WM'00 Conference, February 27 – March 2, 2000, Tucson, AZ

NUCLEAR WASTE REPOSITORY TRANSPARENCY TECHNOLOGY TEST BED DEMONSTRATIONS AT WIPP

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ABSTRACT

Secretary of Energy, Bill Richardson, has stated that one of the nuclear waste legacy issues is "The challenge of managing the fuel cycle's back end and assuring the safe use of nuclear power." Waste management (i.e., the "back end") is a domestic and international issue that must be addressed. A key tool in gaining acceptance of nuclear waste repository technologies is transparency. Transparency provides information to outside parties for independent assessment of safety, security, and legitimate use of materials. Transparency is a combination of technologies and processes that apply to all elements of the development, operation, and closure of a repository system. A test bed for nuclear repository transparency technologies has been proposed to develop a broad-based set of concepts and strategies for transparency monitoring of nuclear materials at the back end of the fuel/weapons cycle.

WIPP is the world's first complete geologic repository system for nuclear materials at the back end of the cycle. While it is understood that WIPP does not currently require this type of transparency, this repository has been proposed as realistic demonstration site to generate and test ideas, methods, and technologies about what transparency may entail at the back end of the nuclear materials cycle, and which could be applicable to other international repository developments.

An integrated set of transparency demonstrations was developed and deployed during the summer and fall of 1999 as a proof-of-concept of the repository transparency technology concept. These demonstrations also provided valuable experience and insight into the implementation of future transparency technology development and application. These demonstrations included: Container Monitoring Rocky Flats to WIPP; Underground Container Monitoring; Real-Time Radiation and Environmental Monitoring; Integrated Facility-Status Data Display Unit; and a Demonstration at the International Conference on Geologic Repositories.

A multidisciplinary team worked together to implement these. Principal team partners included Sandia National Laboratories, the Westinghouse Waste Isolation Division, the DOE Carlsbad Area Office, and the Los Alamos National Laboratory. The success of the demonstrations was only possible through a strong spirit of cooperation, much ingenuity, and personal dedication of the many individuals and organizations involved in the design and implementation in this project.

There are two complementary papers presented in other sessions that describe in detail the transparency technologies used. Please see Schoeneman, B., et al, and Schoeneman, J., et al, in the Poster Session 31 papers.

INTRODUCTION

All nuclear weapons and nuclear energy cycles eventually require long-term management of fissile materials in some form of repository, whether for permanent geologic disposal or for long-term interim storage. With the growth of nuclear energy in Asia and other developing nations, the amount of material at the back-end of the nuclear fuel cycle is growing at an ever-increasing rate. The result of these developments is a growing quantity of back-end materials that has surpassed the development of back-end disposition options. Assuring the "grave" in the "cradle-to-grave" management of nuclear materials is a big challenge faced by many nations and has strong international interest and concern.

Although, geologic disposal of back-end nuclear materials has many advantages in providing permanent, safe, and proliferation-resistant disposition of nuclear materials, the international, political, and technical acceptance of geological disposal is a major issue. A key tool in developing confidence and acceptance is transparency. Transparency is a combination of technologies and processes that provide information to outside parties for independent assessments of safety, and materials control.

Transparency applies to all aspects of the development of the repository system: site selection, characterization, transportation systems, operations, environmental safety, and materials control. At local and national levels, transparency facilitates the domestic acceptance of the facility and associated operations. On an international level, transparency is a critical mechanism for assuring that requirements of disarmament and non-proliferation agreements are satisfied.

From both a safeguard and an environmental safety perspective, a major challenge is developing and adapting transparency technologies and processes to the unique environment posed by geological repositories. In some situations existing technology can be adapted, while in others, new technology must be developed. In addition to adaptation and development, demonstration of effectiveness must be performed to develop the high-level of confidence in the system and information provided. As the world's only operating deep geologic repository, the Waste Isolation Pilot Plant (WIPP) offers a unique opportunity to serve as an international cooperative test bed for developing and demonstrating technologies and processes in a fully operational repository system setting.

To address the substantial national security implications for the United States resulting from the lack of integrated, transparent management and disposition of nuclear materials at the back-end of the nuclear fuel and weapons cycles, it is proposed that WIPP be used as a test bed to develop and demonstrate technologies that will enable the transparent and proliferation-resistant geologic isolation of nuclear materials. The objectives of this initiative are to: 1) enhance public confidence in safe, secure geologic isolation of nuclear materials; 2) develop, test, and demonstrate transparency measures and technologies for the back-end of nuclear fuel cycle; and 3) foster international collaborations leading to workable, effective, globally-accepted standards for the transparent monitoring of geological repositories for nuclear materials (1).

