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DEVELOPING AND TESTING TECHNOLOGIES FOR FUTURE REMOTE MONITORING SYSTEMS

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ABSTRACT

Remote monitoring systems presently operating in facilities in a number of countries around the world are providing valuable information on the installation and operation of such systems. Results indicate they are performing reliably. While the technology for remote monitoring exists today, it may be some time before numerous constraints on implementation can be resolved. However, the constraints should not prevent the designing of systems that can be used for remote monitoring. Selection of the proper technology path for future development should include a flexible approach to front-end detection, data formats. data processing, and other areas.

I. INTRODUCTION

Remote Monitoring System (RMS) field trials are presently operating in facilities in Australia, Sweden, Japan, Argentina, Germany, Italy, and the United States. These systems have provided valuable information concerning installation and operation of remote surveillance systems. The results from the first months of operation indicate remote monitoring systems with front-end detection (i.e., systems that do not employ continuous imagery and data recording, but rather utilize sensors to initiate, or "trigger," such recording) can be used effectively for unattended surveillance. The various systems used in the present field trials are similar in concept but differ in particulars among the types of facilities in which they are installed.

Additional development in RMS technology is required in order to achieve the goal of standardizing an architecture that will accommodate continuing improvements in future systems. Selection of the proper technology path can lead to reduced costs and increased versatility in future systems compared with existing systems. It is important that this architecture accommodate improvements in equipment performance and new technology in such areas as data formats, authentication algorithms, and encryption algorithms. A brief description of two of the existing remote monitoring systems, and some general recommendations for future remote monitoring systems, will be presented.

II. BACKGROUND OF REMOTE MONITORING SYSTEMS

In the 1980s, under the sponsorship of the International Safeguards Program of the U.S. Department of Energy (DOE), Sandia National Laboratories (SNL) developed and tested an integrated monitoring system to monitor the movement of spent fuel in away-from-reactor storage facilities. The system made the first use of computer communications technology in an international safeguards context to improve the efficiency of the safeguards monitoring process. The system used a network link that allowed the sensor and the monitoring functions to be in continuous communication, thus integrating the system into a whole. The system was successful and a modified version, the Channel Monitoring System, a joint product of SNL and the Los Alamos National Laboratory, is in use at the THORP facility in the UK. Subsequently, a demonstration linking the network interface capabilities to the CAVIS-2 system was conducted at the Joint Research Center at Ispra, Italy.

Recently, also under the sponsorship of the DOE, a series of field trials of RMS was begun. These field trials now involve a number of installations around the world. Some of the equipment and hardware used in the early installations has been upgraded, and installations at additional sites are planned in the future.

A. Field Trial in Australia

The first RMS field trial system was installed at the Dry Spent Fuel Storage Facility of the High Flux Australian Reactor located at Lucas Heights, Australia, during the first week of February, 1994.[1,2] This reactor is operated by the Australian Nuclear Science and Technology Organization (ANSTO) and the field test activity has been conducted under a bilateral agreement between the Australian Safeguards Office and DOE.

The Dry Spent Fuel Storage Facility contains fifty spent fuel storage tubes located in the building floor. The tubes are kept under IAEA seals. Monitoring the building interior, the tubes, and the transfer flask used to move the spent fuel into the tubes, provides an opportunity to test a variety of instrumentation in the RMS. A block diagram of the original Australian RMS is shown in Figure 1. The configuration of the equipment in the facility is shown in Figure 2.

As is apparent from these figures, the Australian RMS involves a large number of sensors and network nodes. instrumentation presently includes Authenticated Item Monitoring System (AIMS) motion sensors and AIMS Sensor Transmitters (ASTX) on each of the 50 spent fuel storage tubes. Any motion of the storage tube covers will generate an alarm that is transmitted over a radio frequency carrier to the AIMS Receiver Processor Units (RPU). For test purposes, three of the ASTXs are configured as Reusable In-situ Verifiable Authenticated (RIVA) seals, which are active fiber optic seals that alarm whenever the fiber optic loop is opened. Microwave motion sensors are used on the network to monitor motion in the area. In addition, ultra-wideband radar motion sensors designed by the Lawrence Livermore National Laboratory have been installed.

