

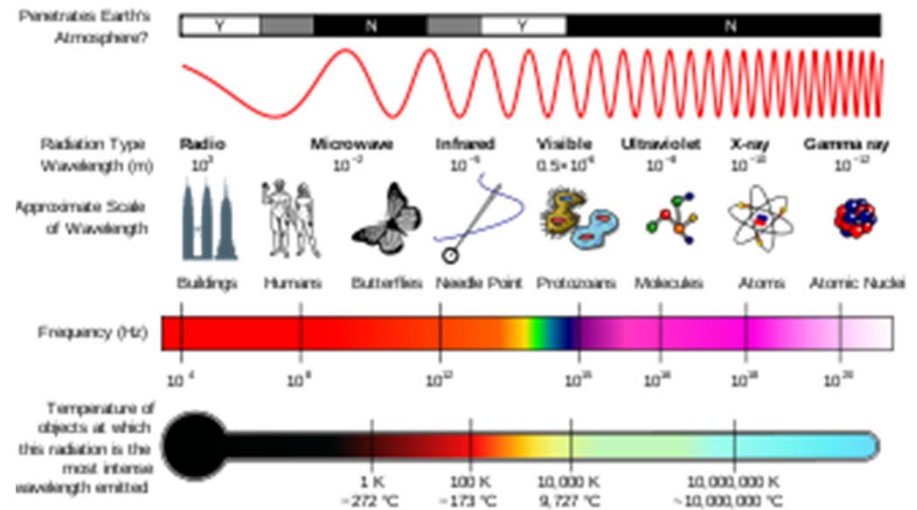
# Monitoring

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INMM Spent Fuel Seminar

Washington, DC

January 31- February 2, 2012



Work supported by Office of Packaging & Transportation  
and Used Fuel Disposition Campaign R&D



**EM Environmental Management**  
safety ✦ performance ✦ cleanup ✦ closure  
**DOE Packaging Certification Program**



U.S. DEPARTMENT OF  
**ENERGY**

# Monitoring Nuclear Fuel Cycle



# Annual Mass Flow for LWR

Drums



Uranium Ore

170 tons



Enrichment

150 tons

Depleted Uranium

Cylinders



20 tons  
1000 MWe  
LWR



Used Uranium Reserve

18.73 tons U

0.25 tons Pu

1.00 tons F.P.  
0.02 tons M.A.



Reprocessing

18.73 tons Uranium  
1.00 tons Fission Products  
0.25 tons Plutonium  
0.02 tons Minor Actinides

Transport Casks & Dry Cask Storage Systems

Used Fuel Storage Spent Fuel

XXX



Disposal (100,000 years)

Disposal (100,000 years)

