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WIPP Transparency Project – Container Tracking and Monitoring Demonstration using the Authenticated Tracking and Monitoring System (ATMS)

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Abstract

The Authenticated Tracking and Monitoring System (ATMS) is designed to answer the need for global monitoring of the status and location of proliferation-sensitive items on a worldwide basis, 24 hours a day. ATMS uses wireless sensor packs to monitor the status of the items within the shipment and surrounding environmental conditions. Receiver and processing units collect a variety of sensor event data that is integrated with GPS tracking data. The collected data are transmitted to the International Maritime Satellite (INMARSAT) communication system, which then sends the data to mobile ground stations. Authentication and encryption algorithms secure the data during communication activities. A typical ATMS application would be to track and monitor the safety and security of a number of items in transit along a scheduled shipping route. The resulting tracking, timing, and status information could then be processed to ensure compliance with various agreements.

The Waste Isolation Pilot Plant (WIPP) is the only operational nuclear waste repository in the world. This facility has been proposed to host a Transparency Technology Test Bed to develop and test technologies to monitor the safety and agreed use of nuclear waste materials. Discussions between the United States Department of Energy (DOE), Westinghouse Electric Corporation/Waste Isolation Division (WID), and Sandia National Laboratories (SNL) resulted in an agreement to demonstrate ATMS on a transuranic (TRU) radioactive waste material shipment. It was decided the shipment would be continuously monitored throughout its transportation phase – from release at Rocky Flats through transportation to the WIPP site. As a hoped for outcome, this activity could serve as a comprehensive demonstration of monitoring technology that could be applicable to other international repository developments. In addition, it was decided to demonstrate this technology in real-time at DOE Secretary Richardson's Conference on Geologic Repositories in Denver in November, 1999. The demonstration was a complete success and generated much interest in the ATMS technology as well as using WIPP as a test bed for other transparency technology development and testing.

This poster session will highlight the ATMS system in general and this WIPP shipment demonstration in particular. For reference purposes, two other companion papers are also being presented at this conference – one in Oral Session 61 by David Betsill et al, and the other in Poster Session 31 by Barry Schoeneman et al.

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1. Introduction

The ATMS provides the status and location of proliferation-sensitive items and individual containers during shipment. The system tracks and monitors items, in transit or stationary, from a mobile or fixed ground monitoring station (see Figure 1). Wireless sensor packs provide near-real-time event and state-of-health (SOH) data, which are collected by a processing unit and transmitted to ground stations through the INMARSAT satellite communications link. Position information is provided by Global Positioning System (GPS) satellites. The major benefit of the ATMS is its ability to monitor virtually any container shipment regardless of the transportation mode (rail, truck, or ship) anywhere in the world.

