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FAST TRACK DEMONSTRATION OF THE STRAIGHT-LINE SYSTEM ARCHITECTURE

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ABSTRACT

Sandia National Laboratories is developing Fast Track as a near term demonstration of the Straight-Line[2] nuclear material monitoring system architecture. It will implement major elements of the Straight-Line system in a realistic system setting. Fast Track will act as a test bed to gain information on monitoring stored, weapon grade nuclear material. The Pantex plant near Amarillo, Texas has agreed to participate as a demonstration site along with sites located in New Mexico and California. Information from sensors, deployed on AL-R8 nuclear material containers and throughout the storage magazine will be collected from each site, processed and disseminated to local and remote users. Initial operation of this system was slated for June 1, 1995. This paper will address the system architecture and engineering aspects of fielding this system on a compressed time schedule. Collection of data in a nuclear environment, transmission, processing and lessons learned from deployment will also be discussed.

INTRODUCTION

Background Information The impetus for the Straight-Line project stems from events surrounding the cessation of the "Cold War." 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]

The Straight-Line concept consists of a tailored sensor suite integrated with the architecture to provide information that will enhance the safety, security and international accountability of stored nuclear material. The goals of the effort are to demonstrate the ability to: 1) provide the right sensor information to the right user in a timely manner, 2) reduce the expenses, exposure, and frequency of human inspection of the material and 3) provide secure trustworthy data to international inspectors to minimize the need for on-site inspections. Straight-Line incorporates several important features not found in previous systems: 1) multi-level 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 remote monitoring needs of safety, security, and international accountability, and 3) incorporate the use of sensors providing analog and digital output with bi-level sensors.

A more detailed description of the Straight-Line project is given in reference 2. References 3, 4 and 5 provide expanded information on the Multi-Level information security, Safeguards & Security and analog sensor aspects of the project respectively.

Project Evolution Demonstration of the Straight-Line concept has occurred in three stages. The first stage was to define the concept by compiling the "user" requirements, e.g., safety, security and international accountability into one comprehensive approach. The second stage involved a quick (eight week) prototypical hardware demonstration of the Straight-Line concept. This was accomplished by integrating existing technologies and applications into a stand alone hardware demonstration known as Table Scratcher. The Table Scratcher hardware was completed in October, 1994 and was used to effectively demonstrate the key information gathering, processing and dissemination aspects of the Straight-Line concept. Fast Track represents the third stage - a six month effort focused on deploying, into a realistic setting, expanded elements of key Straight-Line components at multiple sites across the nation. This paper will describe the components and implementation of Fast Track.

FAST TRACK EFFORT

BACKGROUND Table Scratcher built upon the information dissemination capabilities of the Authenticated Item Monitoring System (AIMS)[6]. Fast Track built upon the Table Scratcher hardware by providing enhancements necessary to deploy the system at multiple sites including the radiation environment at the Pantex facility. The following enhancements were made to the Table Scratcher hardware:

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1) Integration of the analog sensors into a single low power, long life component
2) Addition of a video imaging capability
3) Enhanced User log-in and password security with a database query capability for historical data.
4) Environmentally hardened component packaging.
5) Capability for multiple storage site deployment using RF LAN data transmission.
6) Expanded User networking capabilities through use of modems and INTERNET connections.

The Fast Track hardware was installed at three geographically separated sites: The Pantex Plant in Amarillo, Texas; Sandia's Cooperative Monitoring Center (CMC) located in Albuquerque, New Mexico; and at the Sandia California site - referred to as CASTLE (California STraight-Line Exhibit).

<u>FAST TRACK COMPONENTS</u> The following section is intended to highlight the distinction of the Fast Track hardware with the Straight-Line concept. See references 2 and 7 for more detailed explanations of the Straight-Line configuration and general component descriptions. Figure 1 represents a typical storage magazine configuration and is indicative of the Fast Track configuration.

