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The Present Status of the Technological Development of Remote Monitoring Systems

John C. Matter
Sandia National Laboratories
Albuquerque, New Mexico, USA

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Introduction

Let me begin with some comments about transparency. We all have some perception or vision about the use of transparency for nuclear technology and nuclear non-proliferation. Although we probably have some common understanding of what it implies, there is no precise definition that is agreed upon. One of the most significant ideas in transparency is that it is considered to be a voluntary or unilateral action. The party, or organization, or nation that wants its activities to be transparent voluntarily provides information to other parties with the expectation of receiving some acceptance or good will in return. The organization giving the information determines what information to provide, how much, how often, and when. This is in contrast to official treaties and monitoring regimes, in which specific verification information and activities are prescribed. This should have the advantage for the transparent organization of being less intrusive and less costly than a treaty monitoring regime. Information related to sensitive nuclear technology, proprietary processes, and physical security is more easily protected. The difficulty for both parties, the transparent organization and the information recipients, is in determining what information is necessary for the desired confidence building. It must be recognized that this state of transparency or confidence will only be achieved over an extended period of time, when history confirms that the information was reliable in conveying the true picture.

There are three general methods of providing transparency information that are typically recognized. These are educational resources, monitoring systems, and site visits. Examples of educational resources are brochures and reports, videotapes, exhibits, visitor centers, and web sites. Monitoring systems collect data and provide information about operating facilities and activities via an historical review and/or a near real time interface. Site visits allow direct visual observation and people interaction and can also help explain any unexpected results of a monitoring system.

The concept of remote monitoring is very consistent with the world of transparency. With the risk of introducing too many adjectives, a more complete name is remotely accessed unattended monitoring systems. There are generally considered to be three primary functions and parts in a remote monitoring system: sensors, communications network, and computer information management. A set of sensors is located with or

around the facility or process or activity that is being monitored to provide some of the information for transparency. Virtually any type of sensor can be included in a remote monitoring system. For nuclear transparency, relevant types of sensors include radiation sensors, video cameras, containment seals, motion sensors, presence sensors, environmental sensors, etc. The communications network performs data collection, data storage, and data dissemination to the users. It can also provide for configuration and control of the sensors. This basic communication infrastructure normally has both local or on-site components and remote or off-site components. The computer information management subsystem provides the window to the recipients of the transparency information. It performs data display and data analysis and contains some level of an interactive interface between the user and the remote monitoring system. This is the key component where the transformation from data and numbers to knowledge and understanding needs to occur.

The history of remote monitoring is both long and short. There are examples of remote monitoring technology and system demonstrations from more that 20 years ago. However, there was not widespread acceptance of this monitoring approach in the nuclear world. Obviously its benefits were not perceived to outweigh its costs during this period. In the last 3-5 years there has been considerable renewed interest in remote monitoring. There are both political and technical reasons for this change. On the political side, the Cold War has ended but there are significant new concerns about nuclear proliferation. On the technical side there have been the revolutions in communications and computer technology. Combined, there is now a new perception that remote monitoring systems may at last contribute to increased efficiency and improved effectiveness in monitoring for nuclear nonproliferation and transparency. This still remains to be proven but now there is a concerted effort to do this.

There are at least three system engineering issues that must be carefully considered and will ultimately determine the success of remote monitoring systems. These are what I will call intelligibility, surety, and architecture. Intelligibility is the issue of whether or not the recipients of the remote monitoring system data will be able to interpret it and gain meaningful information that allows them to make reasoned and useful decisions. There are at least two sub-issues that must be addressed and overcome: the quantity of the data and the complexity of the data. I am glad to report that there is an increased emphasis on these issues in the remote monitoring research and development world today. Surety is the issue of the security of the data and the data systems. Transparent organizations require that malevolent parties cannot modify the released data, obtain access to restricted data, or sabotage computer software or databases. Information recipients must be assured of the source and authenticity of the data. Fortunately, the strength of modern cryptographic methods is much improved and should be adequate to this challenge, given that national export controls of this technology are reasonable. Architecture is the issue of a system design and implementation that is flexible and compatible with the future. It is a given that transparency goals and technology components will change over time. Transparency goals will shift to different issues and audiences. The history of technology shows an accelerating pace of new developments, especially in the areas of communications, computers, and software. The system architecture issue must be successfully addressed to insure a positive result to the overriding cost-benefit analysis.

