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Practices and Technologies in Hazardous Material Transportation and Security DHS 1107

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Prepared for
Mack-Blackwell Rural Transportation Center
National Transportation Security Center of Excellence
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ACKNOWLEDGEMENT
This material is based upon work supported by the U.S. Department of Homeland Security under Grant Award Number 2008-ST-061-TS003.

Executive Summary

The University of Arkansas (UA) team is responsible for investigating practices of hazardous material transportation in the private sector. The UA team is a sub-contractor to the project “Petrochemical Transportation Security, Development of an Interactive Petrochemical Incident Location System (PILS), DH-08-ST-061-004” with the PI institution being Texas Southern University National Transportation Security Center of Excellence. This Report presents synthesis of research activities in the relevant area and overview of technologies used by J.B. Hunt Transport.

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Texas Southern University National Transportation Security Center of Excellence – Petrochemical Transportation Security

Development of an Interactive Petrochemical Incident Location System (PILS)

Department of Homeland Security
Supplemental Funding Opportunity

DH-08-ST-061-004

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Practices and Technologies in Hazardous Material Transportation and Security

Final Report

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November 23, 2011

Abstract:

The University of Arkansas (UA) team is responsible for investigating practices of hazardous material transportation in the private sector. The UA team is a sub-contractor to the project "Petrochemical Transportation Security, Development of an Interactive Petrochemical Incident Location System (PILS), DH-08-ST-061-004" with the PI institution being Texas Southern University National Transportation Security Center of Excellence. This Interim Report presents synthesis of research activities in the relevant area and overview of technologies used by J.B. Hunt Transport.

Introduction

Identifying hazardous material (HAZMAT) transportation gained momentum in the wake of the terrorist attacks of September 11, 2001. According to the Bureau of Transportation Statistics, in 2004 there were 11 million trucks making shipments into America from Canada and Mexico and trade with the two countries accounts for 31.1% of the total U.S. trade (*1*). The scope of this project focuses on hazardous material transportation and security. Therefore, the work conducted by the University of Arkansas team is on private practices of transporting hazardous materials. Businesses have a different focus on HAZMAT transport versus government entities; they are concerned with the minimization of risk *and* cost.

The need to monitor the transport of hazardous goods to minimize them as potential targets for terrorists is highlighted by the 10 year (1999 to 2008) Hazardous Materials Incident Report of the Pipeline and Hazardous Materials Safety Administration of the U.S. Department of Transportation (*2*). U.S. Department of Transportation defines hazardous materials as belonging to one of nine hazard classes: Class 1, Explosives; Class 2, Gases; Class 3, Flammable liquids; Class 4, Flammable solids; Class 5, Oxidizers and Organic Peroxides; Class 6, Toxic Materials and Infectious Substances; Class 7, Radioactive Materials; Class 8, Corrosive Materials; and Class 9, Miscellaneous Dangerous Goods (*3*).

Aspects of the risk in transportation of HAZMAT might be divided into two factors: 1) the likelihood of various accidents occurring. 2) The damage caused by an accident that does occur (*4*). The following case studies incorporate these factors into their HAZMAT systems. This report first presents several case studies on using technology for monitoring and managing transportation of hazardous materials. The report then discusses technologies of space based tracking technology for nationwide trucking movements used by J.H. Hunt Transport. It is anticipated that many firms with large size logistic and supply chain operations may employ similar technologies for monitoring freight movements.

Case Studies

SERRI Project at the University of Kentucky

At the end of 2008, the University of Kentucky researchers completed a project on hazardous material transportation with DHS funding via the Southeast Region Research Initiative (SERRI) (5). There are over 800,000 hazardous materials (hazmat) shipments over the nation's roads each day. According to the U.S. Department of Homeland Security (DHS), terrorist activity related to the transportation of hazardous materials represents a significant threat to public safety and the nation's critical infrastructure. Specifically, the federal government has pointed to the government's inability to track hazmat shipments on a real-time basis as a significant security vulnerability.

