SAND 99-1577C

TRACKING AND MONITORING NUCLEAR MATERIALS DURING TRANSIT

William D. Pregent, Suzanne M. Kelly, Sandia National Laboratories
Albuquerque, NM 87185 USA 505/844-0882 FAX: 505/844-3322

Abstract

Sandia National Laboratories (SNL) has completed a prototype Cargo Monitoring System (CMS). The system illustrates a method to provide status on nuclear material or waste while in transit during normal and potentially, abnormal scenarios. This accomplishment is tied to a concept to provide "seamless continuity of knowledge" for nuclear materials, whether they are being processed, stored, or transported. The system divides the transportation-tracking problem into four domains. Each domain has a well-defined interface that allows each domain to be developed independently. This paper will describe the key technologies employed in the system.

Sandia is developing a modular tag that can be affixed to cargo. The tag supports a variety of sensor types. The input can be Boolean or analog. The tag uses RF to communicate with a transportation data unit that manages and monitors the cargo. Any alarm conditions are relayed to a central hub. The hub was developed using the Configurable Transportation Security and Information Management System (CTSS) software library of transportation components, which was designed to facilitate rapid development of new systems. CTSS can develop systems that reside in the vehicle host(s) and in a centralized command center.

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

Introduction

A key element of many arms control and non-proliferation concepts is "constant monitoring" of nuclear material while in storage. This can be done by attaching Electronic Sensor Platforms (ESPs) to the material's container. The ESPs, also referred to as tags, are equipped with sensors to monitor the material and a radio with which to report the sensor's condition. With such an arrangement, the authorities responsible for the material are in constant touch with it and are able to provide better security for the nuclear material. Additionally, the authorities are able to demonstrate to others that the material is properly controlled and secured.

However, if it becomes necessary to move the material to another location, this "constant monitoring" is typically lost. One solution is to report the sensors' status during transportation just as it is reported during storage. The Cargo Monitoring System (CMS) provides the means whereby the material can continue to be monitored while being transported. This system illustrates how we might be able to contribute to a "seamless continuity of knowledge" for nuclear material or waste during the transportation phase. The system provides the ability to monitor cargo state-of-health during normal and potentially, abnormal scenarios. The CMS can enhance safety and security for the transportation organization.

DISCLAIMER

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

System Architecture

The system architecture of the Cargo Monitoring System is based on a model of a Fleet Management System consisting of the following domains:

- Container domain. The container domain includes the trailer interface and materials monitoring.
- Trailer domain. The trailer domain includes sensor monitoring, vehicle interface, and container interface.
- Vehicle domain. The vehicle domain includes the mobile application, location determination, resource monitoring, emergency notification, driver interface, and trailer interface.
- Command Center domain. The command center domain includes the central site and the activities that take place there: database maintenance, report generation, resource allocation, communication, incident management, mapping, information management, vehicle interface, and operator interface.

Container Domain	Trailer Domain	Vehicle Domain	Command Center Domain
materials monitoring, trailer interface	sensor monitoring, vehicle interface, container interface	operator interface, trailer interface, command center interface, location detection, emergency notification	resource allocation, mapping, vehicle interface, operator interface

Figure 1. Domains of a Fleet Management System

The value of this architecture is in decomposing a system into logical units, thus separating the complex problem of fleet management into more comprehensible tasks to implement. Once divided into domains, each domain can further be divided.

Architecture Implementation

In implementing the architecture of the Cargo Monitoring System, the development effort has focused primarily on the trailer, vehicle, and command center domains. The container domain is centered around the use of ESPs, which are being developed in other programs. Figure 2 illustrates the prototype Cargo Monitoring System that has been developed.

