# Safety and Security Technologies for Radioactive Material Shipments

Prepared for
U.S. Department of Energy

Prepared by
Level VI Program
Ad Hoc RAM/Security/ITS Committee
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March 2011

# Background

In 2005, the U.S. Department of Energy (DOE) approached the Commercial Vehicle Safety Alliance (CVSA), Radioactive Material (RAM) Subcommittee and asked the committee to conduct a study on technologies that would benefit the safety, security, inspection, and tracking of DOE radioactive material shipments. Emphasis was placed on the transportation of Spent Nuclear Fuel (SNF) that would eventually be transported to Yucca Mountain, Nevada for permanent disposal. DOE offered grant funding from the Office of Civilian Radioactive Waste Management (OCRWM) to complete the study. CVSA entered into an agreement with DOE to complete the study. An Ad Hoc committee was formed with members of the RAM Subcommittee, Transportation Security Committee, and Intelligent Transportation Systems (ITS) Committee. The Chair of the Ad Hoc Committee was Lieutenant Bruce Kynaston from the California Highway Patrol. Captain Bill Reese from the Idaho State Police was the Co-Chair. In September 2007, Lieutenant Kynaston resigned as the Chair due to a job assignment change. Captain Reese took over as the Ad Hoc Committee Chair at that time.

In early 2009, CVSA was informed by OCRWM that the funding for the Ad Hoc Committee work was being cut and funding would not continue past September 30, 2009. Effective October 1, 2009, the committee received funding from the DOE Office of Environmental Management through the Waste Isolation Pilot Project (WIPP) to continue the work of the Ad Hoc Committee and finish the report on technologies.

The members of the committee made several site visits to look at current and emerging technologies. The site visits included:

- California Highway Patrol Port of Entry at the Mexican Border South of San Diego. The Adaptable Radiation Area Monitor (ARAM) system was observed. ARAM is a portal radiation monitoring system used at fixed facilities. All commercial vehicles entering the port travel through the ARAM.
- At the port of entry in California a demonstration on Zonar, a vehicle information reporting system, using radio frequency identification (RFID) technology was observed. The system had some applicability for vehicle inspections, primarily pre-trip and post-trip inspections by drivers.
- Qualcomm Systems facility in San Diego. Multiple types of satellite technology were observed. These technologies included: satellite vehicle tracking, untethered trailer tracking, driver panic buttons, vehicle disabling technology, and driver sign on theft prevention technology.
- Tri-State Motor Transit's main terminal in Joplin, Missouri. Tri-State is one of the largest shippers of radioactive material and explosives in the country. When the committee visited their terminal they were using Qualcomm systems to track their trucks with satellite technology. They also used PC*MILER|FleetCommander to merge multiple technologies into one platform/database for ease of use. PC*MILER|FleetCommander is a sophisticated fleet tracking and optimization software system designed to reduce operating expenses, leverage powerful real-time fleet visibility and reporting

tools, and improve customer service capabilities. The system converts raw data from transportation management and mobile communications systems into real-time business critical information. Tri-State also used a trailer tracking technology called SkyBitz, which is passive satellite based tracking technology used on trailers. SkyBitz's secure InSight web application includes detailed street level mapping for all of North America and provides total fleet visibility with a variety of standard reports that can be downloaded for import into spreadsheet programs like Microsoft Excel.

In December of 2006, Chairman Reese attended a Hazardous Materials Cooperative Research Program (HMCRP) Oversight Panel Meeting in Washington, D.C. During the meeting four new HMCRP projects were selected. One of the projects was HM-04: *Emerging Technologies Applicable to the Safe and Secure Transportation of Hazardous Materials*. This project, when completed, was going to have broad applicability to the study the Ad Hoc Committee was conducting for CVSA.

In March 2008, the Ad Hoc Committee met in Denver. At this meeting there were presentations on several different types of applicable technologies. These technologies included:

- Hazmat Safety and Security Technology Field Operational Test (FOT)
- Commercially Available Hazmat Technologies Developed for the Hazmat FOT
- Wireless Technology, Commercial Vehicle Safety & Security
- TRANSCOM Tracking and Communications System
- IRRIS Systems
- Hazardous Materials Cooperative Research Program-Project HM-04
- Overview of the Domestic Nuclear Detection Office's Southeast Transportation Corridor Pilot Program
- Review of future Credential Programs
- Security in the Transportation Phase

During the initial phases of this project the Ad Hoc Committee discovered several other programs, committees, and/or stakeholder groups that were also working on similar studies or considering similar studies. The Ad Hoc Committee reached out to these groups in an effort to streamline the process for everyone and to help avoid duplication of effort.

