AUTHENTICATED TRACKING AND MONITORING SYSTEM (ATMS)
TRACKING SHIPMENTS FROM AN AUSTRALIAN URANIUM MINE

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Abstract

The Authenticated Tracking and Monitoring System (ATMS) answers the need for global monitoring of the status and location of sensitive items on a worldwide basis, 24 hours a day. ATMS uses wireless sensor packs to monitor the status of the items and environmental conditions. A receiver and processing unit collect a variety of sensor event data. The collected data are transmitted to the INMARSAT satellite communication system, which then sends the data to appropriate 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.

Following discussions between the Australian Safeguards Office (ASO), the U.S. Department of Energy (DOE), and Sandia National Laboratories (SNL) in early 1995, the parties mutually agreed to conduct and evaluate a field trial prototype ATMS to track and monitor shipments of uranium ore concentrate (UOC) from an operating uranium mine in Australia to a final destination in Rotterdam, the Netherlands, with numerous stops along the way. During the months of February and March 1998, the trial was conducted on a worldwide basis, with tracking and monitoring stations located at sites in both Australia and the U.S. This paper describes ATMS and the trial.

1. Introduction

The Authenticated Tracking and Monitoring System (ATMS) provides the status and location of proliferation-sensitive items during shipment. The ATMS 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 a satellite communications link (the International Maritime Satellite, INMARSAT). Position information is provided by Global Positioning System (GPS) satellites. The major benefit of the ATMS is its ability to monitor virtually any shipment regardless of the transportation mode (rail, truck, or ship) anywhere in the world.
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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. The Department of Energy (DOE) and the Defense Special Weapons Agency (DSWA) jointly sponsored the development of ATMS at Sandia National Laboratories (SNL). Commercial applications for ATMS include inventory control and tracking of any high-value items.

Discussions were held between the Australian Safeguards Office (ASO), DOE, and SNL in 1995 regarding the practical application of the ATMS. It was proposed and accepted that a field trial, evaluation, and demonstration of the proof-of-concept of ATMS be conducted on shipments of uranium ore concentrate (UOC) from one of the two operating uranium mines in Australia to a destination in Europe. This trial was conducted on a worldwide basis with monitoring stations located in both Australia and the U.S. Evaluation and feedback information obtained from this first-time worldwide trial has proven to be useful in the future and final development of ATMS.
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 proof-of-concept ATMS is shown in Figure 2.

![ATMS Proof-of-Concept Diagram](image)

Figure 2. ATMS Proof-of-Concept

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.

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.) The TDU, loaded with the appropriate maps and tracking software, displays in a tracing manner where the shipment has previously been and currently is, along with current and past AIMS sensor information. Using a Windows™-based environment, this tracking and sensor status information is displayed in a very user-friendly manner. Not only is the shipment platform completely mobile on a worldwide basis, so too is the ground station. All that is required is power, 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 lap-top) and any and all ground stations.

3. ATMS Sensor System

The battery-powered AIMS secure sensor transmitter packs report authenticated significant sensor activations, known as “events,” to the nearby RPU. 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.
Figure 3. ATMS Shipment by Railcar

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.

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 borrowed 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 FY98, the ATMS field prototype was successfully demonstrated and evaluated globally. It has functioned on the streets of Moscow, across the great expanse of the Australian outback, and in numerous congested U.S. cities. Several systems now exist and are available for further demonstration and evaluation.

5. Trial Objectives in Australia

The overall goal of the trial in Australia was to demonstrate ATMS in the field as part of an actual uranium ore concentrate (UOC) shipment. The ATMS trial system monitored and tracked a transportainer from the Olympic Dam mine in South Australia to Rotterdam, Holland, over land and sea. From a satellite communications perspective, there is unobstructed satellite horizon on the route between the mine site and Adelaide. The Olympic Dam mine site, located several kilometers from the township of Roxby Downs, SA, Australia, lies in the arid mid-north of South Australia. This mine site is approximately 520 kilometers northwest of Adelaide, SA. Currently, UOC is packed in drums and loaded into International Standard (ISO) shipping transportainers. The transportainers are placed onto flatbed trailers and transported in a convoy of up to 10 or more vehicles to Port Adelaide, with a total shipment of up to 20 or so transportainers in one trip. Generally, these shipments occur once every three months. Because these shipments are not routine, they are timed to meet the cargo ship at the port for the sea voyage to Rotterdam. The transportainers are then unloaded at the port from the flatbed trailers to the cargo ship.