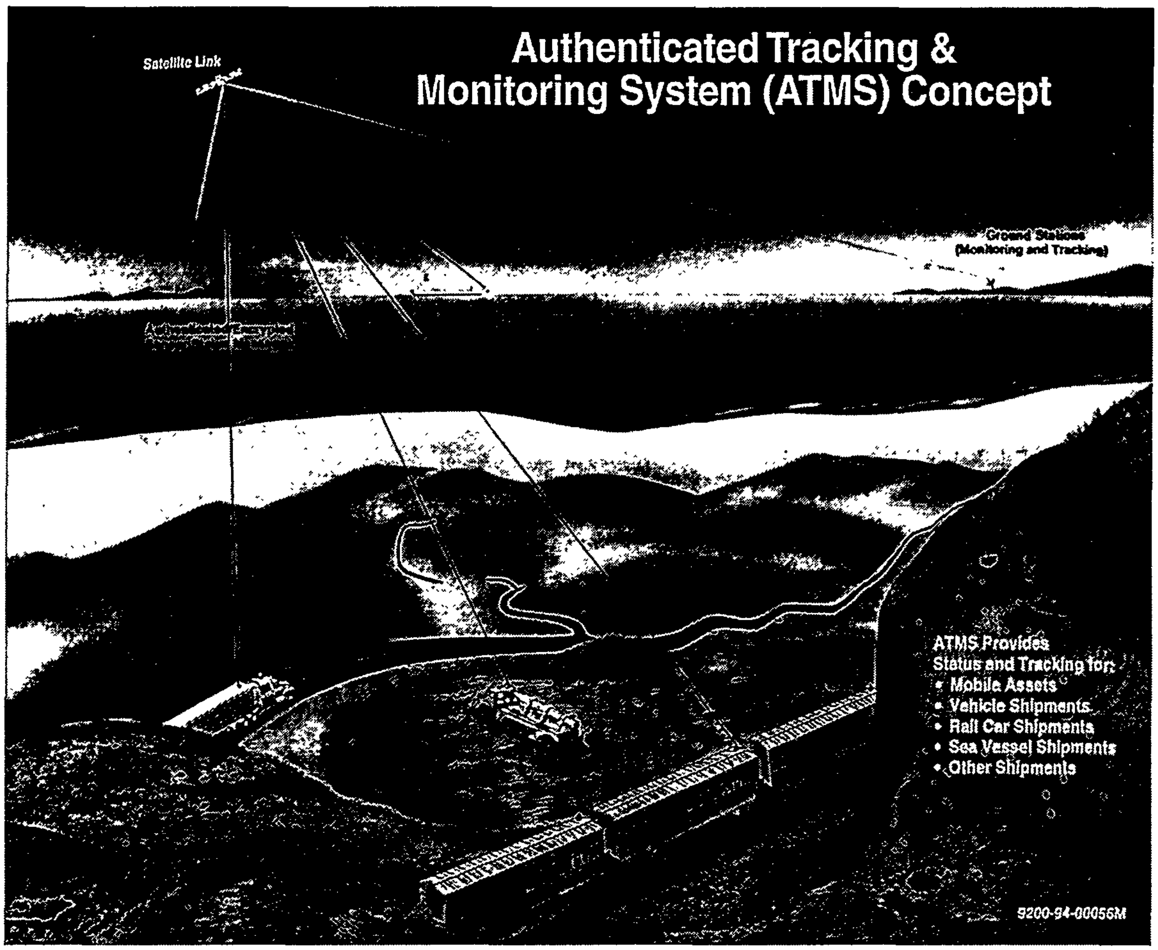

Figure 1. ATMS Operational Concept

Applications for the ATMS include arms control, verification of nonproliferation treaties, military asset control (location and status), or any type of bilateral or multinational nuclear-weapons dismantlement agreement. This type of tracking can also be applicable to monitoring the disposition of nuclear waste and spent fuel at the back end of the fuel cycle. DOE and the Defense Threat Reduction Agency (DTRA) jointly sponsored the development of ATMS at Sandia National Laboratories. Commercial applications for ATMS include inventory control and tracking of any high-value items.

For purposes of a highly effective and visible demonstration of ATMS's tracking and monitoring capabilities, it was further decided by all participants to utilize and demonstrate ATMS with an actual live WIPP shipment during Secretary of Energy Bill Richardson's Conference on Geological Repositories in November, 1999. Although it is recognized that this type of container tracking is not required for WIPP shipments, it was decided to run the demonstration on an actual WIPP shipment to demonstrate the types of transparency experiments and technology development that could take place using WIPP as a test bed for transparency technology. This highly successful demonstration took place during the conference on November 1st and monitored the waste material shipment (status and tracking) from the Rocky Flats facility continuously to the WIPP facility. Parts of this recorded shipment were subsequently utilized and highlighted during Undersecretary Moniz's presentation at the conference.

2. ATMS Concept Overview

To monitor shipment status, the ATMS concept uses an authenticated wireless radio frequency (RF) sensor subsystem, modeled after the Authenticated Item Monitoring System (AIMS). The AIMS sensor suite can detect item motion/movement, intrusion, safety concerns, environmental conditions, and containment. An authentication/encryption algorithm provides a high degree of system data security.

Dynamic shipment location and tracking information is obtained through on-board GPS receivers. The resulting sensor data and dynamic location information are then combined and transmitted using both authentication and encryption via the worldwide INMARSAT satellite system. These data are then relayed to monitoring and tracking ground stations in near-real-time (e.g., 5 minutes). These ground stations display shipment location/tracking and sensor status using Microsoft® Windows™-based software and information management utilities. The block diagram of the current ATMS is shown in Figure 2.

