# DEVELOPMENT OF THE RFID SYSTEM FOR NUCLEAR MATERIALS MANAGEMENT*

Kun Chen, Hanchung Tsai, and Yung Y. Liu
Argonne National Laboratory
9700 S Cass Ave., Argonne, IL 60439

**ABSTRACT**

Radio frequency identification (RFID) is one of today's most rapidly growing technologies in the automatic data collection industry. Although commercial applications are already widespread, the use of this technology for managing nuclear materials is only in its infancy. Employing an RFID system has the potential to offer an immense payback: enhanced safety and security, reduced need for manned surveillance, real-time access to status and event history data, and overall cost-effectiveness. The Packaging Certification Program (PCP) in the U.S. Department of Energy's (DOE's) Office of Environmental Management (EM), Office of Packaging and Transportation (EM-63), is developing an RFID system for nuclear materials management. The system consists of battery-powered RFID tags with onboard sensors and memories, a reader network, application software, a database server and web pages. The tags monitor and record critical parameters, including the status of seals, movement of objects, and environmental conditions of the nuclear material packages in real time. They also provide instant warnings or alarms when preset thresholds for the sensors are exceeded. The information collected by the readers is transmitted to a dedicated central database server that can be accessed by authorized users across the DOE complex via a secured network. The onboard memory of the tags allows the materials manifest and event history data to reside with the packages throughout their life cycles in storage, transportation, and disposal. Data security is currently based on Advanced Encryption Standard-256. The software provides easy-to-use graphical interfaces that allow access to all vital information once the security and privilege requirements are met. An innovative scheme has been developed for managing batteries in service for more than 10 years without needing to be changed. A miniature onboard dosimeter is being developed for applications that require radiation surveillance. A field demonstration of the RFID system was recently conducted to assess its performance. The preliminary results of the demonstration are reported in this paper.

## INTRODUCTION

RFID technology allows objects to be automatically identified by means of radio waves.[1-4] An RFID system generally consists of tags and readers. The tags are attached to the objects to be identified, and the reader communicates with the tags through radio waves. In contrast to traditional bar code technology, the RFID tags can operate at a significant distance away from the reader and need not be in the line of sight. The RFID technology is being widely adopted in enterprise supply chain management to improve the efficiency of inventory tracking and management. Other applications include airport luggage security, passport identification, toll collection, and animal identification.[5-8]

Since 2006, EM-63's PCP has been developing an RFID system for tracking nuclear material packaging during storage, transportation, and disoposal.[9-10] Customized RFID tags (Mk-1) have been developed for several nuclear material packages, such as Models 9975, 9977, and ES-3100, the designs of which have been certified by DOE and the Nuclear Regulatory Commission for transporting Type B radioactive materials. The following sections of this paper provide brief descriptions of the salient features of the Mk-1 tags, readers, and packaging tracking system and highlights of a recent field demonstration (DEMO) of the packaging RFID tracking system during transportation and storage.

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## Mk-1 TAGS AND READERS

The form factor of the Mk-1 tags is designed to be universal for drum-type packaging, so that only the supporting back plate and seal sensor need to be customized for bolt attachments. Figure 1 shows the Mk-1 tags bolted to the Model 9975, 9977, and ES-3100 packaging. Figure 2 shows the interior of the Mk-1 tag with the back plate removed. The electronic core is in the middle compartment that includes the seal sensor board. The batteries and the battery management board are on the left, and the right compartment provides an expansion space for additional sensor development in the future.


Figure 1. Mk-1 tags bolted to Model 9975, 9977, and ES-3100 packaging.