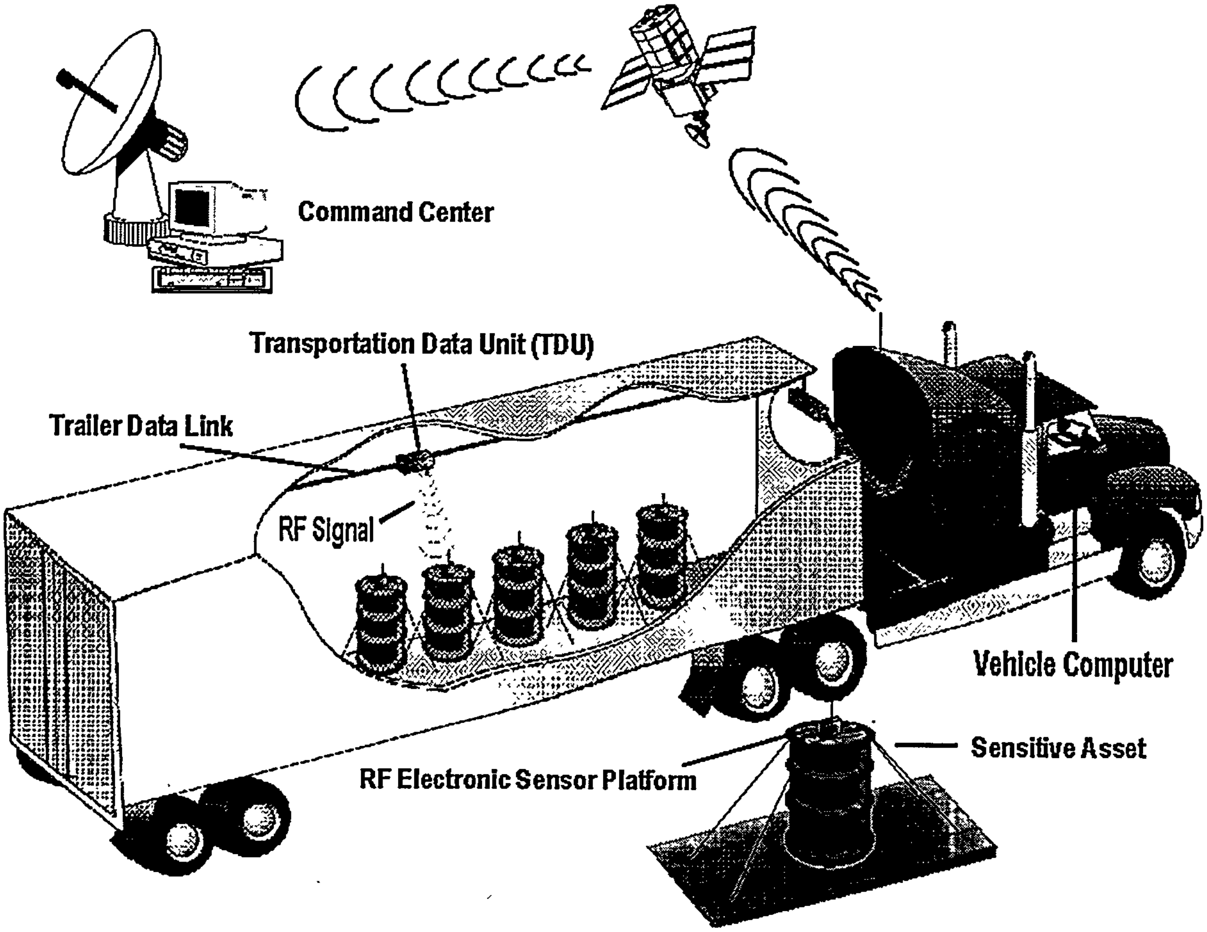

Figure 2. Cargo Monitoring for a Transportation Application

The key components of the CMS as related to the fleet management system domains are shown in Figure 3. The container and trailer domains have been prototyped utilizing embedded processor technology. The exception to this is the Configuration Computer, which will be discussed later. The advantages of embedded technology are small size, low power, and high reliability.