In 2004, the U.S. Federal Motor Carrier Safety Administration (FMCSA) completed a study to determine if "smart truck" technology such as GPS tracking, wireless modems, panic buttons, and on-board computers could be used to enhance hazmat shipment security. The FMCSA study concluded that smart truck technology will be highly effective in protecting hazmat shipments from terrorists. The FMCSA study also concluded that smart truck technology deployment will produce a huge security benefit and an overwhelmingly positive return on investment for hazmat carriers.

The FMCSA study led to the U.S. Transportation Security Administration's (TSA) Hazmat Truck Security Pilot. This congressionally mandated pilot program was undertaken to demonstrate if a hazmat truck tracking center was feasible from a technology and systems perspective and to determine if existing truck tracking systems can interface with government intelligence centers and first responders. The Hazmat Truck Security Pilot demonstrated that a hazmat truck tracking center is feasible and in August 2007, Congress enacted legislation that directs TSA to develop a program - consistent with the Hazmat Truck Security Pilot - to facilitate the tracking of motor carrier shipments of security-sensitive materials.

In a different initiative, the U.S. Environmental Protection Agency is interested in implementing an electronic manifest rule that would allow companies to use electronic manifests instead of paper manifests for their hazardous waste shipments. Hazardous waste is a small subset of the much larger hazmat universe and the transportation of hazardous waste is co-regulated by EPA and the U.S. Department of Transportation. EPA and DOT regulations recognize EPA's hazardous waste manifest as satisfying DOT's hazmat shipping paper requirement. EPA estimates that the use of electronic manifests instead of paper manifests has the potential to generate over $300 million/year in cost savings. EPA has expressed strong interest in using a public/private partnership to build a national hazardous waste electronic manifest processing center. Under this approach, a private party would build and operate the processing center at its own expense and collect a transaction fee for processing electronic manifests.

The Kentucky Transportation Center (KTC) of the University of Kentucky led a project funded by DHS via the Southeast Region Research Initiative (SERRI) to evaluate TSA and EPA needs. SERRI is managed by BWXT Y-12 of Oak Ridge, TN. KTC project partners for the SERRI project were: Morehead State University (Morehead, KY); Coldstream Digital LLC (Lexington, KY; Great Falls, VA); General Dynamics Advanced Information Systems (Buffalo, NY), and ThoughtWorks Inc. (Chicago, IL).

KTC's SERRI project began August, 2007 and was completed October 2008. The project was designed to assess the feasibility of establishing the North American Transportation Security Center in Kentucky. The Transportation Security Center, as envisioned by the KTC project team, will serve as the implementing tool for a model hazmat regulatory program in Kentucky that will require:

• high-risk hazmat transporters to install "smart truck" technology on their vehicles;

• shippers and carriers to send electronic manifests and electronic route plans to the Transportation Security Center;

• carriers to report vehicle location and alerts to the Transportation Security Center (real-time XML data feed); and

• companies to pay hazmat regulatory fees.

The Transportation Security Center will also serve as the implementing tool for a model hazardous waste electronic manifest regulatory program.