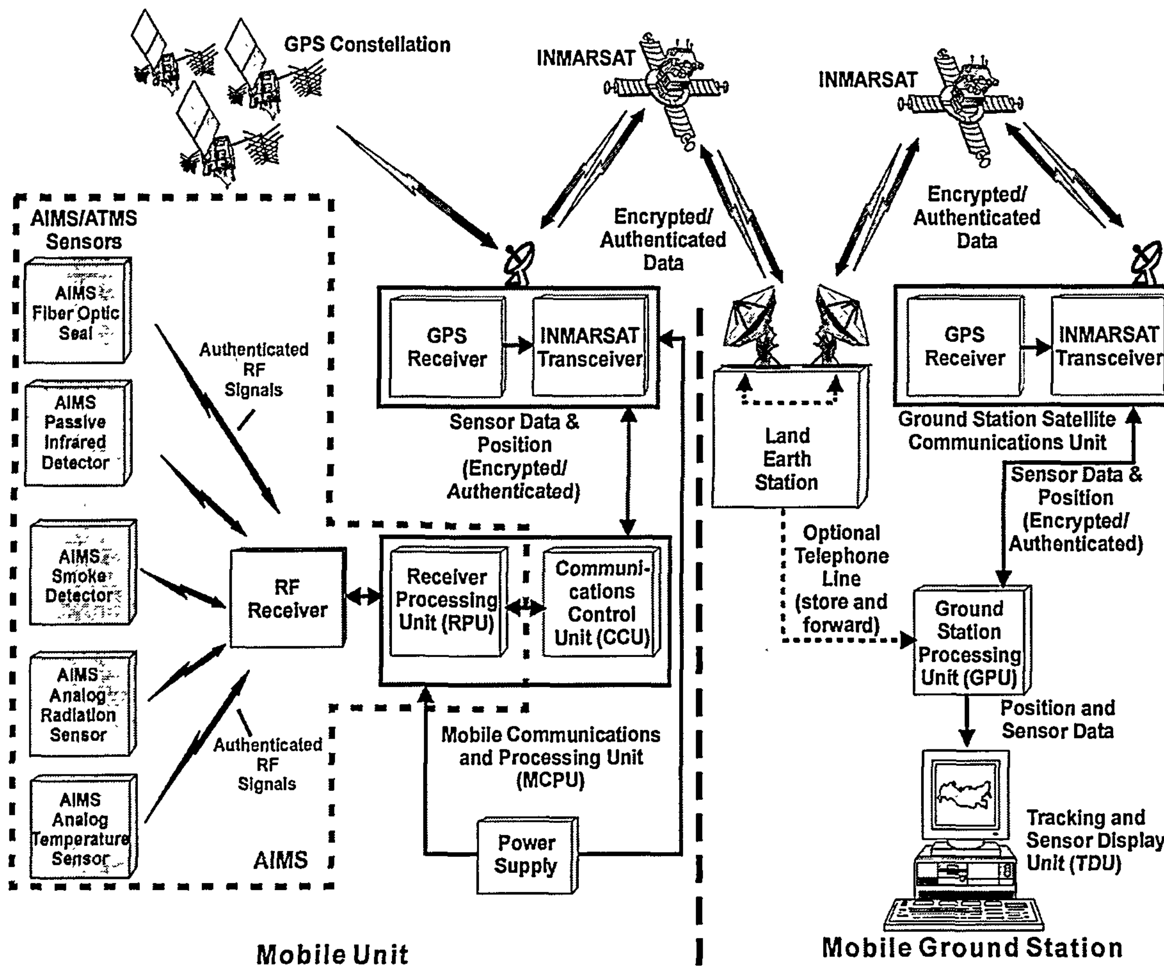

Figure 2. ATMS Block Diagram

The left side of the diagram depicts the wireless AIMS sensor subsystem (contained within the dotted line). The AIMS sensor information, obtained from the Receiver Processing Unit (RPU), is periodically combined (e.g., every 5 minutes) with the current GPS position data by the Communications Control Unit (CCU). The sensor and position information are combined and this information is queued for transmission. Once the proper transmission time interval has expired, the combined data are then authenticated and encrypted by the CCU and transferred to the outbound INMARSAT transceiver for satellite transmission over the INMARSAT worldwide network. One of many INMARSAT Land Earth Stations (LESs) receives the data and then re-transmits it back to the satellite network for subsequent reception by the appropriate mobile monitoring ground stations. It might be noted that the ATMS developers chose INMARSAT because of its worldwide coverage. If the application is limited to localized area, such as the United States, other satellite communication networks could alternatively be employed.