The Ad Hoc Committee also realized during this timeframe that it had embarked on a difficult and rapidly changing study. The technologies of interest were very broad and constantly changing. It was determined that the best approach was to wait for the HMCRP HM-04 project to be completed. The HM-04 project was focusing on short-term and long-term technologies. Committee members agreed that the results of the project would answer most of the questions and provide much of the information needed to give recommendations to the DOE.

# Recent Activity

In September 2010, the Ad Hoc Committee received a draft copy of the HM-04 project report titled *Emerging Technologies Applicable to Hazardous Materials Transportation Safety and Security* and members met to review this report. The report has the emerging technologies broken down into nine broad categories:

1. **Networked RFID/ubiquitous sensors and cargo monitoring** which include sensor systems tied into a central monitoring site.

2. **Pressure gauges and chemical detection sensors** that can detect pressure changes and chemical releases accurately and with minimal false alarms.

3. **Fiber-optic/photonic sensors & optical scanners** that use light to carry information for cargo monitoring.

4. **Advanced locks and seals** with sophisticated features like encryption that are difficult to defeat and which can be remotely monitored for status, identification, and intrusion.

5. **Intelligent video tracking & surveillance** with the ability to capture the image of a specific vehicle and handing off this image from one linked camera to another so that its route is tracked.

6. **Wireless power** to transfer energy without wires for those situations where power is needed but connecting wires are inconvenient, hazardous, or impossible.

7. **Nanopiezoelectronics** to generate electricity at the nanometer scale by applying mechanical stress on a nanopiezoelectronic device**.**

8. **Plastic thin-film organic solar cells** that can be molded into a variety of shapes to occupy space that would not be possible for current, conventional solar cells. They operate with flexible polymer batteries.

9. **Container integrity** improvements such as specialty and treated steels, engineered metal structures, composites/fiber-reinforced plastics, insulation and thermal protection, armor and self-sealing technologies, and impact resistant coatings and fittings.

Five members of the Committee were each assigned one or two of the emerging technology categories to review and evaluate. The Ad Hoc Committee also decided to organize their results into five technology application areas that are of importance to the safety and security of radioactive material shipments by motor carriers. These five areas are:

1. **Inspection Technologies**. These include technologies that will assist the roadside inspector with Level VI inspections. These technologies also can be used by the drivers to complete pre-trip and post-trip inspections. There may also be some applications for technologies that could assist with or take the place of en route inspections.

2. **Security Technologies**. These include technologies that make the driver, shipping cask, tractor, and trailer more secure. Some of these technologies overlap into the tracking technologies (Area #4).

3. **Radioactive Material Dose Rate Measurement and Isotope Quantification Technologies**. These include portal monitors at fixed sites and other technology that can be used to check the dose rate or verify the isotopes in a package.

4. **Shipment and Tracking Technologies (tractor, trailer, and individual package)**. These include primary and secondary technologies that are used to track the tractor, trailer, and/or individual package.

5. **Electronic Shipping Paper Technologies**. This is an emerging area that is garnishing a lot of attention. Accessibility of shipping documents remotely by inspectors, regulatory personnel, and emergency responders is the focus.

# Results

## Current Technologies

The Ad Hoc Committee reviewed current technologies from the site visits, presentations from the March 2008 Committee meeting and literature obtained for various products. From these reviews the technology areas considered important to the safety and security of radioactive material shipments are:

- **Detection Technologies**
  Detection technologies include devices that detect, identify and quantify radioisotopes. They also include devices that detect changes in environmental conditions such as temperature or humidity. They can be stationary, mobile or attached and can report status in real time via wireless communications. These technologies are applicable to inspection and security of a shipment as they provide current information on the contents and status of the cargo.

- **Authentication and Vehicle Disabling Technologies**
  Authentication technologies include biometrics (e.g., fingerprint or signature), smart credentials, and keyless starter system for driver verification and theft protection. Vehicle disabling technologies include panic button and accelerator and fuel control (activated locally or remotely). These technologies are applicable to the security of shipments.

