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Author(s): J. West, S. Betts, K. Michel, M. Schanfein, and T. Ricketts

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UNATTENDED MONITORING SYSTEM AT A STATIC STORAGE AREA WITH REAL-TIME EVENT NOTIFICATION

J. West, S. Betts, K. Michel, M. Schanfein, and T. Ricketts

ABSTRACT:
Domestic Safeguards at Los Alamos National Laboratory (LANL) and throughout the Department of Energy (DOE)/National Nuclear Security Administration (NNSA) complex has historically relied on administrative and non-integrated approaches to implement nuclear safeguards at its facilities. Besides the heavy cost born by the facility and the compliance oversight organization, the safeguards assurance is only periodic, potentially allowing an adversary a longer time before detection. Even after detection, the lack of situational awareness makes it difficult to assess events. By leveraging unattended monitoring systems (UMS) used by the International Atomic Energy Agency (IAEA), we have designed a baseline system that has high reliability through fault tolerant designs for both hardware and software. Applying IAEA design goals to assure no loss of data and using a dual containment strategy, this system is a first step in implementing modern safeguards monitoring systems at LANL and, hopefully, applications at other DOE/NNSA sites. This paper will review the design requirements and how they will be met, to provide a real-time event notification for a static storage location. The notification system triggers communications to pagers and email addresses for a fast response by facility personnel to the violation of a defined safeguards exclusion zone. Since the system has to be installed in an existing facility, the challenges to the designers will be presented. Aside from the initial baseline system that relies on surveillance cameras and seals, other optional upgrades will be detailed, showing both the power and the promise of unattended systems for domestic safeguards. We will also include a short discussion of the business obstacles to modernizing safeguards and how a UMS system may be applied to dynamic activities at a nuclear facility. Ultimately, the current lack of such modern monitoring systems reflects the many business obstacles internal to DOE/NNSA to the use of modern safeguards in the DOE Complex.

BACKGROUND

The concept of UMS was promoted by the IAEA as a way of increasing safeguards assurance and minimizing facility impacts while reducing IAEA costs. This approach represents a win/win situation for all parties. The Agency, employing safeguards support programs from member states, developed a broad suite of UMS technologies. The largest contributor is the United States Support Program utilizing funds from the Department of State and employing technologies from the DOE national laboratories. The IAEA relies heavily on the use of UMS to provide continuous monitoring of nuclear facilities, representative of the entire fuel cycle, around the world. This is part of its treaty-based mandate to assure that nuclear material in these facilities is not being diverted from peaceful uses. The primary overall goal for these systems is to never lose safeguards significant data. The growing reliance on UMS and the stringent data loss goal demands that these systems have high reliability through fault tolerant designs for both hardware and software. UMS at the IAEA is expected to have over 100 systems in the field by the end of 2005. These systems use a broad range of sensors (examples include: optical, radiation, temperature, vibration, flow, and pressure) to unobtrusively monitor the Facility Operator's activities and provide continuity of knowledge of the nuclear materials associated with these activities in support of the NPT and other agreements. The majority of these systems are cabinet-based where cables from the various sensors are brought back to a cabinet that houses a single data generator (a unit that time stamps the sensor's response) or multiple data generators. The central concept is a distributed, autonomous sensor/electronics package with local intelligence, storage, and power which enable it to accomplish safeguards data acquisition and temporary data storage independent of the Facility Operator systems. These data generators are then linked to a data collection computer. Where multiple data generators exist, they are often linked through a local area network (wire or wireless) to a single data collection computer. Customized software that polls the data generators to collect the data and transfer it onto the resident data collection computer is used. Following the collection of data, inspectors use this independently collected data to periodically compare against a Facility Operator's Declaration. The assessment of the independent IAEA data from the UMS is done using graphical review software with automated algorithms and, in some cases, more detailed analysis. This software may employ many automated features to facilitate the review, such as: review of data integrity, event counting, sequential event analysis, quantification of nuclear mass, and reconciliation with the Facility Operator's Declaration.

NEED

The Nuclear Materials Management group (NMT) at LANL will be receiving and assuming responsibility for two FS65 packages containing MOX fuel. These units will be stored in the Chemistry and Metallurgy Research (CMR) building. NMT was interested in an innovative approach to address safeguards concerns with this material in the proposed storage location. In response, the LANL Safeguards System Group (N-4) in partnership with the Safeguards Science Technology Group (N-1) proposed to implement an unattended monitoring system to maintain continuous safeguards on this material with real-time event notification. Historically, N-1 has developed and implemented unattended monitoring systems which have been used by the IAEA for safeguarding nuclear material throughout the world since the late 1980's[1]. We proposed to use proven technologies to develop a fault tolerant design using the same IAEA/N-1 safeguards principles. The key difference between the application for NMT versus the application for the IAEA is the requirement for a real-time response.