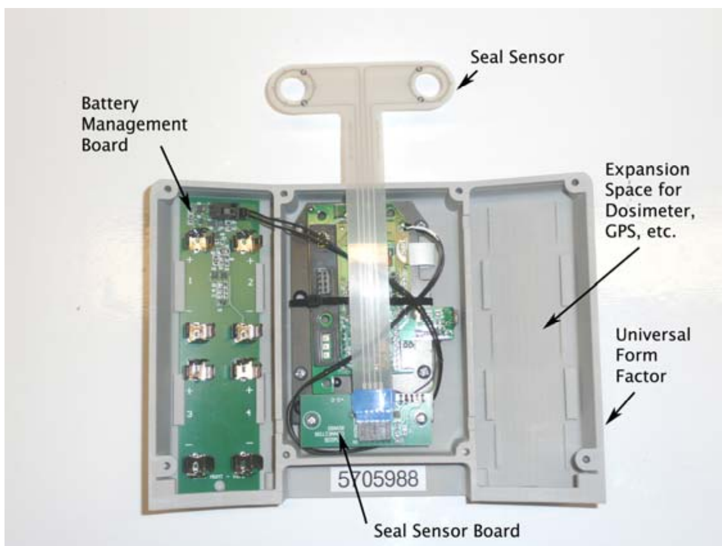


Figure 2. Interior of the Mk-1 tag.

The MK-1 tag is equipped with multiple sensors for seal integrity, temperature, humidity, shock, and battery status. The seal sensor is located under one or two of the seal bolts of the drum cover. When the bolt is loosened, the change of force and electrical resistance of the sensor trigger an alarm.[10] The alarm is broadcasted to the readers within range. The environmental sensors include those that react to temperature, humidity, and shock. The shock sensor, when set for high sensitivity, could also be used for motion detection. A radiation dosimeter is being developed and integrated into the tag. An earlier study[10] shows that in a radiation field of 200 mR/h, the electronic core of the tag can survive for more than 17 years. With four A-size Li-$SOCl_2$ batteries and smart battery management circuitry, the tag may be operated for more than 10 years without requiring a battery change.

The reader can be installed inside a truck trailer or storage facility to monitor the tags. The reader communicates with the tags through ultra-high-frequency (UHF, 433.9 MHz) radio waves. When the UHF is used, the range of transmission is up to ≈100 meters. For a large storage facility with thousands of drums, multiple readers can be deployed. The 433.9-MHz reader works well with metal objects. Low frequency (LF, 123–132 kHz) communication is also available for applications that require a limited range of communication, such as portal monitors.

## PACKAGING TRACKING SYSTEM

A simple combination of RFID tags and readers is not sufficient to meet the requirements for managing nuclear materials. A tracking system is needed to follow the complete life cycle of the packaging, starting from initial loading, through possibly multiple transports and temporary storage at different sites, to a long-term storage and/or disposal site. All the information collected in the life cycle of the packaging, either by RFID or other means, is stored in a central data repository. The data need to be presented in a format that is suitable for quick retrieval and analysis by authorized users from remote locations and that affords a high degree of information security. Figure 3 shows a conceptual framework for the packaging RFID tracking system. Although the tracking system is still being developed, its capability and potential have already been demonstrated in the field demonstration, which is discussed in the next section.