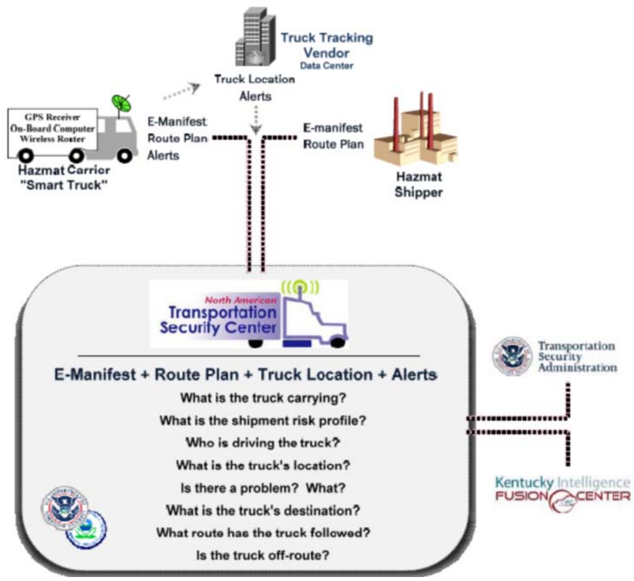

FIGURE 1 Hazmat tracking at the North American Transportation Security Center

Figure 1 illustrates the hazmat tracking features of the Transportation Security Center. A "smart truck" equipped with an on-board computer, GPS receiver, and a wireless modem will use an internet connection (satellite or cellular) to interact with the Transportation Security Center and a commercial fleet tracking data center. E-manifest transactions between the carrier and the Transportation Security Center will provide the Transportation Security Center with information on the types and quantities of materials the transporter is hauling as well as shipment status (i.e. awaiting pickup, in transit, etc.). Data from the carrier's fleet tracking data center will provide the Transportation Security Center the carrier's exact location at all times. The shipper and/or carrier will also submit route plans. Alerts from the shipper or carrier will be generated when different events occur. The Transportation Security Center will merge e-manifest, vehicle location, route and alert data to provide government officials real-time visibility into the security status of hazmat shipments. In the event of a security incident, the Transportation Security Center will interact with State and Federal operations centers Kentucky's Intelligence Fusion Center is the state action agency in the Commonwealth.

The project team examined four types of market "drivers" that influence the design and operation of the North American Transportation Security Center. They are:

• regulatory and legislative drivers;

• technology drivers;

• lessons learned (experience drivers); and

• business drivers.

Market driver analyses supported development of plans for the design and operation of the Transportation Security Center as well as plans for a model regulatory program. The project team prepared four deliverables.

1. A high-level systems plan for the North American Transportation Security Center describes how Transportation Security Center systems will be structured and how they will function. The North American Transportation Security Center will merge information on shipment and vehicle location to enable real-time shipment tracking.

2. A concept of operations plan for the North American Transportation Security Center describes the needs the Transportation Security Center will satisfy and how it will be structured to meet those needs.

3. A regulatory program plan presents model statutes/regulations that would be implemented in conjunction with hazmat tracking and hazardous waste electronic manifest programs by Kentucky's Cabinet agencies.

4. Recommendations regarding Kentucky's membership in the Alliance for Uniform Hazmat Transportation Procedures (the Alliance) are presented. The Alliance is a state-based organization sponsored by the National Conference of State Legislatures (NCSL) and established in conjunction with the FMCSA. The Alliance has established uniform procedures for state hazmat registration and permitting programs. Three states bordering Kentucky – Ohio, West Virginia, and Illinois – are Alliance members.

Transportation Routing Analysis Geographic Information System (TRAGIS) by Oak Ridge National Laboratory

The Oak Ridge National Laboratory (ORNL), a Department of Energy facility managed by UT-Battelle, developed a routing system called Transportation Routing Analysis Geographic Information System (TRAGIS) (6). It is a client-server web application where the user interface and map data files reside on the user's personal computer and the routing engine and its large data files reside on the server. TRAGIS has two components: WebTRAGIS which is the primary client user interface and BatchTRAGIS which is a specialized user interface that allows multiple routes to be prepared and then calculated at one time. ORNL uses TRAGIS to model transportation routing (highways, rails, and waterways) for the Department of Energy. It provides data on the population density around the routes of transportation by using LandScan USA Interim, a high resolution population distribution data modeled from the 2000 Census and the highway network, which is a 1:100,000-scale database representing over 235,000 miles of all Interstate highways, most U.S. highways, and major state highways.

An advantage of the system is that transportation routes can be determined to conform to U.S. Department of Transportation (DOT) highway route-controlled quantities (HRCQ) regulation (49 CFR 397.101) for the transportation of hazardous materials. It has identified nuclear power plants, military and commercial airports and Department of Energy sites. TRAGIS can calculate alternative routes by blocking roads and areas.

In WebTRAGIS the user selects the origin and destination of a route by selecting 'nodes.' They represent place names of locations such as airports, military bases, cities and so on. If a node is unknown it can be manually added in TRAGIS. The next step is the selection of one of the following route types: 1) commercial; 2) quickest; 3) shortest; 4) HRCQ; 5) HRCQ + Nevada; 6) WIPP; and 7) Other. These choices control how the impedance of the route is calculated. The goal is to calculate the route with the least impedance. The final step is choosing the population buffer along the specified route. The population buffer can be set using the values of 400, 800, or 2500 meters. The default value is 800 meters. WebTRAGIS uses the values to calculate the population density around the route. Once the criteria are input the route can be calculated. Alternative routes are calculated in WebTRAGIS to compare impedance values with the original route and are assigned a penalty value ranging from 1 to 100. This allows the user to compare multiple routes.