European recycle  
- Saves 15% uranium  
- But no reduction in waste life

Direct disposal is the current U.S. policy

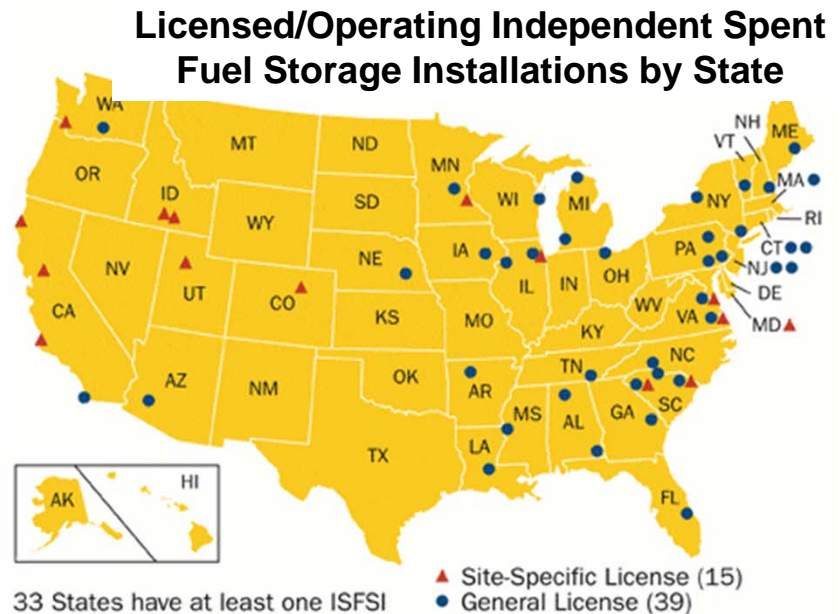


*Monitor what, where, when, how?*

# Dry Cask Storage of Used Fuel — NOAA weather monitoring



**Pool to Dry Cask  
since 1986  
≈1,400 in 2011**



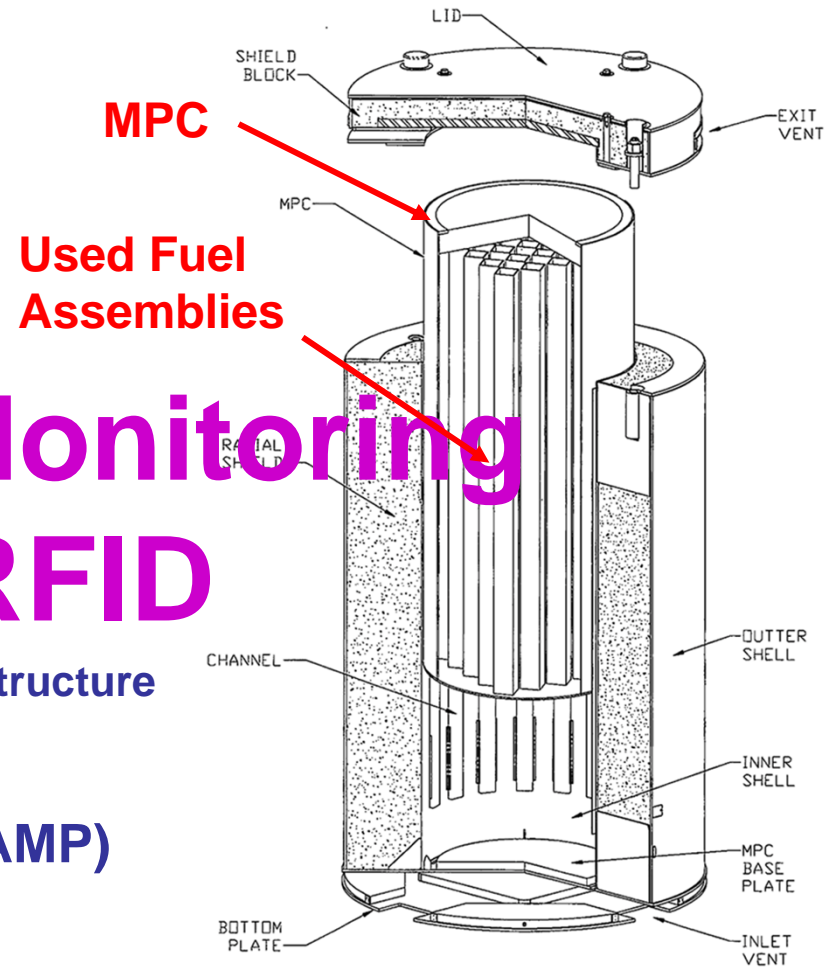
**10 CFR 72 and 73; NUREG-1927**

# Extended Long-Term Storage — Safe and Secure



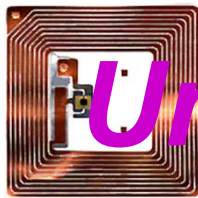
## Remote Monitoring by RFID

- Environmental degradation of structure system and component in dry casks
- Aging Management Program (AMP) for safe operation & license renewal
- Conditions and Performance Monitoring are key elements in AMP