The RF sensor units (door, volumetric motion, nuclear container and fiber optic seal) depicted in the figure contain the basic capabilities of the Table Scratcher hardware but were repackaged and optimized for the radiation environment of a nuclear storage magazine for weapon grade components. The analog sensors (radiation total dose, radiation dose rate, temperature) were reconfigured and repackaged using stainless steel to provide shielding against neighboring containers. Figure 2 shows an analog sensor assembly and fiber optic seal mounted on an AL-R8 pit storage container. Testing and calibration the sensor response was conducted at Lawrence Livermore National Laboratory and Pantex to ensure that the packaging and signal conditioning electronics provided an accurate indication of the presence of nuclear material.

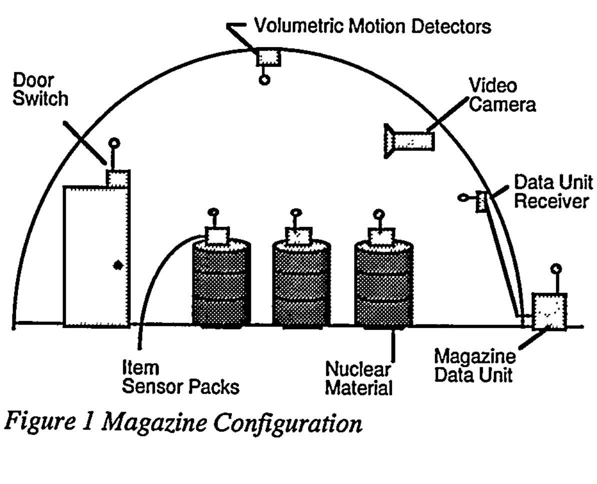

Figure 1 Magazine Configuration

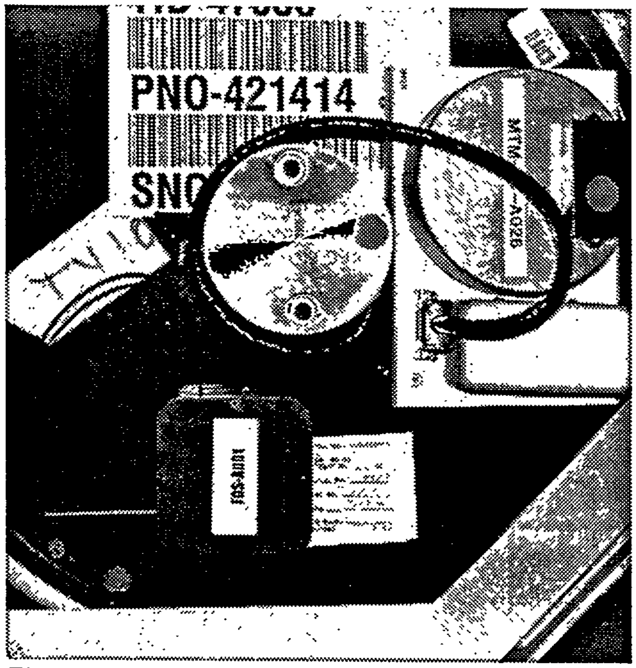

Figure 2 Analog Sensor assembly & Fiber optic seal

Video images of the storage magazine was a key addition to the Table Scratcher hardware. Video images are captured using a frame grabber and image compression software as described in references 7 & 8. The Table Scratcher Magazine Data Unit (MDU) functions were extensively modified to provide the necessary communications with the video camera across an Echelon network. Incandescent lights provide the necessary illumination for image collection.

A balanced magnetic switch is mounted on the magazine door to detect entry. A passive infrared motion detector senses thermal motion as an independent, redundant sensor verification.

Low power RF transmission from the vault sensors utilize a commercial unlicensed frequency band. The Magazine Data Unit serves as the initial processing point for the information. It is located within close proximity of the magazine and is powered by photovoltaic solar cells with battery backup.

The Site Data Unit collects and stores information from the site MDU's and provides the interface with the National Data Unit. The user terminals provide an intuitive, graphical interface of the storage data to various types of end users on a need-to-know basis. The user terminals interface at both the site level with the SDU and at the national level with the NDU.