Test-bed activities include: development and testing of monitoring measures and technologies; international demonstration experiments; transparency workshops; visiting scientist exchanges; and educational outreach. These activities are proposed to be managed by the Department of Energy/Carlsbad Area Office (DOE/CAO) as part of The Center for Applied Repository and Underground Studies (CARUS).

THE IMPORTANCE OF TRANSPARENCY AT THE BACK END OF THE NUCLEAR FUEL CYCLE

At the September 1998 General Conference of the International Atomic Energy Agency (IAEA), Secretary of Energy Bill Richardson outlined the legacies from the first five decades of the nuclear century and the steps that must be taken to meet the future challenges they present. Among these legacy issues are two that make clear the urgent need to provide for safe, secure, and transparent disposition of nuclear materials resulting from both the weapons and civilian nuclear power fuel cycles. Specifically, these two legacy issues are:

> "The vast amounts of fissile material from nuclear weapons reductions that need to be controlled."
>
> "The challenge of managing the fuel cycle's back-end and assuring the safe use of nuclear power." (2)

Transparency is defined as a cooperative process of providing information about disposition systems to outside parties so that they can independently assess the safety, security, and legitimate management of nuclear materials. All nuclear weapons and nuclear energy cycles eventually require long-term management of fissile materials in some form of repository. This final disposition phase we commonly term the back end of the cycle. The development of repositories for the geologic isolation of nuclear materials around the globe will require the development, demonstration, and application of transparency technologies and processes to be successful. There is a unique opportunity to foster that development and demonstration through the use of the WIPP, the world's first operating deep geologic repository.

After decades of study, it is clear that the safest, most secure, and indeed, only permanent means of disposal for hazardous nuclear materials is in a deep, geologic repository. Making repository operations transparent furthers resolution of these nuclear legacies in these important areas:

- Arms control and non-proliferation. Diversion of materials at the back end of the nuclear materials/weapons cycle is a long-term risk to national security. Creation of viable back-end management options is an important component for reduction of proliferation risks and the implementation of some arms-reduction processes.

- Political viability and public acceptance of the next generation of nuclear technology. Successful management of the back end of the nuclear fuel cycle has a major impact at the front end of the next generation of nuclear energy. Political resistance to nuclear technology around the globe is strongly influenced by the lack of safe, secure, and transparent disposition alternatives for nuclear materials. Transparency contributes to public acceptance by allowing direct observation of the processes involved.

- Environmental security. A well-designed and managed back end of the nuclear-materials cycle will significantly reduce the risk of contaminant releases that could result in local and possibly trans-national impacts on public health and safety.

THE CMC/WIPP REPOSITORY TRANSPARENCY WORKSHOP

The Cooperative Monitoring Center (CMC) at Sandia National Laboratories (SNL) in Albuquerque, New Mexico provides a forum for international and regional experts to explore ways that technology can facilitate achieving and maintaining a wide range of bilateral, international and regional nonproliferation and transparency objectives. Sandia Laboratories' history includes a long involvement with verification and monitoring programs that, in combination with complementary expertise at Los Alamos National Laboratory and other DOE National Laboratories, has resulted in a broad spectrum of technology-based tools that are available for application to the challenges of cooperative monitoring. The CMC maintains a monitoring demonstration and technology display area to facilitate awareness of these systems, as well as providing assistance to technical experts from around the world in acquisition of the technology-based tools they need to assess, design, analyze, and implement nonproliferation and transparency measures.

During February, 1999, a workshop sponsored by the Cooperative Monitoring Center and WIPP was held to explore applications of transparency to the back end of the fuel cycle (3). The objective of the CMC/WIPP Repository Transparency Monitoring Workshop was to initiate the development of broad-based concepts and strategies for transparency monitoring of nuclear materials at the back end of the fuel/weapons cycle, including both geologic disposal and monitored retrievable storage. Two primary areas of focus were: 1) determining why and what to monitor, and 2) identifying potential roles that the WIPP facility could play as a monitoring technology development and demonstration test bed facility. The work on "why and what to monitor" focused primarily on drivers for transparency monitoring by identifying stakeholder concerns and the information needed to address those concerns. Work on potential WIPP roles focused on concepts for a long-term vision that would utilize the WIPP facility as a monitoring technology test bed and on generating ideas for near-term activities and next steps.

One of the most important products of the workshop was the development of a process for mapping stakeholder concerns and the information needed to address these concerns into a framework that is applicable to a broad range of national and international settings. Within this framework, three categories of stakeholders are recognized: Local; National; and Regional/International.

The range of concerns of these stakeholders was found to generally fall into three main groups: Safety - operational and environmental; Diversion - legitimate use and safeguards; and Viability - political and economic.

