LA-UR-97- 2102
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Title: **Global Nuclear Material Monitoring**

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Submitted to: DOE Office of Scientific and Technical Information (OSTI)

Global Nuclear Material Monitoring

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Abstract

This is the final report of a one-year, Laboratory-Directed Research and Development (LDRD) project at the Los Alamos National Laboratory (LANL). This project provided a detailed systems design for advanced integrated facility monitoring and identified the components and enabling technologies required to facilitate the development of the monitoring system of the future.

1. Background and Research Objectives

The amount, complexity and throughput of nuclear materials is increasing at nuclear facilities worldwide. Continuous unattended surveillance and radiation monitoring systems can significantly reduce the inspector and guard time in the facilities. However, these systems produce large databases that can require large amounts of inspector and operator time for review and analysis. With complex and diverse data, it is difficult and time consuming for safeguards inspectors to examine all of the data for consistency and to find anomalies that could be caused by diversion of nuclear materials.

Technology based on pattern recognition software has been developed [1] to automate the review and analysis of safeguards databases. When normal trends and patterns in the data can be characterized, such anomalies reveal themselves. Software that can recognize patterns through advanced analysis can be an efficient aid to inspectors. The software can analyze all the data and identify anomalies for more thorough review by the inspector or facility operator.

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To efficiently analyze all of the data, it is necessary to integrate diverse sensors including containment and surveillance (C/S) systems, radiation, personnel, and mechanical data into a synchronized database for the computer-aided analysis. The goal of our LDRD project was to identify the architecture and technology required to make this integration possible. This included laying out a detailed plan for advanced integrated facility monitoring and identifying the components and enabling technologies required to facilitate the development of the monitoring system of the future. The intent of this work was to improve the focus of Los Alamos research so that it better supports the development of facility monitoring, and to better direct our development of new systems so that they incorporate the components that will meet current and anticipated nonproliferation needs.

2. Importance to LANL's Science and Technology Base and National R&D Needs

Los Alamos has long provided monitoring systems for nuclear facilities worldwide. New policies and changing world political environments have provided opportunities to install these systems and enhance the international security of countries that handle strategic materials. This project provided a long-range look at future requirements for the monitoring of nuclear material. Such requirements enabled researchers to identify those areas where analysis algorithms can be incorporated into a monitoring system or where new algorithms must be developed. Furthermore, this project described the level to which integration must be taken in order to effectively incorporate the many and varied sensors required in the future. Developers can then use these system-level requirements to demonstrate flexible technologies that can be applied not only to nuclear facilities, but others as well. This project supports a Los Alamos core competency in analysis and assessment.

3. Scientific Approach and Accomplishments

This project focused on the definition of a flexible, integrated monitoring approach for nuclear facilities. This approach incorporates aspects of item signature identification, perimeter portal monitoring, advanced data analysis, and communication. Advanced analysis has not yet been included in monitoring systems; to date, they are primarily data collection and review systems. Our design approach, which incorporates analysis as an integral component, is intended to provide a capability for extrapolating information from the integrated nondestructive assay (NDA) instruments and the C/S data that are collected.

The end result will be the foundation for a cost-effective monitoring system that could provide the necessary transparency even in areas that are denied to foreign nationals of both the US and Russia should these processes and materials come under full-scope safeguards or bilateral agreements. Monitoring systems of this kind could provide additional benefits, including improved security and safeguards at nuclear facilities and lower personnel radiation exposures. Our efforts were directed at a full definition of the components of this system, together with identification of key technologies that are necessary to carry out the implementation.

In the next sections we describe the main ideas in the system design, the enabling technologies, and work that was begun on the development of these technologies.

System design

An effective integrated facility monitoring system can be described in terms of six basic functions: material tracking, personnel tracking, information management, assay, processing the collected data, and combining all of the above functions into one system. Present systems incorporate many of these functions, but no systems incorporate them in a completely integrated manner. It is desirable that these functions be implemented so that information can be passed between the different components, enhancing decision-making and safeguards assessment.

Because nuclear materials emit unique signals, smart radiation sensors play an important role in monitoring the movement of the materials. Smart sensors do more than just monitor movements; they provide camera triggers, quick-response alarms, local data storage, and time synchronization. These sensors are under development at Los Alamos and should be incorporated into monitoring systems in the near future.

A major component of monitoring activities in a nuclear facility will be collecting information on who is moving material, where it is being moved, and when. This information can be combined with the information from the material tracking sensors discussed above to keep track of who is moving nuclear material and to establish the patterns of movement of the facility personnel and material. These material control and accounting (MC&A) systems and individual identification systems will be coupled with motion-tracking and activity-analysis systems to provide additional information about the activities inside protected areas such as vaults.