# What is Radio Frequency Identification (RFID)?

- Tags: collect and send signals autonomously or when prompted



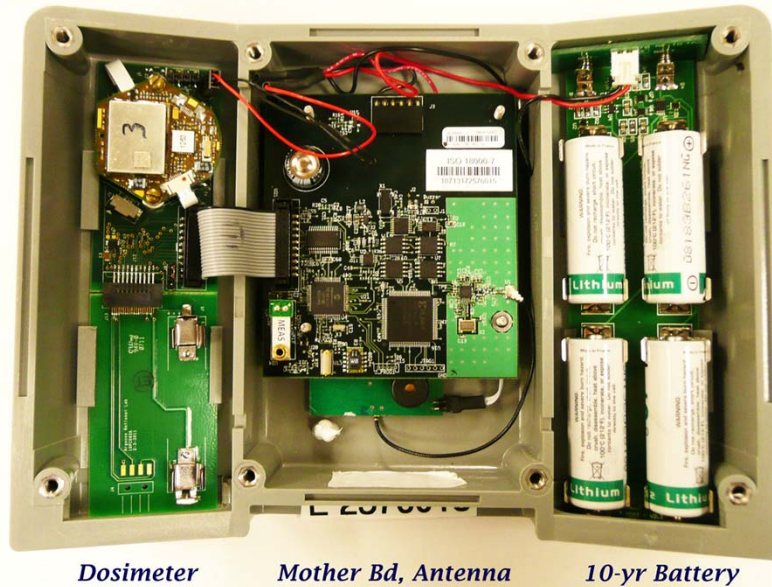
*Unique ID, Wireless  
Location and Event Specific  
Time Stamp, State of Health*

- Readers: communicate with tags and receive signals



- Application software: process data into information for action

# ARG-US RFID Surveillance Tags (patented)



- Flexible form factor
- Expandable sensor suite (seal, shock, temperature, humidity, radiation, battery status, etc. (e.g., salinity, hydrogen))
- Long-life batteries >10 yr
- Good radiation resistance (>17 yr at 200 mR/h); further radiation hardening of electronics possible

# Web-based ARG-US Platforms

## Storage

**Environmental Management**  
DOE Packaging Certification Program

**Packagings RFID Tracking System**

Site Map of ANL Bldg. 212

U.S. Map

Location: ANL Bldg. 212

Overhead View of Site, Zone 1

Drums at Selected Location in Zone 1

Drum ID: 018  
Tag: 5703193  
Model: ES3100  
Originator: Y-12/ORNL  
Tag Last Queried: 5/16/08 23:09 GMT  
Sensor Status: **Warning**  
Seal: OK  
Shock: OK  
Temperature: 21°C (-25 to 45°C)  
Battery: **Low**  
Humidity: 38% (0 to 70%)  
Radiation: N/A  
Contents: Empty drum with "fictitious" U metal and alloy cylinders, U-235 enrichment = 100 wt%, max. mass U-235 = 15 kg (with spacers). CSI = 0. (See Table 1: Loading limits for metal and alloy in solid geometric shapes in CoC USA/9315-B(U)/F-90, Rev. 7 for additional details.)

Summary Status of ANL Bldg. 212

Total drums: 96 Database updated: 5/2/08 15:55 GMT  
Alarm / No Response: 0 Page refreshed: 5/19/08 19:57 GMT  
Warning: 1 Refresh rate: 1 minute

Event History of Drum 018

Event Time (GMT)	Event
4/30/08 19:49	Arrives at ANL - Bldg. 212 - (Zone 1, W, 15, Bot)
4/30/08 19:49	Leaves location ANL - Bldg. 212 - (Zone 1, D, 1, Bot)
4/30/08 19:48	Alarm was cleared manually.
4/30/08 19:47	<b>Shock Limit Exceeded @ -10</b>
4/30/08 19:47	<b>Shock Limit Exceeded @ -10</b>
4/30/08 19:47	Arrives at ANL - Bldg. 212 - (Zone 1, D, 1, Bot)
4/18/08 14:38	Contents of the package have been entered.

