NOTICE: Volume I has been approved for public disclosure. Throughout this document, there are references made to Volume III, which is considered to be Sensitive Security Information (SSI). Therefore, distribution of Volume III is restricted without the prior written permission of the U.S. Department of Transportation.

Hazardous Materials Safety and Security Technology Field Operational Test

Volume I:

Evaluation Final Report Executive Summary

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USDOT ITS Joint Program Office
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FOREWORD

The following volume content definitions are provided to aid the reader in reviewing this detailed, multivolume effort presented as the **Hazardous Materials Safety and Security Technology Field Operational Test Evaluation Final Report**.

Volume I: Executive Summary – This current volume presents the overriding results generated from the evaluation of this FOT including overall benefit-cost results, industry deployment potential for FOT technologies, and policy options for consideration.

Volume II: Evaluation Final Report Synthesis – This volume provides information synthesized from the detailed reference sections contained in Volume III. This volume presents the “bottom line” results from the FOT activities, including the following topics, and concluding with potential policy options for consideration:

- The Importance of HAZMAT Security and the Need for Technology
- FOT Overview
- Evaluation Approach Overview
- Technical Performance
- Efficiency Assessment Findings
- Security Assessment Findings
- Safety Assessment Findings
- Benefits-Cost Results for Market Potential and Deployment
- Public Sector and Institutional Interfaces
- Potential Options to Realize Deployment Potential
- Conclusions

NOTE

Volume III is a Sensitive Security Information document and is not available for public distribution.

Volume III: Evaluation Final Report Detail – This volume provides the five key reference documents used to support the evaluation and results for the HAZMAT FOT under one cover:

- **Section 1: HAZMAT FOT Overview.** This section provides the rationale behind this FOT, including a synopsis of FOT activities; identifies the FOT configuration; and describes the technologies deployed for this FOT.
- **Section 2: HAZMAT FOT Technical Performance, Efficiency and Safety Benefits Assessments.** This section outlines the baseline data collection effort and related technology prototype testing. This section presents quantitative and qualitative performance reviews of each of the individual deployed component technologies. The section includes the Efficiency and Safety Benefits Assessments that feed into the Section 4: Benefit-Cost Assessment.
- **Section 3: HAZMAT FOT Security Benefits Assessment.** This section presents the Security Benefits Assessment and covers the analytical framework and Delphi process developed to support the Security Analysis and to feed the Benefit-Cost Assessment in Section 4.

- **Section 4: Benefit-Cost Assessment and Industry Deployment Potential.** This section presents the Efficiency, Safety and Security Benefit-Cost Assessments and Market Potential Analysis for Industry Deployment built upon the detailed Efficiency, Safety, and Security Benefits Assessments in Sections 2 and 3.
- **Section 5: Public Sector Component.** This section presents the evaluation of the Public Sector FOT, which is an add-on component to the larger HAZMAT FOT.

ABBREVIATIONS

ATRI	American Transportation Research Institute
BSG	Biometrics Solutions Group
COTS	Commercial-off-the-Shelf
CVSA	Commercial Vehicle Safety Alliance
E-seal	Electronic Seal
ESCM	Electronic Supply Chain Manifest
FMCSA	Federal Motor Carrier Safety Administration
FOT	Field Operational Test
GPS	Global Positioning System
HAZMAT	Hazardous Materials
ITS	Intelligent Transportation Systems
JPO	Joint Program Office
LTL	Less-than-Truckload
MCMIS	Motor Carrier Management Information System
OBC	On-Board Computer / Communications
PIN	Personal Identification Number
PSRC	Public Sector Reporting Center
ROI	Return on Investment
SAIC	Science Applications International Corporation
TSA	Transportation Security Administration
USDOT	U.S. Department of Transportation

EXECUTIVE SUMMARY

The catastrophic events of September 11, 2001 and the ongoing war on terrorism have heightened the level of concern from Federal government officials and the transportation industry regarding the secure transport of hazardous materials (HAZMAT). Security concerns focus on the potential of HAZMAT shipments as targets for terrorists. HAZMAT shipments through intermodal connectors, modes, and facilities are all attractive targets for terrorists, and pose a much greater concern to public safety than most other shipment types. HAZMAT shipments, especially fuels and chemicals, are especially attractive targets due to the multiple points of vulnerability. These vulnerabilities exist at shipper, motor carrier, and shipment recipient facilities, and during shipment movement en route throughout the nation's roadway infrastructure.

Numerous international and domestic incidents occurred over the past several years that demonstrate the real threat potential that HAZMAT shipments pose. For example, the following events all occurred in a 2-month period in 2002:

- March 31, 2002: A 29-year-old driver for a propane distributor drove away with a 3,000-gallon bobtail. He made a telephone threat stating that he wanted to kill President George W. Bush and that he would use the bobtail as a "bomb".
- April 11, 2002: A terrorist driving a truck carrying liquefied natural gas ignited his cargo in front of a synagogue on the Tunisian Island of Djerba, killing 17 people, mainly German and French tourists. Al Qaeda claimed responsibility for the blast.
- May 16, 2002: A tractor-trailer carrying 10 tons of deadly cyanide in 96 drums was stolen after three armed men held up the vehicle north of Mexico City. Six drums were never found.
- May 2002: A fully loaded tanker truck pulled into Israel's largest fuel depot and suddenly caught fire due to an explosive charge connected to a cellular phone. The fire was extinguished, but had the truck exploded, destruction and death would have resulted.

Events such as these demonstrate the security and safety risks associated with HAZMAT shipments. The Federal Motor Carrier Safety Administration (FMCSA), working in close cooperation with the Transportation Security Administration (TSA), has attempted to proactively address public and private sector HAZMAT security concerns by identifying potential security risks related to HAZMAT transportation and proposing solutions to minimize those risks. FMCSA embarked on a program to improve HAZMAT security and safety by using regulatory measures, security assessments, and outreach efforts.

Part of this effort was to sponsor an industry competitive procurement to conduct a national-level field operational test (FOT). This resulted in FMCSA awarding a contract for a team led by the Battelle Memorial Institute (Battelle) (Deployment Team) to test currently existing major technologies that could offer solutions to minimize security risks of truck-based HAZMAT shipments. Supporting Deployment Team members included: QUALCOMM; the American Transportation Research Institute (ATRI); the Commercial Vehicle Safety Alliance (CVSA); Savi Technologies; the Biometrics Solutions Group (BSG); Total Security-US; and the Spill Center.

To evaluate the technologies tested in this FOT, their costs, benefits, and the operational processes require to be performed, the FMCSA, supported by the Intelligent Transportation Systems (ITS)/Joint Program Office (JPO), awarded an Independent Evaluation contract in August 2002. Science Applications International Corporation (SAIC) (Evaluation Team) led the Independent Evaluation for this HAZMAT FOT.

Overview of the Field Operational Test

This Hazardous Materials Safety and Security Technology Field Operational Test was focused on four different HAZMAT truck transportation scenarios representing the following industry segments:

- Bulk Petroleum
- Bulk Chemical
- Less-than-Truckload (LTL)
- Truckload Explosives industries

The scenarios were chosen based on the results of a hazardous materials risk and threat assessment that was conducted as the initial phase of this project by the Deployment Team, and was combined with a desire to test the technology in different industry types. The risk and threat assessment methodology was used to identify the types of materials that were of highest concern, as well as the most likely attack scenarios (***theft*** of a material, ***interception/diversion***, and ***legal exploitation***). Specific vulnerabilities were also identified during this phase of the project, which served as the basis for selecting the technologies within each scenario.

As detailed in Table 1, a wide variety of existing technologies were tested within each scenario. These technologies were integrated based on meeting specific functional requirements that FMSCA had set for the Deployment Team contract.[1] FMCSA also stipulated that these would need to be commercial off-the-shelf (COTS) technologies, such that they could conceivably be implemented rapidly by the motor carrier industry in the very near future.

The technologies were grouped together into several packages within each scenario. The grouping assisted in addressing the wide range of vulnerabilities identified in the risk/threat assessment, and for testing several different cost tiers reflecting a range of carrier deployment options based on market conditions. Based on this premise, the various technology components were separated into six technology tiers, ranging from a low-end cost of approximately **$800** per vehicle to a high-end of approximately **$3,500** per vehicle.

The technologies were matched to testing scenarios, which were developed to address the functional requirements and the threats and vulnerabilities identified in the Threat/Risk Assessment. With the overall goal of the FOT being to test technologies installed in 100 vehicles, each scenario tested a total of **25 vehicles**, with various combinations of technology installed on each vehicle. Table 2 provides a summary of each scenario and the technology components to be tested by scenario.