GIS-Based HAZMAT Management System by University of Alabama

The University of Alabama developed a GIS-based hazardous waste transport system (HWTS) that uses probabilistic risk assessment which is the product of the probability of occurrence of a hazardous waste accident and the consequences of that accident (*4*). The goal is to calculate the route that would cause the least amount of damage should a hazardous waste incident occur. Each route segment is scored by taking the vulnerability of the facilities multiplied by the risk of the road segment. HWTS identifies high-impact areas subject to a hazardous waste accident such as schools, hospitals, retirement homes, day care centers vulnerable to a hazardous waste accident. In route selection, the user defines an origin and a destination. The level of impact of a hazardous waste accident on each road segment is assigned a value and is represented by rings surrounding the facilities in HWTS. Facilities located along the road segments are given a score based on the vulnerability of the facilities multiplied by the risk of the road segment.

The researchers from the University of Alabama conducted their case study using the city of Birmingham as their example and used 1995 TIGER files from the U.S. Census Bureau. During the case study the routes selected applied to all vehicles not just truck routes. In the case study a waste origin site and a waste destination site are picked by a user (shipment origin and destination). After picking the points, the program generates the shortest route without regard to the impact of hazardous accident. In their study, the distance of the route is 10.54 miles and a score of 38.91. A new route is created by HWTS that takes into account schools located near the route and generates a ring of impact around each school. The proximity of the ring to the road determines the hazardous waste impact value and the roadway distance. Minimizing hazardous waste impact, the new route distance is 11.68 miles with a score of 32.40. From the case study the researchers show that the longer route is safer than the shorter route. Future research includes determining the safest route with the consideration of other facilities such as hospitals and day care centers to the Birmingham case study and providing routes based on the type of shipment, i.e., liquid or gas, corrosive or toxic and so on.

Singapore's Development of a HAZMAT Route Planning System

Singapore is a densely populated area and serves as a major hub for the transportation of petrochemicals to Southeast Asia. It is the world's third largest oil-refining center, behind Rotterdam and Houston (7). The effects of a hazardous waste incident would be catastrophic. The transportation of hazardous materials is jointly regulated by Singapore's National Environment Agency's Pollution Control Department and Civil Defense Force. They determine the safest route, including origin and destination, of the vehicles but do not present alternate routes or provide reasons to why the route was chosen. Researchers at the University of Singapore wanted to develop a hazardous materials system that addresses the security, the cost, and the exposure factors. They use ArcGIS to visually identify the routes and assign a cost to the routes based on the level of safety using a Genetic Algorithm (GA).

The researchers chose a 3 km by 3 km area to test their system and nine routes: three main routes compared to six alternative routes (Figure 2). Their routes are based on five criteria: 1) exposure; 2) socio-economic impact; 3) risks of hijack; 4) traffic conditions; and 5) emergency response. The first criteria, exposure, the researchers created in ArcGIS a 0.8 km buffer zone along all the routes based on FHWA guidelines for combustible hazardous materials. Socio-economic impact refers to the how the damages to the surrounding infrastructure affects the residents socially and financially in the 0.8 km zone. The third criteria, risks of hijack, are areas with little or no covering. They are given a higher score as well as areas with small populations. For the criteria of traffic conditions, traffic density, accident frequency, flow, average speed, and number of signalized intersections are considered (*2*). Higher costs are assigned to congested routes, signalized intersections. For the last criteria, emergency response, routes that are located near hospitals, fire departments, military bases and so on are given a lower cost than routes that are farther away from the emergency response departments.