Search For Drums at All Locations

Reports

Drum ID: 001  
Contents: No Radioactive Material  
Originator: ANL  
Model: 3975

Event History of All Drums  
Event History at This Location  
All Information for This Drum  
History of All Tags During Transport

Argonne NATIONAL LABORATORY SRNL

## Transport

**Environmental Management**  
DOE Packaging Certification Program

**Packagings RFID Tracking System**

Trucks in DEMO Vehicle

U.S. Map

Location: DEMO Vehicle

Overhead View of DEMO Vehicle

Drums in DEMO Vehicle

Drum ID: 070001  
Tag: 5703191  
Model: 9977  
Originator: NTS  
Tag Last Queried: 8/28/09 20:10 GMT  
Sensor Status: Normal  
Seal: OK  
Shock: OK  
Temperature: 27°C (20 to 60°C)  
Battery: OK  
Humidity: 50% (0 to 100%)  
Radiation: N/A  
Contents:

Summary Status of DEMO Vehicle

Total drums: 25 Database updated: 8/28/09 21:10 GMT  
Alarm / No Response: 0 Page refreshed: 9/09/09 17:47 GMT  
Warning: 0 Refresh rate: Manual Refresh Only

Event History of Drum 070001

Event Time (GMT)	Event
8/28/09 19:28	<b>Shock Limit Exceeded @ -9</b>
8/28/09 21:28	Arrives at ANL - Bldg. 212 - (Zone 1, U, 1, Bot)
8/28/09 21:23	Arrives at ANL - Bldg. 212 - (Zone 1, U, 1, Bot)
8/28/09 21:03	Arrives at ANL - Bldg. 212 - (Zone 1, U, 1, Bot)
8/28/09 20:32	Arrives at ANL - Bldg. 212 - (Zone 1, U, 1, Bot)
8/28/09 20:26	Arrives at ANL - Bldg. 212 - (Zone 1, G, 13, Bot)
8/28/09 19:48	Arrives at ANL - Bldg. 212 - (Zone 1, G, 11, Bot)
8/6/09 19:54	Arrives at ANL - Bldg. 212 - (Zone 1, G, 11, Bot)
8/6/09 16:35	Arrives at NTS - Bldg. 001 - (Zone 1, G, 11, Bot)

Search For Drums at All Locations

Reports

Drum ID: 001  
Contents: No Radioactive Material  
Originator: ANL  
Model: 9975

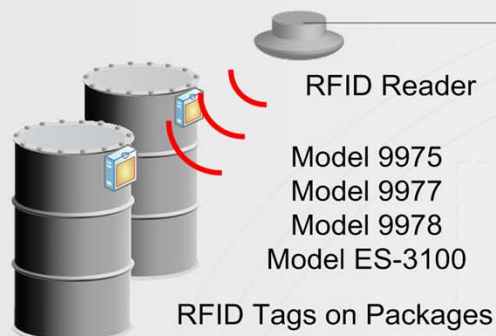
Event History of All Drums  
Event History at This Location  
All Information for This Drum  
GIS Report