[1] It should be noted that this evaluation does not endorse any one vendor or another through the results of this evaluation or the functional product descriptions that follow. The evaluation's focus was to explore the functionality represented by the cited product types tested during the FOT. It was necessary for this test to consider individual products to collect quantitative and qualitative test data for the FOT. The specific products used in this FOT should be thought of as being representative for a class of products that exhibit similar functionalities in the field, and not as the only technology products to provide potential benefits in regard to HAZMAT security and operational efficiency.

Table 1. Overview of HAZMAT FOT Technologies

Technology Category	Application Areas	Brief Description
Wireless – Mobile Communications	Wireless Satellite or Terrestrial Communications (with GPS) and Tracking Digital Phone (without GPS)	• **Wireless Communications with GPS** provide vehicle tracking and two-way communication between the driver and dispatcher. • **Digital Phones** provide integrated work order assignment and status messages between the dispatcher and driver.
In-Vehicle Technologies	On-Board Computers (OBC) Panic Buttons Electronic Cargo Seals	• **OBCs** are data processing units that receive and analyze information from sensors and other devices on the vehicle and then store/present the information in a convenient and easily accessible manner. The OBC provides vehicle disabling and remote locking/unlocking capability. • **Panic Buttons** provide real-time emergency alert messaging notification and localized vehicle shutdown. • **Electronic Cargo Seals** utilize short-range wireless communications to automatically generate an alert if the seal is broken without proper authorization.
Personal Identification	Biometrics Personal Identification Number (PIN)	• **Biometrics** consists of technologies that analyze human characteristics (eyes, facial recognition, fingerprint, hand geometry, etc.) for verification of identify and access to secure systems. • **PIN** systems are the most common identity verification systems and consist of stored data (numbers, letters, characters) used to identify individuals for access to secure systems.
Mobile Data Management	Smart Cards/Electronic Supply Chain Manifest (ESCM)	• The **ESCM** system combines biometric verification, smart cards, Internet applications, and the on-board wireless communications system to ensure proper chain-of-control.
Vehicle Tracking	Routing and Geofenced Mapping Software Trailer Tracking	• **Geofencing** provides the capability to put a "virtual fence" around a vehicle's intended route travel and automatically notifies dispatch/ operations personnel when the vehicle strays beyond this fence. • **Trailer Tracking** consists of both tethered tracking, which provides connect and disconnect events, and untethered tracking, which is combined with Geofencing to provide security to the unconnected trailer.

Table 2. Overview of HAZMAT FOT Scenarios

Scenario	Description	Technology Components
1	Bulk Fuel Delivery	• Wireless Satellite Communication • Global Login • In-Dash Panic Button • Wireless Panic Button • Digital Phone • Terrestrial Communication • On-Board Computer
2	LTL High Hazard	• Wireless Satellite Communication • Global Login • In-Dash Panic Button • Wireless Panic Button • Terrestrial Communications
3	Bulk Chemicals	• Wireless Satellite Communications • Biometric Authentication • In-Dash Panic Button • Wireless Panic Button • Electronic Supply Chain Manifest
4	Truckload Explosives	• Wireless Satellite Communication • Biometric Authentication • In-Dash Panic Button • Wireless Panic Button • Electronic Supply Chain Manifest • On-Board Computer • Wireless Electronic Cargo Seal • Geofencing • Untethered Trailer Tracking

Before full operational testing began in September 2003, a series of Beta Tests were conducted in early July 2003 to validate the system components. For this testing, QUALCOMM utilized its unique "Technology Truck," which allowed for all of the prototype system hardware to be connected to an operational test vehicle. The truck was then driven on several specified routes for the 5-day duration of Beta testing to validate the system design and operational concept.

Full operational testing commenced in September 2003 and continued through April 2004, based on the four scenarios detailed above. Additionally, some testing was conducted between February and May 2004 to examine potential public sector technologies that could interface with the prototype system.

Independent Evaluation Technical Approach

In order of priority, the primary evaluation impact categories examined by the Evaluation Team were security, operational efficiency, and safety.[2] As detailed in Figure 1 on the succeeding page, these impact categories feed the benefit-cost analysis according to macroeconomic/ societal (macro) public sector benefit-cost results (stemming from security benefits) and microeconomic/industry (micro) private sector benefit-cost results (derived from operational efficiency benefits). The macro/societal and micro/industry benefit-cost measurements analysis was conducted to determine the following:

- Do the technologies provide significant macro security and safety benefits?
- If so, are the industry operational efficiency benefits significant enough to drive widespread industry deployment of test technology systems, or is government action warranted to facilitate wide-scale deployment?

The evaluation assessments were conducted within the scope of the FOT and extended the FOT findings to the larger universe of truck-based HAZMAT shipments (for the four primary scenario load types) through rigorous analytical frameworks. These frameworks utilized:

- Primary and secondary industry survey data;
- Detailed motor carrier census records;
- Market analysis of technology products and services that are commercially available; and
- The informed opinions provided by two groups of leading national experts in HAZMAT shipping, public safety, security and risk assessment – an Expert Steering Committee and a 26-member Delphi Panel.

Based on the results of the testing of the technologies in this FOT, these assessments were then made for each scenario to determine what measurable benefits existed. Following this, analytical frameworks were applied to monetize potential benefits and to weigh these against any costs that would have to be incurred to realize the benefits.

Both quantitative and qualitative data were collected to support the technology-based and system-based evaluations. *Qualitative data* were derived from on-site observations and personal interviews during the FOT. Information was gathered on such topics as the operational effectiveness of the technology, customer satisfaction, and institutional challenges. For example, drivers were asked about the ease of use of the various technologies, and how adding the technology impacted their daily operations. *Quantitative data* was collected primarily through system-generated archived reports, providing ongoing data collection of use and performance of technology applications throughout the FOT.

[2] While safety was originally considered as a potential significant impact category for this FOT, it should be noted that the test technologies were designed to enable real-time communications and information exchange among drivers, dispatchers, and other authorized parties; track assets; secure vehicles, loads, and shipping documentation; and enable driver or automated exception alerts in response to crises or deviations in operational characteristics outside of set parameters. The technologies themselves and their usage are not specifically designed to provide explicit or traditional safety benefits (i.e., direct technology intervention to avoid a crash).