SYSTEM REQUIREMENTS

For this application, we assume that removing the FS65 storage containers or cutting into the storage containers while in place are the two most likely events which the safeguards system will need to monitor and respond to. In addition, due to the age of the CMR building, not all desired infrastructure is immediately available for this system. Therefore, alternative approaches must be available in the early stages of operation.

The minimum requirements of the system are as follows:

- Near real-time alarm notification when an exclusion zone, estimated at ~3' away from the outside-facing edges of the FS65 containers, is violated around the packages. Using network access, the system would indicate that the zone of exclusion (ZOE) was penetrated, by providing notification via pager and e-mail. A signal light near the system would also indicate ZOE penetration.

- On a specified desktop PC, alarms will direct a reviewer to images which capture the ZOE violation.
- The system will be designed to minimize false alarms. For example, options will allow the user to specify that an alarm is not sent unless a specified minimum volume of the ZOE is violated, and/or an alarm is not sent unless the ZOE has been violated for a specified time period such as 5 minutes.
- State of Health (SOH) alarms should notify the users when a portion of the system might not be functioning properly. SOH alarms will be communicated in the same manner as ZOE violation alarms.
- No single point failure (backups are required).
- Dual containment (two independent devices, such as cameras and seals).
- Seal on access door.
- Seal on storage container's crane hoist loop..
- Operate with no AC power for the computer(s) and/or camera(s), and store data for a minimum of 3 days.
- Overwrite old images incase the data storage fills up.

Assumptions:

1. Minimal lighting is available for cameras.
2. Safeguards equipment cannot obstruct standard operations on the storage containers.
3. NMT personnel will be trained on the unit prior to operation.
4. Assume spares inventory and maintenance support will cover 1 major component failure per year.
5. Provide low level of maintenance support for 5 years.

DESIGN

The FS65 packages will be stored side by side. In this initial phase, the safeguards concept will consist of monitoring the exclusion zone around the packages with redundant camera systems. The storage area will be monitored by four IPix cameras, one camera at each corner of the storage area. A camera pair consists of cameras placed at opposite corners of the storage area. One camera pair provides a full view of the exclusion area around the containers. The second camera pair provides a complete and independent capability, thus eliminating a single point failure.

The IPix camera, configured with a fisheye lens, will image a 360-degree by 180-degree area. Raw images produced by a single camera are circular and have a warped look (Ref. Figure 1). The images are in color, with high resolution, and may be viewed in an immersive manner, giving a user the sense of being inserted into the image and providing the ability to pan, tilt, and zoom within the image to see more or less detail as required. Note that the camera has no physical moving parts. The camera itself does not pan, tilt, or zoom. The P-T-Z effects are purely virtual.

Figure 1: Sample of raw image taken with an IQInvision IQEye3 camera configured with an IPix fisheye lens. The image area is 360 degrees by 180 degrees in scope. The image is 1.3 megapixels in resolution. (Note: image used is from the IPix Software Development Kit sample package.)

IPix produces a software development kit (SDK) package that can be used to convert fisheye images into immersive, viewable items. Through the use of the IPix proprietary algorithms, accessed via the IPix SDK, the warped fisheye image can be flattened or de-warped, and the immersive P-T-Z controls can be accessed in a viewer.

Figure 2. Fisheye image displayed in an immersive viewer developed by Los Alamos National Laboratory, using the IPix software development kit. The image is de-warped and the viewer software provides the ability to virtually pan, tilt, and zoom within the context of the image. The image is 1.3 megapixels in resolution.

In addition to monitoring a ZOE around the storage containers (Ref. Figure 1 & 2), the cameras will be set up to monitor areas around each camera. This will allow a facility person to be notified if someone attempts to tamper with any of the cameras.

In the initial design, standard e-cup/cable seals will be utilized on the access doors to the containers as well as the crane hoist loop (where the crane connects to lift the FS65 storage containers).