This framework also recognizes that transparency information generally falls into two major categories: Data that can be measured and monitored; and access to processes that provide insight to development and implementation decisions

This transparency framework provides a means of organizing thinking about specific facility scenarios and for comparing the similarities and difference across multiple scenarios. A synthesis of the workshop sessions revealed a number of common concerns (of the United States and many other nations) that transparency measures could address; the most important of which is that public and political perceptions that an unsafe, unsecured repository in any country may have adverse effects on all repository programs.

The workshop also focused on the potential for WIPP as a test bed for the development and demonstration of transparency technologies. Through workshop discussions, a number of concepts were developed for the long-term vision of what this WIPP test-bed role would encompass.

In addition, a number of concepts were developed that could be implemented at WIPP in the short term as "jumpstart" activities, with the goal of providing an early demonstration of the utility of WIPP as a test bed for the application of transparency monitoring technologies in a repository setting. Several of these concepts were subsequently developed into demonstration activities at WIPP, the results of which were displayed at the International Conference on Geologic Repositories in November, 1999. Subsequently, the demonstrations were put on display at the DOE/CAO office building lobby in Carlsbad, NM, and also provide the cornerstone of the WIPP Transparency Test Bed at the SNL offices in Carlsbad.

WIPP TRANSPARENCY TECHNOLOGY DEMONSTRATIONS

Monitoring technologies play a significant role in confidence building for developing public trust and implementing a broad spectrum of potential nonproliferation and transparency measures. To ensure that technologies chosen to solve a problem are implemented in an effective manner, a system-level approach must integrate appropriate core technologies with supporting analyses and customized graphical displays to build a cooperative monitoring system. These systems employ a suite of sensors designed to measure appropriate attributes of a specified process, transmit this measured data to some form of a mass storage, and disseminate information to the intended audience. Many of these monitoring system have been developed and deployed at nuclear material facilities around the world, where they provide information appropriate for confidence building and implementation of nonproliferation and transparency programs.

The purpose of the demonstrations described here was to provide several proof-of-concept experiments that would showcase the effective use of the WIPP infrastructure as a Transparency Technology Test Bed. These transparency monitoring experiments apply current technology to the geologic repository setting to demonstrate that technologies could also be used to monitor nuclear materials in the back end of the waste cycle. Additionally, with the short time frame allowed for the project, the team demonstrated how a cooperative team of DOE contractors could work together to provide a successful demonstration of the technologies for the International Conference on Geologic Repositories.

Taking advantage of activities already ongoing at WIPP facilitated the initial series of monitoring experiments. These transparency monitoring experiments apply current technology to the repository setting to demonstrate transparency technology capabilities in several areas. These experiments utilized several existing process, monitoring, and sensors and systems. The data were processed, and the synthesized information was put into a display of the current state of these monitoring experiments at the facility. The demonstrations also provided a real-time information feed to a password protected transparency demonstration web site. The following is a description of the specific WIPP Transparency Technology Test Bed demonstrations.

Container Monitoring – Rocky Flats to WIPP

There are several commercially available methods currently used to provide continuous monitoring of transportation vehicles, including the Transcom System currently being used by WIPP to track the vehicle used during waste shipments. However, none of these systems provide monitoring capabilities of the individual packages or containers located on a particular vehicle. To meet this need, SNL has developed an Authenticated Tracking and Monitoring System (ATMS) that provides comprehensive parametric monitoring of material located within any platform, including those used for ground, air, and/or sea transportation. The system employs commercially available sensing devices, interfaced using a radio-frequency transmission system, through an authentication algorithm, overlaid with a GPS mapping capability, and transmitted via the INMARSAT marine satellite system to a ground station accessible by the transportation control station.

One of the repository transparency experiments showcased and evaluated an end-to-end monitoring capability designed to continually observe the status of a container of transuranic (TRU) radioactive waste material. The container was to be monitored throughout its life cycle; from the time it was loaded at Rocky Flats, during transportation to the WIPP site, and eventual unloading at the site. While it is understood that waste traveling to WIPP does not currently require this level of transparency, this activity served as a comprehensive demonstration of monitoring technology that will be applicable to other international repository developments. The ATMS was used in this experiment.

For purposes of demonstration only, and due to regulatory and physical mounting issues, it was decided early in the transparency experiments to be impractical (and unnecessary) to monitor the status of the actual transuranic container itself, but instead to place all the desired ATMS sensors within the tractor (cab) and simulate the tampering of a container by activation (opening and closing) of the seals during the TRU shipment. That is, the relief driver would periodically open and close all five active fiber optic seals (within the cab) that would have been placed on the container to secure and seal the container. This simulation of opening and closing the seals from within the cab is virtually identical to someone breaching the seals – had they been routed through sealing fixtures on the actual container itself.