Once the ground station receives this authenticated and encrypted information from the incoming INMARSAT transceiver, it is sent to the Ground Station Processing Unit (GPU), where the location and sensor information is authenticated and/or decrypted. The information is then sent to a standard PC-based Tracking and Sensor Display Unit

(TDU). Either a PC workstation or a laptop PC may be used for the TDU. When the TDU is loaded with the appropriate maps and tracking software, it displays where the shipment is located and where the shipment has previously been. Additionally, current and past AIMS sensor information is tracked. Using a Windows™-based environment, this tracking and sensor status information is displayed in a very user-friendly manner. Both the shipment platform the ground station are completely mobile on a world-wide basis. All that is required is power from a local or transportation source, and even that can be supplied by batteries for very remote monitoring applications.

To show how the status of typical shipments can be monitored, Figure 3 shows a typical monitored shipping scenario via a rail car. Many other shipment scenarios are possible including tractor-trailer, sea vessels, and some aircraft. As an enhanced communication feature, ATMS provides the ability to communicate messages (similar to e-mail) back and forth between the shipment platform (via a laptop) and any and all ground stations.

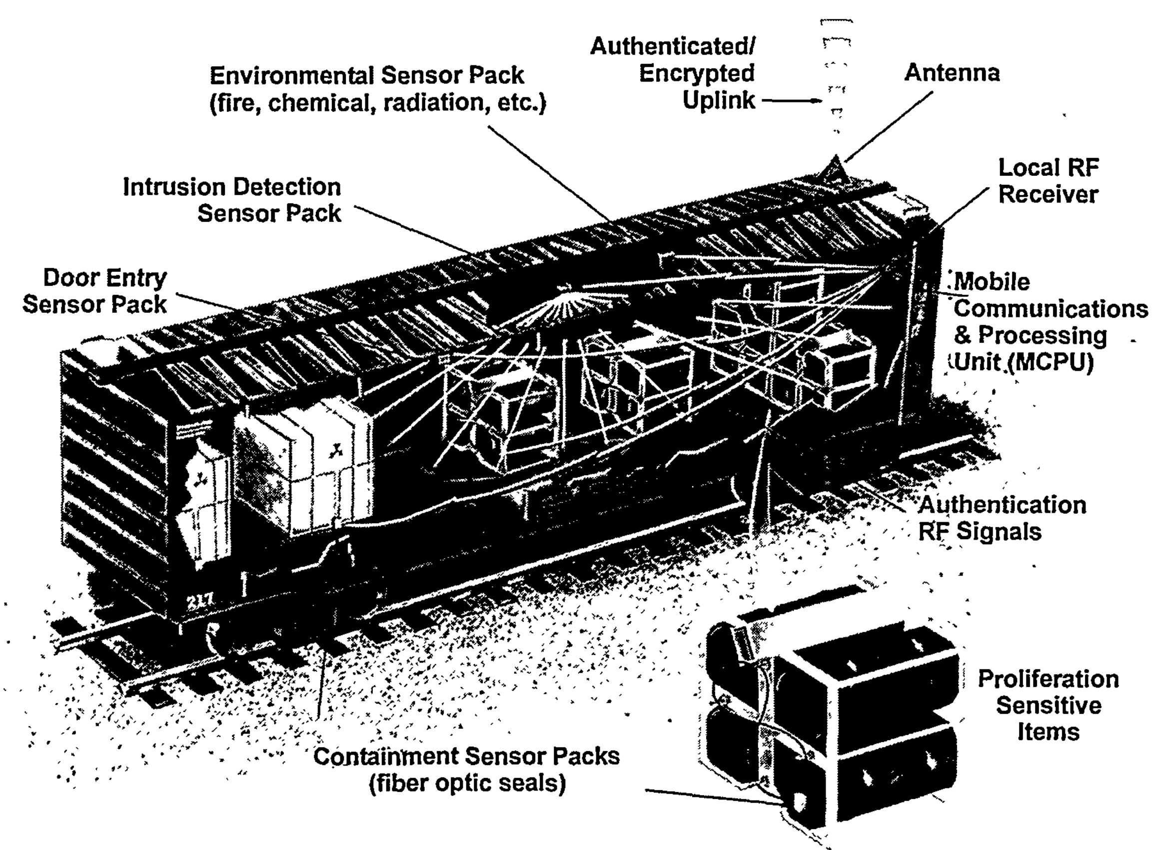

Figure 3.