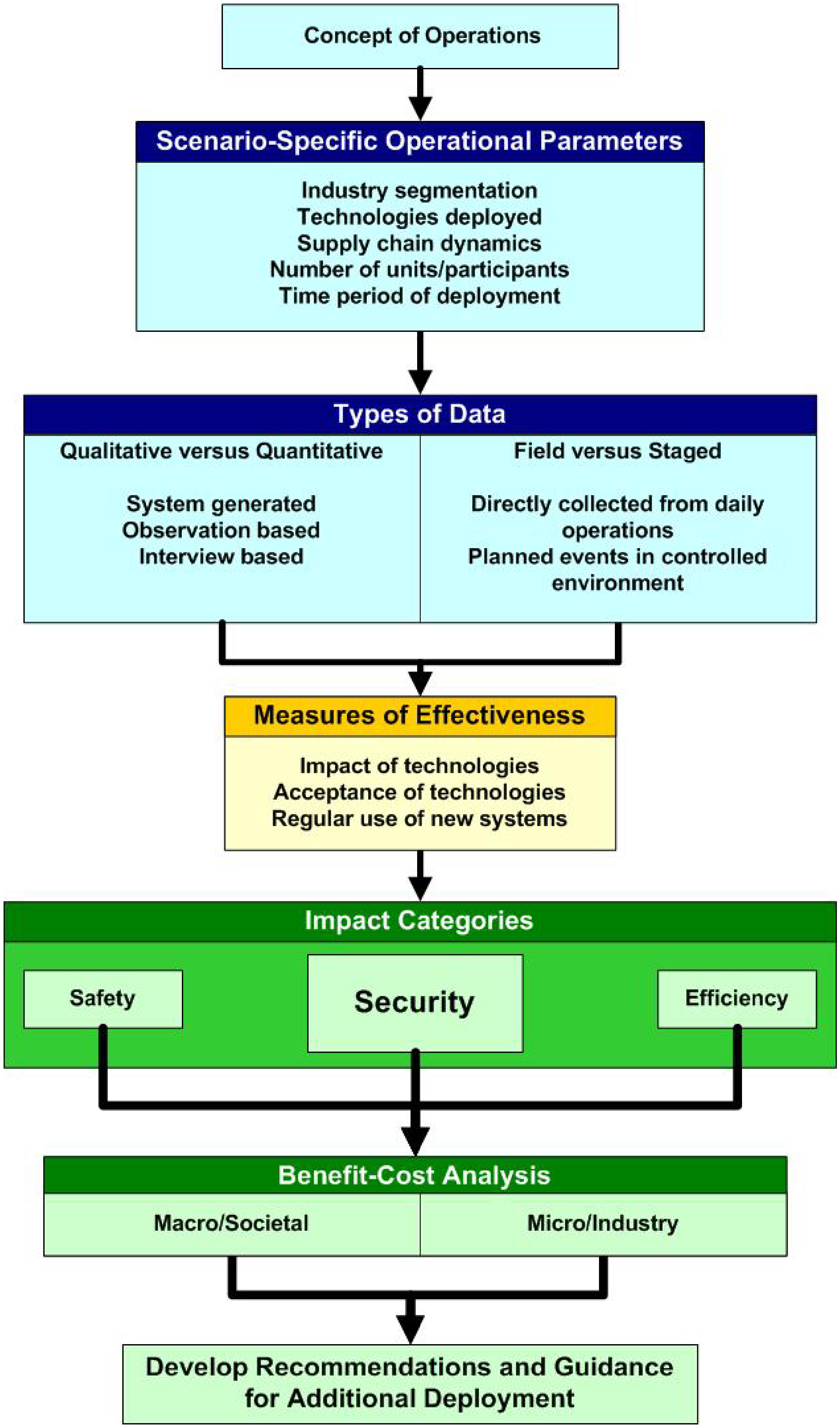

Figure 1. Evaluation Framework.

Evaluation Findings

This evaluation examined the technical and financial performance of several promising technologies for increasing the security of HAZMAT shipments. The intent was to determine what levels of security, safety, and operational efficiency benefits can be attained through deployment of the technologies. The evaluation also examined the levels of investment required to equip fleets with the technologies. Based on the evaluation of the test technologies, conclusions can be drawn regarding: technical performance; security benefits; efficiency benefits; safety benefits; public sector reporting center concept; deployment potential; consolidated benefits and costs; and policy options for consideration, described as follows.

- **TECHNOLOGY PERFORMANCE**

Summary: Technology performance overall for the technologies was good, with most technologies performing well under operational conditions with the exception of Biometric Login and Electronic Seals (E-seals). These two technologies were deemed as requiring additional product development to be fully adapted for and accepted in the HAZMAT trucking environment.

The core enabling technology for the test suites, Wireless Communications with GPS tracking capabilities, has been deployed commercially for several years and performed per expectations during the FOT. The technology also demonstrated its ability to integrate additional security functions with the established communications network providing a reliable data transfer mechanism.

The Panic Button, Vehicle Disabling, Trailer Tracking, and Geofencing applications of the core enabling technologies also performed per specification.

The Biometric identification units supporting Biometric driver logins and access to the ESCM need to be more “forgiving” for climatic conditions and physical application of fingers to the readers. The E-seal system, even after undergoing modification during the FOT, showed cycle times considered too long by the participants. Additionally, a more user-friendly software interface is recommended. The ESCM, as demonstrated in a previous test of application during this FOT, requires the development of interfaces with other systems used by motor carriers. Integrating the ESCM with carrier systems would increase usage of the system.

Technical performance of the FOT technologies was demonstrated through initial Beta Testing, then during the operational test through technology exercises and “staged events” defined by the Evaluation Team. The staged events tested the systems in the field under near real-world conditions. Additionally, day-to-day performance of the test technologies’ performance was captured via participant interviews and analysis of archived event transaction logs.

This evaluation approach resulted in findings that overall, technology performance for the technologies was good, with most technologies performing well under operational conditions. The exceptions included Biometric Login, and to a lesser extent, the E-seals, and the ESCM, which were deemed as requiring additional technical development for the HAZMAT trucking environment.

The “core enabling technology” for the test suites, **Wireless Communications with GPS Tracking Capabilities**, has been deployed commercially for several years and performed per expectations during the FOT. The technology also demonstrated its ability to integrate additional security functions with the established communications network providing a reliable data transfer mechanism. Additionally, all eight participant carriers that have previously and continued to use this Wireless Communications technology attest to the positive efficiency impact it has had on their operations, and all showed robust technology utilization.

Positioning frequency ranged from **17 to 70 minutes** for FOT participants that depended on operational conditions, such as desired customer reporting frequency, type of commodity being hauled, and length of route.

Global Login proved to be a reliable form of driver identification at the four carriers who were assigned the technology during the FOT. Several other carriers used Global Login as a backup to Biometric Login when it failed. The time required for Global Login was consistent across FOT participants. Global Login events were completed successfully several times at each site in about **30 seconds**. Incorrect Global Login events were also conducted to show the ability of the system to reliably detect incorrect login attempts under operational conditions. Incorrect Global Logins also took approximately 30 seconds for the system to detect. Global Login was generally well received by drivers who found that training was brief and simple, especially when compared to the Biometric Login.

The actual experience that test participants had with the **Biometric Login** device used in this FOT was that it was often unreliable in the field. The unreliability was due to the difficulty in finger placement to introduce consistent fingerprints into the Biometric Reader. Correct finger placement would allow either the vehicle to properly start or for employees to log into the ESCM system to work with manifest files. Driver complaints were high for this technology in regard to usability in the field, suggesting a need for overall design improvement, such as a finger guide to properly align drivers' fingers on the reader. In addition to difficulty in finger placement location for participants, if a driver's finger were too hot or too cold, the Biometric Reader would often fail to obtain a successful login event.

Use of the **Electronic Supply Chain Manifest** was disappointing and statistically irrelevant during the course of the FOT, with only **55 manifests** being successfully created, and of these, only 12 were utilized through delivery of the HAZMAT load. Some of this poor usage resulted from problems encountered with the Biometric Login, similar to the problems encountered with the driver login procedure. As a stand-alone system, participant usage also suffered due to the redundancy of having to use both the paper and electronic manifest processes, and also due to user difficulties with the Web interface.

Both in-dash **Panic Buttons** and driver remote Panic Buttons were well accepted by the motor carriers in this test, and **118 test events** were conducted to validate their successful use.[3] Recorded panic alert notifications from the technology exercise site visits took between **25 seconds to about 1 minute** from the moment the Panic Button was pressed to the point when the dispatcher was alerted at the motor carrier facility. Panic Buttons were seen as a viable technology method to alert the motor carrier or law enforcement from remote regions of the nation. Panic Buttons were viewed as having excellent security potential; in fact, several of the participants already had in-dash Panic Buttons installed prior to this FOT and expressed excellent satisfaction with the technology. The only issue associated with the wireless Panic Button was that some drivers felt the key fob (security token) design could cause an alert to be issued by a driver by accidentally bumping the trigger device.

Geofencing was tested in two operational uses for alerting a trucking company when one of its vehicles leaves its designated route (mapped on computer by the dispatcher), and for when one of its vehicles enters a restricted area. Both functionalities involved frequent vehicle positioning via Wireless Communications. Geofencing was viewed by the FOT participant who used it as an

[3] Panic Buttons were not tested during normal operations due to the sensitive nature of the technology and not creating "false alarms".

excellent technology to locate a vehicle that was off route or in an area where management did not want that truck to be positioned. The FOT participant thought it would useful as a tool not only to improve security, but it might keep drivers from stopping for excessive periods of time at unauthorized locations.

The **Electronic Seals** testing in this FOT demonstrated that this technology might not be realistic in a HAZMAT trucking environment at this time. For example, the initial deployment of the E-seals had significant problems in communicating with the on-board communications system with trucks having heavy steel doors. In addition, the cycle of operations for a driver to operate the seal took several minutes, and at times confused the drivers. By the end of the FOT, E-seal operations had improved somewhat.

The **Remote Door Look** system testing, while inconclusive due to only **16 data points**, showed promise of being another cargo security solution that could be considered for HAZMAT loads along with E-seals. This sequence of events was demonstrated during on-site testing at the FOT participant carrier using this functionality on one truck. Additionally, the single participant using this technology concluded that it had worked excellent in daily operations, it had merit as a security device, and it might be a cost-effective means of security for a HAZMAT load.

Both the **Tethered and Untethered Trailer Tracking** technologies were well received by the FOT participant using these technologies under test conditions. Dispatch found useful the ability to detect trailer connects and disconnects with the Tethered Trailer Tracking system, and the ability to track an unconnected trailer as another authorized carrier moved it. Both technologies were used on a consistent basis during the FOT.