In addition to using active fiber optic seals during the shipment, other active sensors were also utilized. These include two necklace-type duress pendants (one for each driver) that would be utilized during an en-route emergency. These duress pendants were also intentionally activated periodically along the route during this trial/demonstration. Also, for purposes of ATMS system evaluation and monitoring, several on-board system parameters were monitored remotely continuously. Analog temperature sensors were utilized to monitor the outside ambient temperature as well as the temperatures within the system electronic enclosures. The system voltages were also monitored. These analog measurements were invaluable in monitoring and evaluating the overall system conditions and system performance during transit. Figure 1 shows a photograph of the TRU tractor cab and trailer instrumented with ATMS hardware as used during the over-the-road container monitoring experiment.

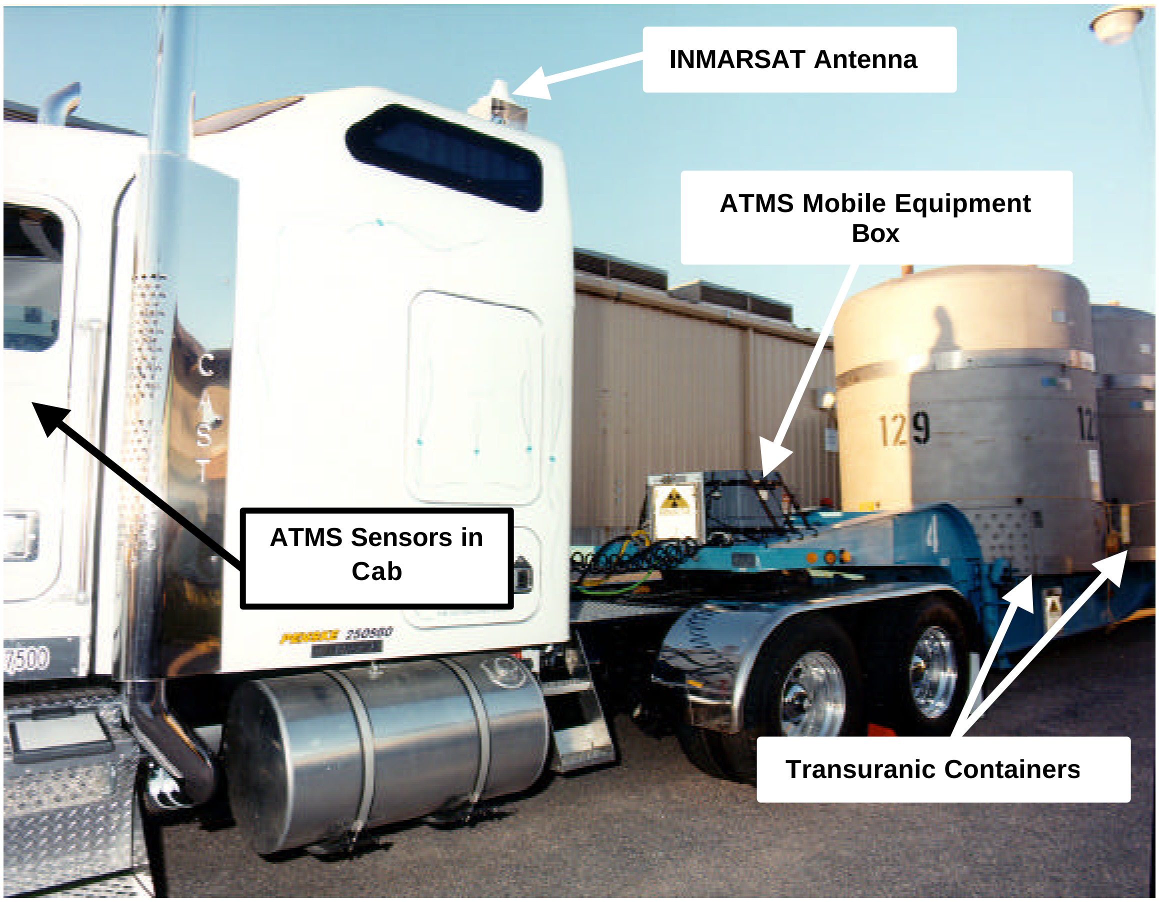

Figure 1. Container Monitoring – Rocky Flats to WIPP. Photograph of the TRU tractor cab and trailer instrumented with ATMS hardware as used during the over-the-road container monitoring transparency experiment.

Underground Container Monitoring

Demonstration containers of TRU waste were monitored continuously in real-time in the underground at the WIPP repository as another of the transparency experiments. Sensors (T-1 sensors) that detect and alert any tampering or movement were attached to the demonstration containers. In addition a system of NTVision video surveillance cameras were installed in the underground demonstration area. The NTVision system detected any intrusion into the area and then recorded and transmitted images of the intrusion. Both the T-1 sensors and the NTVision had electronic tamper indication subsystems to assure that they had not been compromised. The information and images were transmitted in real-time and integrated and viewed through the integrated facility-status display unit, described later in this paper.