Fast Track System Operation

Data Collection The information collection aspects of the Fast Track hardware are very similar to those of AIMS, i.e. authenticated RF transmission. Bi-level security sensors report their state of health at periodic, timed intervals in addition to reporting changes of state, i.e., open to closed and vice versa. The analog sensors report a voltage which corresponds to a temperature, radiation dose rate or total radiation dose on a programmed time basis. The periodic rate for the Fast Track demonstration is once every hour.

Video image snapshots are collected under three conditions: 1) timed video images - once every twelve hours for Fast Track, 2) event driven images - in response to a bi-level sensor event, e.g., door open, item motion or room motion, and 3) user requested video.

Information dissemination The application of sensor and RF tag technology to acquire data is just the beginning of the data stream. The Straight-Line information dissemination architecture provides a delivery system using client-server distributed computing to bring near real-time and historical data directly to a variety of on-line users on a need to know basis. This system represents a major aspect of "Getting the right information to the right user" and consists of an Magazine Data Unit (MDU), Site Data Unit (SDU), National Data Unit (NDU) and culminating with the user interface software.

Magazine Data Unit The MDU consists of an embedded 486 PC using the industry standard PC-104 form factor. Software was developed using ANSI C. The role of the MDU is as follows: 1) collect real-time data from RF tags inside the magazine, 2) capture video frames based on an event, timed interval, and user requested, 3) send data to the Site Data Unit using local area network (LAN) interface.

Site Data Unit The SDU is a turnkey client-server application which operates on a Pentium-based PC using Microsoft Windows NT operating system. Rapid application development techniques were used to create the SDU software using Labview for Windows, a graphical programming language. Microsoft SQL Server database management system is integrated in the SDU through the use of Open Data Base Connectivity (ODBC). The SDU performs the following roles in the Straight-Line information system: 1) Establishes a network connection to each MDU and initializes its configuration at startup. 2) Communicates with each MDU and maintains current status at all times. 3) Collects the MDU data in real-time and stores the data in a SQL Database. 4) Provides logon services and data access for authorized local site users such as safety and security personnel and 5) services requests made to it from the National Data Unit (NDU) and users connected through the NDU. The database is organized into three primary categories: Event Messages, Analog Data, and Video Data.

National Data Unit The NDU is also a turnkey client-server application very similar to the SDU. It operates on identical hardware and was developed using the same language and methodology as the SDU. The NDU has no database and performs these roles in the Straight-Line information system: 1) communicates with each SDU and maintains current status at all times, 2) serves as the primary "on-ramp" for user logon and data access, 3) forwards user requests to the proper SDU and returns the reply.

User Interface Software The user interface software allows users to intuitively navigate Fast Track's distributed information system to find the data they need.

The user interface software was developed using LabVIEW for Windows. The user software uses the TCP/IP communications protocol to communicate with Fast Track's information servers. This protocol allows the user to connect to the Fast Track system using the Internet high bandwidth connections. IBM PC compatible laptops with Internet access were the target platform for this software. Slightly modified versions of the user interface software run on Macintosh and SUN computers.

To access the system, the user selects a server from a pull down menu and logs into the system. Once connected, the user sees a world map. From the world map, the user can navigate through a series of national, site, magazine, and pallet maps to check the status of any container in the system. As the user navigates through the system, the map displays are automatically updated with live data and database queries.

System requests, like image-on-demand and database access, are executed with single mouse clicks. Figure 3 is a sample user window at the magazine pallet level. The window features a container pallet configuration in which the active sensor units are hilighted in a different color, e.g. red or blue, to indicate a stable or active status. Access to specific container information is accomplished by clicking on the container of interest. The left portion of the window provides the user with a preview window of the latest video image. A mouse click on this window will provide an enlarged view. This window also allows the user to request a video image - referenced by the "Take Image" button in the lower right corner of the screen.