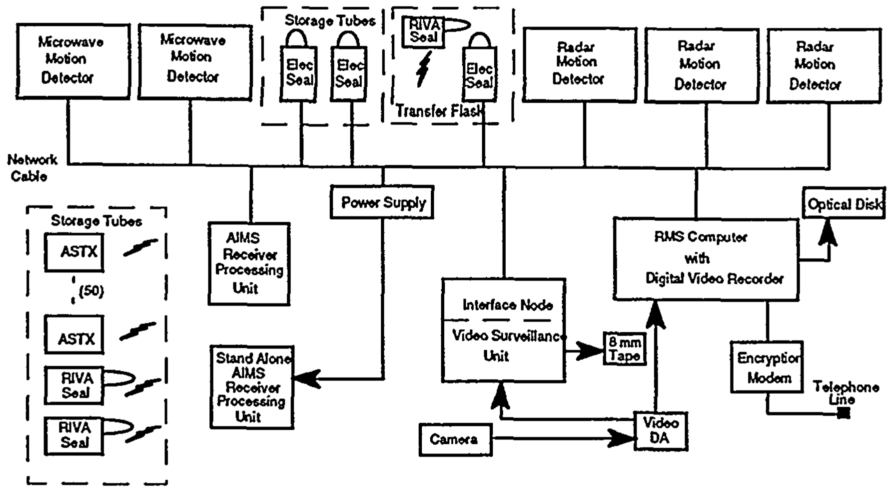

Figure 1. Diagram of original RMS system at Lucas Heights

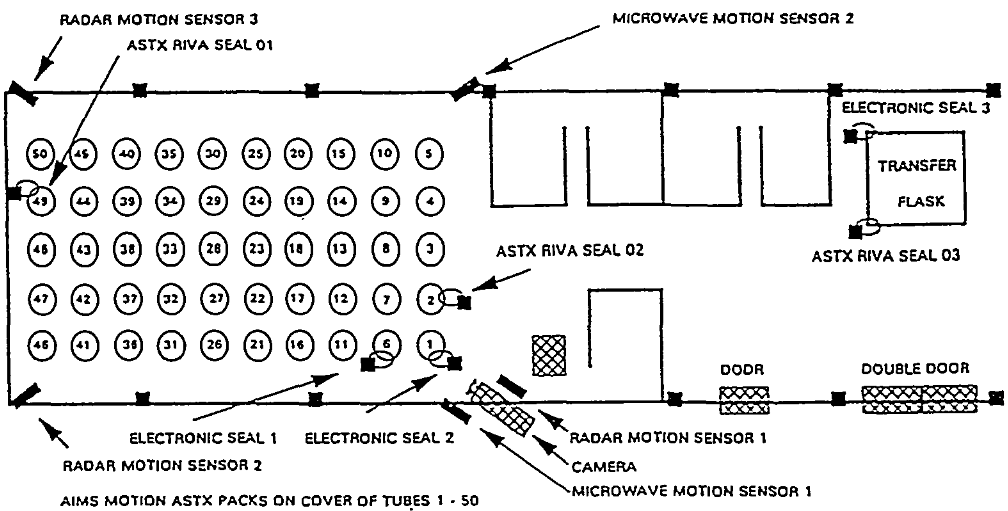

Figure 2. Equipment configuration in Australian RMS

The system instrumentation functions in an integrated manner to collect information regarding the status of the facility and the spent fuel tubes. Detection of any alarm signals from the ASTX or the motion detectors triggers recording of video images on dual video recording systems. An analog recording system called the Video Surveillance Unit is programmed to make recordings when it receives an alarm signal. This unit also records time-lapse images in a manner similar to that used by the Modular Integrated Video System (MIVS). A second video recording system uses a digital compression board in the RMS computer to digitize and compress images and store them on both a hard drive and an optical disk. The images from the two systems can be compared to evaluate the effectiveness of the front-end detection. Recently, a three-dimensional video system, consisting of four video cameras and processing equipment from the 3DIS company, has been connected to a node on the network.