Container Domain	Trailer Domain	Vehicle Domain	Command Center Domain
Electronic Sensor Platform (ESP)	Transportation Data Unit (TDU), Trailer Data Link, Configuration Computer	Vehicle Computer, GPS Receiver, Satellite transceiver, Emergency Computer	Command Center, Satellite transceiver

Figure 3. Key Components of CMS by Domain

Container Domain: Electronic Sensor Platform

Within the container domain is the ESP. The ESP can contain a suite of sensors that are application and material driven. The ESP sensors can monitor various parameters of the material and container, such as radiation, temperature, motion, tie-down integrity, and container seals. The ESP communicates the sensor data with radio link messages. The ESP can be polled for status, or set up for a scheduled reporting interval. It can also send an alarm report message spontaneously if a sensor threshold is exceeded. Figure 4 shows two examples of ESP development at SNL.

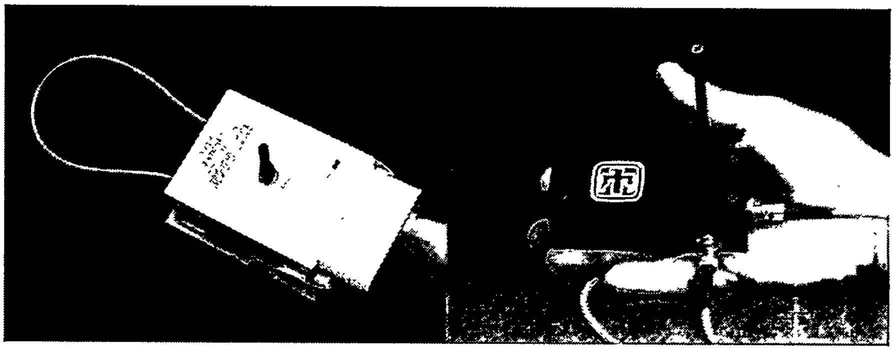

Figure 4. Electronic Sensor Platform Examples

Trailer Domain: Transportation Data Unit, Configuration Computer, and Trailer Data Link

The key component of the CMS trailer domain is the Transportation Data Unit (TDU). The TDU resides within the cargo area of the trailer. It is designed utilizing embedded processor technology due to its low power and small size characteristics. The TDU has numerous interfaces to communicate with ESPs, the trailer data link, and the Configuration Computer. It communicates with the container-based ESPs via a radio transceiver. The ESPs' radio messages are logged in the TDU. Each entry in the log is annotated with the time and reason for entry (polled, alarm, no response, etc.). See Figure 5 for a picture of the TDU prototype.

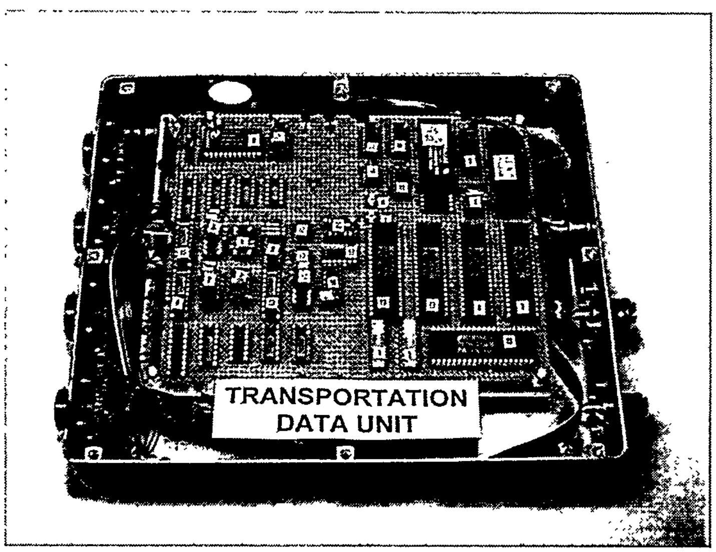

Figure 5. CMS Transportation Data Unit Prototype

The TDU has an interface for the Configuration Computer (CC), from which it can receive a variety of commands to configure it for a trip. The CC does not reside within the trailer, but rather is used as a utility tool during loading and unloading cargo. At the beginning of the trip, the Configuration Computer is connected to the TDU. The CC gives the TDU a cargo list containing the identification number of each ESP. At the end of a trip, the CC is used to download the trip log and cargo list from the TDU. The CC provides an interface to the storage facility monitoring system.