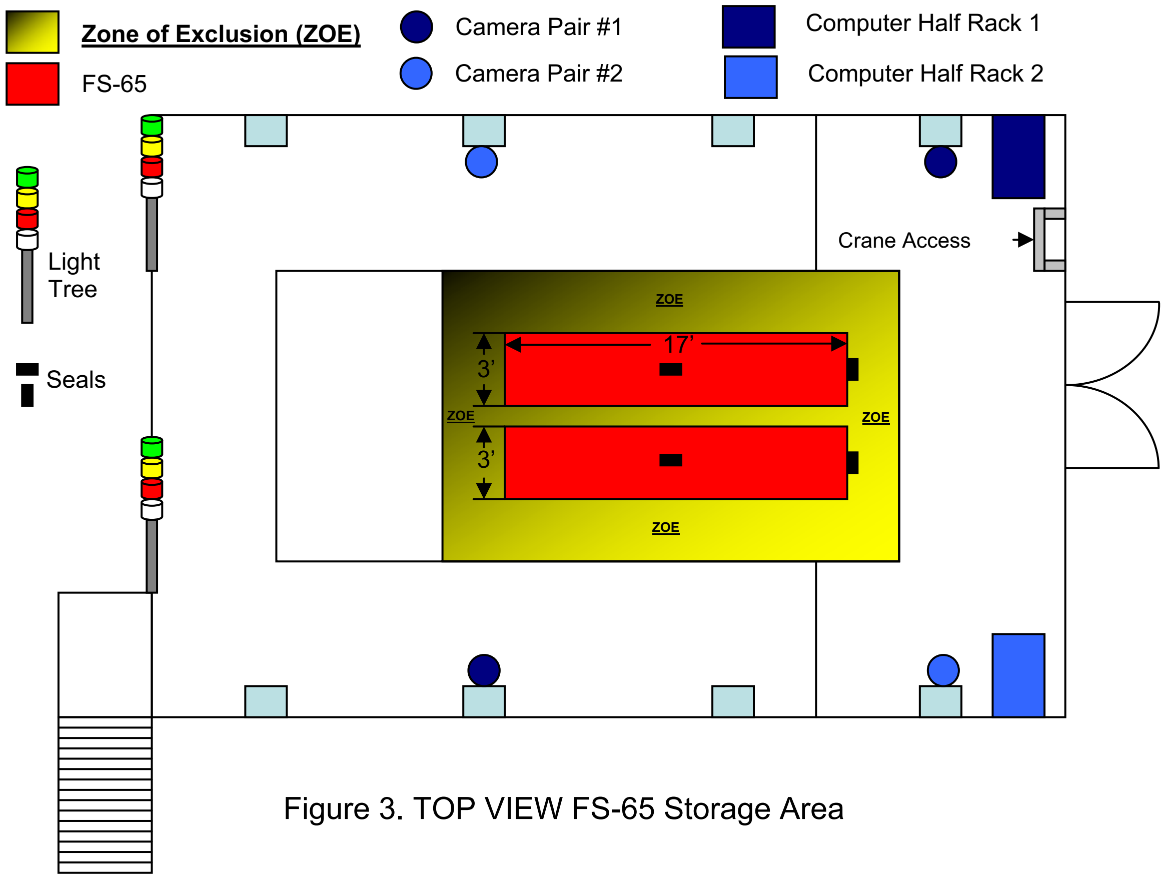

Figure 3. TOP VIEW FS-65 Storage Area

PRIMARY COMPONENTS

For the initial installation, the hardware and software components consist of the following:

Hardware

- IPix cameras
- Data collect computers
- Uninterruptible power supplies
- Tamper indicating enclosures (electronic cabinet and camera enclosures)
- E-cup type metal seals

Software

- Multi-Instrument Collect (MIC)
- Integrated Review Software (IRS)