Argonne NATIONAL LABORATORY

Version 0.6.3.1 Current time: Thu, 03 Sep 2009 17:50:18 GMT

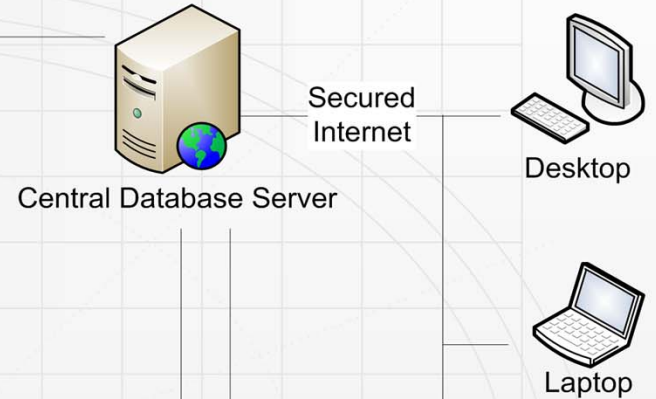


**DEMO: 4/21-25/2008, 1700 miles**



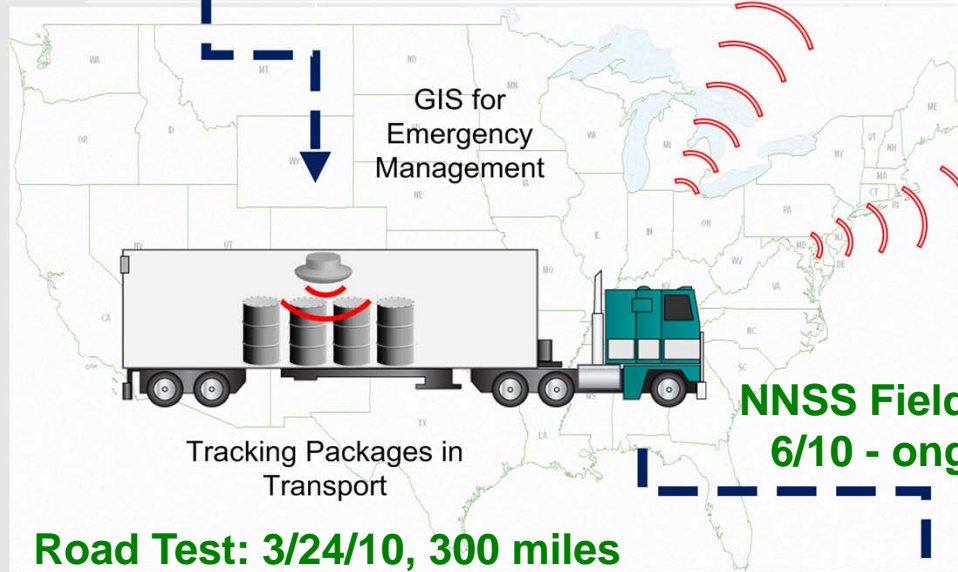
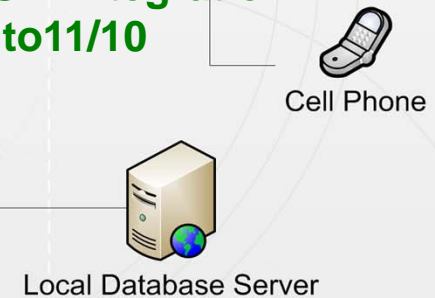
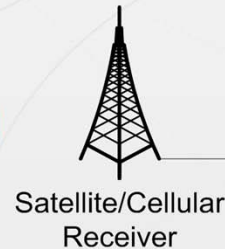
**Mini-demo: 8/27/09, 300 miles**