The user interface software allows the user to easily generate daily reports from the data base. The daily report may include event data, analog data, video data, or all three data types. The software displays the event and analog query data in table format. These tables can be saved to a spreadsheet file for use with other analysis software. The image query returns the time and type of each image. From this list, individual images can be selected from the database and displayed.

The user interface software was designed to demonstrate Fast Track's capabilities and features. The combination of Fast Track's flexible information architecture and the easily modified user interface software allows for control of the information displayed to specific users, i.e. safety, security, thus preserving the "need-to-know" distribution of information.

SITE CONFIGURATIONS

Pantex Site Twenty (20) AL-R8 containers with weapon grade nuclear material were instrumented inside a storage magazine within the protected Zone 4 area of Pantex - see Figure 4. The magazine was instrumented with two RF antennae, a balanced magnetic door switch, a video camera and two light assemblies. No motion sensor was installed. Cabling for the camera, lights and RF receiver antenna was routed through an existing magazine vent hole. The MDU and lead-acid 12v back up batteries were mounted inside a "Cool Cell" located approximately 30 feet from the magazine. The "Cool Cell" provides protection from the environment as well as thermal insulation for the MDU computer components during temperature extremes - see Figure 5.

Power for the MDU is provided by an array of photovoltaic solar cells charging lead-acid back up batteries. This provides for continuous operation even during extended periods of inclement weather - see Figure 5.

The SDU is located inside a service building approximately 300 feet from the magazine. A hardwire local area network (LAN) was established between the MDU and SDU using approximately 300 feet of coaxial cable. An RF LAN is intended to replace the hardwire LAN thus serving as a multiple access RF network for instrumenting multiple magazine within a single site.

The hardware deployed at Pantex was subject to DOE guidelines regarding false alarm rates due to concern over the perceived sensitivity of the information. To address these concerns a 30 day "blackout" period was established for evaluation of the false alarm rates for the system. During this period the system was not networked with the other sites and no information exited site boundaries