Vehicle Disabling was accomplished by integrating **Intelligent On-Board Computers** (OBC) with the Wireless Communications/vehicle operating systems. The OBC permitted the motor vehicle to be disabled in the event of a security breach. These *remote disabling techniques* included blocking fuel or sending instructions via the Wireless Communications system directly to the vehicle’s data bus, which caused loss of throttle power to the motor vehicle. The OBC also was configured to shut down the vehicle whenever there was a *loss of satellite signal strength*, such as when cables are tampered with or the receiver unit is covered. One variant of the vehicle disabling capability that did not require the use of the OBC was *local vehicle disabling*. By the driver depressing the panic button of his key fob, a signal was sent directly to the vehicle to initiate the disablement. The wireless panic button with local disabling capability is carried by the driver and has a range of up to 250 feet. This latter application does not require the OBC to perform the local vehicle disablement.

➢ SECURITY BENEFITS

Summary: The technology suites tested during the FOT, given further development, show promise for significantly reducing vulnerabilities, thereby reducing potential impacts of terrorist attacks. It should be recognized that technology alone, at best, could only address approximately **one-third** of the potential HAZMAT-based vulnerabilities.

The core enabling technology (Wireless Communications with GPS positioning) also provides significant security benefits. The implication is that the core enabling technology has the capability of more than covering its costs to motor carriers, while providing a significant security benefit to society. Given this benefit, policy makers should consider how best to further reduce costs through several possible mechanisms and promulgate information to motor carriers.

The remaining technologies do show considerable potential security benefits (societal benefits), but not necessarily realized by the motor carriers. For example, both the E-seal and OBC with door lock are potential security improvements in the attempt to bolster en transit cargo protection. Both technologies in theory enable remote detection of an intrusion of the trailer by an unauthorized party at any point from pick up to delivery of cargo, and to some extent, make it more difficult for entry into the trailer.

To assess security benefits for these technologies, the Evaluation Team devised a groundbreaking process and corresponding methodologies to assess the security benefits of transportation technologies. Building on previous work conducted by Battelle, Total Security.US, and the Volpe Center, the Evaluation Team combined expert panel review information to assess the potential benefits. As part of this process, a “Security Expert Panel” was established specifically for this project to provide input from TSA and other recognized experts.

The Security Expert Panel was co-chaired by the Deputy Director for Land and Maritime Security at TSA. This Panel also included representatives from major trade associations, the insurance industry, and other security and counter-terrorism experts. This Panel provided input into staged and controlled events testing the technologies. In addition, the Security Expert Panel provided oversight for the Delphi Panel, which included the selection of a wider group of experts in predicting potential security vulnerabilities relating to terrorist attacks.

The Delphi Panel used an iterative process of reviewing and responding to several surveys used to quantify the security impacts of the technologies to identify benefits in the form of vulnerability reductions. These vulnerabilities in truck-based HAZMAT shipping were defined by the Deployment Team and used with the Delphi Panel assessments to derive an overall vulnerability reduction. The Delphi Panel also reviewed and provided comments to the Security Expert Panel on the final analysis.

In implementing this process, the detailed daily operational and staged event data was collected to assess the technical efficacy of the technology suites and participant perceptions regarding the value of the technologies to their operations vis-à-vis reducing operational vulnerabilities to terrorist activity. This information was summarized and presented to the Delphi Panel[4] of 26 nationally recognized experts in HAZMAT transportation security and risk assessment. The Delphi Panelists were requested to render educated expert opinions regarding the ability of the technologies to reduce vulnerabilities in truck-based HAZMAT shipping, as related to three

[4] In the Delphi process, the experts were asked to provide estimates of vulnerability and the beneficiary effect of the FOT-considered technologies via surveys. Both numerical and linguistic responses were developed over a series of group interrogations. Outputs that had linguistic values were then processed using Soft Computing Methods in order to provide input values that support conventional Multi-Attribute Decision Making Methods. The benefit levels, in terms of the vulnerability reduction potential for each shipment type, were evaluated using a weighted sum method that considers the probability of each particular threat. Finally, the process included a computational element to allow economic analysis, such as Cost/Benefit or Net Benefit analysis for each technology application strategy.

primary areas of security threats to HAZMAT trucking operations: ***theft***, ***diversion***, and ***interception*** and their contributing vulnerability factors: ***chain of custody, access,*** and ***response time***.

Using the relative weightings for these factors provided by the Delphi Panel and their informed opinions regarding the technologies' ability to address critical vulnerabilities, overall reductions in vulnerabilities were calculated for each technology combination for each of the test load types. Table 3 presents a sample of the technology-enabled vulnerability reductions.

Table 3. Percent Reduction in Overall Vulnerability by Load Type and Technology Scenario[5]

Technology Scenario	Bulk Fuel	LTL-High Hazard	Bulk Chemicals	Truckload Explosives
Wireless Communications + GPS Position (base)	17%	16%	16%	12%
Driver ID + (WC + GPS Position)	25%	25%	23%	18%
Panic Alert + (WC + GPS Position)	27%	25%	25%	21%
Panic Alert + Remote Vehicle Disabling + (WC + GPS)	32%	32%	31%	25%

The overall vulnerability reductions were then applied to the dollar figures developed as cost estimates for a terrorist attack involving hazardous materials to determine the overall security benefits of the technologies to determine the estimated security benefits. The estimated "worst-case" attack consequences were established through a separate study sponsored by FMCSA. Sample benefit calculations are shown in Table 4.

Table 4. Vulnerability Reductions for Bulk Fuel Scenario and Security Benefits

Technology	Percent Vulnerability Reduction	"Worst-Case" Attack Consequences	Estimated Security Benefits	Estimated Benefit Cost Ratios
Wireless Communication with GPS (base)	17%	$3.7 Billion	$622 Million	1.5:1
Base + Driver Identification	25%		$933 Million	2.1:1
Base + Panic Button	27%		$995 Million	2.3:1
Base + Panic Button + Remote Vehicle Disabling	32%		$1.207 Billion	2.6:1

In all load cases the overall security benefit cost ratio was positive, except for the LTL environment. In this case, the potential consequence and attractiveness of the LTL loads for use as a weapon of mass effect is relatively low and the number of trucks that would require being equipped is relatively high. As discussed above, the primary benefits in both the security and

[5] Vulnerability reductions from 0-10 percent are considered nil; reductions from 11-25 percent are considered low; reductions from 26-50 percent are considered medium; and greater than 50 percent are considered a high reduction.

efficiency impact categories were derived from the use of Wireless Communications with GPS positioning. **It should be noted that partial deployment might not necessarily result in a directly proportional security benefit. In other words, 50 percent deployment may not yield 50 percent of achievable security benefits.** This may occur because while the technology-equipped fleet may not be attacked, a non-equipped fleet would possibly be targeted instead. The deterrent effect of the technologies, if partly deployed, could simply shift terrorist targeting from one fleet to another, with no net change in overall security. Under this assumption, then full deployment is required to realize the security benefits.

Realizing that threat can be unpredictable and vary over time, breakeven numbers of successful attacks that needed to be reduced via the technologies to equal the costs of deploying the technologies was calculated. These breakeven values were calculated using the following formula:

Breakeven Number of Attacks =
(Total Deployment Cost for the Technology / Consequence per Attack)

The breakeven number of attacks is presented as a decision tool – if one believes that the probability of an attack (threat) is greater than the breakeven for a technology combination for a load type, and then to society, the investment in the technology combination can be considered sound. For example, preventing one attack over the 3-year period would easily surpass the breakeven point for all scenarios other than the LTL operations.

For context, the highest breakeven numbers for each load type were compared to prognostications made by the Delphi Panel as to the number of attack attempts on/using truck-based HAZMAT shipments and the proportion of those attempts that are likely to be successful within the next 3 years. The Delphi Panel, at the low end, indicated the number of successful attacks as being likely exceed the breakeven attack numbers for all load types, except LTL-High Hazard loads. In summary, for all load types, except LTL-High Hazard, the Panelists feel there is at least a 5 times greater probability of successful attack than is required for equating security benefits with deployment costs.

- **EFFICIENCY BENEFITS**

Summary: The core enabling technology (Wireless Communications with GPS positioning) is the only technology tested that demonstrated tangible operational efficiency gains within the limits of this FOT. In most cases, this was simply a function of the manner in which the technologies were deployed and utilized. For example, other field operational tests involving untethered trailing tracking have indicated the potential for significant efficiency improvements. However, in this particular FOT, the untethered trailers were tracked solely for security purposes; no inventory management systems were implemented or utilized.

Productivity gains in terms of increased personnel and asset utilization are found to outweigh the costs of deploying the core enabling technology with relatively attractive payback on investment periods. With the proven reliability of the technology in the market place and appropriateness of application to a wide range of fleets, significant industry benefits could be realized through full deployment. Net benefits over costs of up to **$1 billion per year** could be realized. Even with attractive return-on-investment (ROI) and low payback periods, capital constraints and institutional inertia (comfort with doing business in fixed ways) are likely to make penetration of this market a long-term enterprise, especially in the smaller fleet categories.