The video collection system is based upon NTVision software developed by Los Alamos National Laboratory. For the demonstration, two cameras, located underground and viewing simulated waste containers, were monitored by NTVision. The NTVision system continuously evaluates captured video images of the scenes for changes in content. When changes occur above programmed thresholds, a series of images are stored forming a movie of the event(s) that caused the changes in the image content. Additional video information is also available about the video event. This information consists of four images. These images are: the existing reference image (established before the event), the image that caused the event, the difference image (difference between the reference and the event image), and the new reference. NTVision updates the reference images at regular programmable intervals. The parties involved in the transparency experiment can then view the event(s) at any time.

Figure 2 shows a photograph of the T-1 sensors and NTVision video surveillance hardware used in the underground WIPP demonstration area during the underground container monitoring transparency experiment. Figure 3 shows the output video screen of the NTVision surveillance system detecting intrusion into the underground WIPP demonstration area.

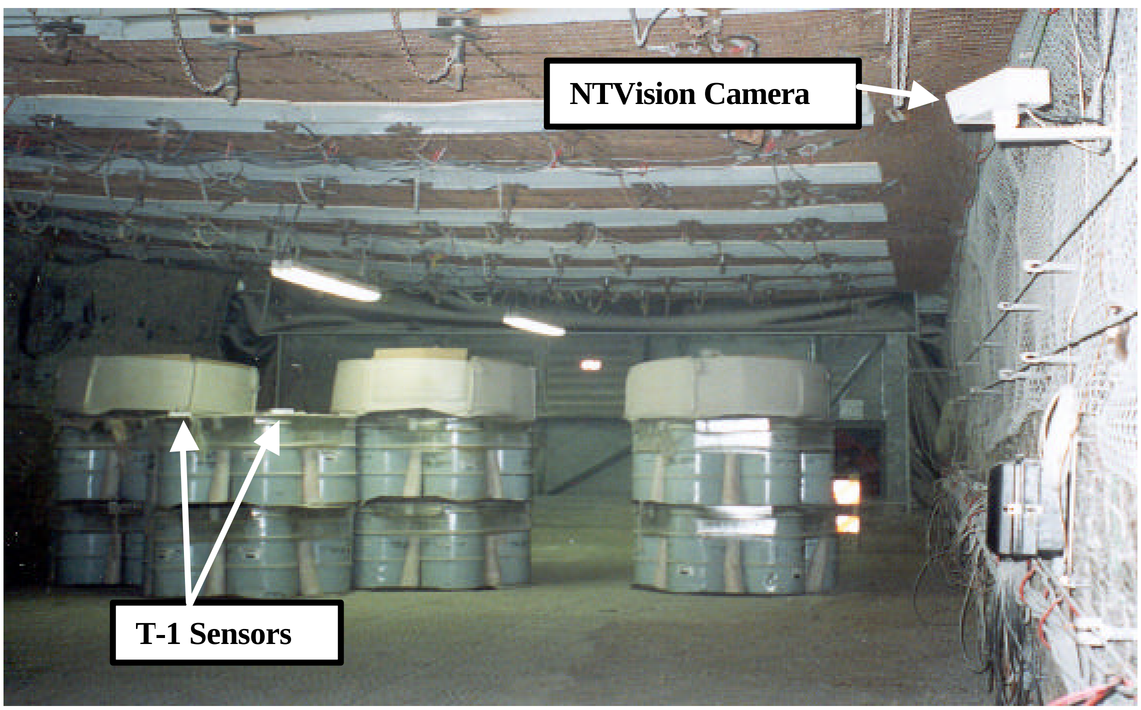

Figure 2. Underground Container Monitoring. Photograph of the T-1 sensors and NTVision video surveillance hardware used in the underground WIPP demonstration area during the underground container monitoring transparency experiment.