There is no Internet access at the Pantex site. Therefore,

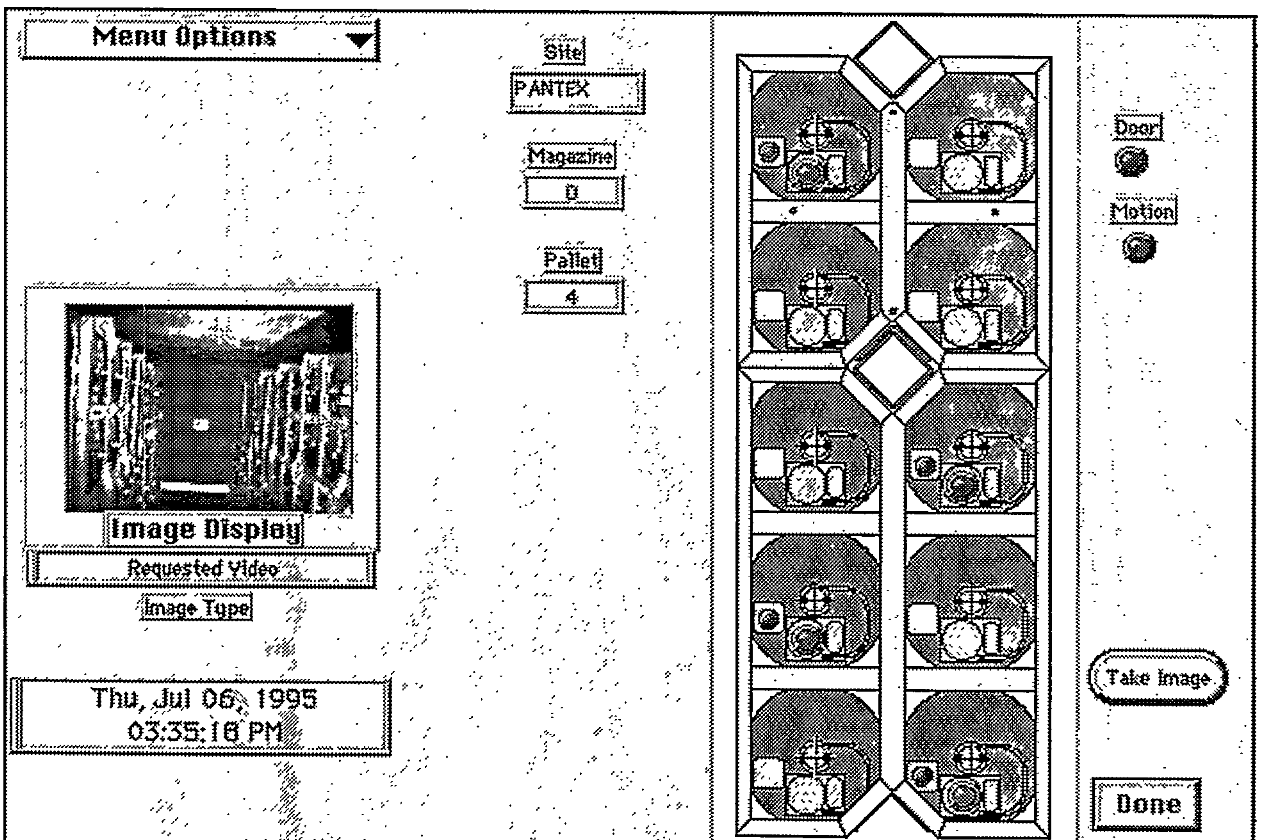

Figure 3 Magazine Pallet User Window

the Pantex SDU will communicate with the NDU via a standard phone line modem. Local user access to the Pantex information is provided via a LAN at the SDU.

CMC & CASTLE The CMC and CASTLE magazine configurations are identical. Each of these sites has an AL-R8, AT-400A (replacement for the AL-R8) and AT-400R (Russian version of the AT-400A) container minus any nuclear material. Each of the containers is monitored with a container item monitor and fiber optic seal. There are two additional item monitors and fiber optic seals at each site. Balanced magnetic door switches and passive infrared motion detectors are also installed at each site as well as video imaging capability.

Each site has a MDU, SDU and supporting hardware to simulate an actual storage site. Each site also supports local user terminals through site LAN's. Access to the NDU is via the Internet access at the CASTLE and CMC.

The Cooperative Monitoring Center in Albuquerque was chosen as the "National" location due its unique role in the field of remote monitoring of nuclear materials.

SUMMARY

STATUS Hardware for the effort was completed May 1, 1995. System integration testing was conducted at Sandia/New Mexico in Albuquerque during the month of May.

Installation of hardware in a magazine at Pantex was accomplished during the last week of May. The Pantex site was essentially operational on June 1st., which was the started of a 30 day offsite communications "blackout" period for system evaluation.

Several software upgrades to the SDU, MDU and user terminals were completed during June. These upgrades completed the information distribution aspects of the effort.

Review of the blackout period data at Pantex resulted in approval for the Pantex SDU to connect with the NDU at the CMC. As of the date of this paper, Pantex is collecting data locally and is not connected to the network. The site will establish a modem link with the NDU at the CMC for demonstration purposes only. A more permanent phone link between the Pantex SDU and the NDU is being established.

The CMC and CASTLE sites were installed during the month of June and became operational late June. The two sites are currently on-line with the NDU which is accessible via the Internet using account and password control.

The Fast Track effort has established a test bed for the Straight-Line components, information and environments. The hardware is slated for a six month evaluation. Reevaluation of the continued operation of the test bed will be made after the six months.

LESSONS LEARNED

Calibration of the dose and dose rate sensor using actual source material in a representative configuration was extremely important due to the difficult task of simulating the source. Noise in the electronics, statistical variations of the nuclear flux and the effect of source shielding need to be characterized to understand the expected sensor response.