The Evaluation Team conducted a detailed operational efficiency and benefit-cost assessment on this core technology based on data collected in this test. The findings were that productivity gains in terms of increased personnel and asset utilization are found to outweigh the costs of deploying this technology with **payback on investment in many cases of approximately 1 year or less** across the scenarios.

An example of the typical operational efficiency gains that were measured and assessed by the Evaluation Team under this effort is a Bulk Fuel motor carrier. This FOT participant recently began using a Wireless Communications with GPS system to more accurately capture time-stamped events (start and end of day, breaks, arrive/leave rack, arrive/leave customer locations, etc.) to track driver productivity and better mange driver activities and scheduling. Based on data from 19 drivers over an 11-week period, the weekly driver productivity reports demonstrated an overall **increase in driver productivity of 11 percent**, bringing the aggregate level to approximately 90 percent of the target the carrier had set. Based on this data, the Evaluation Team calculated an **average savings of $5,800 per year per truck** for Bulk Fuel carriers (versus a case of no technology). Similarly, data was collected from an LTL-Non-Bulk carrier, which demonstrated overall **driver productivity improvements of 3.5 percent** using the technology. In the case of this carrier, the improvement in driver productivity resulted in a conservative **cost savings of $1,920 per year per truck**.

Based on a database of operational efficiency data provided by three of the test participants, the Evaluation Team developed an ROI model for industry use of Wireless Communications with GPS (S – Satellite; T – Terrestrial Communications). This ROI model essentially equates downtime savings associated with eliminated driver call-in stops and unscheduled en-route maintenance/repairs with increased asset capacity. The ability to know where assets are, the state of conditions vis-à-vis maintaining schedule, and knowing driver availability for hours of service allows dispatchers/load planners to assess the feasibility for picking up potential backhaul loads (applicable to the operation).

The ROI model also estimates the value of freed up phone call time for dispatchers talking with drivers, thus allowing them to focus on other duties, or have the time to manage more drivers, if necessary. Other benefits include assessed include lower communications costs, less idling time (associated with driver call-in stops), resulting reduced in fuel and engine wear costs. To explore the low-end efficiency benefits, the project drew on previous work that indicated that not all carriers were able to gain benefits it all areas. For those areas where this situation pertained, a "minimum" benefit was calculated, with benefits shown as a range. The Operational Efficiency benefits are presented in Table 5.

Table 5. Costs, Benefits, Benefit-Cost Ratios, and Payback Periods by Industry Segment (Wireless Communications with GPS Tracking Capabilities)

Segment/ Fleet Size	Annual Cost/Truck[6]	Annual Benefit/Truck	Benefit - Cost Ratio	Payback on Purchase in Months
Bulk Fuel (T)	$1,188	$5,832	4.9:1	3
LTL-High Hazard (S)	$1,524	$2,352 to $9,840	1.5:1 to 6.5:1	3 to17
LTL Non-Bulk (T)	$1,188	$1,920	1.6:1	13
Bulk Chemicals (S)	$1,524	$1,560 to $7,116	1.0:1 to 4.7:1	5 to 34
Truckload Explosives (S)	$1,524	$1,824 to $11,004	1.2:1 to 7.2:1	3 to 25

[6] Costs include purchase and installation costs amortized over 3 years, plus ongoing messaging (with hourly position reports) and maintenance costs. Through discussions with motor carriers and the technology vendor, installation would likely occur during schedule downtime for preventative maintenance. Training of personnel in the use of technologies would generally fall within usual new employee training/orientation processes or within ongoing carrier training/skills enhancement activities.

➢ SAFETY BENEFITS

Summary: The benefits of the technologies as deployed, focus on enhanced driver monitoring capabilities, reduced exposure to crashes, and enhanced HAZMAT incident response. Within this framework, participant opinion indicates that the technical capabilities of the test technologies, coupled with best practices in motor carrier driver/safety management and public sector incident response, show promise for enhancing the safety of truck-based HAZMAT shipments. The technologies demonstrated enhanced ability to monitor drivers and vehicles and provide notification of emergencies with location and load characteristics in a more timely and potentially detailed manner than traditional methods (thus, potentially enhancing emergency response).

Through enhanced fleet management enabled by the core technology of Wireless Communications with GPS positioning, fewer non-revenue miles can be realized. Assuming these miles translate directly to fewer overall miles driven, potential benefits in terms of crash avoidance due to reduced exposure were conservatively estimated to be **$5 million annually**.

The majority of technologies themselves and their usage were not specifically designed to provide explicit or traditional safety benefits. For example, the test technologies are not designed to warn drivers of obstacles in proximity to their vehicles, lane departure, imminent vehicle rollover conditions, or conditions signaling driver fatigue.

This notwithstanding, frequent driver/dispatcher communications allowing the dispatcher to assess the driver's condition or position tracking to assess possible driver speeding may equate to potential reductions in crashes. Additionally, a potential reduction in miles driven via tighter management of fleet operations enabled by Wireless Communications and GPS asset tracking capabilities may equate to reduced exposure to crashes.

The participating motor carriers and enforcement personnel have also described potential post-incident safety benefits by using several of the test technologies. Using Wireless Communications with GPS positioning, panic alert capabilities, and real-time information exchange with law enforcement and emergency response agencies can provide more immediate incident-alert notification; detect vehicle location; and identify the quantity and type of HAZMAT load on the distressed truck. These benefits focus on the ability to more rapidly detect and respond to an incident with the most appropriate mitigating resources to a HAZMAT incident in a more timely and complete manner.

It also was found that there is some reduction in safety consequences due to the reduced exposure of hazardous materials vehicles. This reduced exposure is a result of a reduction in miles traveled obtained through the use of the Wireless Communications system calculated as part of the efficiency benefits calculation. The approximate **savings equal $5 million dollars** from the **$842 million per year crash costs** for the materials involved in the tested scenarios.

➢ PUBLIC SECTOR REPORTING CENTER CONCEPT

information in a timely manner to enhance enforcement response to security events. In expanding the PSRC concept to a full deployment scenario, significant institutional/procedural issues will need to be addressed. Among the more important of these is the administration of information and the notification process, i.e., ensuring that shipment information, alert notification levels (triggers), and key persons to be notified are current and complete.

If not, the effectiveness of the system may be significantly eroded by alerts being directed to personnel or agencies that may not be involved in responding to given incidents, or that appropriate persons/agencies may not be alerted when actually warranted or that information provided is lacking or inaccurate. In either case, confidence in the PSRC and the ability to readily use alert and shipment background information provided via the PSRC is at stake. Addressing this will require coordination, continuity and uniformity of processes among shippers/consignees, HAZMAT motor carriers, and the enforcement/emergency response communities.

Conducted as an adjunct to the primary HAZMAT FOT, the Public Sector Reporting Center (PSRC) concept is an example of a potential solution that provides law enforcement and emergency response personnel with access to accurate, timely, and action-oriented information. As a solution, the PSRC system holds the potential to reduce vulnerabilities, and enables law enforcement and emergency response personnel to prepare, protect, deter, and respond to intentional and unintentional incidents associated with transporting hazardous materials.

On a basic level, the PSRC system successfully demonstrated that it has the ability to improve:

- The response times for emergency and enforcement personnel to respond to a HAZMAT security or safety incident through the implementation of these technologies and the reporting center operational concept.
- The quality of the information provided to first responders through the implementation of these technologies and the reporting center operational concept.

The Public Sector demonstration involved four of the nine carriers participating in the full-scale HAZMAT FOT, and also involved state law enforcement and response agencies from California, Texas, Illinois, and New York. The tests' objective was to assess whether the PSRC systems adequately met the public sector functional requirements with respect to generating customized alerts and handling data generated and delivered as part of the larger FOT, and to identify improvements in timeliness of alert notification.

Based on the Evaluation Team's assessment, for future PSRC or similar system concept testing, the following elements should be considered as enhancements to the current PSRC concept:

- A robust, standardized central data repository for data storage and retrieval must be created with built in redundancy for information collection, fusion, and dissemination.
- An effective interface must be developed to filter data to ensure that sensitive or corrupt data remains outside of any data delivery through the PSRC. As the recipient of key information, the PSRC must forward only critical information to public sector users in a prioritized and easy to manage format, which can be easily integrated with their current systems.
- The PSRC serves as the link between data sources to collect the initial data on one end, and deliver the alert notification data on the other. On the data collection side, mostly private carrier data is the primary source data for the PSRC at this point. In the future, it may be desirable to include information from sources (criminal databases, state commercial vehicle systems, terrorism watch lists, etc.) that might provide in-depth information relevant to criminal or security activity.