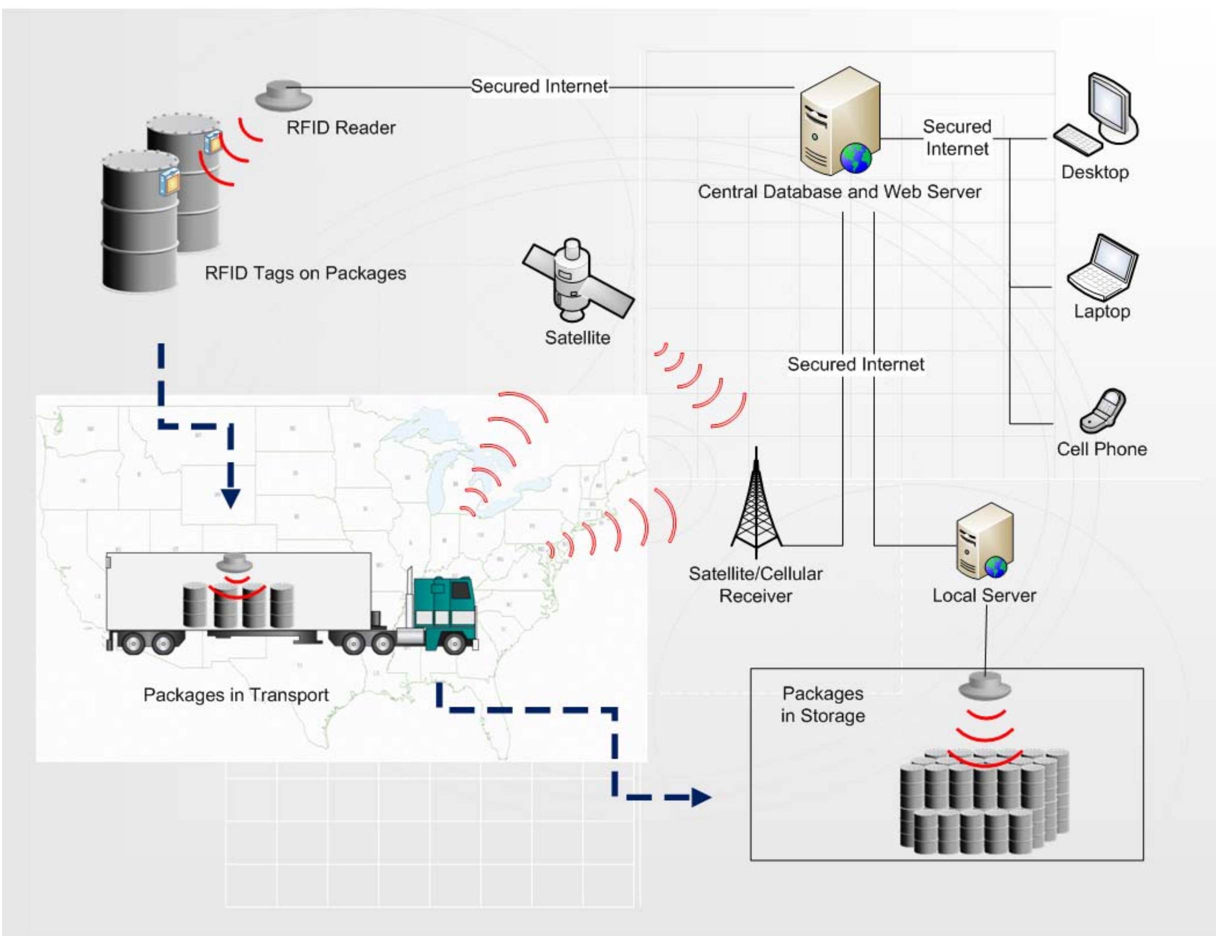


Figure 3. Conceptual framework of packaging RFID tracking system during storage and transportation.

As illustrated in Figure 3, information on each individual package is collected and stored in the memory of a tag attached to the package. The information from multiple tags is transmitted to a reader through radio waves. The reader is connected to a computer via an Ethernet cable. At a storage site, the computer could be a local server that manages multiple readers and stores the information on the packages on that site. The local servers at different storage sites can transmit information to a central database server via secured Internet. For vehicle transportation, the computer could be a streamlined tablet equipped with a global positioning system (GPS). Package and vehicle location information is sent from the tablet computer to the central database server via cellular network and/or satellites. The data are encrypted in transit. The central database server is a dedicated server located in a secured area, with a backup server at an independent location. An SQL server is used for database management, and routine utility checks are performed to assure data integrity. Backups are periodically made for reliable, long-term archive.