Technology

In the second part of my presentation, I will discuss and illustrate some of the current technology that is being used successfully in remote monitoring system field trials and acceptance tests. I will also include a glimpse at some new technologies that are currently under development and that show promise for application in future remote monitoring systems.

These technologies and products are:

1. Smart Bolt

The Smart Bolt is being developed by the All-Russian Research Institute of Experimental Physics (VNIIEF) in collaboration with Sandia National Laboratories (SNL). It is a unique bolt, for nuclear material container lids, that can be used as a mechanical seal and that has electronically embedded tag and seal information. The initial version is a single use smart bolt that works on a principle of destruction of the embedded electronic module if the installed bolt torque is released. A torque wrench is used for installation and a reader/verifier is connected via electrical contacts to initialize and verify the tag. A second reusable version of the smart bolt works on the principle of detecting an electrical capacitance change between its initial installed capacitance measurement and that following a container opening. In this version the tag is read via an opto-electronic connection. Prototypes have been built for both versions and further development and manufacture is planned. In addition, a radio frequency (RF) modem for the smart bolt will be developed in order to have a complete RF tamper-indicating device. (Ref. 1)

2. Integrated Nuclear Materials Monitor

The Integrated Nuclear Materials Monitor (INuMM) under development as Sandia is a low power modular electronic sensor (ESP) platform and transceiver for long term unattended monitoring systems. Its four modules perform the functions of sensor, communication, control, and power. The present three sensor types are gamma radiation spectroscopy in the 0-1 MeV range, fiber optic seal continuity, and motion sensor with vibration rejection. The communication module includes both a low cost commercial radio frequency (RF) chip set version and a SNL designed ultra low power RF version. The control module manages the internal ESP task sequences, maintains time and unique identity, and authenticates messages to/from the transceiver. The power modules use 2000mAHr class AA batteries. The modules are all implemented in tiles that are multiples of 1.25 x 1.25 x 0.25 inches for ease of assembly and physical configuration. (Ref. 2)

3. NTvision

NTvision is a multi-camera video surveillance system developed at Los Alamos National Laboratory (LANL). Each recorded event is summarized by four images: reference, trigger, post event, and object key. The reference image is recorded during system initialization. The trigger event image is recorded from either a scene change or external trigger. The post event image is recorded after the scene change ends. The object key image is the difference image created by subtracting the reference image from the post event image. In addition, an event movie is recorded during the period of changing scenes and is available for viewing. NTvision is based on commercial PC hardware. It interfaces with most standard CCD analog cameras and in the future with some fully digital cameras. NTvision software components are the Windows NT 4.0 operating system, LANL image processing algorithms, and Netscape client/server software. Communications between the server and clients uses TCP/IP protocol over an intranet or the internet. The Secure Socket Layer standard is used for authentication and encryption and the X.509 digital certificate standard is used to provide public/private key pairs. (Ref. 3)

4. MicroChemLab

A miniaturized integrated chemistry laboratory (MicroChemLab) is being developed at Sandia for selective detection of target chemical species. Applications require a small size, lightweight, automated system that performs fast (1 minute), sensitive (1 ppb), and selective analysis. The system design uses multiple channels that consist of three cascaded stages: a selectively adsorbent sample collector/concentrator, connected to a gas chromatograph (GC) column, feeding a surface acoustic wave (SAW) detector array. Increasing the SAW frequency produces two benefits: increased sensitivity and reduced device area. Chemical selectivity is improved by using a multiple array with pattern matching. All three components have been fabricated using batch microfabrication processes and tested individually. Current work is focused on integrating these components into a complete chemical analysis system. The MicroChemLab program includes both gas and liquid phase analysis systems. (Ref. 4)

5. Intelligent Local Node

The Intelligent Local Node (ILON) developed by Los Alamos provides free topology local network connectivity among all the devices – sensors, cameras, instruments, and computers – in a monitoring system. The ILON uses the Echelon Local Operating (LON) technology and expands and enhances its instrument interfaces. The ILON hardware consists of an ILON processor board (based on the 68HC11 microcontroller), an Echelon Lon Talk Module (LTM-10), and an Echelon free topology transceiver (FTM-10 SMX). The ILON firmware is a set of independent modules that are executed, or not, depending on the functionality configured into a given ILON that is selected based on the attached device. These ILON firmware modules include collect/configure, instrument, binary input, binary output, binary concentrator, and master timer. The Echelon LonTalk protocol uses authenticated and acknowledged data transmission. (Ref. 5)