➢ DEPLOYMENT POTENTIAL

Summary: The core enabling technology (Wireless Communications with GPS positioning) for the test suites has the capability to enhance motor carriers' operational efficiencies and generate benefits in excess of deployment costs. Recognition on the part of the technology vendor community of the variability in the needs of HAZMAT trucking operations and responding by providing the basic core functions adapted to specific types of operations and at a range of pricing/financing options should drive motor carrier adoption of the technology and make it a prevalent fleet management technology in the future.

For the technologies that build upon the core technology, market forces are unlikely to support strong adoption of the technologies, at least in the foreseeable future. A possible exception may be imposition of requirements for technology imposed by shippers/consignees that would create a "derived demand" on the part of HAZMAT trucking operations to adopt the technologies.

To assess the propensity of carriers to adopt particular technology solutions, the Deployment Team surveyed motor carriers transporting HAZMAT as part of the FOT research effort. Returned by **153 motor carriers**, the respondent demographics represented a broad diversity of fleet sizes, range of operations, routing variability, general operational characteristics and levels of fleet management technologies currently used and those to be employed in the near-term. These results were validated using other industry technology deployment studies[7] and applied to the demographics of HAZMAT carriers reported in the FMCSA Motor Carrier Management Information System (MCMIS) database to estimate levels of current technology market penetration and total market potential.

The estimated current levels of technology deployment developed through this effort indicate that with the exception of cell phones, paging systems and two-way radio (approximately 87 percent of trucks), Satellite Communications (59 to 63 percent of trucks), and asset tracking (45 to 48 percent of trucks) technology adoption is limited among the four load types. On-Board Computers are used in approximately 12 percent of trucks and 20 percent of trucks are from fleets using Web-based shipment tracking systems (a proxy for the ESCM test system). The percentages for the other technologies are estimated to be at most 13 percent of trucks, with most below 10 percent of trucks.

Also, based on the survey responses, it is estimated that over the next 3 years, modest annual growth is expected for the technologies: Satellite Communications (1.7 to 2.3 percent); Panic Buttons (1.3 to 1.4 percent); Vehicle Tracking (0.8 to 1.1 percent); On-Board Computers (2.4 to 2.9 percent); Automated Driver Identification (1.0 to 1.3 percent); and Remote Vehicle Disabling (1.2 to 1.4 percent). Less than 1 percent annual growth in technology adoption is expected for the remaining technologies, with especially small growth in cell phone/pager systems, as these have already approached near universal adoption.

Based on current levels of technology deployment, Table 6 presents the findings of the deployment potential assessment examining motor carrier benefits and costs in terms of operational efficiency. To realize the full potential benefits, it is estimated that the HAZMAT trucking industry (at the high end) would have to **invest an initial $1.1 billion and incur annual service fees of $535 million per year** over and above current deployment levels. If the purchase costs were **amortized over 3 years**, total annual costs (including monthly service fees) would be **$910 million**. Offsetting these costs would be **increased profitability, estimated to be $1.7 to $4.1 billion per yea**r.[8]

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[7]ATRI – GartnerG2 survey of 150 motor carriers on adoption of in-vehicle technologies, Trucking Technology Survey – 2003; ATRI industry survey of 348 motor carriers to determine levels of technology adoption in 2000 and projections to 2003, in support of the North American International Trade Corridor (NAITC) Comprehensive and Coordinated Intelligent Transportation Systems for Commercial Vehicle Operations (ITS/CVO) Plan; ATA Foundation, *Motor Carrier Technologies – Fleet Operational Impacts and Implications for Intelligent Transportation Systems/Commercial Vehicle Operations*, October 1999.

[8]There may be minimum fleet sizes in these sectors under which the usefulness of integrated communications and tracking systems may be easily reproduced with less advanced methods and technologies, such as cell phones and pagers. Therefore, fleets of 1 to 9 power units were excluded from this analysis based on adoption of Wireless Communications with vehicle tracking capabilities.

Table 6. Deployment Potential Assessment Findings for Wireless Communications with GPS Tracking Capabilities (In Millions of Dollars)

Load Type	Unrealized Market Potential	Technology Investment	Investment Amortized Over 3 Years	Annual Service Fees	Total Annual Costs	Total Annual Efficiency Benefits	Benefit-Cost Ratios
Bulk Fuel	59,264 Trucks	$71	$24	$46	$69	$346	5.0:1
LTL-High Hazard	74,405 Trucks	$164	$55	$57	$112	$175 to $732	1.6:1 to 6.5:1
LTL-Non-Bulk	189,454 Trucks	$227	$76	$146	$221	$364	1.6:1
Bulk Chemicals	32,204 Trucks	$71	$24	$25	$48	$50 to $229	1.0:1 to 4.8:1
Truckload Explosives	4,373 Trucks	$10	$3	$3	$7	$8 to $48	1.1:1 to 6.9:1
Totals	359,700 Trucks	$543	$181	$276	$457	$943 to $1,719	2.1:1 to 3.8:1

Even with attractive ROI and low payback periods, capital constraints and institutional inertia (comfort with doing business in fixed ways) are likely to make penetration of this market a long-term enterprise, especially in the smaller fleet categories. The Evaluation Team concluded that some type of government policy action will likely be needed to spur on the deployment of these technologies such that the security benefits outlined in this report could be realized by society.

➢ CONSOLIDATED BENEFITS AND COSTS

The findings of the security, safety, and efficiency benefit assessments and the industry deployment-benefit-cost analyses were stand-alone analyses examining the economic feasibility of the technologies within each context. To understand the overall economic impacts, the results of the three assessments are consolidated to demonstrate the distribution of benefits among public and private stakeholders. In this analysis, efficiency benefits are allocated to the private sector motor carriers. Security and safety benefits are allocated to society. The benefits and costs represent all trucks equipped (those currently equipped and those not).

The resulting analysis showed positive benefit-cost ratios in all three categories, from a low in the LTL environment of 1.4:1 to a high of 96.9:1 in the Truckload Explosives area. Table 7 presents the percentage of benefits realized by the private sector for each load type. Figures 2 through 5 illustrate the distributions relative to deployment costs. The low percentages attributable to the private sector in the cases of Bulk Chemical and Truckload Explosives are attributable to the fact that the potential magnitude of a terrorist event using these materials is so high; the benefits due to vulnerability reduction are extremely high relative to benefits of improved efficiency.

Table 7. Percentage of Benefits Realized by the Private Sector

Load Type	Percentage of Benefits
Bulk Fuel	60% to 72%
LTL	81% to 92%
Bulk Chemicals	5% to 13%
Truckload Explosives	1% to 3%

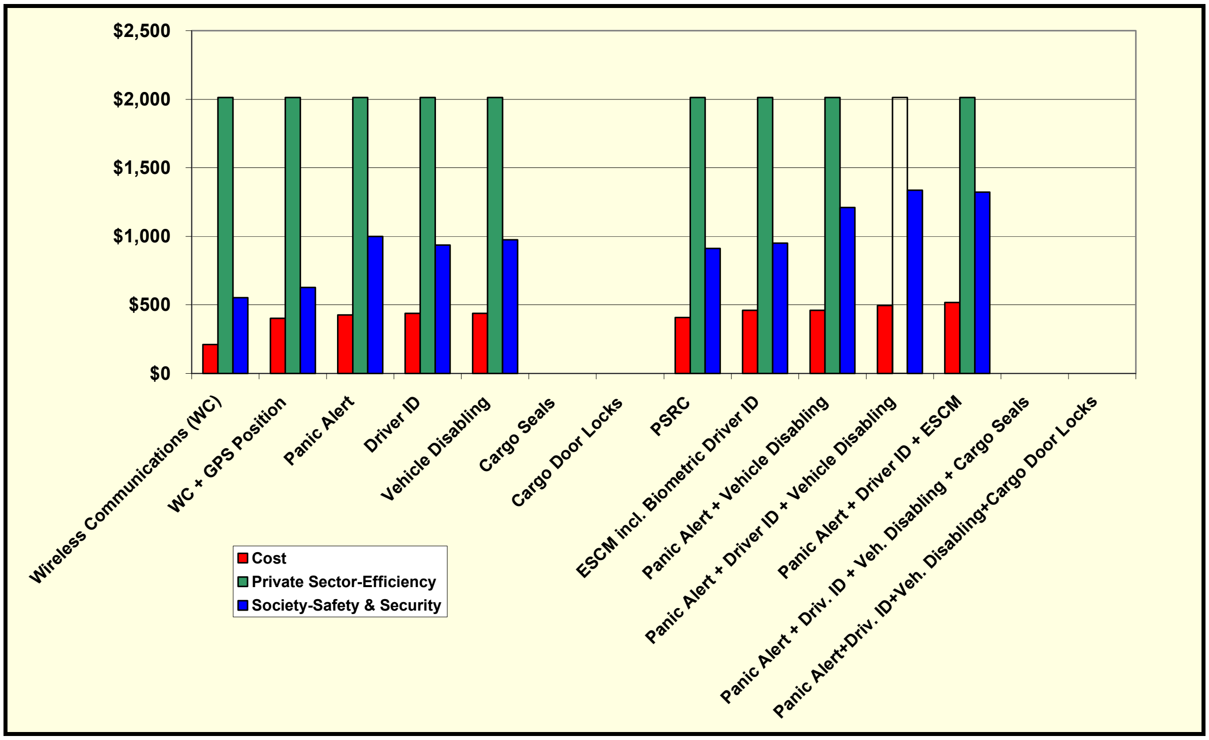

Figure 2. Deployment Costs and Benefits by Stakeholder Type for Bulk Fuel Loads (For 3 Years – In Millions of Dollars)

