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STRAIGHT-LINE A NUCLEAR MATERIAL STORAGE INFORMATION MANAGEMENT SYSTEM

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ABSTRACT

Sandia National Laboratories is developing Straight-Line -- a pilot system to demonstrate comprehensive monitoring of nuclear material in storage. Straight-Line 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 immediately. 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 System² (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. This paper will present the overall architecture and status of the Straight-Line project.

INTRODUCTION

The Clinton Administration announced on September 27, 1993 that the United States would "... undertake a comprehensive approach to the growing accumulation of fissile material ... and ... ensure that where these materials already exist they are subject to the **highest standards of safety, security, and international accountability...**"¹ (emphasis added by authors).

Continuous, 'round the clock' sensor monitoring of these materials would be valuable in enhancing the nation's ability to ensure the "highest standards of safety, security, and international accountability". Sensors can be used to

ensure that the material is in place, unaltered, and stable. Comprehensive sensor monitoring would also reduce the risk, expense, and frequency of manual inspection of the material.

In the past, monitoring of stored nuclear material was done usually for one user. However, comprehensive sensor information that enhances safety, security, and international accountability will require a wide variety of sensors and a variety of users -- domestic and international. Moreover, significant amounts of Pu may reside in pit form⁶ for several years. Providing sensor information is complicated by the fact that some of the sensor information may be classified.

Two approaches can be taken to providing the solution to the collection and dissemination of comprehensive sensor information. One approach is to use several existing systems in parallel - i.e. one system for international accountability, one for safety, and another for security. However, parallel systems could experience the following difficulties:

- Higher costs - parallel systems may require duplicative hardware, more maintenance, and more support personnel. Considering there are tens of thousands of items to monitor, controlling costs is essential.
- Incompatibility and system integration problems: Limited space on the on nuclear material containers, classification issues, radio frequency (RF) interference, power constraints, environmental conditions, etc. may be problematic for multiple systems.
- Parallel systems will require more hardware -- degrading reliability.
- Existing systems have been built for specific customers for specific purposes. The ability to add

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different types of sensors or change the dissemination of sensor information is limited

- A longer lead time is needed to implement comprehensive sensor monitoring using several systems in parallel.

The other approach is to take the key modules from existing systems, make some modifications and create an integrated system to provide comprehensive monitoring. The advantages of this approach include:

- Creating a flexible system will allow one to easily change or add sensors. Changing the information dissemination would also be easy. Thus changes in government policy can be implemented in a timely manner.
- A single radio RF based system may provide lower installation and maintenance costs.
- An integrated system would be better able to handle the collection and secure dissemination of classified and unclassified sensor information.
- Using the internet to disseminate the information on a need to know basis will facilitate the ability of off-site users to acquire various types of data in a timely manner.
- Compatibility and system integration problems are minimized
- The US may find it easier to encourage other countries to ensure that their material is subject to the highest standards of safety, security, and international accountability by offering up one comprehensive monitoring system rather than three separate systems.

Project Straight-Line is Sandia National Laboratories' effort at exploring and demonstrating the concept of integrated comprehensive monitoring of stored nuclear material

- The primary building blocks were already provided by Sandia's other material monitoring programs. At the heart of Straight-Line is the RF transmitter platform -- a modified version of the AIMS² (Authenticated Item Monitoring System) transmitter units. The Straight-Line unit is capable of unattended operation for 5 years in a pit storage environment, can be equipped with a wide variety of sensors, and is packaged to satisfy both domestic and international users.
- Another emphasis of the Straight-Line project has been to use Sandia's internet and network expertise to securely disseminate classified and unclassified

sensor information to different types of users on a need to know basis using the internet.

- The project also required a significant system integration effort to make sure all the parts work together.

The overall goal of the Straight-Line program is to get the right sensor information to the right user to enhance the safety, security, and international accountability of stored nuclear material. This paper will describe the program's effort to reach this goal, including:

- Collecting the Sensor Data
- Disseminating the Sensor Data
- Progress made towards the Straight-Line goal

COLLECTING THE SENSOR DATA

At the heart of Straight-Line is the RF collection of sensor data. Figure 1 illustrates a Straight-Line equipped storage magazine. RF technology was selected to minimize installation costs and make Straight-Line as site independent as possible. (The only exception is the video camera -- it is connected by wire to the Magazine Data Unit (MDU)).