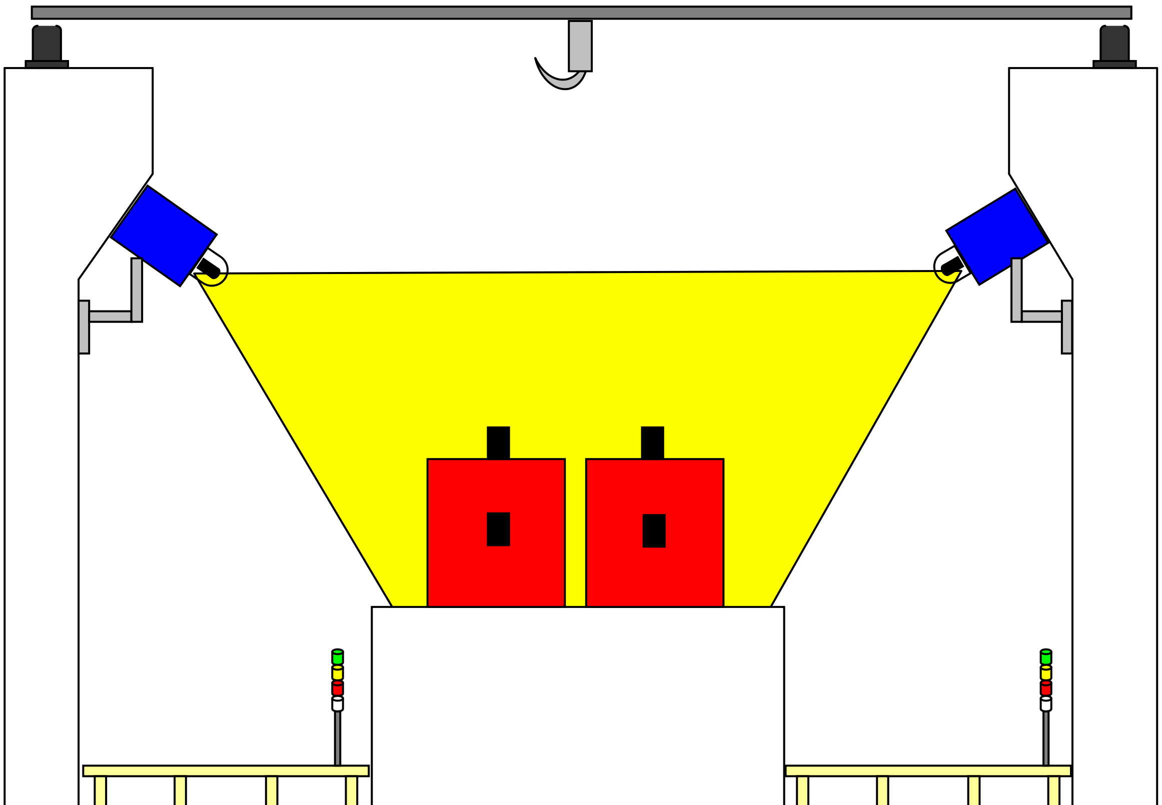

Figure 4. (FRONT VIEW) FS-65 Storage Area

LANL has developed both data collection and review software applications for unattended systems. They have been principally used by the IAEA, but they have begun to be used in homeland defense initiatives.

MIC's primary function is the polling of up to 40 data generators to collect, store, and transmit data. In addition, MIC has a suite of additional software packages to support this primary function. It includes: startup service, file transfer service, delete files, binary files to text, debug tool, tracker (State of Health), file copy routine, and display instrument messages.

The viewer application will display immersive images, as well as any other standard image format type image file (i.e. BMP, JPEG, VIFF, TIFF, etc.). The application uses the IPix Corporation software development kit (SDK) library to de-warp IPix images and provide virtual P-T-Z functionality, and it is fully integrated into the Integrated Review Software (IRS) suite of tools[2,3]. As such, any image displayed can be correlated to any of the other data types that are collected and analyzed by the IRS tools (i.e. radiation data, isotopic data, GPS data, operator declarations, mass analysis, etc.). Using the integrated features of the IRS in concert with very powerful imaging equipment, a comprehensive and more complete understanding of the monitored area is achieved.

FACILITY OBSTACLES

The addition of this system to an established facility involves the normal constraints for any retrofit type project. Potential constraints include available power, network connectivity, lighting, overhead crane operation and maintenance, consideration for routine activities in the area. The operational start date for the system often defines whether or not the constraints are obstacles. Because this system can be fully mounted in self-contained cabinets, it can become operational without the requirements for penetrations or conduit, requiring only mains power. This allows for early operation while normal permanent-type installation activities take place in parallel. The only other initial constraint that impacted the requirements was network connectivity. Without this connectivity, it was not possible to implement real-time notification using pagers and e-mail. In the interim, light trees would be relied upon for notification. Since this was an operational facility with significant traffic, a procedure would be implemented to locate a light tree in a clearly observable location and facility personnel would be instructed to maintain awareness of them and react accordingly.

BUSINESS OBSTACLES

Besides facility obstacles, a more wide-ranging and important consideration is why the DOE Complex has failed to modernize safeguards using commercially available technologies (which have been rapidly deployed in business for decades). This subject alone demands an in-depth inquiry to not only determine what obstacles are present, but, also, to determine what funding systems can be put into place to assure continuous safeguards modernization, as monitoring technologies continue to evolve and mature over time. This subject will not be covered in this paper; nevertheless, the authors would like to point out some areas that can be researched.

