Abstract
Sandia National Laboratories (SNL) under DOE sponsorship is engaged in nuclear nonproliferation activities with the Power Reactor and Nuclear Fuel Development Corporation (PNC) of Japan. From 1995 to the present SNL and PNC have been participating in a cooperative project to implement and assess the use of remote monitoring to achieve nuclear nonproliferation objectives. Implementation of remote monitoring at the PNC Joyo facility took place during 1996 and continues to date. An International Fellowship began in the Fall of 1995 and has complemented the nonproliferation study. Plans are underway to extend the Fellowship and to upgrade the existing Remote Monitoring System to include another area at the Joyo facility. SNL and PNC are currently exploring the possibility of exchanging experts with the objective of promoting regional confidence building in Northeast Asia, possibly using some of the same remote monitoring technologies. This paper will provide an overview of these activities and report on the status of cooperative nonproliferation activities being conducted by PNC and SNL.

Introduction
The objectives of this project were to carry out a cooperative effort in nonproliferation with the design, implementation, and installation of a Remote Monitoring System (RMS) at the PNC Joyo facility, and to perform a study to assess the use of remote monitoring to achieve nuclear nonproliferation goals. The study was to be performed at the Joyo facility supported by an International Fellowship program.

Implementation of remote monitoring at the PNC Joyo Facility began in 1996 and continues to date. In July 1996, the RMS was installed in a spent fuel storage facility to monitor the movement of spent fuel into and out of a storage pond. The system uses sensors and a digital camera to monitor the movement of a loaded cask into the facility, the unloading of the cask, and the movement of the empty cask out of the facility. Radiation (gamma) sensors monitor the entry hatch to determine whether the cask
contains radioactive material, and a neutron detector located underwater is used to detect movement of spent fuel assemblies into or out of the storage pool. The neutron detector allows discrimination between spent fuel and other objects such as control rods that might be stored in the facility.

**Nonproliferation Application of Remote Monitoring**

Two aspects of nuclear nonproliferation to which remote monitoring may be applied are providing international accountability for: 1) nuclear weapons and nuclear material in nuclear weapon states and 2) nuclear material used for peaceful purposes in non-weapon states. Remote monitoring is a tool that could be used to promote regional confidence-building by providing assurance that nuclear materials will not be diverted to weapon programs internally or externally.

Remote monitoring is the telecommunication of data from an on-site location to a remote location. The remote location can be a local office, a regional office, or an international agency. An on-site monitoring system can be configured to accommodate a wide range of facilities including material processing, nuclear fuel fabrication, and storage facilities. A remote monitoring system can incorporate seals, motion sensors, radiation detectors, video cameras, or other instruments as needed to detect and record undeclared activity.

It is clear that an unattended monitoring system can collect a very large amount of data. If the data is being remotely monitored at multiple locations, it will be desirable to enable different levels of access depending on the information requirements of various system users. For example, environmental and safety information can be made available to local health officials or even to the public. Nuclear safeguards information can be made available to international inspectorates, and other levels of information access can be established as needed. Sandia National Laboratories is currently developing a remote monitoring system with the capability to provide multiple levels of information access.

The remote monitoring system implemented at the PNC Joyo facility under a PNC/DOE agreement monitors the inventory of spent fuel in a spent fuel storage facility. The system monitors fuel movements through a combination of radiation sensors, motion sensors and a video camera. Monitored activities include the arrival and departure of shipping casks, the movement of items (nuclear and non-nuclear) within the pond, and maintenance procedures in the storage pond area. Changes in the storage pond inventory have been clearly distinguishable from other activities in the pond room. The remote monitoring system has demonstrated that a continuity of knowledge of the storage pond inventory can be monitored and verified from off-site.

**Description and Function of the Joyo Remote Monitoring System**

The remote monitoring system consists of an on-site monitoring system and remote-site data review stations. The on-site system is actually a stand-alone system that consists of a data acquisition system (DAS), various sensors, and a digital camera system. The data
review stations (DIRS) are capable of data display, and data archiving. Conventional
phone lines are used as the telecommunications link to transmit on-site collected data to
remote locations. (See Figure 1)

![Figure 1 Joyo Remote Monitoring System Block Diagram](image)

The system contains four different types of sensors: break beam, motion, gamma, and
neutron. There are nine sensors altogether and each sensor communicates to a network
node. All the nodes are interconnected and form a Local Operating Network (LON).
This LON technology is commercially available from the Echelon Corporation. The
LON has been designed so that all nodes can communicate with each other exchanging
both sensor and state of health information over a single two-twisted pair, 18-gauge,
copper wire cable. Each node is capable of processing sensor data and providing
authenticated data transfers over the LON to the data acquisition computer. The Joyo
remote monitoring system is connected in a free topology configuration, which allows a
more flexible solution for connection of nodes onto the network.