We have identified the information management systems that will store the massive quantities of data that should be collected. These include standard material control and accounting systems [e.g., Local Area Network Material Accounting System (LANMAS)], an authorization database, and a database for sensor data. The integration of these databases is important, and we have begun to integrate authorization and LANMAS. This task is described below.

Assay systems include signature detectors that look for signatures specific to particular sources and quantities of special nuclear material. These systems must be integrated with material movement sensors to verify the movement of a particular item from one vault to another.

Analysis techniques applied to facility data can be divided into three general categories: summarizing activity, interpreting and understanding data, and reconciling the sensor record with the facility declaration. Tools are being developed in all of these categories, and we describe some of that work below.

Our vision of integrated facility monitoring is to obtain as much information about the functioning of the nuclear facility as possible, in an attempt to define an acceptable background pattern of activity against which we hope to detect anomalous illegal or proliferant activity. Huge quantities of information should be stored and processed and safeguards should be more effective.

Enabling technologies

One of the key steps in this project was to identify technology developments that enhance the effectiveness and completeness of facility monitoring systems, so that Los Alamos can focus its effort in developing systems. The identified technologies include smart sensors, data-mining tools, simulation integrated with facility monitoring, integrated data collection and review for multiple and disparate sensors, anomaly detection algorithms for safeguards applications, and integration of safeguards material accounting databases with personnel authorization.

We focused part of our effort on the development of some of these enabling technologies. We describe these technologies in the following sections.

Integrated data collection

Future integrated monitoring systems will link together a large variety of sensors that continuously collect data. The central data acquisition computer must have software to accept data from the multiple sensors and to organize it into a data base for future analyses. This software was developed to automatically take data from multiple, distributed instruments as well as from one instrument at a time. The software communicates with remote instruments and transfers data and messages between the computer and the remote instruments. The software allows the user to review small segments of data and to copy data files from the data collection computer to other computers via network interfaces or to removable media. The software also archives data locally.

Networking

The Echelon-based LON network that connects neutron sensors to central data collection computers was integrated into a test monitoring system. This was an important task because this commercial network provides time-synchronization as well as authentication. Both are important to safeguards systems.

Smart sensors

We developed the concept of the Intelligent Shift Register (ISR) sensor to provide distributed intelligence on a neutron-based sensor. This provides data filtering and buffering to facilitate the data flow to the central data acquisition computer.

Anomaly detection

Neural network algorithms for anomaly detection are described in Reference 1. As part of this project, we pursued two other approaches: finite state machines and parsers. We tested our algorithms using data collected in a test facility and displayed the results for the user so that anomalous activity was flagged and a stored video image of the room was displayed along with other information. In this manner, the user could see what was taking place in the room during the anomalous event.

Integration of material accounting with facility monitoring

Integrating LANMAS with a Facility Monitoring System allows the user to track and record the movement of material or items throughout a facility. Authorization to move material or items may be scheduled ahead of time through the normal LANMAS interface. The person(s) authorizing the move have no direct access to the material or items being moved, which provides three person control of the material or item. The persons authorized to move material have a time window to complete the move. The persons moving material must also accept the material at the authorized destination. All transactions required to move the material or items are recorded and time-stamped.

Figure 1 illustrates this concept as it might be implemented with personnel authorization at a facility that stores nuclear material.

Integrating simulation with facility monitoring

The purpose of facility monitoring is to detect a discrepancy between a facility's nominal status and its true status, and the detection sensitivity increases when the nominal status is well known. An accurate facility simulation model usually contains more information about the nominal facility states and operating conditions than any other compendium of facility data and so can be of great use in planning and executing facility monitoring programs.

In the planning stage, a facility simulation can be used to test the effectiveness of candidate monitoring procedures and algorithms. For example, a simulation program can be used to generate simulated outputs from process instruments in a bulk processing facility both under standard operating conditions and when undeclared material transfers occur. Proposed anomaly-detection algorithms can be applied to these simulated process instrument readings to determine the algorithm's capabilities and limitations in distinguishing between nominal and anomalous operating conditions.