Potential areas of investigation

- Lack of understanding of the capabilities and importance of safeguards by all levels of management.
- Lack of safeguards compliance incentives to modernize.
- Lack of facility infrastructure funding for continuous modernization of safeguards.
- Lack of facility cost benefit analysis to evaluate current administrative versus future safeguards practices using UMS.
- Failure to integrate safeguards and security.
- Failure to require modern integrated safeguards in new construction projects.
- Failure to provide for implementation of DOE-developed safeguards technologies.
- Failure to maintain good communication and collaboration between the domestic and international safeguards programs within DOE.
- Failure to keep apace of commercial technologies for their applications in safeguards.

OPERATION

If the ZOE is violated, then a signal light will be turned on and an e-mail and a page will be sent to a list of personnel identified by NMT group management. The person responding would be directed to review the images that correspond to the time of the ZOE penetration event, and to take any other actions deemed necessary by NMT. The exact Concept of Operations (CONOPS), describing the events which should take place if a problem is identified during the image reviews, will need to be developed by NMT and security personnel.

Training

N-1 will provide a training course based on the Users' Manual, and it will provide a training course for personnel on the use of the system. The purpose of the training is to teach personnel the types of alarms that the system will generate, the options to define the alarms, what the alarms mean, and how to use the imaging software to view alarm images.

Maintenance

N-1 will provide support for operations and maintenance following installation and testing during the first six months while the system is in a preliminary acceptance phase. In addition, maintenance will be provided for the subsequent 5 fiscal years, at a level to support ~ 1 major failure a year, standard maintenance such as changing of batteries, and training.

UPGRADES

Potential upgrades on such a system are entirely dependent on the items of interest and the environment. Some potential upgrades for consideration in this application are as follows:

- Active Fiber Optic Seals – Breaking these seals would trigger the system's alarm. The seals could be placed on the storage containers and on a bridge crane block.
- Neutron Detectors – These detectors would monitor the background conditions and would be used to trigger the system's alarm if a threshold condition were exceeded in either direction.
- Gamma Detectors – These detectors would be used like the neutron detectors but would see a near-zero condition and would only trigger an alarm if a threshold is exceeded.
- Infrared Cameras –These cameras would monitor the heat signature and would be used to trigger the system's alarm if a threshold condition were exceeded in either direction.

DYNAMIC MONITORING

Current efforts are underway to design continuous unattended real-time monitoring for material control and situational awareness in an operating facility. Such a system will have three primary functions: material control for safeguards, physical response for security, and event assessment for security and operational recovery. It will have the potential to fully integrate the safeguards and security monitoring at a facility in a single control room. A brief summary of the primary concepts for such a system is as follows:

Design philosophy

The design philosophy for a fault tolerant design is based primarily on redundancy for high reliability to avoid single point failures; this applies to all applications.

Conduct of Operations

- The operator at the plan-of-the-day meeting enters all activities in the monitoring systems event tracking computer system.
- During operations, the system provides real-time tracking of all personnel and items.
- During operations, the system indicates the status of each expected sensor event.
- During operations, any unexpected event is indicated as an unplanned event or an alarm condition, based on a rule set specifically for the facility.
- Control room operators can then assess the situation and provide specific responses ranging from engaging facility-specific communication, to contacting the tagged operating personnel, to targeting an armed response.

Sensors

Gamma and neutron radiation detectors
Cameras
Infrared motion sensors
Radio-frequency identification tags for items and personnel
Balanced magnetic switches
Fiber optic seals

Locations

Operational enter and exit points
Emergency exit points
Maintenance access points
Corridors
Personnel
Items

CONCLUSION

In our new threat environment, it is critical that the DOE and NNSA begin to leverage the unattended monitoring system technologies used by the International Atomic Energy Agency in facilities across the DOE/NNSA Complex. By applying IAEA design goals to assure no loss of data, and using a dual containment strategy, LANL has designed a baseline system that has high reliability through fault tolerant designs for both hardware and software. Employing a building-block approach using commercial hardware and software components for sensor deployment and custom software for a rules-based facility responsive system, allows the maximum flexibility for a potentially wide range of application in a cost effective manner. It is the authors' hope that this system will be a first step in implementing modern safeguards monitoring systems at LANL and, eventually, for applications at other DOE/NNSA sites.

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