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TECHNICAL RESULTS OF Y-12/IAEA FIELD TRIAL OF REMOTE MONITORING SYSTEM

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ABSTRACT

A Remote Monitoring System (RMS) field trial has been conducted with the International Atomic Energy Agency (IAEA) on highly enriched uranium materials in a vault at the Oak Ridge Y-12 Plant. The RMS included a variety of Sandia, Oak Ridge, and Aquila sensor technologies which provide containment seals, video monitoring, radiation asset measurements, and container identification data to the on-site DAS (Data Acquisition System) by way of radio-frequency and Echelon LonWorks networks. The accumulated safeguards information was transmitted to the IAEA via satellite (COMSAT/RSI) and international telephone lines.

The technologies tested in the remote monitoring environment are the RadCouple, RadSiP, and SmartShelf sensors from the ORSENS (Oak Ridge Sensors for Enhancing Nuclear Safeguards) technologies; the AIMS (Authenticated Item Monitoring System) motion sensor (AMS), AIMS fiber-optic seal (AFOS), ICAM (Image Compression and Authentication Module) video surveillance system, DAS (Data Acquisition System), and DIRS (Data and Image Review Station) from Sandia; and the AssetLAN identification tag, VACOSS-S seal, and Gemini digital surveillance system from Aquila.

The field trial was conducted from October 1996 through May 1997. Tests were conducted during the monthly IAEA Interim Inventory Verification (IIV) inspections for evaluation of the equipment. Experience gained through the field trials will allow the technologies to be applied to various monitoring scenarios.

Introduction

The United States Department of Energy (DOE) and the International Atomic Energy Agency (IAEA) conducted a field trial at the Oak Ridge Y-12 Plant to jointly evaluate the application of a Remote Monitoring System (RMS) to routine IAEA safeguards; and to determine an operational configuration for remote monitoring of the Y-12 vault under IAEA safeguards. The remote transfer

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of authenticated safeguards data from unattended equipment installed in nuclear facilities around the world is expected to realize the following benefits for both the IAEA and facility operators:

- Increased monitoring confidence;
- Flexibility in when and how data analysis is performed;
- Reduced radiation exposure to operators and Agency inspectors;
- Reduced interruption of facility operations; and
- Cost savings resulting from a reduction of on-site inspections.

The purpose of the field trial conducted in Oak Ridge was to evaluate a suite of safeguards technologies (containment devices, identification tags, attribute measurement sensors, surveillance cameras) that could be used in a remote monitoring system. The experience gained would provide information and data for the IAEA to "compare remote monitoring with current safeguards practices to determine to what degree the current practices should be reduced or modified to take credit for the implementation of remote monitoring."[1]

A secondary outcome of the field trial is the design of a specific system optimized for the Oak Ridge facility. The challenge is to design a system that will minimize costs and increase reliability and confidence and which is flexible enough to meet the technical and policy requirements of potential applications[2].

System Configuration

A technical description of the system as installed for the field trial is described in Corbell[3], et. al. A system block diagram is shown in Figure 1. Two trays were instrumented for evaluation during the field trial. The technologies were grouped by the following functions: containment, material attributes, surveillance, local data communications, data acquisition, remote data communications, and