Example of ATMS Shipment by Railcar

3. ATMS Sensor System

The battery-powered AIMS secure-sensor transmitter packs report authenticated significant sensor activations, known as "events," to the nearby RPU via RF. In addition to event reporting, each sensor sends periodic authenticated messages that indicate the SOH of each sensor, and thus assures that all sensors are on-line and have not been tampered with. The RPU processes and packetizes all incoming sensor pack messages and then sends this information to the CCU for subsequent satellite transmission via the INMARSAT transceiver.

Environmental and safety sensors detect and report conditions surrounding the selected items that exceed acceptable limits (e.g., temperature trip points). Environmental sensors include smoke detectors, temperature detectors, humidity detectors, flame detectors, radiation detectors, and chemical detectors. Containment sensors monitor the physical emplacement of selected items and thereby verify that they have not been moved or tampered with. As an example, active fiber-optic seals are routed through container turnbuckle tie-downs so that it is extremely difficult to move or remove the selected item without breaching the fiber-optic loop, thereby causing an event. Containment sensors include motion sensors, active fiber-optic seals, and load cells/links. Intrusion detection sensors can monitor the physical presence and movement of an individual in the area of the selected item or an attempt to enter the area containing the item. Intrusion detection sensors include microwave detectors, infrared detectors, balanced magnetic switches, and wire grid detectors.

Figure 4 shows a variety of AIMS/ATMS sensor packs, both analog and bi-level, in various packaging arrangements for different applications, as well as the receiver, at the lower left.

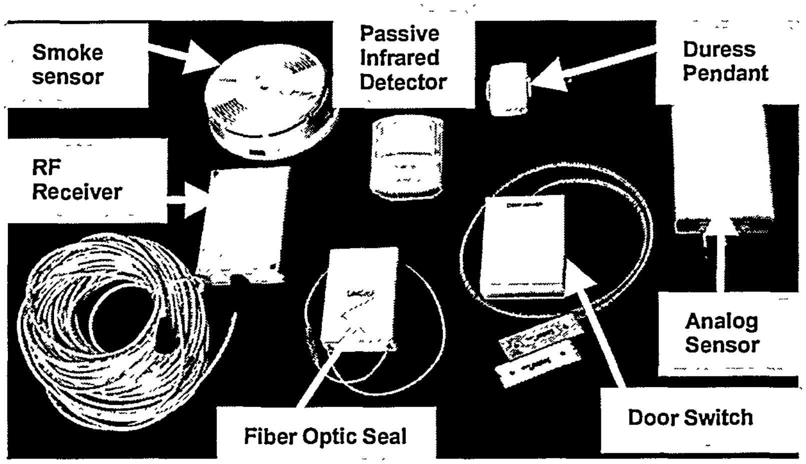

Figure 4. AIMS/ATMS Secure Sensor Transmitter Packs and Receiver

In summary, the activation of sensor inputs, sensor pack tampering, missing SOH messages, or messages that are not properly authenticated comprise events that are time-tagged by the RPU and immediately transferred via the CCU to the transceiver for satellite transmission and subsequent ground station reception and display.

4. ATMS Current Status

ATMS was born with a proof-of-concept demonstration in August 1993. Using equipment incorporated from other projects, a road shipment of mock weapon containers was successfully tracked and monitored for three days as it traversed five western states in the U.S. Sufficient interest was generated to fund, beginning in mid-FY94, the development of a field prototype. Initial tasks included developing system requirements, obtaining INMARSAT licensing, designing the communications control and ground station processing units, procuring prototype hardware, and rudimentary encoding software.