The central database server provides remote access to authorized users via secured Internet. Figure 4 is a screen shot of part of a web page that shows the packaging RFID tracking system in a hypothetical storage application. The U.S. map in the upper right pane displays storage sites, which are accessible by moving the cursor or clicking on the dropdown box (the location shown is Argonne Building 212). The site map of this building is in the upper left pane; it models the storage building configuration. The overhead view of Site, Zone 1, in the lower left pane shows the packages, which are grouped into three clusters for storage. The packages can be stacked in storage, as shown in the lower right pane of Figure 4. By moving the cursor to the

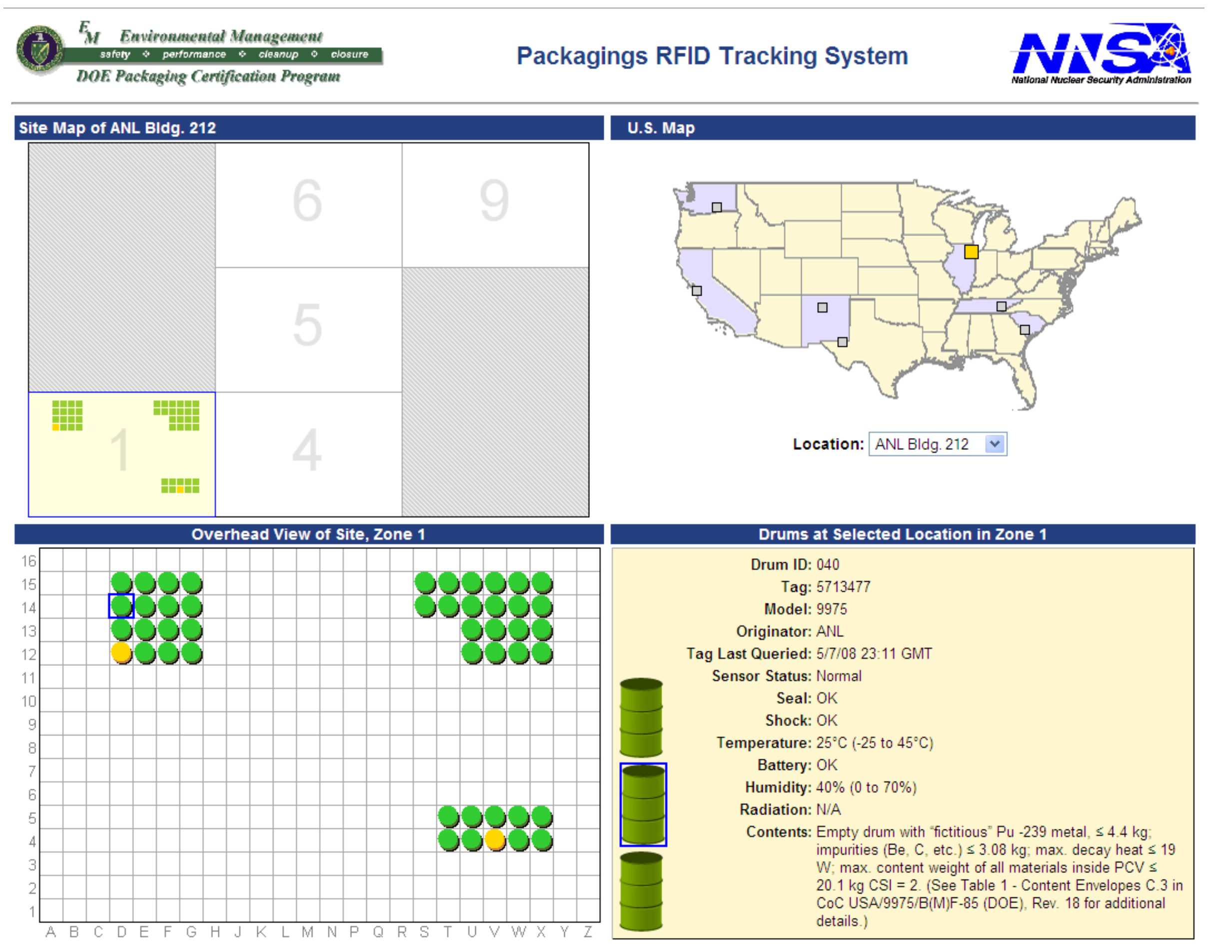


Figure 4. Web page showing packages in storage.

middle of the stack, the individual package (Drum ID 040) can be selected, and all vital information on it (e.g., ID, model, sensor status, and contents) will be instantly displayed.