6. Recodable Locking Device

The Recodable Locking Device (RLD) in development at Sandia performs two primary functions: code discrimination and energy switching. The RLD uses six decimal-encoded wheels to create one million possible codes. Because the code is only stored in a mechanical device, discovery is not possible through software operations. When the RLD verifies a proper code entry it mechanically activates a switch. The preferred switch is an optical shutter between an optical source and detector. The RLD is fabricated using Micro-Electro-Mechanical Systems (MEMS) technology. Sandia uses surface silicon micromachining via a lithographic process to create four levels – three movable and one stationary – of polycrystalline silicon that enables articulated machinery with moving parts. The input to the RLD is provided electrically and is converted to mechanical by electrostatic comb drives. The RLD is considered unspoofable because the owner functions on the secure side are isolated from the operating system for local or remote access on the public side. Three classes of applications are envisioned for the RLD: a safety device in high consequence systems, a high assurance lock to prevent unauthorized access to protected information in a computer, and intentional use denial when an adversary attack is detected in computer security. (Ref. 6)

7. Knowledge Generation

Knowledge generation (KG) is a methodology and process for analyzing and interpreting data to gain information that is useful for reaching conclusions and making decisions. For nuclear transparency and remote monitoring, there are several classes of useful information, including confirming that actual activities are the same as the declared activities, analyzing an activity in order to design an adequate monitoring system, and interpreting system status messages to verify the monitoring system is operating normally. For reconciliation of monitored and declared activities, a process model is developed and used to define a baseline reference sequence. Then the measured event data are compared with the expected data for the declared activities. For monitoring system design, the monitoring objectives are combined with the activity description in a systems analysis to establish the necessary locations, items, and parameters to be monitored. System analysis includes facility/process analysis, vulnerability analysis, threat assessment, and scenario assessment. For confirming normal system state of health, the monitoring system model establishes the normal states and parameter ranges. Then system status messages are compared with normal data. This knowledge generation process is currently being applied by Sandia to confirming continuity of knowledge at a Candu type reactor during the transfer process from the spent fuel pool to the dry storage silos. (Ref. 7)

Applications

In the third and final part of my paper, I will present an overview of some of the recent and planned remote monitoring systems from the worlds of nuclear transparency, non-proliferation, and safeguards. Note that the technologies and their implementation in these different classes of applications are often indistinguishable; this in itself may provide economies and promote acceptance for remote monitoring.

These applications and systems are:

1. Neighborhood Environmental Watch Network

The Neighborhood Environmental Watch Network (NEWNET) is a Los Alamos network of environmental monitoring stations with public access through the Internet. Currently the majority of the stations are located in Wyoming and Utah, surrounding the Nevada Test Site, and in New Mexico, around Los Alamos National Laboratory. Most of the remote data collection platforms use solar charged battery power and have instruments to measure gamma radiation, wind speed and direction, temperature, humidity, and barometric pressure. The data are periodically transmitted via satellite to data collection facilities in Los Alamos and Las Vegas. The NEWNET data are checked for transmission errors and annotated, but are not altered. The purpose of NEWNET is to provide the public with data on actual radiation levels and to foster an awareness of the relative risks presented by these levels of radiation. The goal of this program is to promote better understanding of the environment through collaboration between the public, government, educational institutions, and industry. The NEWNET web home page includes pages and links to access NEWNET data, and for information on the NEWNET system, radiation resources, and related organizations. (Ref. 8)

2. Radiation Inspection System

The Radiation Inspection System (RIS) developed by Sandia has been tested at a major airport and an international port of entry to measure the passage of radioactive materials. The RIS uses a large volume (8 inches x 8 inches x 3 inches) NaI gamma ray spectrometer and a moderated He-3 neutron detector. At the port of entry, the commercial vehicles stopped briefly at the RIS position. Triggering algorithms in the detection software enabled the recording of the radiation signature. Gamma ray spectra, gamma ray count rate histories, and neutron count rates were recorded for each RIS event. A source characterization tool was developed, and it performed automatically in about two minutes on a personal computer. The best match between the computed and measured spectrum is obtained using nonlinear regression, and it yields the most probable radioactive isotopes and shielding configuration for the spectrum. Many of the events involved multiple radionuclides in shielding configurations that corresponded to radiopharmaceuticals used in nuclear medicine and other isotopes used in industry and research. (Ref. 9)