The first field prototype, completed in FY96, included two-way satellite communication between the monitoring station (either fixed or mobile) and the cargo vehicle, authentication and encryption of the INMARSAT data channel, and a user-controlled software interface that provided tracking and cargo monitoring information displays on an interactive control screen.

During the latter part of FY96 and early FY97, the ATMS field prototype was successfully demonstrated and evaluated globally. It has functioned on the streets of Moscow, throughout the great expanse of the Australian outback, across the oceans from southern Australia to European destinations, and in numerous congested U.S. cities. Several systems now exist and are available for further demonstration and evaluation.

5. The WIPP Transparency Trial/Demonstration

For purposes of demonstration only, and due to regulatory and physical mounting issues, it was decided early in the WIPP demonstration discussions to be unnecessary to monitor the status (sealing etc.) of the actual transuranic container itself, but instead to include all the desired AIMS sensors within the tractor (cab) and simulate the tampering of the container by human activation (opening and closing) of the seals during the shipment phase. That is, the relief driver would periodically open and close all five active fiber optic seals that, in a real application would have been placed on the container, therefore securing and sealing the container. This simulation of opening and closing the seals from within the cab is virtually identical to a person 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 activated periodically during this trial/demonstration route. Also, for purposes of ATMS system evaluation and monitoring, several on-board system parameters were continuously monitored remotely. 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 the overall system conditions during transit.

Due to the importance and visibility of this trial/demonstration, it was also decided early in the demonstration planning phase to implement a fully redundant system on the shipment platform (tractor-trailer rig) and at the ground monitoring station at the exhibit hall of Secretary Richardson's Conference on Geologic Repositories in November, 1999. In other words, two identical systems were implemented on the tractor-trailer rig and the ground monitoring station: System A and System B. This means that for the trial/demonstration there were two identical sets of sensors, two RPUs, CCUs, transceivers and two power systems. In this way, both systems report, in a redundant fashion, to each ground station transceiver, GPU, and TDU. (In hindsight, this turned out to be unnecessary as both systems performed flawlessly during the entire trial.)

Preparation work for the ATMS trial/demonstration (for showcasing at the Geological Repository Conference) began on the weekend of October 30th with the two full sets of equipment being transported to Denver. The A & B mobile sub-systems (the portion of the system that monitors the shipment) were delivered to the CAST trucking facility for installation on the selected tractor of the tractor trailer rig. The A & B ground station subsystems were taken to the Denver Conference Center along with the rest of the display and booth set up equipment.

During the weekend, both segments of both systems (A & B) were set up and checked for proper operation. Only one major problem was encountered and that had to do with the ground station INMARSAT antenna having adequate line-of-sight coverage to the "Atlantic Ocean Region West" (AORW) Inmarsat geostationary satellite. It turns out that in this portion of the United States, the AORW satellite is the only INMARSAT satellite available for use. (As a side note, this area of the country is the only place on earth served by only one satellite. All other places have at least two and sometimes three satellites to provide coverage.) Having the conference, and hence the receiving antenna, in downtown Denver, required finding an antenna position to provide line-of-sight coverage free of large and tall building structures. However, after surveying the building and surrounding area, and after some experimental tests, a suitable location was found.

Prior to the ground station setup, the mobile portions of A & B were installed on the selected WIPP transportation tractor unit with 12 volt DC power being derived directly from the power system of the tractor. This installation process took place at the CAST facility. Late Sunday the 31st, the entire systems (A & B) were on-line and fully operational.

Very early on the morning of Monday November 1st, the tractor was driven to Rocky Flats for coupling to the already "container loaded" trailer unit. Once connected, and inspected, the ATMS system was tested and its operation verified one final time prior to departure to WIPP. Figure 5 below shows the final loaded transport ready for departure with the ATMS resident equipment sets.