The other portion of the web page not shown in Fig. 4 contains features that provide summaries of event histories (e.g., handling and alarms), as well as detailed reports of packages by site and across the DOE complex. Another important functionality embedded in the web page is the capability to search packaging by a singular criterion and/or a combination of criteria (e.g., drum ID, model, temperature). This search capability should prove very useful for designing a statistically based sampling strategy that involves thousands of packages in a materials surveillance program at large storage sites.

**FIELD DEMO**

A field demonstration was recently conducted to assess the performance of the packaging RFID tracking system during transportation and storage. The demo was jointly supported by EM-63, the National Nuclear Security Administration (NNSA), Savannah River National Laboratory (SRNL), and Oak Ridge National Laboratory (ORNL). Fourteen empty drums (five model 9975s, five model 9977s, and four model ES-3100s, each fitted with an Mk-1 RFID tag and banded onto three pallets) are shown to be ready for loading into a tractor-trailer (Figure 5). An RFID reader was installed inside the trailer under the ceiling and above the pallets of drums. The reader is connected by cables to other equipment (e.g., computer, GPS antenna, cellular/satellite modem) operated by a test engineer in the cab. A chase vehicle was also employed in the demo as a mobile command center, and the entire operation was supported by network and security staff at the home base of Argonne National Laboratory.

Figure 5. DEMO packages (Model ES-3100, 9977, and 9975) fitted with RFID tags on pallets waiting to be loaded onto the tractor-trailer.

The demo was conducted during the week of April 21, 2008. It consisted of three segments:

- Transport demo from Argonne to SRNL (April 21 and 22), followed by a storage demo at SRNL (April 23 a.m.);
- Transport demo from SRNL to ORNL (April 23 p.m.), followed by a storage demo at ORNL (April 24 a.m.); and
- Transport demo from ORNL to Argonne (April 24 and 25), followed by a storage demo at Argonne (April 25 p.m.).

Remote access via secured Internet was provided to more than 50 observers (with a user ID and password) across the country so that they could follow the demo in real time during transportation and storage. A web page for transportation was developed, showing the tractor-trailer and an overhead view of the packages in the trailer, similar to those displayed in the panes of Figure 4. The transportation web page is linked to a Google map so that the physical location of the tractor-trailer can also be displayed in nearly real time.

The demo lasted 5 days, and the packaging RFID tracking system performed reliably except early in the demo when the power cable between the tractor and trailer had intermittent connection issues. The built-in sensors in the Mk-1 tags — notably those for the seal, shock, and humidity — were triggered in more than three dozen "staged" and unplanned incidents over the entire duration of the demo. These incidents demonstrated the ability of the RFID tracking system to monitor violations and promptly send alarm notifications (emails, text messages, etc.). In all cases, the sensors performed as expected. A detailed analysis of the sensor performance and alarm events will be provided in a topical report.

There were four staged incidents during the transportation segments of the demo. The nature of these incidents (i.e., seal or shock sensor violations) and their locations are shown in Figure 6. The seal violations were produced by loosening the drum bolts, and the shock violations were produced by a hand tap. Within 10 minutes after each staged incident, notifications were sent to designated recipients with an attached geographic information system (GIS) spatial query report covering a 10-mile buffer zone around the incident.