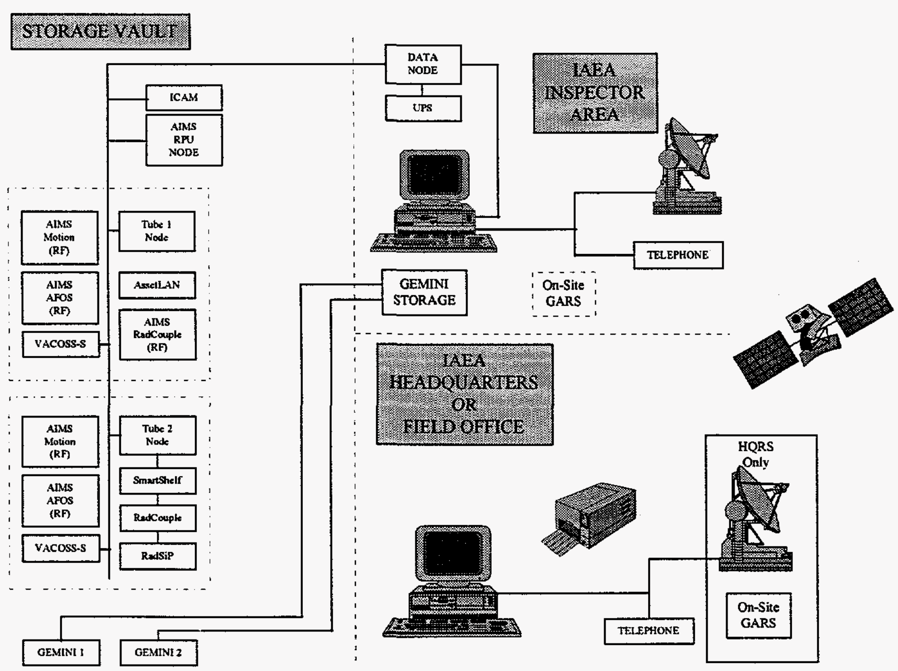

Figure 1: Y-12 Field Trial System Block Diagram

data review.

All sensor nodes operated in such a way that when a change in the status of sensor or access to the sensor enclosure is detected, the sensor transmits a message of the current status. Each node was configured to produce an alarm when the sensor would detect a change in the operating status of the sensor. Additionally, the nodes reported a generic state of health message each twenty minutes and the radiation sensors reported sample data on a configurable interval.

Sample Data:

Tests were conducted during the normal IAEA Interim Inventory Verifications to provide ground truth data for evaluation of the technologies. The tests involved accessing, removing, replacing, and securing the containers. Table 1 is a sample listing of sensor events filtered for the baseline sensors during a test conducted on April 14, 1997. During the test, the ICAM was programmed to be triggered by the VACOSS seals. Figure 2 contains an image captured during this test. Test activities can be assessed using Table 1.

Evaluation Summary

Containment: The AFOS and the VACOSS seal monitored access to the tube entrances. Both seals monitor continuity of the optical fibers. The AFOS uses a plastic fiber while the VACOSS uses a glass fiber. The fiber optic seals performed as expected; however, both will require mechanical modifications when they are placed into operation in a RMS.

The AMS monitors the tray for "motion started" and "motion ended". The AMS also performs de-