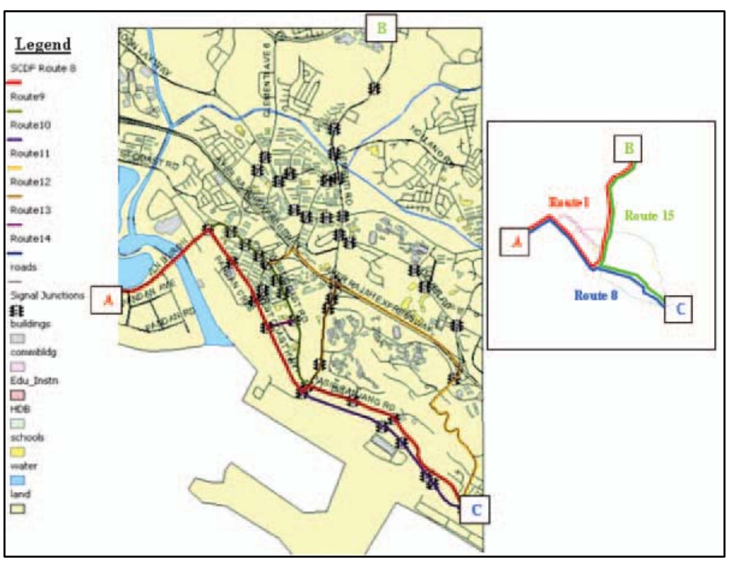

FIGURE 2 The 3 km by 3 km test area with the 9 routes in Singapore

The criteria are further divided by factors which are given a score ranging from as low as 1 to as high as 7 depending on the number of factors under the criteria. For example, using the emergency response criteria, the scores relate to the distance of emergency response facilities to the route with 1 being close and 5 being far. Table 1 lists the factors for each of the criteria.

TABLE 1

Criteria	Factors
1. Exposure	• Type of residence (A1) • Commercial and government buildings (A2) • Industrial buildings (A3) • Schools and tertiary institutions (A4) • Mass Rapid Transit stations (A5)
2. Socio-Economic Impact	• Type of residence (B1) • Commercial and government buildings (B2) • Industrial buildings (B3) • Waterbodies (B4) • Petrol/gas stations (B5) • Bridges (B6) • Mass Rapid Transit stations (B7)
3. Risks of Hijack	• Population density (C1) • Vegetation/foliage cover (C2)
4. Traffic Conditions	• Traffic density (D1) • Traffic speed (D2) • Number of signalized junctions (D3) • Accident frequency (D4)
5. Emergency Response	• Proximity to fire stations (E1) • Proximity to police stations (E2) • Proximity to army camps (E3) • Proximity to hospitals (E4) • Network redundancy (E5)

The project uses a GA to assign a weight to each criterion with the goal of minimizing the generalized cost (*2*). The GA process is similar to natural selection. Rather than representing a phenotype such as eye color, the "children" in the GA process represent solutions. Likewise the fitness of the solutions represents more correct solutions rather than how it successful it will be at reproducing. The GA creates a population of strings which represent solutions to the problem. New populations are created by ranking the candidate solutions. First populations are created based on the generalized cost equation. The costs are evaluated and mates are selected. Next the populations reproduce and mutations occur. With each successive reproduction the GA's answer becomes closer to the solution, much like an iterative process.

In analyzing the results the researchers first compared the weights of each of the five criteria with the nine routes before comparing each routes' generalized cost equation. Based on the weights determined for the five criteria, the results suggest that the main considerations are exposure and socio-economic impact (*2*). The researchers state that the considerations have changed since September 11, 2001 with more emphasis needed on hijack and emergency response criteria. Future research includes investigating the outcome of adding different weights to specified criteria in the GA.

GIS Spill Management Information System by a partnership between USACE and Vanderbilt

The Spill Management Information System (SMIS) was designed to overcome many of the communications and coordination challenges generated following a spill incident by providing responders with access to uniform information comprised of real-time incident information and maps, contaminant transport models, chemical response data, areal displays of contaminant procession, and locations of sensitive receptors (8). The project goal was to develop a SMIS, coupling geographic information systems (GIS) with advanced water quality and air dispersion models to provide real-time information to emergency responders following an incident involving hazardous materials.

SMIS models an accident in the air and in the water. Air contaminant modeling is accomplished by the Computer-Aided Management of Emergency Operations software and the Areal Locations of Hazardous Atmospheres air dispersion model. The water quality monitoring is accomplished by the USACE CE-QUAL-W2 program. Output data from both of the programs are viewed in ArcView GIS providing the user a 2-D graphical representation of the data (Figure 3).