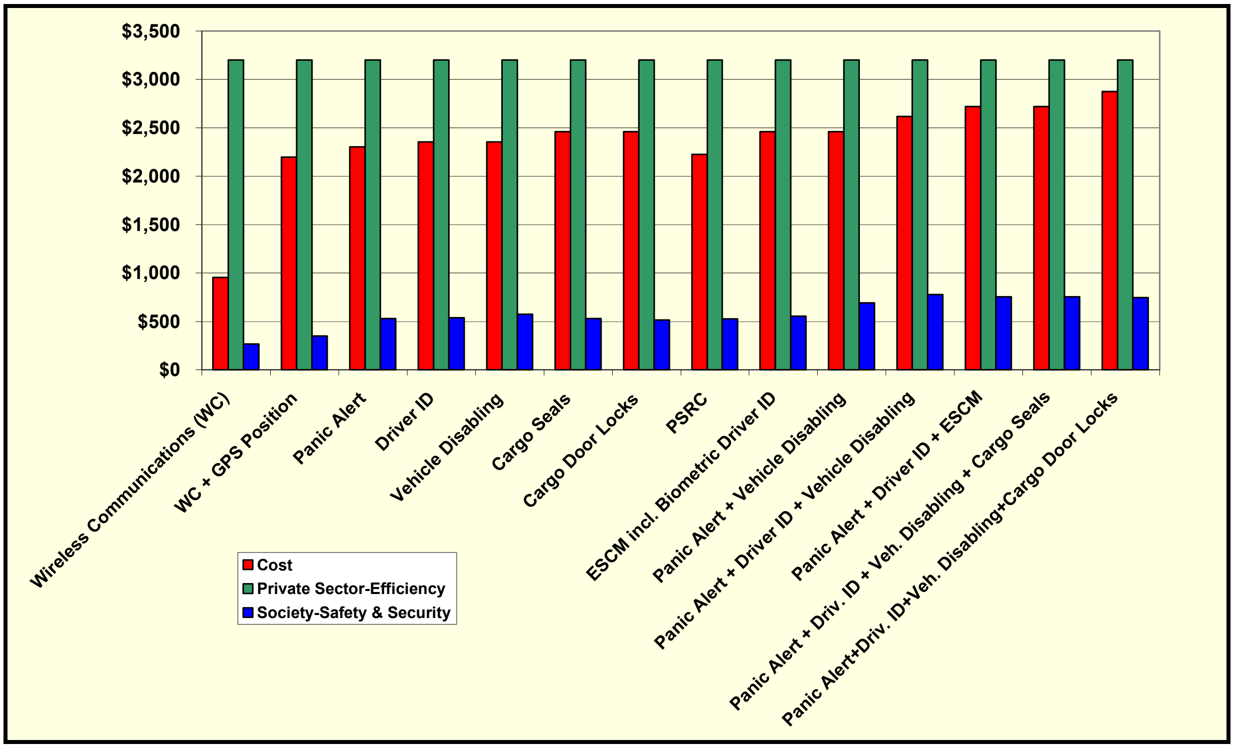

Figure 3. Deployment Costs and Benefits by Stakeholder Type for LTL High-Hazard Loads (For 3 Years – In Millions of Dollars)

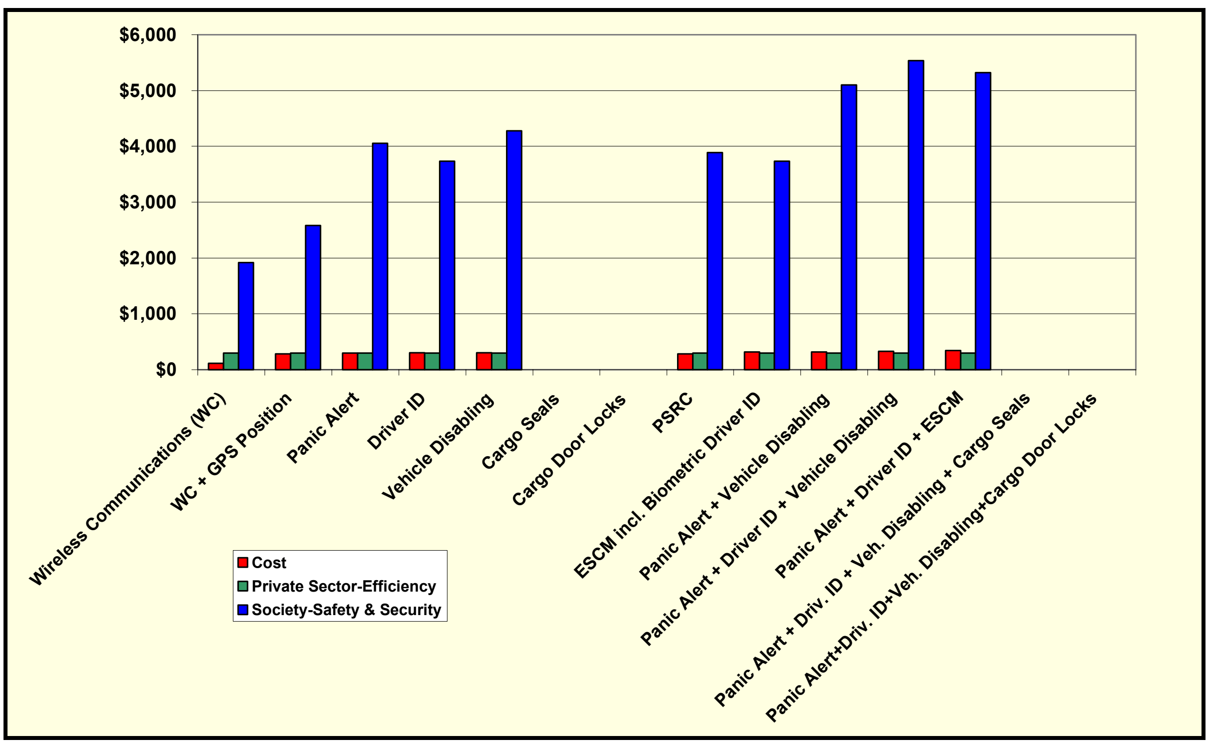

Figure 4. Deployment Costs and Benefits by Stakeholder Type for Bulk Chemical Loads (For 3 Years – In Millions of Dollars)