- **Tracking and Communications Technologies**
  Tracking and communications technologies are satellite (e.g., GPS) and other wireless-based devices for directing, following, and locating truck, trailer, and container; geofencing; and real time mapping of road conditions and points of interest (e.g., traffic; location of nearby safe parking, law enforcement and emergency response agencies). Communications between vehicle and authorized remote user systems provide current status and enable response based on situation (e.g., vehicle off route, emergency, etc.). These technologies are relevant to the security and tracking of shipments.

- **Electronic Vehicle Information Technologies**
  Electronic vehicle information technologies are tags, seals, locks and memory devices that record information about the vehicle and cargo. They may employ RFID to monitor, enter, update and retrieve information. Information that is typically stored includes manifest, shipping papers, pre- and post-trip inspection data and cargo condition. These devices can also be applied to provide a continuous measurement of container integrity, container security, and tracking of the container with the trailer. These technologies are applicable to the inspection, security, tracking and electronic shipping papers technology application areas.

Table 1 summarizes the results of the reviews of the current technology categories. It indicates which of the current technology categories are useful in each of the five areas associated with the safety and security of radioactive material shipments: inspection, security, dose measurement and isotope quantification, shipping and tracking, and electronic shipping papers.

**Table 1. Current Technology Categories Relevant to Radioactive Materials Shipment Technology Application Areas**

| Current Technology Category | RAM Shipment Technology Application Area | | | | |
|---|---|---|---|---|---|
| | Inspection | Security | RAM Measurement | Shipment/ Tracking | Electronic Shipping Papers |
| Detection Technologies | X | X | X | | |
| Authentication & Vehicle Disabling Technologies | | X | | | |
| Tracking & Communications Technologies | | X | | X | |
| Electronic Vehicle Information Technologies | X | X | | X | X |

## Emerging Technologies

The Ad Hoc Committee members reviewed the nine emerging technology categories of the HM-04 project report with respect to the five technology application areas important to the safety and security of radioactive material shipments. Besides applicability to radioactive material shipments they also considered the state of technology development, availability, reliability, and cost. The results of their evaluations by emerging technology category are:

1. **Networked RFID/ubiquitous sensors and cargo monitoring.**
   This technology is currently available and is being improved upon in the short term. It is simple technology and can be used for shipment tracking and security purposes. This technology usually relies on wireless technology and/or RFID readers at fixed locations so it is not as reliable as satellite technology. However, this technology can be used with satellite technology. In that case, it would be very reliable. It would be a good back up tracking and security system or a primary system if used with satellite technology. Driver information could also be placed on the sensors for security. It is an inexpensive technology when compared to other technologies, and has some potential in the inspection and electronic shipping paper categories.

2. **Pressure gauges and chemical detection sensors.**
   This technology is currently available and also is being researched and developed for expanded use in the long term. It has applicability as a security technology, radioactive material dose rate measurement technology, and limited applicability for inspection technologies. The ability to remotely monitor the radiation levels of shipments would be very beneficial to stakeholders along the shipping routes. This technology is relatively new and they are still working out some of the problems. It does have low to moderate cost with some availability in the short term and additional availability in 6 to 10 years.

3. **Fiber-optic/photonic sensors & optical scanners.**
   Fiber-optic communication systems generally include an optical transmitter to convert an electrical signal into an optical signal to send into the optical fiber, a cable containing bundles of multiple optical fibers that is routed through underground conduits and buildings, multiple kinds of amplifiers, and an optical receiver to recover the signal as an electrical signal. This technology has been used for decades and would presumably be the least expensive. Photonics covers all technical applications of light over the whole spectrum from ultraviolet over the visible to the near-, mid- and far-infrared. Most applications, however, are in the range of the visible and near-infrared light. Fiber-optics is a form of photonics. Optical scanners use photonic (fiber optic) technology to process data. Data placed into a bar code can be read using optical scanner devices. This technology has low to moderate cost and has potential applicability in the security and tracking areas and limited applicability in the inspection and electronic shipping paper categories.

4. **Advanced locks and seals.**
   RFID uses communication via electromagnetic waves to exchange data between a terminal and an object such as a product, for the purpose of identification and tracking. Some tags can be read from several meters away and beyond the line of sight of the reader. These features are useful for inspection applications as well as for shipping and tracking. A locking fiber optic seal provides a security "tag" that can be placed on a package, vehicle, or any combination using the photonic or RFID technologies thus providing protection from tampering or intrusion. This technology has low to moderate cost and potential applicability in the security, tracking, and inspection areas.