During a trip, the TDU will record and relay alarm reports from the ESPs to the Vehicle Computer in the cab of the vehicle via a trailer data link interface. If the Vehicle Computer requests it, the TDU can also send a status report for each tag in its cargo list. If the cab is disconnected (as in an accident scenario), the TDU can communicate with an emergency computer that emulates the Vehicle Computer.

The trailer data link utilizes a bus architecture. The bus facilitates the easy integration of sensors throughout the trailer, and allows data to be shared with other trailer systems.

It is planned that in the future, the TDU will expand its capabilities. One new function will be the addition of a 3-axis accelerometer capable of making a detailed recording of shock levels during an accident. Knowing the g levels experienced by the cargo allows emergency responders to gain prompt knowledge of the stresses the cargo has experienced. A radiation sensor will also be added. Data from this instrument gives emergency responders vital information about hazards from ruptured containers before entering the vehicle.

Vehicle Domain: Vehicle Computer

The Vehicle Computer provides CMS with the functionality necessary in the vehicle domain. It provides a two-way satellite interface between the vehicle and the Command Center. It contains an interface to the trailer data link, thus enabling it to communicate with the TDU, as well as other trailer-based systems. It provides an operator interface to the vehicle driver/passenger to allow them to observe status and control appropriate trailer functions. The Vehicle Computer incorporates the Global Positioning System (GPS) to provide tractor position information.

The Vehicle Computer (and Configuration Computer) used in CMS is based on the Configurable Transportation Security and Information Management System (CTSS) developed at Sandia National Laboratories. The CTSS product is a framework-oriented library of transportation components that software application developers can use to facilitate rapid deployment of new systems. The CTSS library was developed based on the architecture shown in Figure 6. This architecture pre-identifies software as belonging to a specific level. Software within each level only interfaces directly to software in touching layers. Hardware-dependent software, such as operating systems and compilers are associated with the platform level. Generic infrastructure and system services software such as messaging, data based management systems, and concurrency controls belong to the middleware layer. Software in the middleware layer is available in Commercial-off-the-Shelf (COTS) forms and is typically available for multiple hardware platforms. The CTSS component library comprises the framework layer. This library contains software components that are useful to applications building secure transportation systems. Example components are classes implementing trailer objects, container objects, and GPS objects. The application level is custom-written to meet the needs of a specific user community.

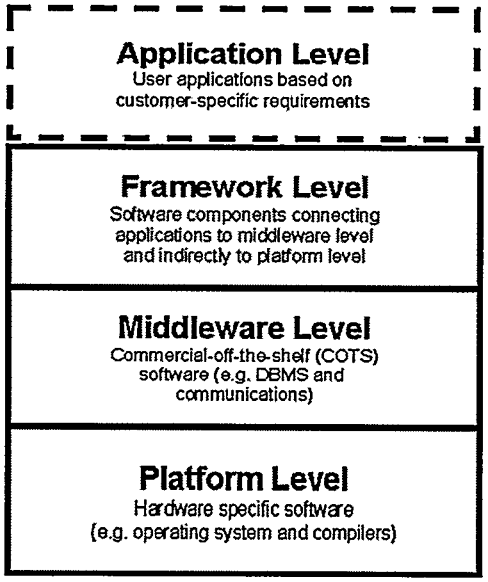

Figure 6. CTSS Architecture

The CMS Vehicle Computer uses the three lower levels already integrated by the CTSS software and adds its own custom application layer. The application layer provides an interface for a driver or passenger. A sample of this interface is shown in Figure 7.