3. Remote Monitoring of Automated Air Sampling

Finland and the U.S. are collaborating on a comprehensive system for remote monitoring of an automated air sampling station and its data. The purpose is to demonstrate the use of environmental air sampling with remote data transmission for possible future use by the IAEA. The automated air sampling station was developed by the Radiation and Nuclear Safety Authority (STUK) in Finland and the surveillance system for the sampling station was delivered by SNL. The air sampler circulates air through a filter cassette that is handled robotically. Real time monitoring is performed by NaI scintillation detectors and is intended for alarm purposes. Nuclide composition of radioactive materials on the filter is analyzed using a high-resolution gamma ray spectrometer with an electrically cooled HPGe detector. An aerosol tag added to the filter during sampling reveals possible tampering efforts. Additional process data and weather are collected. The surveillance system monitors access to the equipment room, motion within the room, and access to the air sampling station and the equipment cabinet. The STUK air sampler data are available to authorized users via their LAN and the Internet. The STUK air sampler data with the surveillance data are also available to authorized users via telephone modem. The field trial showed that it is possible to construct a fully automated air sampling station that can be operated unattended, including protection and monitoring of the sample and the data. (Ref. 10)

4. Authenticated Tracking and Monitoring System

The Authenticated Tracking and Monitoring System (ATMS) developed by Sandia was demonstrated and evaluated while tracking a shipment of uranium ore concentrate from a mine in Australia to a port in Rotterdam, the Netherlands. ATMS is an integrated remote monitoring system that includes an authenticated local radio frequency sensor network to monitor items being shipped and their environment, a Global Positioning System (GPS) receiver to track shipment location, an International Maritime Satellite System (INMARSAT) transceiver for mobile communications, and a ground station with tracking and sensor display software. The sensor suite used in the Australian field trial included door position sensors on the cargo transportainer, active fiber optic seals, and temperature sensors. The data communications were authenticated from the sensors to the ground station and encrypted from the satellite transceiver to the ground station. The system operated unattended for six weeks during the ocean voyage from Adelaide to Rotterdam and experienced some weather extremes during the route around Cape Horn and across the equator to the North Sea. (Ref. 11)

5. U.S./Russia Storage Monitoring Collaboration

Sandia National Laboratories and the Russian Federal Nuclear Center – All Russian Research Institute for Experimental Physics (VNIEEF) [also known as Arzamas-16] are collaborating on ways to assure the safety, security, and international accountability of fissile material. The focus is on identifying, demonstrating, and evaluating technologies and systems that can reduce the need for human access to the material, reduce radiation exposure, monitor nuclear material safety, provide continuity of knowledge of the material, and reduce the need for on-site inspections. This work began in 1997 with a remote (empty) container-to-container demonstration that shared data between the SNL Cooperative Monitoring Center and Arzamas-16. It continued in 1998 with a magazine-to-magazine demonstration between an (empty) SNL California storage magazine and an

Arzamas-16 simulated storage area. In both cases the data were remotely viewed via the Internet. There are 1999 plans to extend this effort to a facility-to-facility demonstration between an active nuclear material storage site at a U.S. Department of Energy facility and an Arzamas-16 storage facility. The intent is to include real material in actual operations. (Ref. 12)

Summary

I hope I have been able to show you that an adequate set of technology components already exists for use in remote monitoring for nuclear transparency, and that the next generation is already being developed. Furthermore, more organizations and nations are beginning to use these technologies in systems for remotely accessed unattended monitoring in evaluations and applications for nuclear transparency and nonproliferation. Well-engineered systems will prove to be effective, efficient, and affordable.

The time is also right politically for the successful widespread implementation of remote monitoring systems. The Cold War is apparently over, yet there is a widely recognized need for the public and international sharing of information related to the use of nuclear resources. Let's all work together to move ahead to implement these remote monitoring systems in order to realize their attendant benefits for nuclear transparency.

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