5. **Intelligent video tracking & surveillance.**
   The intelligent tracking and surveillance systems approach has a limited pool of use. The use of it in ports, harbors, airports, and large depots would be effective but would not be feasible in an over the road transportation system. The need for additional equipment and the cost would be enormous. Even if added to the current Innovative Motorist Information Systems on the road today, these cameras are not placed close enough to keep frequent enough contact on any vehicle. Also the quality of most of the cameras currently deployed for traffic systems is not good enough for the capturing and processing of character imaging. There would be a need for the cameras to capture license plates, US DOT numbers, and company names if these are not transmitted by RFID. This technology has applicability in the security and shipment tracking areas; however, it has a very high cost.

6. **Wireless power.**
   Wireless power seems to have a promising future. With the current cell phone wireless charger already on the market, the jump to powering systems to protect Hazmat / RAM is not far off. Due to the versatility of this kind of system the possibilities are endless. The restrictions that are currently in powering systems such as running cables from the power source to the end choice are no longer inhibiting progress. This power system will work on just about any design whether the transport vehicle is a boat, truck, or railcar. The only downfall of this technology is finding a common system and protocols for the template. By keeping a common template of the system in a module form, manufacturers would be more competitive which in turn would keep costs down. It would also allow buyers to integrate other manufacturers into their systems without the need to completely scrap their entire system and start over if they are unhappy with their current product or service. This is a category of technology that could have widespread use in the five technology application areas for the safety and security of radioactive material shipments. It provides a source of electrical power that is cost effective and versatile.

7. **Nanopiezoelectronics.**
   This emerging technology will enable electronic devices to be powered by tiny vibrations which in transportation applications would possibly be caused by roadway vibrations or a small flag mounted on a vehicle. In 2009 it was estimated that nanopiezoelectronics would be market ready in five to 10 years. With

nanopiezoelectronics, electrical storage devices may not be needed. This technology will fit in more than one application area; however it can primarily be classified in the "shipment and tracking technologies" area. Electronic devices could send tracking information to sensors or satellites. As a power supply system this technology can also fit into the "security technologies" and "electronic shipping paper technologies" application areas. Cask and trailer tracking could be powered by nanopiezoelectronics systems for security applications. Electronic shipping paper transmitting systems could be powered by these systems as well. This is an enabling technology in that it helps to provide electrical power for sensors and other devices that would otherwise be more expensive due to battery maintenance and replacement costs. The technology is still in the primary developmental stage so cost is yet unknown.

8. **Plastic thin-film organic solar cells.**
Effective use of this technology is very close to market and will power electronic devices. Basically, it is a thin, semi-transparent, solar power generating system. A truck or cask could have an organic solar "layer" put on over the paint that will produce electricity. In 2008, solar cells were being produced for market with 3-5% efficiency ratings. Today, cells have 10% efficiency in research and development laboratories. With this technology electrical storage devices will have to be used for times of low or no light. This technology will fit in more than one application area; however it can primarily be classified in the "shipment and tracking technologies" area. Electronic devices could send tracking information to sensors or satellites. As a power supply system this technology can also fit into the "security technologies" and "electronic shipping paper technologies" application areas. Cask and trailer tracking could be powered by these solar power generating systems for security applications. Electronic shipping paper transmitting systems could be powered by these systems as well. New technology with more development is expected in two to five years. The cost is dependent on the application.

9. **Container integrity.**
Advances in container integrity could prove to be beneficial in the field of radioactive material transportation for both highway and rail shipments of spent nuclear fuel, high level radioactive waste and transuranic waste. Emerging technologies may prove to be beneficial in product containment in the event of an accident or container sabotage. There are a number of approaches being investigated to make large containers better able to withstand impacts without increasing weight. These technologies have not been fully developed but could be functional in the near term, two to 10 years depending on the technology. This technology is applicable to the shipment and tracking technology application area and the security technology application area.

Table 2 summarizes the results of the evaluations of the emerging technology categories. It indicates which of the emerging technology categories might be useful in each of the five areas associated with the safety and security of radioactive material

shipments: inspection, security, dose measurement and isotope quantification, shipping and tracking, and electronic shipping papers.