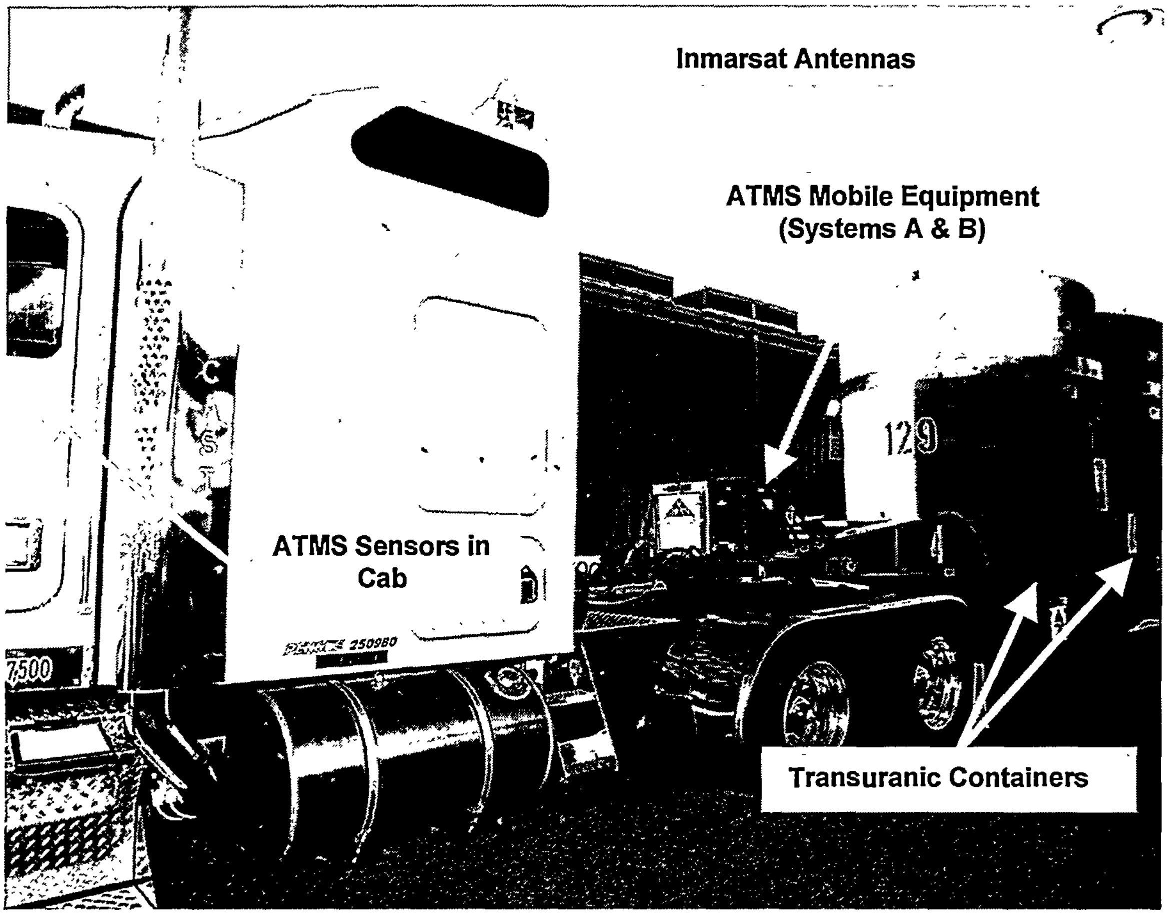

Figure 5
Final Loaded Transport

At approximately 9:00 am the shipment began and was monitored by conference attendees (including Dr. Moniz, Undersecretary of the Department of Energy) at the ground monitoring station at the conference exhibit hall. Other than an unrelated local automobile accident that resulted in a traffic jam (which caused a "monitored" delay and slight route diversion), the rest of the trip to the WIPP site was smooth and continuous. Figure 6 below shows a typical tracking and monitoring display of ATMS during this shipment. Note that Louisville is a suburb of Denver.