The radiation environment of the storage magazine was overestimated for the purpose of shielding the electronics. The geometry of the magazine, quantity of material and age resulted in an actual environment that was an order of

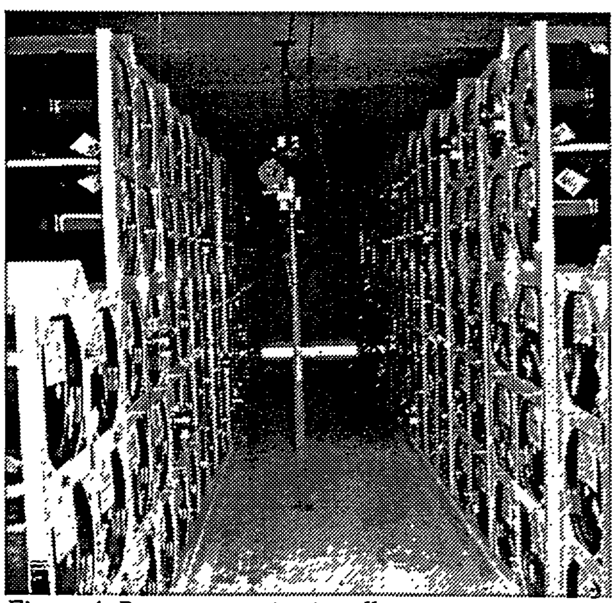

Figure 4 Pantex magazine installation

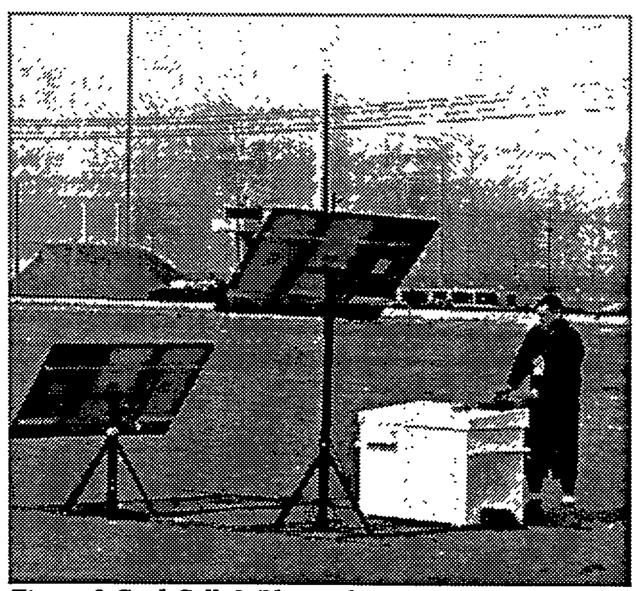

Figure 5 Cool Cell & Photovoltaics

magnitude less than the worst case calculated dose.

A significant portion of time was planned and expended in system integration testing. This test phase is especially important when integrating existing components or subsystems into a new application.

Fast Track was a schedule driven project focusing on a quick deployment of hardware at multiple sites. Project decisions were made and defended based on these established priorities; 1) schedule, 2) performance 3) cost.

Fielding a demonstration system at a DOE facility required a great deal of communication and training with the facility personnel. Documentation of the project was developed to a greater degree than would normally be necessary for development. Joint concurrence between Sandia, Pantex and DOE was negotiated for the following documents: System proposal, classification guidance, security plan, test plan, installation plan, quality plan, project plan.

FUTURE ACTIVITIES Demonstration of multi-level information security is being accomplished under a separate effort as documented in reference 3. This effort will effectively demonstrate the ability to disseminate information to a variety of users on a strict need to know basis. and is scheduled to be completed by September 30, 1995.

Improvements in the RF sensor electronics and transmitter receiver for size power and cost reductions will be completed. Miniaturization and optimization of the analog sensors will also being accomplished.

Motion and "pit crack" sensor development will be initiated culminating with integration into the test bed.

The project will also work to coordinate with other remote monitoring activities within the DOE complex.

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