**Table 2. Emerging Technology Categories Relevant to Radioactive Materials Shipment Technology Application Areas**

| Emerging Technology Category | RAM Shipment Technology Application Area | | | | |
|---|---|---|---|---|---|
| | Inspection | Security | RAM Measurement | Shipment/ Tracking | Electronic Shipping Papers |
| Networked RFID/ ubiquitous sensors & cargo monitoring | X | X | | X | X |
| Pressure gauges & chemical detection sensors | X | X | X | | |
| Fiber-optic/photonic sensors & optical scanners | X | X | | X | X |
| Advanced locks & seals | X | X | | X | |
| Intelligent video tracking & surveillance | | X* | | X* | |
| Wireless power | X | X | X | X | X |
| Nanopiezoelectronics | | X | | X | X |
| Plastic thin-film organic solar cells | | X | | X | X |
| Container Integrity | | X | | X | |

* Limited applicability due to very high costs

# Conclusions

The Ad Hoc Committee examined several current and emerging technologies that have the potential to benefit the safety and security of DOE radioactive material shipments. The technologies were evaluated for relevance to one or more of five application areas considered by the Committee to have importance to the safety and security of radioactive material shipments. The conclusions of the Committee with respect to the five application areas are as follows.

1. **Inspection Technologies**

   A CVSA Level VI inspection is completed on all HRCQ and transuranic waste shipments at the point of origin. The use of inspection technologies can benefit the driver during pre-trip and post-trip inspections. There is also a potential for inspection technologies to be used by states along the route. En route states could

use existing or emerging inspection technology in lieu of or in conjunction with completing an en route Level VI inspection or other level of CVSA inspection. These technologies would prove beneficial by increasing shipment efficiency, safety and security.

Current and emerging technologies that support inspections include detection and electronic vehicle technologies, networked RFID/ubiquitous sensors and cargo monitoring, pressure gauges and chemical detection sensors, fiber-optic/photonic sensors & optical scanners, advanced locks and seals, and wireless power.

**2. Security Technologies**

Security technologies have broad applicability and crossover into other areas. Shipment security is the most important aspect of radioactive material transportation. The higher the risk and/or value of the cargo the higher the need is for security. Security concerns can be broken down into four areas:

- **Driver** – The driver is the most important component of shipment security. The driver should have panic buttons or other vehicle disabling technology available for use and should have to activate/deactivate anti-vehicle theft controls when entering and leaving a commercial vehicle loaded with radioactive material.
- **Power Unit** – The power unit should have a primary and secondary tracking capability. It should have an anti-theft system installed and panic buttons or other driver-activated disabling devices. The vehicle should also have the capability of being controlled via a satellite link. If the shipment was hijacked and the vehicle's computer could be accessed via satellite, the fuel could slowly be shutoff to slow down and disable the vehicle.
- **Trailer** – The trailer should have separate primary and secondary tracking capabilities so the trailer could be tracked if the shipment were hijacked and the tractor was separated from the trailer. This is currently a major security concern because trailers typically have no tracking capability.
- **Shipping Casks** – Each shipping container should have a primary and secondary tracking device on the shipping casks. Like trailers, individual shipping casks are currently not tracked.

Current and emerging technologies that support security include detection, authentication and vehicle disabling, tracking and communications, and electronic vehicle information technologies; networked RFID/ubiquitous sensors and cargo monitoring; pressure gauges and chemical detection sensors; fiber-optic/photonic sensors & optical scanners; advanced locks and seals; intelligent video tracking & surveillance; wireless power; nanopiezoelectronics; plastic thin-film organic solar cells; and container integrity.

3. **Radioactive Material Dose Rate Measurement and Isotope Quantification Technologies**

Portal radiation monitors at fixed ports of entry are now in use and are expanding across the country. The latest technology incorporates isotope quantification and identification technologies. This technology is expensive but market place competition should lower or make pricing more reasonable-and grants are available to assist with the initial purchase. This type of technology could be used en route in lieu of or in conjunction with some other form of CVSA inspection. Radiation dose rate monitors installed within the shipment and coupled with a tracking technology such as TRANSCOM would allow real-time radiation monitoring while the shipment is en route. Having real-time radiation dose rate measurements and global positioning data would increase the safety and security of the shipment, act as a decision making tool for states along the route on whether or not an en route inspection is needed and provide emergency personnel with critical data in the event of an accident or incident.

Current and emerging technologies that support dose rate measurement and isotope quantification include detection technologies; pressure gauges and chemical detection sensors; and wireless power.