Secured Internet



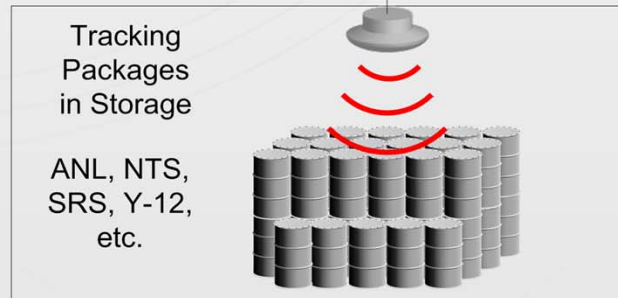
Secured Internet

**TRANSCOM Integration:  
5 to 11/10**



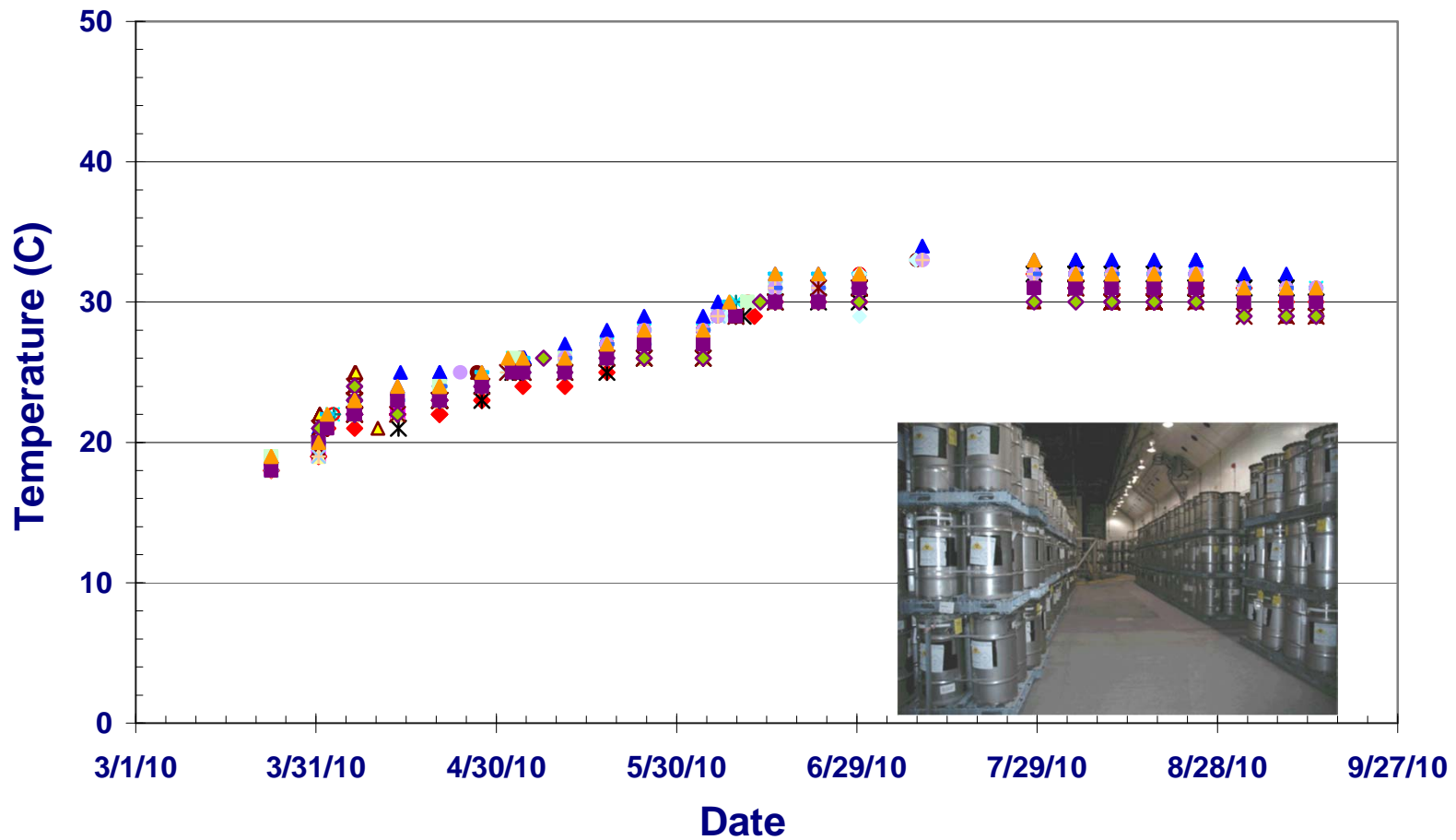
**NNSS Field Test:  
6/10 - ongoing**

**Road Test: 3/24/10, 300 miles**



**Cat-I Vault Field Test  
(Phase I): 3 to 9/10**

# ARG-US RFID Environmental Monitoring – Cat-I storage vault (temperature, humidity, shock)



Temperature history of 20 RFID tags at different vault locations

# LANL/OSRP Truck Road Test (300-mile loop in 6.5 h)

Packagings RFID Tracking System - Windows Internet Explorer

https://rfid.dis.anl.gov/pcp-test/webform1.aspx

File Edit View Favorites Tools Help

Windows Live Bing What's New Profile Mail Photos Calendar MSN Share Sign in

Packagings RFID Tracking System

**Summary Status of Big Bird**

Total drums: 10 Database updated: 3/24/10 19:28 GMT  
 Alarm / No Response: 0 Page refreshed: 3/24/10 19:31 GMT  
 Warning: 0

[Change to location Big Bird](#)