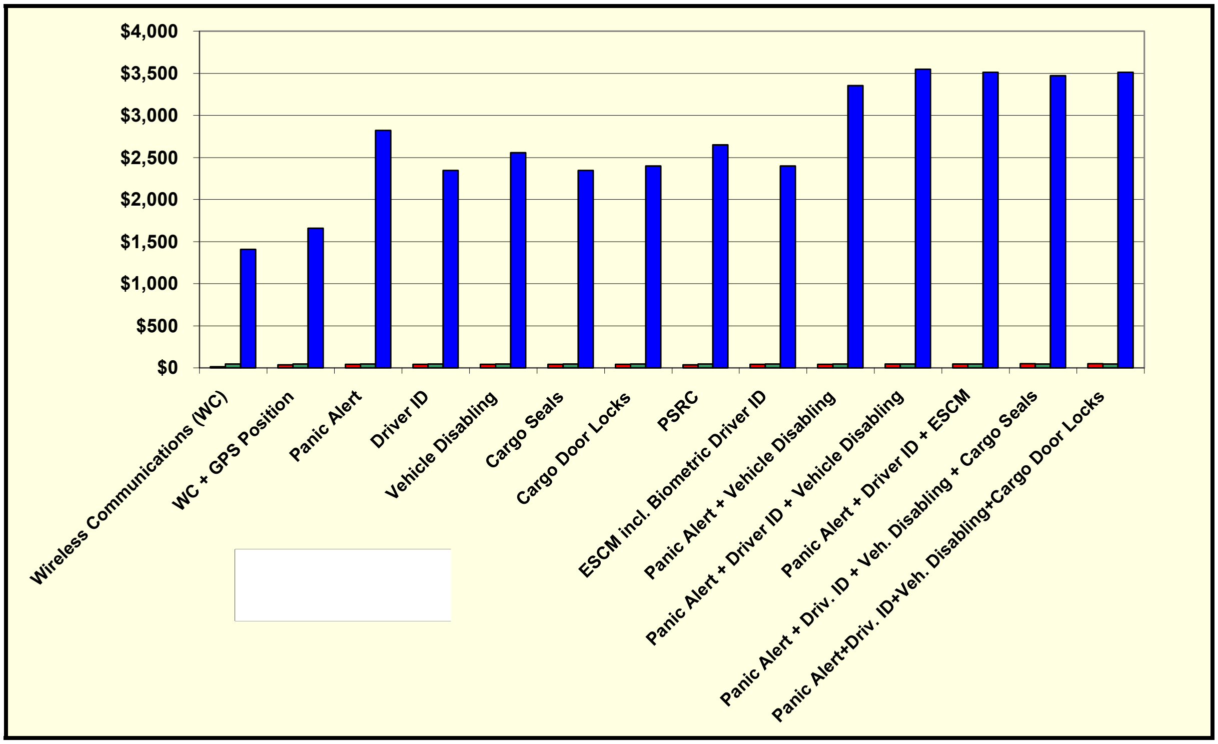

Figure 5. Deployment Costs and Benefits by Stakeholder Type for Truckload Explosives Loads (For 3 Years – In Millions of Dollars)

➢ POLICY OPTIONS FOR CONSIDERATION

Summary: The technologies tested show promise for enhancing the security of truck-based HAZMAT shipments. The core enabling technology for the operational test, Wireless Communications with GPS positioning demonstrates a positive return on investment to motor carriers with the additional technologies providing limited discernable (as deployed within the FOT) additional efficiency benefits. To reach full deployment and thus, realize the societal security benefits, future policy regarding the technologies needs to address a number of significant financial, technical and legal issues that affect the motor carrier industry. Options for addressing these issues include creation of financial incentives to invest in technology; support of additional research and development for promising safety, security, and efficiency-enhancing technologies; ensure data privacy for motor carriers; conduct outreach describing the benefits of technology; and, in the event of new rulemaking, focus on performance-based compliance to allow motor carriers flexibility in meeting any new security requirements.

The described levels of benefits are assumed to be only achievable through full deployment of the technology solutions. As described by the test participants, the Expert and Delphi Panelists, along with well-documented technology deployment issues of the motor carrier industry, several issues/concerns need to be carefully addressed before levels even approaching full deployment could be reached. The issues presenting the most significant barriers to full deployment of potentially beneficial technology systems include: technology cost, technical performance/ efficacy, potential liability issues and data privacy issues.

There are several possible strategies that could be employed singularly or in combination to stimulate industry deployment of technologies that show promise for reducing vulnerabilities in truck-based HAZMAT shipping.

For nearly all motor carriers, return on investment is the lead factor in the decision to adopt technology systems. As found in this FOT, aside from Wireless Communications and asset tracking, many of the technologies tested do not demonstrate a tangible improvement in motor carriers' bottom line, but show promise for reducing vulnerabilities in truck-based HAZMAT shipping, and therefore, rendering potentially significant societal benefits. In establishing policy, the Government needs to weigh these potential societal benefits against the possibility of negatively impacting the trucking industry's ability to move freight efficiently.

Multiple solutions may be required to realize societal benefits in a fair, consistent, and cost-effective manner. What may be appropriate for one type of operation may result in economic harm to another type of operation. Therefore, if base security requirements are clearly defined and mandated, the focus needs to be on measurable performance results and provide the trucking industry flexibility in how the mandated standard may be attained.

Governmental strategies that may be employed to encourage deployment include:

- Support research and development for adopting commercially available and emerging technologies that show promise for enhancing security through continued field testing.
- Create financial incentives to encourage research and development and technology purchases, grants, or facilitating cooperative purchasing arrangements.
- Enact legislative and procedural action to address data privacy issues.
- Promote technology acceptance through focused outreach and public relations efforts.
- Craft regulation/rulemaking requiring the adoption of solutions to address HAZMAT trucking vulnerabilities. These should be performance-based requirements that provide motor carriers flexibility in how they meet the requirements.

➢ FINDINGS AND CONCLUSIONS

This complex HAZMAT Safety and Security Technology Field Operational Test was conducted in the pursuit of improving Homeland Security vis-à-vis protection of truck-based hazardous materials shipments. With over 800,000 HAZMAT shipments per day, many involve materials that could be used for terrorist attacks with the staggering potential consequences in terms of deaths, injuries, property damage, and business disruption. The possibility of even one shipment used by terrorists for an attack underscores the immediacy of implementing countermeasures rapidly. With resources in limited supply and many counter-terrorism fronts to contend with, meeting the "clear and present danger" to HAZMAT trucking requires implementing solutions that are currently available, reduce risk, and that provide tangible and quickly realized benefits to stakeholders proportional to their level of investment.

This evaluation examined the technical and financial performance of several promising technologies for increasing the security of HAZMAT shipments to determine what levels of operational efficiency and security benefits can be attained through deployment. To date, no studies were uncovered that have attempted the analysis conducted here, particularly relating to security benefits. This groundbreaking effort called upon the input and guidance of many nationally recognized experts in HAZMAT shipping, security and counter-terrorism, and risk analysis and management, to assess the capabilities of the technology systems tested in the National Hazardous Materials Safety and Security Technology Field Operational Test.

Based on the evaluation of the test technologies, the findings include:

- Technology performance overall for the technologies was good, with most technologies performing well under operational conditions with the exception of Biometric Login, Electronic Seals (E-seals). These two technologies were deemed as requiring additional product development to be fully adapted for and accepted in the HAZMAT trucking environment.
- The Wireless Communication system with GPS tracking provided a positive return on investment for all four of the test scenarios, and also provided the base for vulnerability reduction, with the additional technologies providing incremental gains.
- The tested technologies showed the capability to significantly reduce the vulnerability of hazardous materials transportation, with the greatest reductions for the attack profile: theft.
- In all cases except for the LTL scenario, preventing only one terrorist attack by using the tested technologies over a 3-year period would lead to a tremendous societal cost savings well beyond the break even point for benefits and costs.
- The combined benefit-cost analysis showed positive benefit-cost ratios in all categories, from a low in the LTL environment of **1.4:1 to** a high of **96.9:1** in the Truckload Explosives operations.
- In considering the distribution of overall benefits between private-sector motor carriers and society as a whole, it was found that motor carriers would realize **60 to 72 percent**; **81 to 92 percen**t; **5 to 13 percent**; and **1 to 3 percent** of benefits for Bulk Fuel, LTL High-Hazard, Bulk Chemicals, and Truckload Explosives operations, respectively.

In conclusion, several key points are proffered: The threat of terrorism is a reality. Organizations such as Al Qaeda will exploit nearly any weakness in Western society to inflict physical and psychological harm upon persons and the destruction of property and critical infrastructure. Given the ubiquitous, mobile, and potentially harmful impacts of truck-based HAZMAT shipments, attempts to procure and use these loads as weapons could be considered just a matter of time until they occur. This FOT was designed to test the ability of commercially available technology systems to reduce vulnerabilities in HAZMAT shipping while providing sufficient returns on investment to motor carriers to encourage deployment.

As demonstrated, these technologies promise to enhance not only security, but also operational efficiencies and potentially, safety. It should be noted that technology alone is not the complete answer to HAZMAT trucking security. At best, the technologies are estimated to reduce vulnerability and hence, potential terrorist consequences by approximately **36 percent**. Technology, along with sound security practices and supported by ongoing public and private outreach, training, and security programs, are needed to meet a constantly present threat. Additionally, the technology-enabled reductions in HAZMAT shipping vulnerabilities and potential deterrence effects may never be validated empirically, as one may never truly know the degree to which terrorist intent has been thwarted.

While the technologies do show promise for enhancing safety, security, and efficiency, market forces may be slow in moving the HAZMAT trucking industry towards full deployment and realization of benefits. Government intervention may be required to facilitate the deployment process.