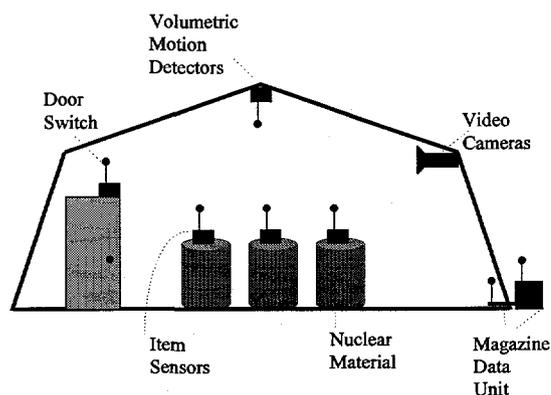


Figure 1 - RF collection of sensor information in the storage magazine

Straight-Line RF sensor packs transmit sensor data to the MDU at predetermined intervals and when "events" are detected -- i.e. a motion detector detects motion. The MDU records this information and also sends it immediately to the Site Data Unit (SDU). Figure 3 illustrates this concept.

The Straight-Line RF unit is based on the AIMS unit. However, the Straight-Line unit incorporates several key changes. The AIMS unit used only "bi-level" sensors. However, the Straight-Line unit can use not only bi-level sensors, but analog sensors (i.e. sensors that return a voltage between 0 and 2.5 volts that could represent temperature, pressure, etc.). The Straight-Line units also

accept a serial bit stream from sensors that provide digitized data. Moreover, the unit uses standard interfaces to facilitate incorporating a wide variety of sensors.

Another key enhancement is the RF unit's ability to transmit on more than one frequency. This was done so that the Straight-Line could be used at multiple locations around the world and still comply with local frequency allocation rules. Currently, the unit can transmit in the RF bands of 902-928 MHz or 2.4-2.45 GHz. Other frequencies will be added in the future.

The digitized sensor data may also be encrypted (i.e. the sensor creates classified sensor data) or authenticated (to assure the integrity of the data as it travels from the sensor to the user) per user requirements. The encryption occurs immediately at the sensor, thus turning the data into unclassified ciphertext. This ciphertext can then be safely transmitted over regular communication networks (the phone system or the internet) without risk of compromise.

Specific sensors used by Straight-Line currently include:

- Balanced Magnetic Door Switch (detects if the door is open or closed)
- Passive Infrared Volumetric Motion Detection (detects motion in the room)
- Item Motion (motion of a nuclear material container)
- Fiber Optic Seal (detects if seal is broken)
- Container and Ambient Temperature
- Radiation -- Gamma Spectrum
- Radiation -- Total Dose Gamma
- Pressure (of an internal container)
- Tamper Detection (of the RF Unit)

Other sensors that produce standard bi-level, analog, or digital output can be added easily per user requirements. Moreover, the Straight-Line program is planning to develop additional specialty sensors in 1996. This includes an acoustic signature monitor to detect cracking in a pit.

DETAILED INFORMATION ABOUT THE RF UNIT

The layout of the Straight-Line RF Unit is described in figure 2. The unit consists of three main sections -- the battery pack, the Tag Interface Module (TIM), and the Monitor Transmitter Module (MTM).

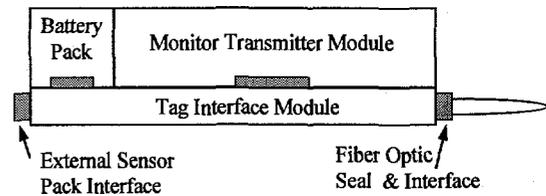


Figure 2, The Straight-Line RF Unit

The TIM performs two basic functions. First, it serves as a platform for mounting and connecting the RF unit's modules. Second, it serves as an interface between the MTM and external sensors connected to the TIM. The TIM can be attached to any container or structure (i.e. walls) in several different ways depending on the nature of the mounting surface. Methods of attachment include magnets, bolts, adhesive, and spot welding.⁸

The battery pack contains a D-size, 3.6 volt lithium thionyl chloride cell to power the RF unit. The battery has a capacity of 13.5 amp-hours⁸. Depending on the configuration of the unit, this battery will provide operational power to the unit for up to 5 years or more.