The RMS computer makes the sensor and video information available to remote stations through an off-site communication link. The data and images are encrypted before transmission off site, and access to the computer requires both the correct encryption keys and passwords. For this installation, off-site communications use commercial telephone lines. At the present time data and images are monitored from Canberra, Australia, and Albuquerque, New Mexico.

The Australian field trial has produced encouraging results in the period since its installation. It has been regularly interrogated from both Albuquerque and Canberra. The system hardware and software have performed reliably, and the digital images have good resolution. The RMS has shown how a number of technologies can be combined to introduce new approaches to on-site monitoring. The system has successfully collected safeguards information from a nuclear facility and transmitted it to receiver stations without the need for on-site inspections.

B. Field Trial in Sweden

In August 1994 a remote monitoring system was installed in the operations hall of a light water reactor at Barseback, Sweden.[3] The objective of this system is to detect and record the transfer of spent fuel from the reactor. A block diagram of the RMS is shown in Figure 3. The hardware consists of a network of nodes that collects data from microwave motion sensors.

The positioning of the microwave sensors is shown in Figure 4. Two sensors monitor the exit hatch, one detects movement of the crane into a position that could allow spent fuel handling activities to occur, and one detects activity in the cask preparation area.

The motion sensors have a number of adjustments for sensitivity thresholds and active volume that have been used to reduce triggers resulting from non-spent-fuel activities. In addition, the node logic has been programmed to require activity in an area for a specified time before sending a trigger signal. This system thus provides images only when activities involving the movement of large objects occur in the reactor hall. Furthermore, a lockout period is used following each motion trigger that causes the system to ignore any additional motion triggers for a period of two minutes. Thus the minimum interval between recorded images is two minutes. This ensures that visual images of all significant activities are collected, but that the number of images cannot exceed one every two minutes while the activity continues.

When the motion sensors detect activity for a specified time in selected areas of the operations hall, they trigger the recording of video images. Again dual video recording is used by including both a Video Surveillance Unit and the RMS computer. The Video Surveillance Unit also records time lapse images at intervals of six minutes. A mains power monitor sends signals over the network to a "loss of AC power" alarm box.

Remote access to the RMS has been established from Stockholm, Sweden, and Albuquerque, New Mexico. Commercial telephone lines are used for