All Big Bird (T4) Drums										
Drum ID	Tag	Model	Sensor Status	Tag Last Query	Seal	Shock	Battery	Temperature	Humidity	
5714152	5714152	9977	Normal	3/24/10 19:28 GMT	OK	OK	OK	13°C (-50 to 60°C)	36% (0 to 100%)	
5714152	5714152	9977	Normal	3/24/10 19:23 GMT	OK	OK	OK	13°C (-50 to 60°C)	37% (0 to 100%)	
5714152	5714152	9977	Normal	3/24/10 19:18 GMT	OK	OK	OK	12°C (-50 to 60°C)	37% (0 to 100%)	
5714152	5714152	9977	Alarm	3/24/10 19:13 GMT	Open	OK	OK	12°C (-50 to 60°C)	38% (0 to 100%)	
5714152	5714152	9977	Alarm	3/24/10 19:08 GMT	Open	OK	OK	11°C (-50 to 60°C)	37% (0 to 100%)	
5714201	5714201	9977	Normal	3/24/10 19:28 GMT	OK	OK	OK	12°C (-50 to 60°C)	38% (0 to 100%)	
5714201	5714201	9977	Normal	3/24/10 19:23 GMT	OK	OK	OK	12°C (-50 to 60°C)	38% (0 to 100%)	
5714201	5714201	9977	Normal	3/24/10 19:18 GMT	OK	OK	OK	12°C (-50 to 60°C)	38% (0 to 100%)	

Overhead View of Big Bird | Drums in Big Bird | Drum ID: 5714152

Real-time location, time stamps of events/alarms of 10 RFID tags

# TRANSCOM post-integration road test — automatic alarm notifications

- Alarm window popped up on TRANSCOM screen  $\leq 2$  min; automatic notification of text messages sent by Argonne RFID Command Center via email or to cell phones
- Operator at Argonne RFID Command Center determined cause of alarm, issued a location- and event-specific GIS report, and cleared the alarm remotely.

The screenshot displays the TRANSCOM web application interface. On the left is a Google Maps view of the Tahoe area, with a red circle highlighting a specific location near Kankakee, IL. The main window features a 'Main Menu' with options like Shipments, Scheduler, and Campaign Schedules. A red alarm notification window is overlaid on the right, displaying the following information:

- RFID Tag: 5714225 on Shipment RFID102510-1
- ALARM DETECTED
- 10/27/2010 10:06
- Near Lat -87.867500 Lon: 41.078056
- 3.6 Mi S of Kankakee, IL

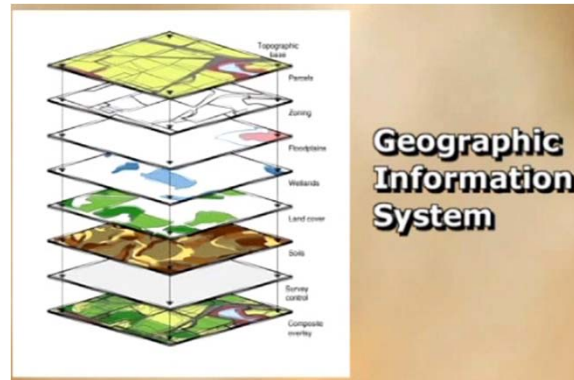
Buttons for 'Acknowledge', 'Visit RFID Site', and 'Defer' are visible at the bottom of the alarm window. Below the main window, there is an 'Overhead View of Tahoe' showing a grid and a diagram of a train car with a red dot indicating the alarm location. To the right of the overhead view is a 'Drums in Tahoe' panel with the following details:

- Drum ID: 5714225
- Tag: 5714225
- Model:
- Originator:
- Tag Last Queried: 10/27/10 16:09 GMT
- Sensor Status: **Alarm**
- Seal: **Open**
- Shock: OK
- Temperature: 20°C (-20 to 60°C)
- Battery: OK
- Humidity: 37% (0 to 100%)
- Radiation: N/A
- Contents:

EMS Facilities within 10 Miles of Tahoe (41.0784,-87.8676)  
(As of 10/27/10 16:13 GMT)