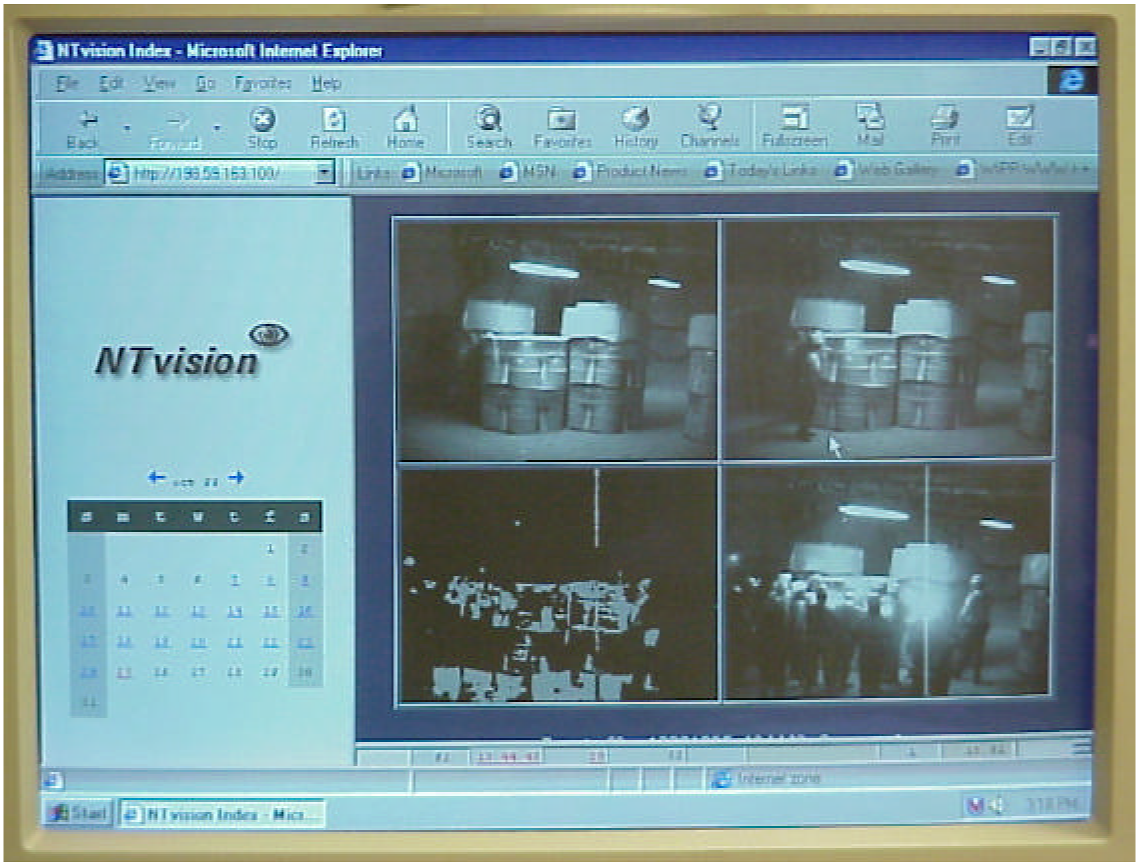

Figure 3. Output video screen of the NTVision surveillance system detecting intrusion into the underground WIPP demonstration area.

Real-Time Radiation and Environmental Monitoring

This experiment focused on transparency monitoring of operational safety and environmental quality parameters. The experiment utilized existing monitoring sensors and systems, processing the data, and synthesizing the information into a single, facility-status display.

The real-time radiation and environmental monitoring component of the demonstration include monitoring selected surface and underground environmental and safety conditions at the WIPP. The surface conditions monitored and displayed are: wind speed and direction, barometric pressure, relative humidity, and precipitation. The subsurface conditions monitored and displayed are: air flow, barometric pressure, relative humidity, and radiation counts of alpha and beta levels. Figure 4 shows an example of the custom user interface showing video output from the real-time radiation and environmental monitoring transparency experiment.