The Monitor Transmitter Module contains most of the electronic circuitry, including the transmitter, control logic, internal sensors, and tamper detection. The internal sensors include tamper detection, motion detection, and the fiber optic seal. These sensors can all be authenticated.

The MTM can be programmed via an RS-232 connection. This allows one to program how the unit monitors each sensor. The authentication keys are also loaded via RS-232. In the case where these sensors are used by an international accountability organization (i.e. IAEA), that organization would conduct the programming.

The external sensor pack interfaces allow for the following external sensors to be "plugged" into the RF unit:

- 2 Bi-level Sensor Ports (short circuit or open circuit)
- 3 Analog Sensor Ports (0 to 2.5 volts)
- 1 Serial Data Sensor Port

The data from sensors which create classified information will be immediately encrypted and then sent to the serial data sensor port of the MTM.

The operational concept for the units is for an international accountability organization to have custody of the MTM and load the authentication keys into the unit. The units are then programmed by the international organization to parameters agreed upon by both the host nation and international organization. The host nation will then add any extra external sensors required and load encryption

keys into external sensors as needed. After programming, representatives from the host nation and international organization place the unit in the storage magazine.

After installation, the units then report their status at the programmed interval. However, if an event is detected (i.e. motion detected), the unit will report immediately. The video camera will also take a snap shot whenever an event is detected.

It should be noted that the Straight-Line RF units and MDU were designed to be compatible with the Modular Integrated Monitoring System⁵ (MIMS) system. The MIMS bus can be connected to the MDU. Thus all the sensor data collected by the MDU will be available to the MIMS system.

The video camera system used by Straight-Line is the Image Compression and Authentication Module (ICAM).

DISTRIBUTING THE INFORMATION

Once the data is collected by the MDU, the system then needs to securely disseminate the information to users on and off the site. This process begins by the MDU transferring the information to the Site Data Units as shown in figure 3.

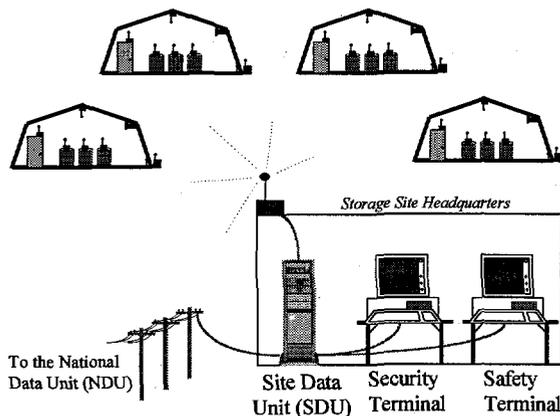


Figure 3 -- A typical Site Configuration

The Site Data Unit serves several functions. It provides sensor data to local users such as security and safety officials. The SDU then uses a high speed encryptor and transmits the data to the National Data Unit to facilitate dissemination of the sensor data to off-site users (see figure 4). Because the storage magazines may contain a wide variety of sensor information, it's important that the Straight-Line system provide data on a need-to-know basis. It is important also to prevent eavesdroppers from "listening in" on the data as it flows to the users.