The data acquisition system (DAS), which is a 486-based, PC compatible computer,
running Windows NT V3.51 operating system, interfaces to the LON network via a serial
communication port. Between the DAS and the LON network, a node with a single
board computer is responsible for translating LON information to PC serial data
communications. The DAS is used to collect pertinent sensor and video data, for data
storage, and telecommunication of data to remote sites. Limited data review is available
on the DAS for system configuration, maintenance and troubleshooting. A modem is connected to the computer to provide telephone communications to the Data Image and Review station (DIRS) at remote locations. The DIRS computers, which have access to the DAS, are 486 or Pentium based computers running the Windows 95 operating system. Remote Access Service (RAS) is the modem communication program used between the DAS and the DIRS. RAS is a standard communication service that is provided with Windows NT and Windows 95.

A digital video camera system is also connected to the LON and images are captured when it is triggered by sensors on the LON network. The video module is capable of digitizing video frames, compressing the digital image, authenticating the compressed digital file, and storing the image file until it can be transmitted to the DAS computer. At present, the Joyo system is configured to receive image trigger messages from the break beam and microwave motion detectors. However, any sensor node can be programmed to trigger video image capture.

There are currently three remote sites that are able to access the DAS and acquire information. One is located in another building at the Joyo facility, another is at PNC’s headquarters in Tokyo and the third is at SNL’s Cooperative Monitoring Center (CMC) in Albuquerque, New Mexico. Only one DIRS can be connected at any single time to the DAS. Information accessible by a remote DIRS includes state of health information for all nodes and sensors, records of previous events, trigger histories of video data, video images acquired, and the current status of the system.

With the proper authorization, the Joyo remote monitoring system may be accessed by local, state, and international inspectors for nuclear material accountability. Presently, the IAEA and state inspectors make site visits to acquire video surveillance tapes and re-verify inventories on the stored material. With this remote monitoring system an inspector can “dial-in” and download data to a remote station without making costly site visits.

The primary function of the Joyo remote monitoring system is to monitor spent fuel assemblies that are received at the Joyo Spent Fuel Storage Facility #2. (See Figure 2) Spent fuel assemblies are transported in a cask and delivered to the outside of the storage facility’s hatch door by truck. Two gamma detectors are mounted on opposite sides of the hatch door entrance to acquire gamma count information as the cask is passed through the opening. The gamma detectors indicate the presence of nuclear material, and to some extent, the quantity of nuclear material present. The data taken from the two gamma detectors begins the continuity of knowledge by indicating the presence of nuclear material.

After the cask has passed through the hatch door, Microwave motion sensor #4 and the break beam are triggered and a video image is recorded of the cask in transport. An overhead crane then transports the cask to the Cask Lid Removal area in the storage pond. At this position Microwave motion sensor #3 is triggered and a video image of this event
is recorded. Once the cask has been placed in the Cask Lid Removal area, the lid is removed from the cask.

The cask is then moved to the Fuel Element Removal area at the bottom of the pool. Fuel elements are removed from the cask and transferred to underwater storage location. These activities trigger Microwave Motion Sensor #2 and images are captured of this process every five minutes until the process terminates. A neutron detector is located in the pond adjacent to the Fuel Element Removal area. This detector is used to distinguish between spent fuel and other objects being transferred into the storage pond as they are unloaded. The magnitude of the neutron signal as the assemblies are passed by the sensor are used as an attribute indicator of the elements.

Through the radiation count data and video images of the remote monitoring process, a continuity of knowledge is preserved throughout the transfer process. This information can be used by local, state and international inspectors.

**Current Status and Future Plans**

The main objective of the field trial evaluation at the Joyo facility is to demonstrate the technical feasibility of a remote monitoring system in a nuclear nonproliferation application. This includes the overall system reliability, data authentication on-site and through a communication link to a remote site, data confidentiality in the remote transmission, and the conclusiveness of the results based on the data. Field trial results of the Joyo remote monitoring system will be available in the second quarter of FY98.
During the third and fourth quarter of FY97, DOE and PNC hope to expand the current remote monitoring system at the Joyo facility. It is proposed that the system be expanded to include the Fresh Fuel Storage Area #1 at the Joyo facility. The installation of the expanded system would not only add additional monitoring capabilities, but will also allow for a new software upgrade that operates on a multi-tasking operating system. The current DAS software is not designed to take advantage of multi-tasking operations. The expanded system would also allow for Ethernet communications between data nodes and Internet communications between the DAS and DIRS computers.

SNL and PNC recognize the importance of continuing to develop technologies in the area of nuclear nonproliferation. To support this task, SNL and PNC are planning to exchange experts in addition to the International Fellowship currently supported by PNC, DOE, and SNL. These personnel exchanges will allow SNL to better understand the challenges that pertain to the Japanese nuclear safeguards industry, and PNC will benefit by learning the technologies SNL and other DOE labs have developed for nuclear nonproliferation/safeguards purposes. The success of these programs allows for a continued collaborative relationship between SNL and PNC.

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