of human inspection of the material. 3) Provide trustworthy data to international inspectors to minimize their need to make on site inspections. In pursuit of these goals, Straight-Line unites technology from Sandia's Authenticated Item Monitoring System (AIMS) and other programs to communicate the authenticated status of the monitored item back to central magazine receivers. Straight-Line, however, incorporates several important features not found in previous systems: 1) Information Security -- the ability to collect and safely disseminate both classified and unclassified sensor data to users on a need-to-know basis. 2) Integrate into a single system the monitoring needs of safety, security, and international accountability. 3) Incorporate the use of sensors providing analog or digital output.

Applications and Demonstrations

Domestic Applications - This section discusses those implementations which are in active operational configurations. As indicated in the above description, VSIS has been operational for several years and is being projected for upgrades because of the advantages of such a system. The SAMMS system at INEL currently allows the extension of physical inventory taking to every two years as opposed to six months under normal conditions. The Monitor system is also being utilized at INEL and is expected to provide another two years extension when it is approved. Portions of the PAMTRAK system getting information from the RandTec Versatags and the Monitor system are being used at the Savannah River Plant's K-basin storage area and allow for inventory extensions up to one year.

Domestic Demonstrations - Both PAMTRAK and Monitor have been demonstrated at several facilities in the U.S. The PAMTRAK and Monitor installations at ANL-W are still being operated. Monitor and material monitoring aspects of PAMTRAK have also been demonstrated in Russian facilities. The CAVIS and SMARTSHELF systems are being demonstrated at the OAK Ridge Y-12 plant. The Straight Line system is being demonstrated at the Pantex Plant.

International Demonstrations - An early version of the AIMS has been installed for several years at a Japanese nuclear facility. The ATMS has been widely demonstrated in the continental United States for highway shipments and is currently being discussed with the Russians for rail monitoring applications. The first IRMP field demonstration began in February 1994 at an

Australian research reactor spent fuel storage facility. A joint U.S. and International Atomic Energy Agency (IAEA) field trial of remote monitoring is underway at an Oak Ridge highly enriched uranium (HEU) storage vault.

Summary

Significant efforts are being expended around the world to achieve non-proliferation goals. The U.S. and many other governments are actively involved in supporting these efforts. In the past few years some improvements have been implemented and more are underway. It is expected that these efforts will positively impact the protection and control of most of the existing nuclear materials that are potentially useable for nuclear weapon proliferation.

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