SMIS has five inputs: Location of Spill Injection on Waterway; Selection of Spill Contaminant; Quantification of Spill; Time Interval Selection; and Inflows/Outflows. The Data output contains: Time Series Contaminant Transport; Animation; Supplementary Contaminant Information; Aerial Plume Dispersion; GIS Risk Analysis Routines. Within SMIS, GIS possesses three major functions: (i) providing an interface between the SMIS and its users; (ii) linking inputs, the predictive models, and outputs; and (iii) managing spatial and aspatial databases.

The research did not mention the algorithms governing the risk assessment programs. Rather, the paper serves as a call to action for agencies to adopt SMIS providing the case study Cheatham Reach of the Cumberland River as an example. In the case study a 50,000 L spill of benzene is simulated for 1 hour and 4 hours in Cheatham Reach to monitor the levels of contamination. The paper (7) further states that SMIS can serve to enhance preparedness, response time, information time, information access, and the employment suitable containment transport modules. Emergency response personnel would be the best candidates for the software. Using the case study as an example, they would know the levels of contamination along the reach as well as the location.

Future research involves adding: (a) threat zone analysis queries to evaluate spill impacts on sensitive areas; (b) web-based SMIS for field portability; (c) resource analysis to estimate the level of response required for particular spills; and (d) application of enhanced or alternate water and air dispersion models (*3*). A newer version of SMIS (2.0) with 3-D modeling has been developed earlier this year that applies to inland waterways.