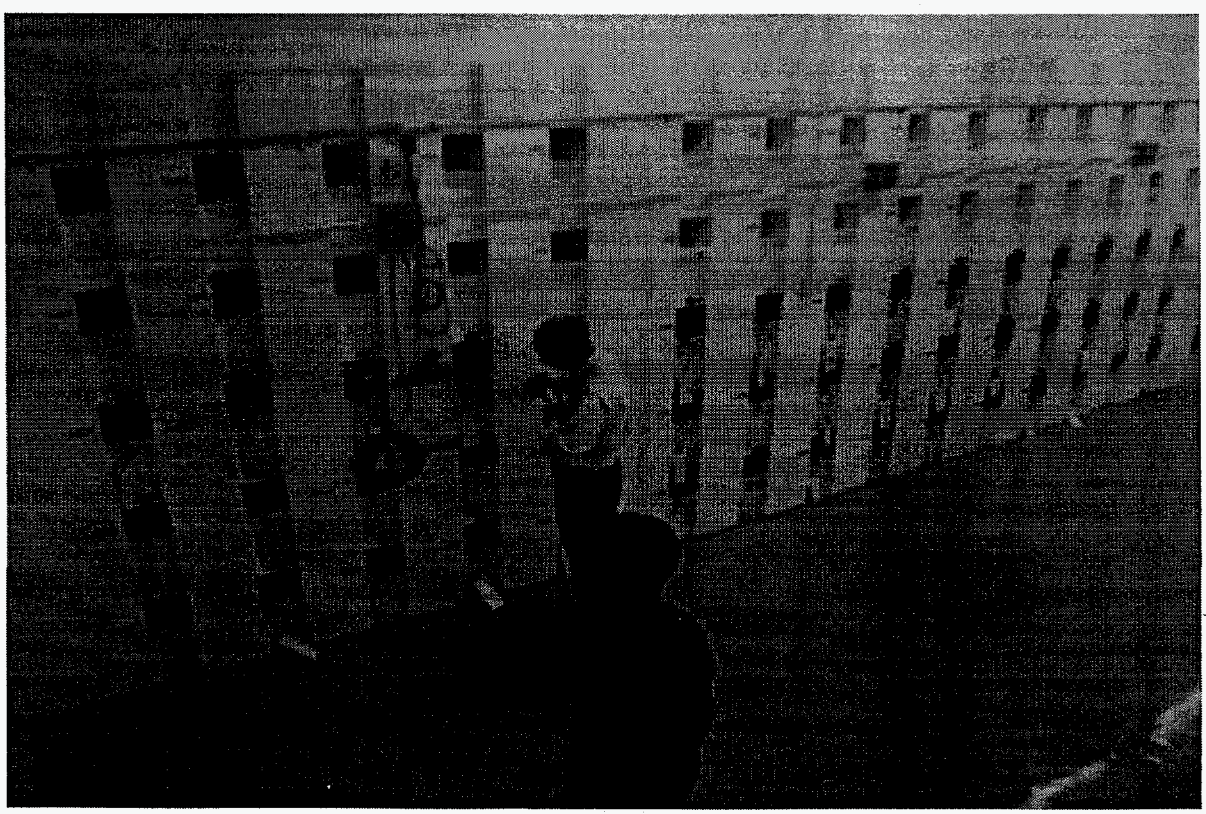

Figure 2: ICAM Image - April 14.1997

Date	Time	Sensor	Event
4/14/97	08:44:25	Tray 1 Front Motion	Motion Detected
4/14/97	08:44:36	Tray 2 Front Motion	Motion Detected
4/14/97	08:44:37	Tray 2 Back Motion	Motion Detected
4/14/97	08:45:28	Tray 1 Front Motion	Motion Ended
4/14/97	08:45:31	AFOS Tube 1	Case Tamper Det
4/14/97	08:45:40	Tray 2 Front Motion	Motion Ended
4/14/97	08:45:41	Tray 2 Back Motion	Motion Ended
4/14/97	08:45:42	AFOS Tube 1	Case Tamper Rem
4/14/97	08:45:48	AFOS Tube 1	Seal Open
4/14/97	08:46:02	AFOS Tube 1	Seal Closed
4/14/97	08:46:20	AFOS Tube 1	Case Tamper Rem
4/14/97	08:47:23	AFOS Tube 2	Seal Open
4/14/97	08:47:45	AFOS Tube 2	Seal Closed
4/14/97	08:47:56	AFOS Tube 2	Seal Open
4/14/97	08:47:58	AFOS Tube 2	Seal Closed
4/14/97	08:49:09	Tube 1 VACOSS Seal	Node Event Info
4/14/97	08:49:35	Tray 1 Front Motion	Motion Detected
4/14/97	08:50:09	Tube 1 VACOSS Seal	Node Event Info
4/14/97	08:50:11	Tube 1 VACOSS Seal	Node Event Info
4/14/97	08:50:39	Tray 1 Front Motion	Motion Ended
4/14/97	08:50:44	ICAM	Sensor Trip
4/14/97	08:51:10	Tube 2 VACOSS Seal	Node Event Info

Table 1: Sample Event List - April 14, 1997

sign integrity monitoring of the storage facility containment. The AMS performed successfully in monitoring motion of the tray. The RMS was reconfigured so that the "motion ended" alarm from the AMS would only occur after the sensor had been in a static position for greater than 60 seconds.

The AssetLAN and the SmartShelf sensors include a Dallas Semiconductor ID electronic tag attached to each material container. A tag reader attached to each ID tag and to the sensor node reports the presence or absence of the ID tag in a specific location of the tray. Both components perform similarly but they are early in application development and require improved ID tag reader connections as well as improved grounding techniques.

Material attributes: The RadCouple and the RadSiP sensors report a radiation measurement from each container. The RadCouple sensor performs a gross gamma dose rate measurement. The RadSiP radiation sensor performs a measurement of the enrichment of the uranium material. Both sensors were configured with alarm limits to monitor the continuous presence of a container of material. It was determined that the Rad-Couple sensor did not have the sensitivity required to monitor the radiation levels which existed at the Y-12 storage facility.

Surveillance: When the ICAM received a trigger message from a sensor, it captured a single frame of video. The video was used for assessment of the trigger event. Because there were no expected triggers during routine operation, the ICAM was configured to capture images on a 14 hour interval for image evaluation. The ICAM will be modified to record interval images so that in the case of an event, a series of images would be captured. The series of images would allow an inspector to assess what was occurring just before, at the time of, and just after an event triggered the ICAM.

To further evaluate the use of triggered images versus interval images, the Gemini system was installed in a stand alone mode. The Gemini was configured to capture images on a 10 minute interval. Gemini images were reviewed at the Y-12 facility before being transferred to the IAEA for further evaluation in Vienna. Both of the surveillance systems authenticated the image files at the camera housing before the images were transferred to the data acquisition system for archiving.