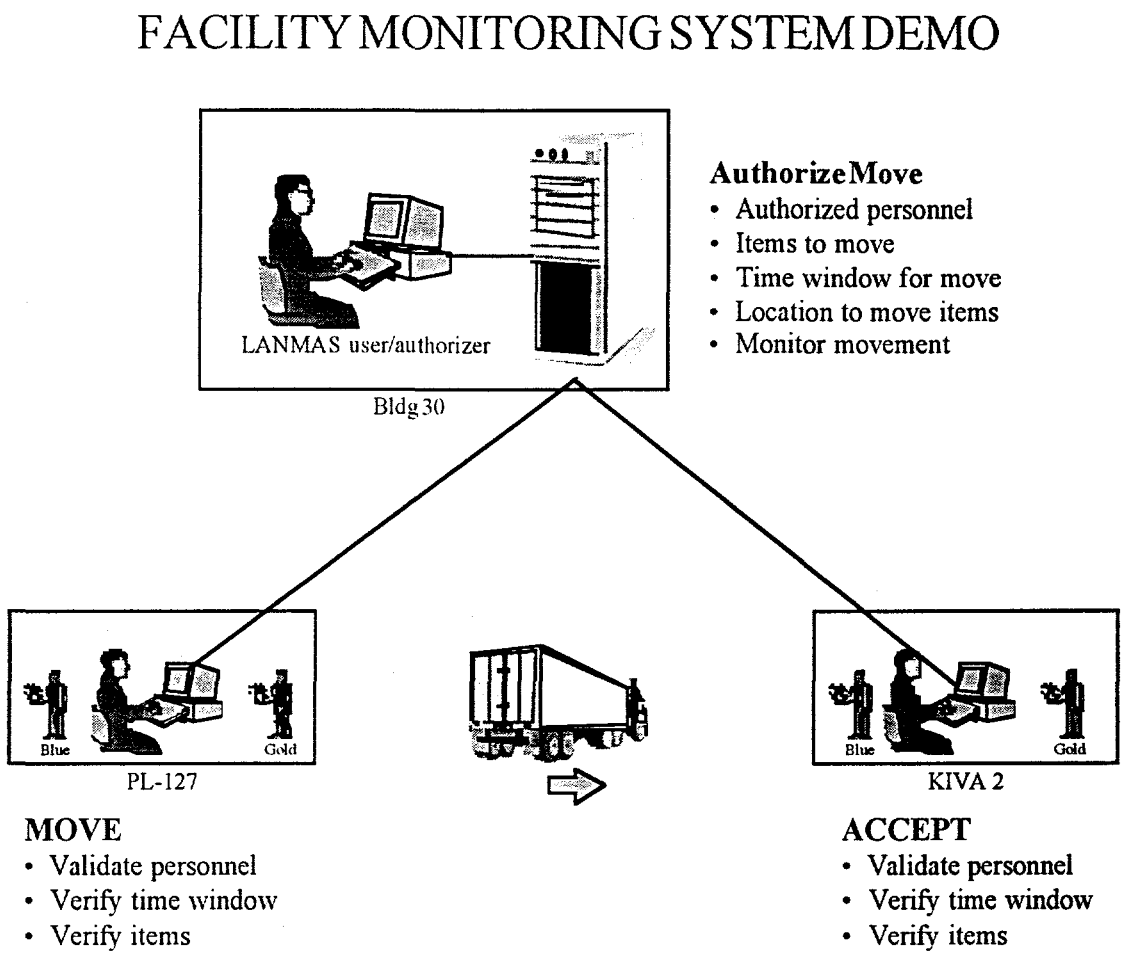

Figure 1: Integrating facility monitoring into nuclear material sccounting.

In applications of facility monitoring, a facility simulation can be run in parallel with actual facility operations to improve the detection capability for departures from standard operating conditions. Current indications of process instruments can be used with the facility model to predict future facility states, and these predicted states can then be compared with the observed ones. Deviations between predicted and observed values can be used to detect anomalous operation and to localize the anomaly.

An advantage of simulation over other methods of evaluating and implementing facility monitoring methods is that simulation produces correct time sequencing of events. This provides a more realistic test of detection algorithms than, for example, simple accumulation of detection probabilities over the steps of a diversion scenario.

Publication series

Finally, a publication series on Los Alamos projects in global nuclear material monitoring was initiated. The first in the series will be the monitoring system for the Japanese facility Monju. These publications will be an important means of announcing our work in this area to potential sponsors.

Publications

1. Howell, J. A., "Analysis of Facility Monitoring Data," Los Alamos National Laboratory document LA-UR-96-2571, to be published in the proceedings issue of *Nuclear Materials Management* (1996).
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3. Howell, J. A., "Facility Monitoring Workshop," Los Alamos National Laboratory publication LA-CP-95-251 (November 1995).
4. Boor, M., Martinez, B., Painter, J., Smith, J., "Integrating Facility Monitoring into LANMAS" Los Alamos National Laboratory, Safeguards Systems Group document (1996).

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[1] Menlove, H. O., Howell, J. A., Rodriguez, C. A., Eccleston, G. W., Beddingfield, D., Smith, J. E., and Baumgart, C. W., "Integration of Video and Radiation Analysis Data," *Nucl. Mater. Manage.* **XXIII**, 843-849 (1994).