# Pilot RFID Command Center at Argonne – *Information for Action*

## Platform/protocol development



## Training/certification Operational Support



# Adaptation of RFID for Monitoring Dry Casks\*

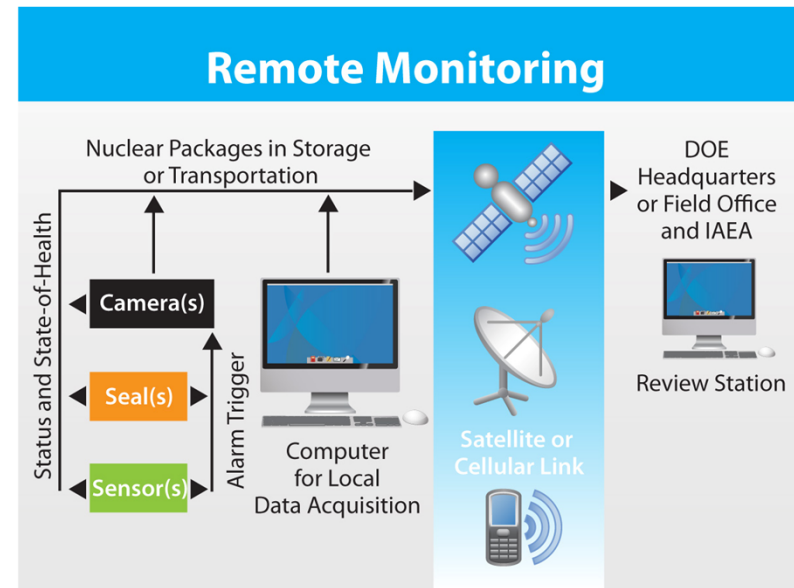
- Major challenges are the ability to monitor
  - Integrity of helium cover-gas in canister/cask
  - Absence of massive cladding breaches
  
- Near-term R&D
  - Monitor exterior conditions of canister with existing technologies (e.g., ultrasound, infrared, RF)
  
- Long-term R&D
  - Monitor interior conditions of canister/cask with
    - *Advanced sensors operable in harsh environment*
    - *Energy harvesting for extended long-term operation*
    - *Through-wall signal transmission*

***\*EPRI ESCP is pursuing dry cask monitoring with TransNuclear and Constellation at Calvert Cliffs (NUHOMS) in 2012.***

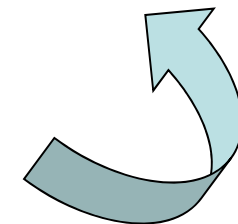
# Advanced Wireless Communication

- **Wireless Sensor Network (WSN)**
  - Wireless mesh network (IEEE 802.15.4)

*Argonne RFID Command Center as testbed for prototype*



- **Integration with existing ISFSI surveillance systems (e.g., video cameras, motion detection, etc.)**



# Quotes from BRC Final Report

- Executive Summary, “... *global issues of nuclear safety, non-proliferation, and security.*”
- P.44, “Specifically we urge continued work by NRC, DOE, industry ...to explore fuel degradation mechanisms, ...*better understand of the behavior of dry storage systems and their contents over time, investigating the feasibility of enhancing instrumentation in existing dry and wet storage systems*, and promote the standardization of cask designs.”
- P. 84, “With regard to transportation security, the NRC has existing security regulations...is currently undertaking a separate rulemaking to codify further transportation security requirements. The proposed protective strategy for transportation includes
  - Advanced planning ...
  - Increased notifications ..
  - *Continuous and active shipment monitoring*
  - Use of armed escorts ...
  - Background investigations of personnel ...
- P.89, “More generally, the primary regulatory challenge for storage facilities ... *remains ensuring their performance over extended periods of time* ... **ISSUES AND CHALLENGES IN REGULATING STORAGE AND TRANSPORTION**”



# Summary

- **RFID is an enabling technology for remote monitoring of DCSSs at ISFSIs**
  - Sensors are key for continual/real-time conditions and performance monitoring
- **Challenges are to monitor interior conditions of dry casks**
  - Canister integrity
  - Cladding integrity
- **ARG-US RFID technology can be leveraged/adapted for in-cask/in-canister monitoring, and for spent fuel pool instrumentation, hardened vents**
  - Temperature, humidity, seal integrity, shock, radiation, hydrogen
  - Integration with existing ISFSI security surveillance systems
- **ARG-US RFID technology can be leveraged/adapted for used fuel transportation security and safeguards applications**
  - Near real-time tracking and monitoring
  - Fully integrated with DOE TRANSCOM

# Acknowledgment

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<http://rampac.energy.gov/RFID/RFID.htm>

<http://www.dis.anl.gov>

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