Certain physical and logistical constraints were imposed on the trial by the very nature of the shipment and the agencies responsible for the shipment. Because the trial accompanied an actual shipment, the trial had to minimize its impact on the overall shipping process.

Because personnel did not have access to the interior of the shipment transportainer for the installation of the ATMS equipment, particular attention and care had to be taken to protect the exterior mounted equipment and sensors from exposure to the expected weather and handling environments on both the land and extended sea portions.
5.1 The Trial System/Equipment

The ATMS sensor suite for this trial was chosen to monitor the status and security of the chosen transportainer (i.e., breach of the container), the ambient outside temperature and certain ATMS system parameters. Balanced magnetic door switches along with fiber-optic seals (routed around and through the door hasps) were mounted on the outside of the transportainer and were used to monitor the security of the transportainer. An analog temperature sensor was used to monitor the ambient temperature of the outside of the transportainer. Figure 5 shows the sensor installed on the selected transportainer.

To measure the selected system parameters of the RPU, CCU, and transceiver (the monitoring/transmitting equipment), an analog voltage sensor was used to monitor battery voltage along with two more temperature sensors to measure the electronics temperature and the temperature directly outside the electronics enclosure. The values of these analog parameters, along with the condition of the door sensor and fiber-optic seal, could all be monitored from both ground stations setup in Albuquerque and/or Canberra.

Because this was to be the first world-wide unattended trial of ATMS, and because of this trials importance, it was decided early on to implement a fully redundant system on the shipment platform. In other words, two identical systems were implemented on the shipment platform: System A and System B. This means that for the trial there were two identical sets of sensors, two RPU's, CCU's, transceivers and two power systems. In this way, both systems report, in a redundant fashion, to each ground station transceiver, GPU, and TDU. Figure 6 shows both A and B sets of equipment during testing prior to the trial.

5.2 The Trial

The actual trial shipment began on February 24, 1998 from the small mining town of Roxby Downs, South Australia. (Days prior to this, full system setup, testing, and checkout occurred.) The set of transportainer fiber-optic seals, door sensors and temperature sensors (both A and B) were mounted to the outside of the transportainer prior to loading onto the
truck. Next, the set of monitoring/transmitting equipment was installed in and on the cab of the truck and power from the truck’s batteries was connected to both systems A and B. After checking the systems for proper operation, the convoy began an 8-hour journey to Adelaide. The convoy is shown in Figure 7. Note that the first truck in the convoy carried the transportainer that was being monitored. The trip was monitored along this portion of the shipment as shown.

![Figure 7. Truck Convoy Carrying UOC](image)

Once the shipment reached the port of Adelaide, the transportainer was removed from the truck and temporarily stored for several days in a storage yard (a Sea-Land terminal) prior to loading upon the sea vessel. During storage, all transportainer parameters and sensors were continuously monitored as before.

On April 1, the transportainer (with sensors still attached) was loaded onto the designated P&O shipping vessel along with literally thousands of other transportainers (mostly wine and lamb). The monitored transportainer was loaded to the far aft of the ship toward the bottom level. Consequently, for the sea portion, the transportainer was located outside on the deck of the ship, which exposed the sensors to a long period (approximately 4 weeks) of adverse and dramatically changing climatic conditions (from Australia under the tip of South America up through the equator, then on to Europe). The monitoring/transmitting equipment (both systems A and B) were installed in the ship’s radio room on one of the upper decks. The INMARSAT transceiver antenna and the AIMS sensor receiving antenna were both mounted outside on the ship’s upper deck with a good “open sky view.” (The ship’s smoke stack was a partial obstruction; however, luckily, this did not pose a problem for INMARSAT transmissions during the trial.) The systems (A and B) were then checked out for proper operation.

The next day, April 2nd, the ship left for its first stop in Melbourne, then to Sydney and on to New Zealand for numerous stops. After New Zealand, the ship left for its long journey to Europe without a single stop. Figure 8 shows a typical screen display for the long haul portion of this journey. After about four weeks the ship made its first stop in Spain, then on to various stops in Europe finally ending up in Rotterdam about six weeks later. At that point, the first worldwide trial of ATMS was completed and deemed a success.
6. Conclusions

The experience and logistical lessons learned from this prototype ATMS field trial in Australia and throughout the world has proven invaluable to the future development of ATMS. When fully developed and deployed, the ATMS will provide a worldwide capability to track and monitor virtually any type of selected high-value item. 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 proliferation-sensitive items; however, the ATMS has a very broad spectrum of potential future applications.