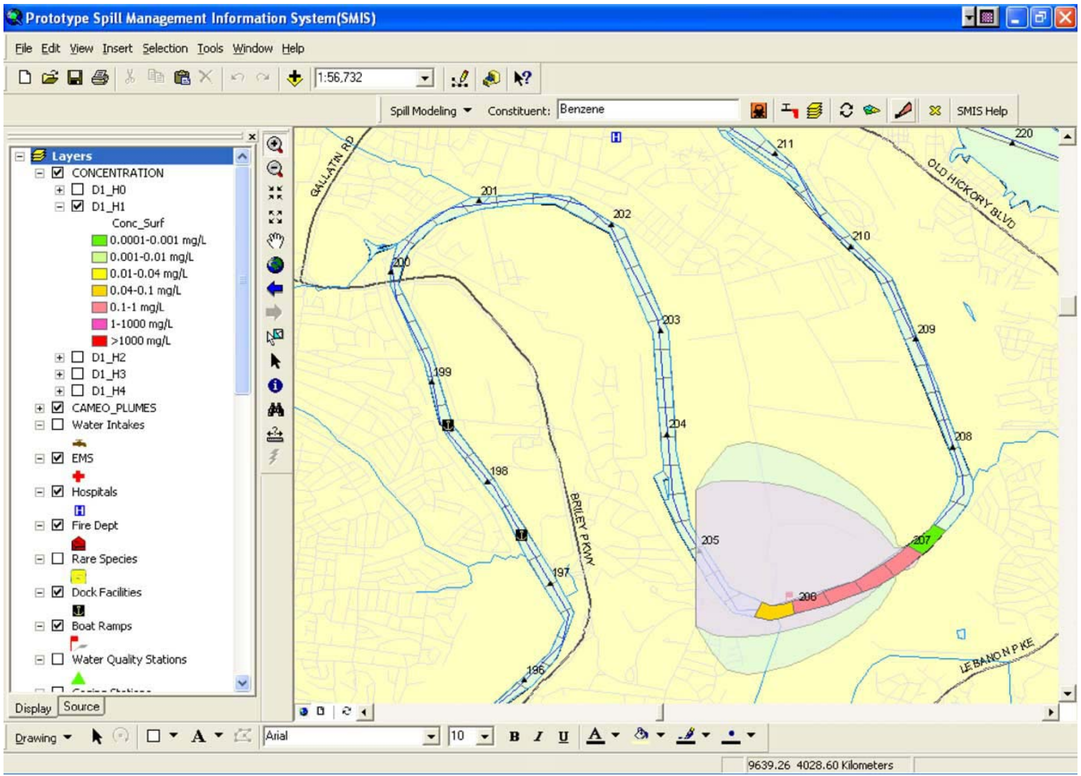

FIGURE 3 Spill contamination levels of benzene in Cheatham Reach

Transportation Security Practices of J.B. Hunt Transport

J.B. Hunt Transport Services, Inc., one of the largest transportation logistics companies in North America, provides transportation services throughout the continental United States, Canada and Mexico by utilizing an integrated, multimodal approach. Its service offerings include transportation of full truckload containerizable freight with company-controlled revenue equipment and company drivers or independent contractors. It also has arrangements with most of the major North American rail carriers to transport truckload freight in containers and trailers. Its customer base includes a large number of Fortune 500 companies. This synthesis summarizes truck tracking security measures used by J.B. Hunt for its trucking services.

The company has a detailed operational procedure call Hazardous Materials in its Operation Manual. An important technology deployed by J.B. Hunt in recent years is the use of GPS tracking of its fleet of tractors. At this time, 85% of all J.B. Hunt tractors have GPS tracking with two-way satellite based communication system. Its trailers rely on one-way satellite based communication through cellular network for location information. J.B. Hunt uses a real-time mapping utility to track all tractors in the US. The technologies used by J. B. Hunt include Qualcomm GPS/Communication units in all trucks, and Skybitz GPS units in most trailers. It uses software developed in-house to pull in feeds from both Qualcomm and Skybitz units to display truck and trailer locations in real-time. They also access Skybitz directly via the web to locate and track trailers. Through the space based communication technologies, threat of any kind can be relayed to drivers in 30 minutes anywhere in the US.

Figure 4 illustrates the operation of Skybitz for tracking trailers. It uses both GPS satellites and a commercial satellite. Figure 4 shows a real-time query of truck locations through an Internet browser. Figures 5 and 6 show the location of a truck and its route. Figure 7 is the Skybitz user interface. The geo-fencing capability in Figure 8 allows J.B. Hunt security staff to lock the truck if it is moved out of a defined virtual fence or limits.

Conclusion

In this report, the investigator discusses several case studies relating to hazardous material transportation and technologies used to mitigate resulting threats. In addition, based on site visit of J.B. Hunt Transport located in Northwest Arkansas, communication technologies used to locate trucking assets are summarized, which play a critical role in providing real-time information during time of spill and threat. It is clear that web-based information and remote sensing technologies have become necessary platforms for monitoring freight movements and hazardous material transportation.