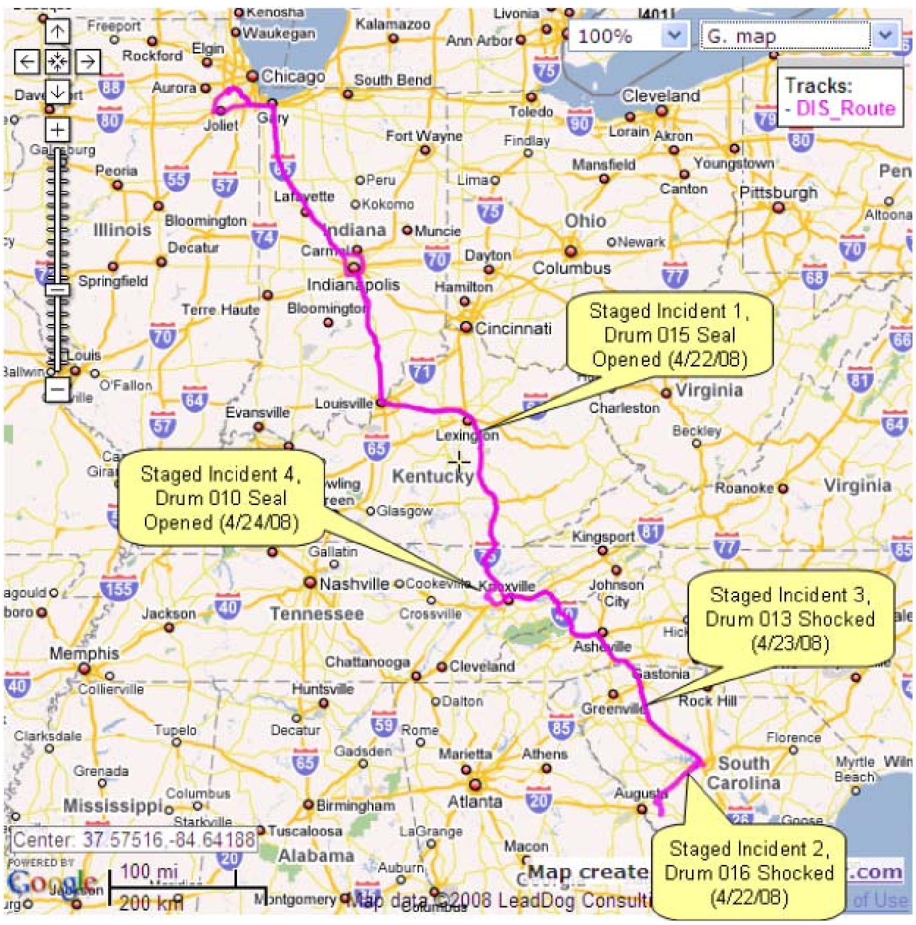


Figure 6. DEMO route showing the locations and nature of the four staged incidents. The route is plotted by using the actual GPS latitude/longitude data collected during the demo.

A typical GIS buffer-zone report contains contact information (address and phone numbers) for local police stations, fire stations, hospitals, etc., that is useful to first responders and emergency management personnel. The notifications and the GIS reports were sent from the mobile command center in the chase vehicle during the transportation demo; this operation will be automated in the future at the central database server at Argonne that can generate and deliver relevant GIS reports within a critical time window, especially after a major transportation accident.

## CONCLUSIONS AND FUTURE ACTIVITIES

The PCP of EM-63 has developed a packaging RFID tracking system for managing nuclear materials. A field demo of the tracking system during transportation and storage was recently successfully completed. Although the RFID tracking system is still being developed, it has demonstrated its potential for enhancing safety, safeguards, and security; reducing the need for manned surveillance; providing real-time access to status and event history data; and providing overall cost effectiveness. In the near future, the PCP plans to pursue implementation projects at DOE sites that will take advantage of the packaging RFID tracking system. Two implementation projects under consideration involve the use of the RFID Mk-1 tags and the development of a technical basis and method for temporarily storing Type B transportation packaging beyond 1 year without performing the required annual-maintenance leakage tests.

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