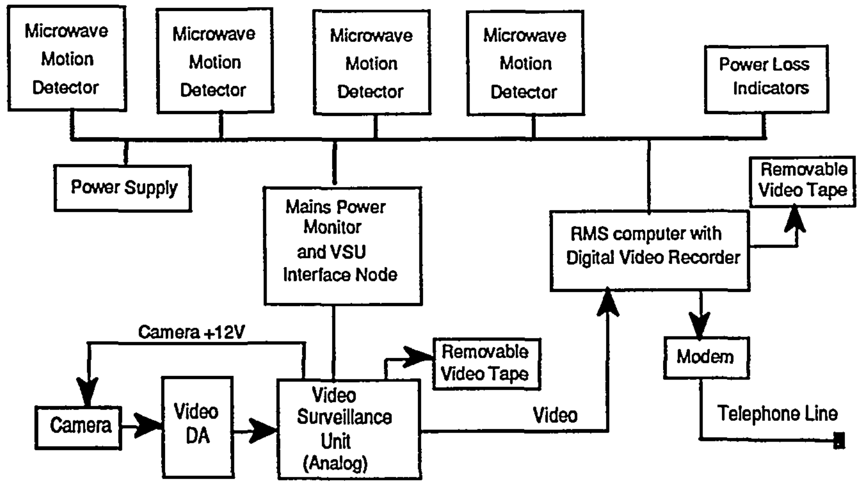

Figure 3. Block diagram of the Swedish remote monitoring system

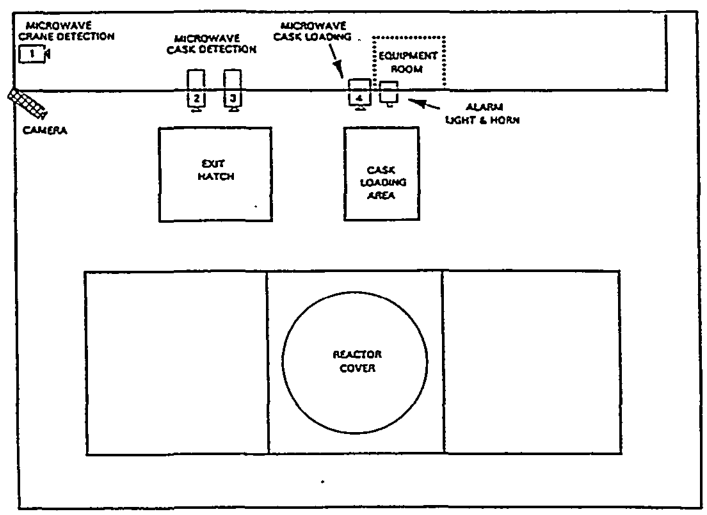

Figure 4. Positions of motion sensors in Swedish RMS

transmission of data and images. Results to date indicate that all cask movements within the reactor hall have been detected and imaged, while only a few images have been collected of activities not involving a spent fuel cask.

III. REMOTE MONITORING

In each of the present RMS field trial installations, data and images from the facilities under surveillance are remotely monitored via telephone lines. Remote monitoring stations can retrieve data and images from the RMS computer in the facility, can modify software on the computer, and can reconfigure the system if desired. Access to the RMS computer cannot be obtained without the correct encryption keys and passwords.

The RMS systems have been performing well. There have been no major problems with any of the hardware or software. Data and images have been obtained on a regular basis from the systems. The Australian RMS has captured a number of images showing guards walking through the facility at night, local staff performing various functions during the day, and IAEA inspectors at work.

All spent fuel movements at Barseback have been imaged. The sensor network has effectively screened out thousands of images that a time-lapse system located at this facility would have recorded. Reducing the number of images taken reduces the amount of time that is required to transmit and review the data and images. An example of the data reduction that has occurred can be illustrated by the fact that only 47 images were captured by the Swedish RMS during the first month of operation at Barseback. In the same time period a time-lapse recorder such as the MIVS would have collected approximately 14,400 images on two recorders. The number of images to be reviewed have thus been reduced by a factor of more than 150 (300 if both tapes had to be reviewed). During this period no spent-fuel activities occurred in the facility.

Spent fuel was moved out of the Barseback reactor during October 1994. The movement of one spent fuel cask into and out of the reactor hall took approximately 49 hours. During this time period a MIVS would have collected about 1000 pictures on two recorders. Instead, in the same period, the RMS received 272 triggers from the four microwave sensors and, in response to these triggers, 141 images were recorded. There were 86 images associated with triggers of cask loading and crane movement activities. This left only 55 images to be reviewed to determine the times of cask entry and exit from the reactor hall.

IV. FUTURE SYSTEM FEATURES

The RMS field trials can provide valuable information on how to design tomorrow's safeguards systems. In the future, systems for safeguards applications should have the capability to be monitored remotely, should utilize selective triggering of images, and should supplement imagery with sensor data. While the technology for remote monitoring exists today, it may be some time before the numerous constraints on remote monitoring, political and otherwise, can be resolved to make such monitoring possible on a worldwide basis. However, the constraints should not be used as an excuse for not designing systems that can be used for remote monitoring.

The block diagram in figure 5 shows some of the key features that should be part of a complete approach to remote monitoring. However, the block diagram does not show some of the very important software programs and related data formats necessary for total system integration. Some of the key features are:

Front-end detection - A network of sensors provides the capability of collecting trigger signals from a number of different types of sensors. Since the network can contain microprocessors at every node, distributed processing of sensor signals before they are transmitted to an Acquisition and Storage Module is possible. If the proper sensor suite is installed to trigger the capture of video images then the number of images to be stored will decrease significantly.