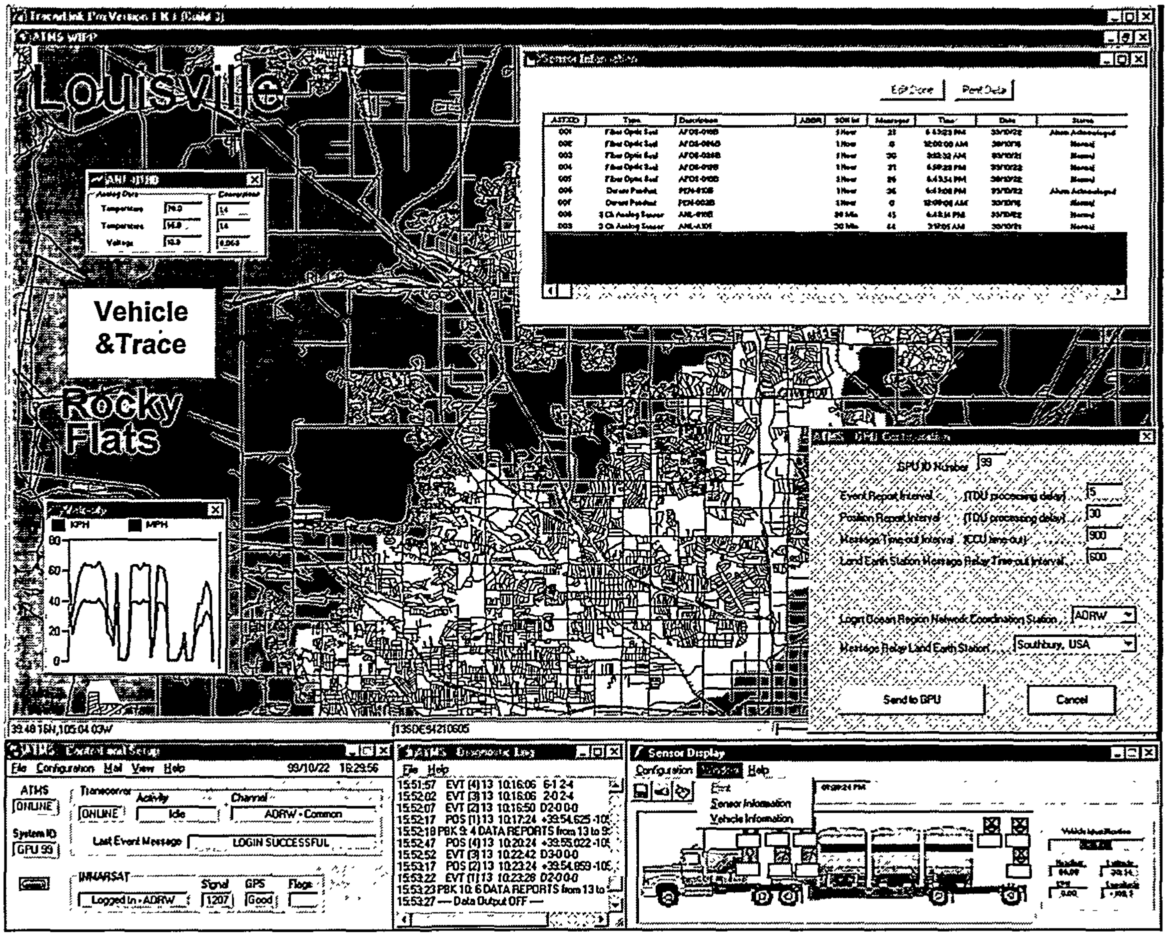

Figure 6
Typical ATMS screen during the shipment

Items to note in Figure 6 above (these are shown for exposition and can be removed individually to allow more room for the map display alone, if desired):

- Lower left: Inmarsat status and control panel
- Lower middle: Recorded incoming messages
- Lower right: Sensor status along with current heading and velocity
- Middle left: Recorded transport velocity (note stop-and-go history due to traffic)
- Middle upper left: Current system temperatures and voltages
- Upper right: Record of on-line sensors with State of Health (SOH) intervals etc.
- Middle right: System report interval selections; Satellite and Land Earth Station selection

6. Conclusions

The experience and logistical lessons learned from this ATMS field trial and other recent trials throughout the world have proven invaluable to the future direction, development and deployment of ATMS. When fully deployed, the ATMS will provide a worldwide, 24-hr/day capability to track and monitor virtually any type of selected high-value shipment. The system incorporates sensors, electronics, and tamper-resistant technologies, including encrypted and authenticated messages and robust tamper-indicating enclosures. The system is mobile, battery-powered, and survivable in environmental conditions commensurate with its anticipated use. The trial described in this paper was limited to tracking and monitoring of a waste shipment as an example of technology that could be demonstrated at the WIPP Transparency Technology Test Bed; however, the ATMS has a very broad spectrum of potential future applications.

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