Local data communications: The RMS uses the Echelon LonWorks and the AIMS RF networks for sensor message communications between sensors and the master data node. LonWorks utilizes a message based protocol for the sensor network. The protocol was configured to provide authentication of sensor messages. The ICAM also transferred images (large data files) across the sensor network using the LonWorks File Transfer Protocol (FTP). The sensor network performed extremely well for the monitoring network. The FTP was enhanced to provide error free transfer of images across the network. The LonWorks network proved the benefits of utilizing a standard for the sensor network for ease of integrating sensors from different suppliers. The flexibility of different media was not demonstrated during the field trial but the protocol for using LonWorks was successfully demonstrated.

Data acquisition: The RMS used the DAS for data acquisition, local storage, authentication and interfacing to the data review locations. The DAS interfaced to the network through the master data node. The master data node was based upon the Coactive Aesthetics (CA-386-N1) host based node. The transfer of sensor messages from the master data node was via a serial port on the DAS computer. A real time display of sensor events provides limited data review on the DAS. Two basic displays are available on the DAS: the last two messages from the network and the last message (scrolling) from each sensor within the network. Data was stored and authenticated on the DAS on a daily basis.

Remote data communications: The remote data communications used Norton-Lambert's Close-Up (a DOS remote control software application). Close-Up allows either a manual interface between the remote and the host computers or an automatic transfer of files between the computers. The automatic transfer program functioned well. The majority of data transfer was accomplished using the public access dial-up capabilities on the local telephone companies. Typically, data transfer rates between 14400 and 28800 bits per second were accomplished from the multiple DIRS locations. The performance of the public access telephone links was acceptable but specific performance of a link varied due to the specific telephone circuit at connection time. In addition to the dial-up capabilities, a satellite link was installed for comparison with dial-up communications link. Unfortunately, insufficient data were collected during the field trial to make a conclusive comparison between the dial-up and the satellite links performances.

Data review: Review of the system data was conducted on DIRS computers located at IAEA (Vienna, Austria, and Toronto, Canada), Oak Ridge, and Sandia. After the data was transferred to the DIRS, it was appended to the data base on the DIRS for review and analysis. The set of messages was divided into four levels representing system and material messages and system and material alarms. It was determined that system requirements for the DIRS should include a Pentium processor based computer; otherwise, the speed performance was marginal. The DIRS review of the data authentication was presented on a calendar display of each month. All data except for two days were authenticated on the DIRS. Additionally, the calendar display showed the highest level of event message per day. A histogram is available for review of the total event count per day. The detail screen provides a plot of events per unit of time (approximately seven minute interval) for a 24 hour period (midnight to midnight). A scrollable window is presented for review of each day's events. The material attribute sensors made radiation level measurements and these data are reviewed in a "detail" option screen.

Filters provide a means for reducing the volume of data in the various screens. The filters allowed selection of specific sensors as well as the message level. The filters performed as expected but definition of the message levels is currently a complicated task which must be coordinated with the end user for operational use.

The volume of data collected from the RMS included component evaluation, system status and safeguards relevant data. For operational use, the data collection will be restricted to system status and safeguards relevant information. There is a need for involving the IAEA in the design of the analysis routines for inclusion in the DIRS component.

Conclusions:

During the field trial, there were recommendations for improvements to all components evaluated including improvements in operations for adverse environment conditions; improved message definitions from a sensor; and improved review techniques of the data.

As a result of the field trial, it is concluded that a remote monitoring system can meet IAEA requirements for inventory extension with demonstrated confidence and can reduce cost, impact on the facility, and risk of compromising sensitive information. The IAEA will continue to pursue the remote monitoring approach with a long-term goal to achieve near real-time inventory verification and further reduction of material access and costs.

The field trial started with requirements and objectives as defined in a Work Plan. The selected components were designed, integrated and installed into Vault 16 during FY96. The field trial was conducted for an eight month period during FY97.

All technologies evaluated throughout the field trial were applicable for use in safeguards monitoring. The component evaluation results met the field trial objectives with one exception. The exception was a matter of site specific radiation levels and not necessarily component capability.

A recommended system for operational use has been proposed and is being discussed between the DOE and the IAEA.

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[1] Killinger, Whichello, Lemaire, Rodriguez, and Tzolov, "An overview of IAEA remote monitoring activities," pp 998-1002, *INMM Proceedings*, July 1996.

[2] Sheely and Whitaker, "Evaluation of remote monitoring at the Oak Ridge HEU storage vault - first thoughts on final application", pp 531-535, INMM Proceedings, July 1996.

[3] Corbell, Moran, Pickett, Whitaker, Resnik, and O'Toole, "Technical Implementation in Support of the IAEA's Remote Monitoring Field Trial at the Oak Ridge Y-12 Plant," pp 1014-1018, INMM Proceedings, July 1996.

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