Independent verification - The use of sensors other than video change

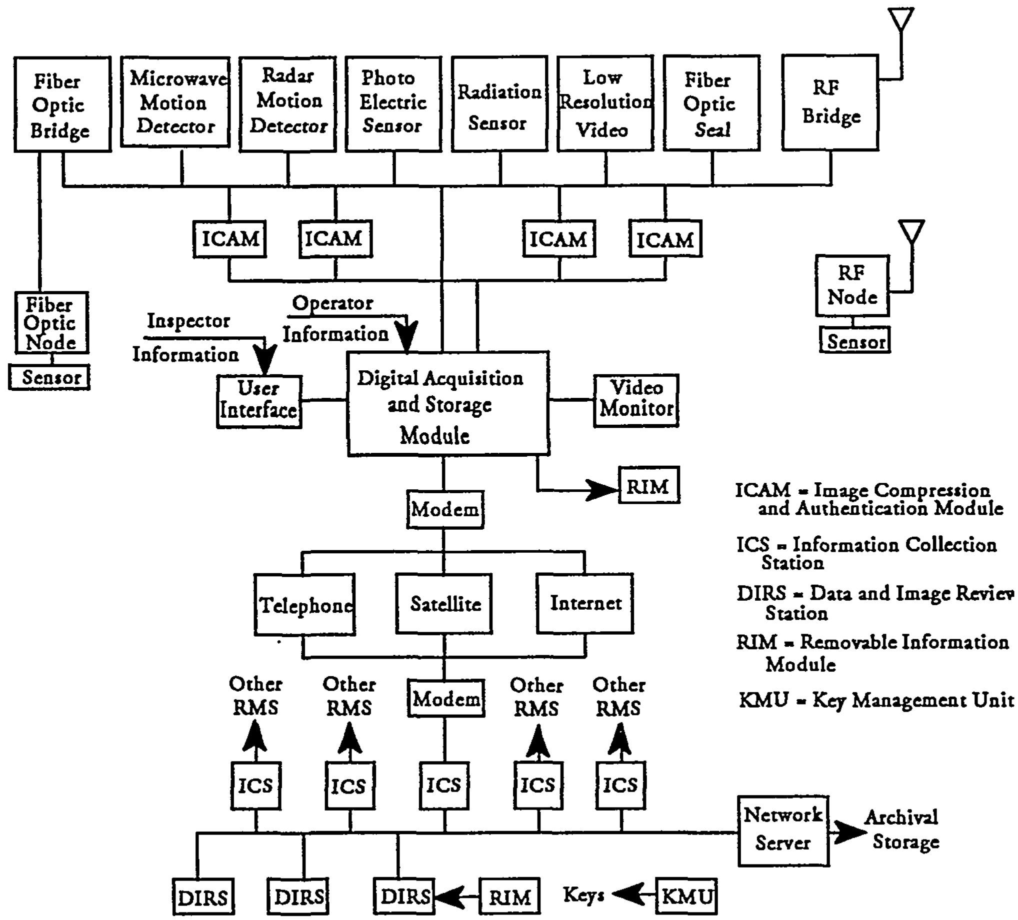

Figure 5. Future RMS features

detection provides an independent data set to help confirm activities in a facility. For example, motion sensors can be used to verify that there was no activity at a monitored site during periods when images were not being captured.

Image Compression and Authentication Module - Camera images must be authenticated to insure that substitution has not occurred. The function of a data compression and authentication module is to capture and digitize a video image, compress the resulting file, and authenticate the file before sending it over a serial link to the Acquisition and Storage Module.

Removable Information Module - This module should provide a means for on-site data and image removal. Optical disks provide compact, high density, removable media and have many advantages over the various tape formats. It is also possible to use removable hard disks but, at the present time, cost seems to be against their use.

Acquisition and Storage Module - The data and images are collected and stored by this module. An embedded computer in the module would perform authentication and encryption on all the collected data and images. Thus standard modems can be used to communicate over various links such as telephone, satellites, or the internet.

Data Review - An Information Collection Station could be part of a remote monitoring review center. Trained operators could call and collect remote information in encrypted files and send the files to a network server for storage. Inspectors could then access the stored files by obtaining the encryption keys from a Key Management Unit and going to a Data and Image Review Station to review the data.

V. SUMMARY

Current field trials of Remote Monitoring Systems are providing practical data and operational experience to aid in the design of tomorrow's systems. The technical performance data gained with the present systems will provide the insight needed to develop the equipment that will operate reliably as part of the next generation of safeguards.

ACKNOWLEDGMENT

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