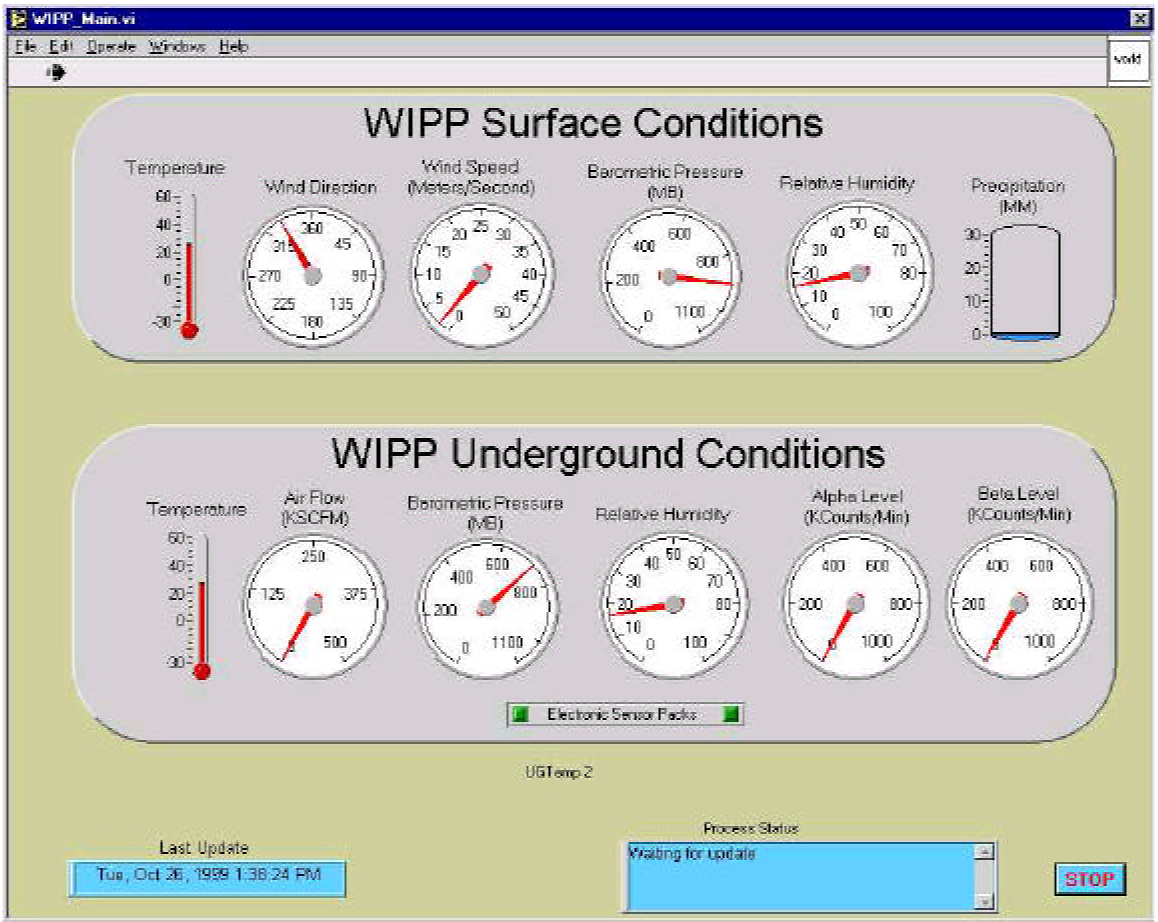

Figure 4. Monitoring system custom user interface showing example output from the real-time radiation and environmental monitoring transparency experiment.

Integrated Facility-Status Data Display Unit

An integrated data display unit was developed as a user-friendly interface between the data collected and the analyst/end user. The data display allows the user to simultaneously view the variety of information being collected as part of this experiment. In addition, educational and interpretive information was displayed as part of the unit. The data from the transparency monitoring experiments was synthesized into a display via two subsystems. The first subsystem showed the current state of these monitoring experiments at the facility, and provided a real-time information feed to a password protected transparency demonstration web site.

The second subsystem collected data from all sources other than video. This collection system is based upon the Material Monitoring System (MMS) developed by Sandia National Laboratories. This system has three components, the Data Collection Component (DCC), the Data Storage Component (DSC) and the Custom User Interface (CUI). These three components communicate over standard Ethernet connections.

Demonstration and Recognition at the International Conference on Geologic Repositories

The transparency jumpstart activities that demonstrated a few key elements of an overall transparency strategy for the backend of the nuclear fuel/weapons cycles were showcased at the DOE International Conference on Geologic Repositories in Denver, Colorado, October 31-November 3, 1999. Figure 5 shows a photograph of the real-time transparency experiments shown at the WIPP exhibit booth at the conference.

Figure 5. Real-time transparency experiments shown at the WIPP exhibit booth at the DOE International Conference on Geologic Repositories in Denver, Colorado, October 31-November 3, 1999.

Assistant Secretary of Energy, Dr. Ernie Moniz, incorporated a description and images of the WIPP jumpstart activities into his presentation to the conference attendees and used the TRU waste shipment tracking demonstration as a specific example (Figure 6). He emphasized the need for repository transparency technologies and that WIPP should be used for transparency technology development on an international scale.