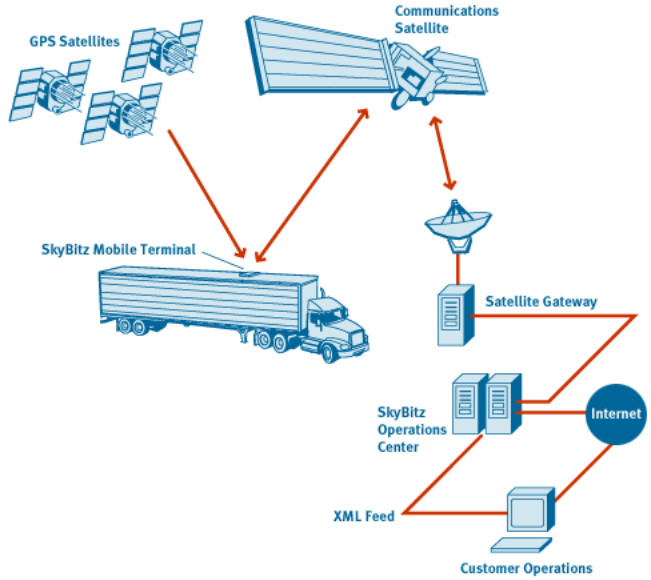

Figure 4 How SkyBitz Trailer Tracking Works

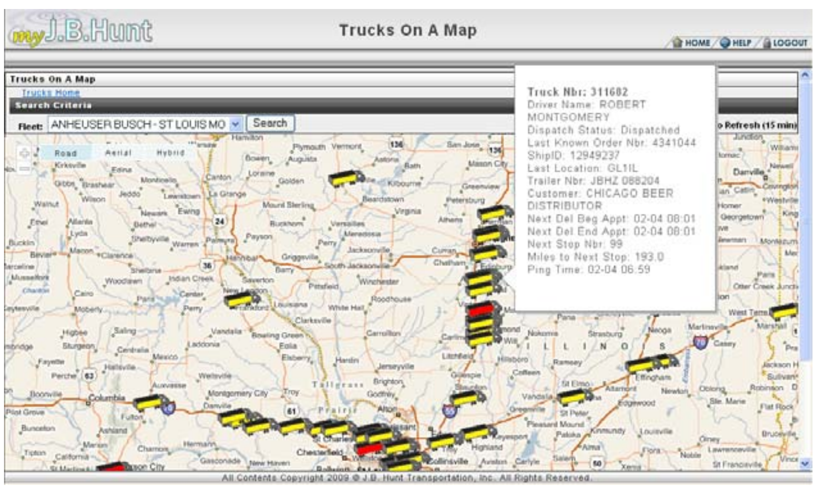

Figure 5 Trucks on a Map

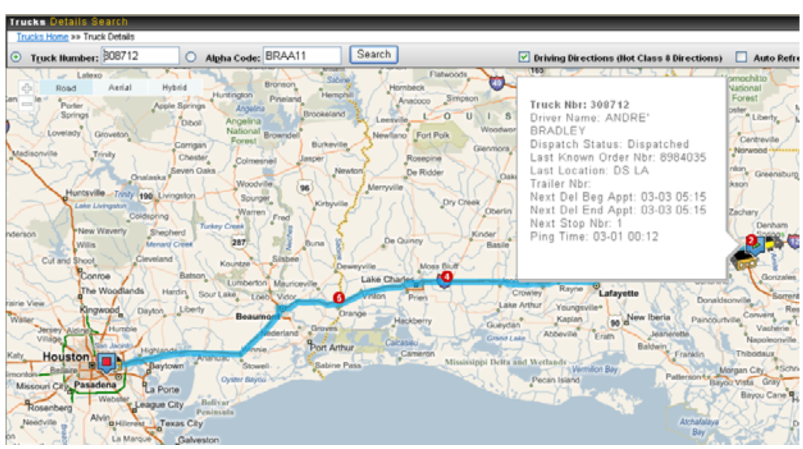

Figure 6 Truck on a map with route details

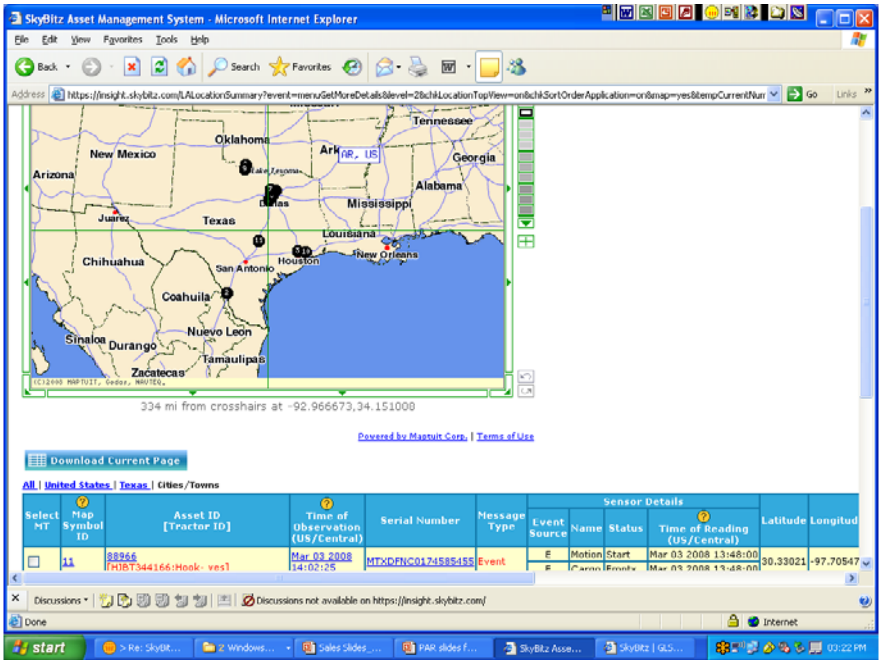

Figure 7 Skybitz software interface

Figure 8 Geofencing to lock down a trailer to a defined space

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