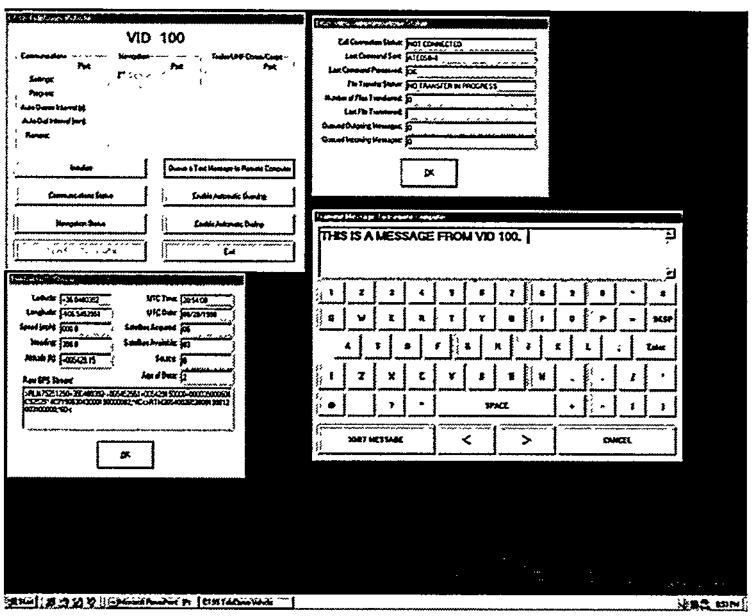

Figure 7. Sample Vehicle Interface

The vehicle computer establishes a communication path with the trailer and can accept unsolicited messages from the trailer. Should the TDU have generated a spontaneous message due to a sensor alarm condition, the trailer data link can in turn pass the message to the vehicle computer. The message information is relayed to the CTSS Command Center for analysis. The message information also can be displayed to the vehicle driver/passenger.

Command Center Domain: Command Center

The Command Center used in the CMS is a generic command center that can receive tractor/trailer/vehicle status information, track vehicle positions, and issue commands to the mobile assets. The CMS Command Center also makes use of the CTSS software library and only provides an operator interface for processing the information from the mobile assets. The interface is spatially oriented. Vehicles are super-imposed as icons on a map. When a sensor alarm message is received from a vehicle, the information is displayed on the command center display. Figure 8 shows an example display.

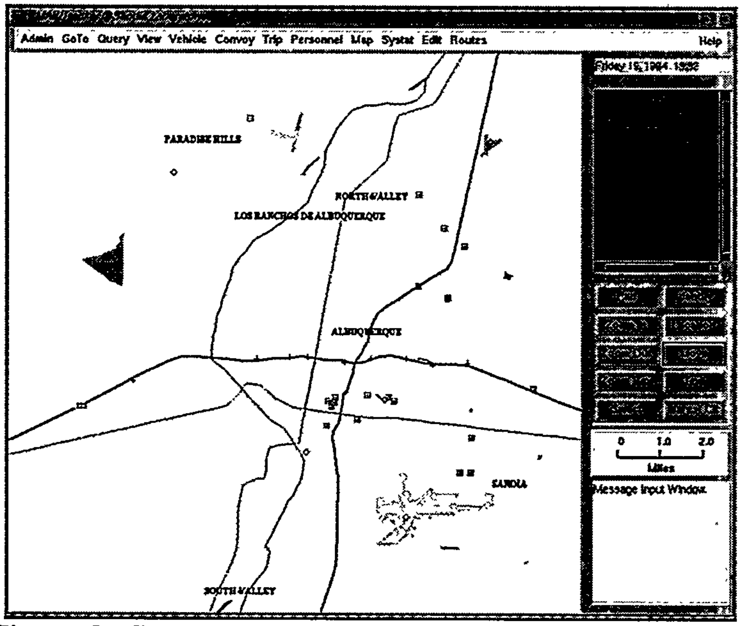

Figure 8. Sample Command Center Operator Interface

Conclusion

Sandia National Laboratories has prototyped and demonstrated a Cargo Monitoring System. Cargo Monitoring is a method to provide status on nuclear material or waste while in transit during normal and potentially, abnormal scenarios. The Cargo Monitoring System has shown that it can enhance safety and security for the transportation organization responsible for the material by keeping in constant touch with the materials' status. This information can become critically important in an accident or threat situation.

Acknowledgement

The authors would like to acknowledge the work of David G. Skogmo, Carla A. Ulibarri, and Mark H. Price, Sandia National Laboratories, for their outstanding efforts on the Cargo Monitoring System development.