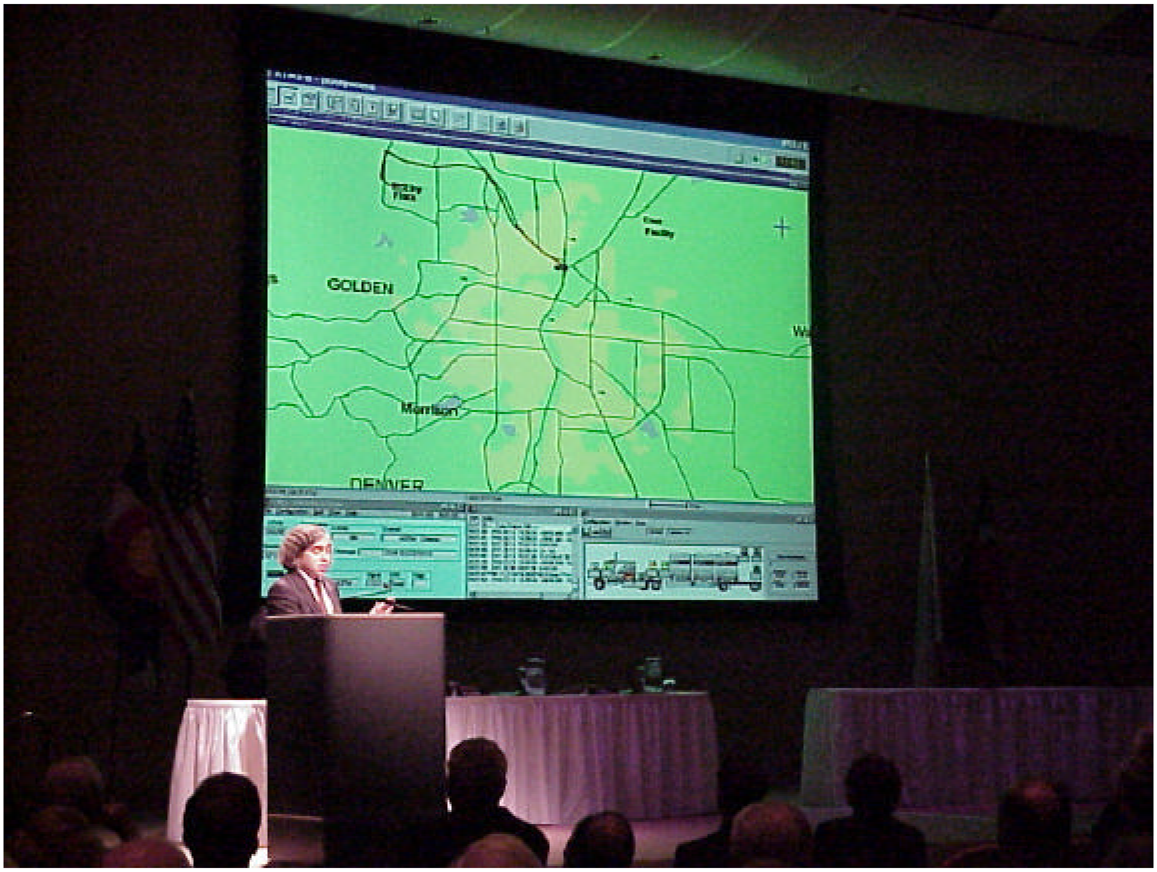

Figure 6. Assistant Secretary of Energy, Dr. Ernie Moniz, describing the WIPP transparency experiments in his presentation to the conference at the DOE International Conference on Geologic Repositories in Denver, Colorado, November 2, 1999. Here, an image of the TRU shipment being monitored by the ATMS is shown as it moves through Denver.

Also, at the conference there was a working session on "Safety, Security, and Transparency Monitoring of Nuclear Materials in Repository Systems: The Role of International Collaboration." Specific recommendations (4) proposed by session participants included: "1) the Waste Isolation Pilot Plant (WIPP) should be developed as a test bed for international collaboration on safeguards, security and transparency of geologic repository systems; 2) Continued development in geophysical technology is essential to ensure the long term transparency and safeguards of repository systems; and 3) Considerable international interaction is required to develop accepted practices and principles for repository safeguards."

CONCLUSION AND NEXT STEPS

Transparency provides information to outside parties for independent assessment of safety, security, and legitimate use of nuclear materials – including the back end of the nuclear fuel cycle. Transparency consists of a combination of technologies and processes that can be applied to all elements of the development, operation, and closure of a geologic repository system. Such technologies can be used as a vital tool in gaining acceptance of nuclear waste repositories. As shown by these demonstrations at the WIPP, transparency technologies can be successfully applied in geologic repository settings.

A Transparency Technology Test Bed is being developed at WIPP as part of the Center for Applied Repository and Underground Studies. This unique test bed will develop and test a broad-based set of concepts and strategies for transparency monitoring of nuclear materials at the back end of the fuel/weapons cycle. The demonstrations described in this paper were put on display at the DOE/CAO office building lobby in Carlsbad, NM, and provide the cornerstone and initial activities of the WIPP Transparency Test Bed at the SNL offices in Carlsbad.

Finally, it took an integrated, dedicated, multidisciplinary team working together to implement the demonstrations described in this paper. The success of the demonstrations was possible only through a strong spirit of cooperation, close coordination, a good deal of ingenuity, and much personal dedication of the many individuals and organizations involved in the design and implementation in this project.

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Acknowledgement:

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000.