4. **Shipment and Tracking Technologies (tractor, trailer, and individual package)**

The current TRANSCOM system used by DOE is very effective and has evolved over the last two decades. The initial system had the satellite transponder on the trailer. The current system has it on the tractor. DOE needs to have tracking capabilities and backup capabilities on the tractor, trailer, and each package. The primary system needs to be the most secure and reliable technology available. The backup system should be a different technology and should also be a reliable technology.

Current and emerging technologies that support shipment and tracking include tracking and communications and electronic vehicle information technologies; networked RFID/ubiquitous sensors and cargo monitoring; fiber-optic/photonic sensors & optical scanners; advanced locks and seals; intelligent video tracking & surveillance; wireless power; nanopiezoelectronics; plastic thin-film organic solar cells; and container integrity.

5. **Electronic Shipping Paper Technologies**

This is a new emerging area. When this study was started for DOE, this area was not one the Committee was asked to consider; however, the Committee members agreed it should be included in the evaluation. The U.S. Pipeline and Hazardous Materials Safety Administration (PHMSA) is very interested in this technology for security and emergency response applications. There is currently an HMCRP project studying electronic shipping papers: *Evaluation of the Use of Electronic Shipping Papers for Hazardous Materials Shipments* (HM-05).

Current and emerging technologies that support electronic shipping papers include electronic vehicle information technologies; networked RFID/ubiquitous sensors and cargo monitoring; fiber-optic/photonic sensors & optical scanners; wireless power; nanopiezoelectronics; and plastic thin-film organic solar cells.

# Recommendations

The material reviewed to complete this report was vast. The technologies that were examined during this study are changing on a constant basis. Specific technologies that are currently available and that the Ad Hoc Committee recommends for the safety and security of radioactive material shipments are RFID, GPS, biometrics, seals and locks. These technologies have been tested, in operation for some time, and have good performance records.

For future use, DOE needs to choose the most reliable and promising technologies. To make this process beneficial to all interested parties DOE needs to:

- Involve the four regional state government groups in the overall process;
- Address all five technology application areas presented in the report;
- Pay special attention to shipment security and tracking. Stakeholders are especially interested in tracking not just the tractors, but the trailers and shipping casks as well;
- Make a special effort to involve stakeholders from states who currently do en route inspections due to state laws or policies. If these stakeholders are involved up front it may pay DOE dividends in the end by reducing and/or eliminating en route inspections due to the technologies used and accessibility by these stakeholders;
- Upgrade TRANSCOM to report in real time dose rate measurements of the package; and
- Follow the progress of the HMCRP Project HM-05 studying electronic shipping papers and obtain a copy of the final report for review and possible implementation.

# Appendix: Additional Information Sources

## Current Technologies

The following are web site links associated with the current technologies reviewed by the Ad Hoc Committee. Further details about these technologies can be found at these links.

- Adaptable Radiation Area Monitor (ARAM)
  https://www-gs.llnl.gov/?q=defense-adaptable_radiation_area_monitor
- IRRIS
  http://www.geodecisions.com/irris/
- PC*MILER|FleetCommander
  http://www.alk.com/pcmiler/
  (Note: FleetCommander is no longer supported by ALK Technologies. Products with similar functionality are PC*MILER Web Services and ALK|FleetSuite)
- Qualcomm Systems
  www.qualcomm.com
- SkyBitz
  www.skybitz.com
- TRANSCOM
  http://tcc.doeal.gov/
- Zonar
  www.zonarsystems.com

## Emerging Technologies

The information that the Ad Hoc Committee used for the emerging technologies review was obtained from the Hazardous Materials Cooperative Research Program (HMCRP) project HM-04 report titled *Emerging Technologies Applicable to Hazardous Materials Transportation Safety and Security.* Further details about these technologies can be found in the HM-04 report. This report is available from the Transportation Research Board (TRB) web site. To obtain this document follow these instructions:

1. Go to the TRB homepage: http://www.trb.org/Main/Public/Home.aspx.
2. In the bar at the top of the page, click on "Publications."
3. From the web page that opens, on the left under the Cooperative Research Program Series, locate "Hazardous Materials (HMCRP)" and click on it. Underneath will appear two dropdown choices, one of which is "Project Reports."
4. Click on "Project Reports" and the reports that have been published to date under the HMCRP will be listed.
5. Click on the image of the HM-04 report and select either "View This PDF" or "Buy This Book."