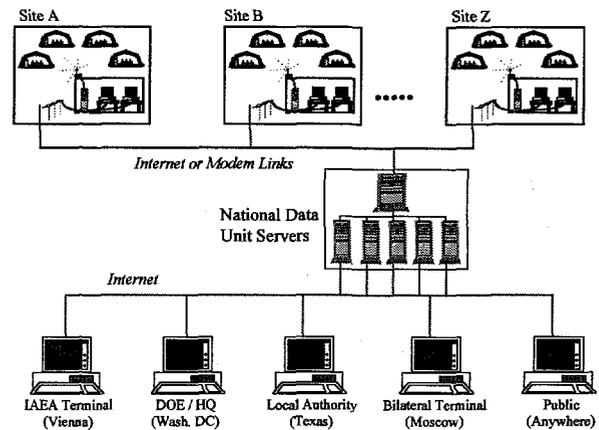


Figure 4 - Distribution of site information to off-site users

Straight-Line's approach to this multi-level security problem has been to use commercially available hardware and software used by businesses on the internet. The key to the system is to set up a "secure web page" for each different type of user. A "web page" allows one to transfer many types of data - files, pictures, sounds, etc. utilizing the user-friendly World Wide Web of the internet.

The National Data Unit contains a central processing computer that collects data from the SDUs, and a separate processor for each user type. The user processors are then used to maintain "secure web pages".

Moreover, the web page can be changed quickly and easily. Additions or deletions of information to the web page can be implemented immediately whenever official policy changes. The web page can provide current sensor data and allow the browsing of historical data. Users can also command the video camera to take a picture (if allowed by the system administrator).

The following is a list of how a new user would go about accessing the sensor data.

- A new user will apply for access. Assuming the user has the proper approvals, they will be enrolled into the system.
- The user will then be given a one-time password generator -- similar to "S-Key" or SecureID Card implementations. These generators will provide a random list of "one time" passwords.
- The user will then use a web browser such as Netscape to contact the appropriate web page. The web page will be "secure", and thus link encryption will be established between the user and the NDU. This will be done automatically by using commercially available software such as Netscape's Web Browser and Netscape's Commercial Server

Software. Thus the privacy of communications between the NDU and user is maintained.

- The page will then ask for a specific, one-time password. The user will then use a password generator to create the password. This is also the only time that password will be valid. Thus even if an eavesdropper discovers the password, they will not be able to use it.
- If the password is valid, the user will be admitted to the web page, and will be able access the appropriate data.
- If the web page provides classified sensor data, the data will still be encrypted. The user will download the encrypted data onto a floppy disk, and then transfer the floppy disk to a classified computer that is not attached to the internet. The classified computer will then use a STU-III modem to communicate with a classified key management computer. The key management computer will then provide the decryption keys for the classified data.

Fire-walls and other commercially available equipment are used to prevent users or hackers from unauthorized access to the rest of the system. More information regarding the information security of Straight-Line can be found in reference #5.

CURRENT PROGRESS

In June 1995, the Straight-Line program completed installation of the first phase of the system at three different sites around the nation. These sites include the DOE Pantex plant in Amarillo, Texas, the Cooperative Monitoring Center at Sandia in Albuquerque, New Mexico, and at Sandia in Livermore, California. This phase was named "Fast-Track" and is detailed in reference #4.

The Fast-Track effort demonstrated the collection of a variety of sensor information (from multiple sites) useful in enhancing the safety, security, and international accountability of stored nuclear material. The effort also provides a test-bed for future Straight-Line development.

Straight-Line's implementation of multi-level information security will be demonstrated by October 1995. This will include the establishment of "secure web pages", and the encryption of all information while on the internet (link encryption). Algorithms and implementations to protect classified information will also be identified. One note - the sensor information used in this effort will be "artificial". Real sensor information that requires protection will not be used until the system is officially approved by the appropriate United States authorities.

In 1996, the Straight-Line program will vigorously pursue official government approval for the Straight-Line system to be used with real Unclassified Controlled Nuclear Information (UCNI) and classified sensor information (information covered by the Atomic Energy Act).

SUMMARY

Project Straight-Line is Sandia National Laboratories' effort at exploring and demonstrating the concept of integrated comprehensive monitoring. To accomplish this goal, the thrusts of Straight-Line effort have been to:

- Modify and enhance existing RF units to provide a wide variety of sensor information.
- Provide secure, need-to-know dissemination of both classified and unclassified information using the internet.

The program will continue pursuing these areas to provide the right sensor information to the right user to enhance the safety, security, and international accountability of stored nuclear material. Moreover, future Sandia efforts will be directed in providing comprehensive monitoring for the entire life-cycle of nuclear material - processing and transport as well as storage.

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