Potential Terrorist Uses of Highway-Borne Hazardous Materials

MTI Report 09-03

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POTENTIAL TERRORIST USES OF HIGHWAY-BORNE HAZARDOUS MATERIALS

January 2010

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16. Abstract

The Department of Homeland Security (DHS) has requested that the Mineta Transportation Institute's National Transportation Security Center of Excellence (MTI NTSCOE) provide any research it has or insights it can provide on the security risks created by the highway transportation of hazardous materials. This request was submitted to MTI/NSTC as a National Transportation Security Center of Excellence. In response, MTI/NTSC reviewed and revised research performed in 2007 and 2008 and assembled a small team of terrorism and emergency-response experts, led by Center Director Brian Michael Jenkins, to report on the risks of terrorists using highway shipments of flammable liquids (e.g., gasoline tankers) to cause casualties anywhere, and ways to reduce those risks. This report has been provided to DHS.

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We received a wealth of information and assistance from the Department of Defense about the security measures that are required of highway shipments of arms, ammunition, and explosives. We are particularly indebted to Fred Schutz, of the Office of Transportation Policy in the Office of the Secretary of Defense (OSD-ATL), and Clay Carter, Kathleen Rockwell, and Robert Essick of the Surface Deployment and Distribution Command (SDDC).

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Program, provided numerous documents, connected us with many other people with additional insight, and provided an excellent commonsense view on the problems we analyzed.
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EXECUTIVE SUMMARY

The U.S. Department of Homeland Security (DHS) has requested that the Mineta Transportation Institute's National Transportation Security Center of Excellence (MTI NTSCOE) provide any research it has or insights it can provide on the security risks created by the highway transportation of hazardous materials. This request was submitted to MTI NTSCOE as a National Transportation Security Center of Excellence. In response, MTI NTSCOE reviewed and revised research performed in 2007 and 2008 and assembled a small team of terrorism and emergency-response experts, led by Center Director Brian Michael Jenkins, to report on the risks of terrorists using highway shipments of flammable liquids (e.g., gasoline tankers) to cause casualties anywhere, and ways to reduce those risks. This report has been provided to DHS.

The team's first focus was on surface transportation targets, including highway infrastructure, and also public transportation stations. As a full understanding of these materials, and their use against various targets became revealed, the team shifted with urgency to the far more plentiful targets outside of surface transportation where people gather and can be killed or injured. However, the team is concerned to return to the top of the use of these materials against public transit stations and recommends it as a separate subject for urgent research.

The following is a summary of key judgments:

- The national threat level remains at yellow, indicating an "elevated" threat. Al Qaeda's leaders and those inspired by its exhortations remain determined to carry out terrorist attacks on American targets abroad and in the United States.

- The number of significant jihadist terrorist attacks, outside of Afghanistan and Iraq, declined in 2007 and 2008, and a greater number of terrorist plots have been uncovered and thwarted in the early stages. Terrorist plots uncovered in the United States since 9/11 have been characterized by local planning and low skill levels.

Al Qaeda-inspired terrorists, currently the most formidable terrorist threat, remain committed to large-scale bombings requiring vehicle-borne explosives.[1] VBIEDs continue to be a preferred attack mode when high body counts and massive damage are the objectives. (Not all terrorist organizations seek high body counts. Environmentalist extremists, for example, seek spectacular property damage.)

- The acquisition or manufacture of large quantities of explosives by terrorists is difficult, and it has been made more so by increased security and monitoring of ingredients such as ammonium nitrate fertilizer—a common ingredient in explosive devices when mixed with fuel oil.

- Terrorists, notably in Iraq, have attempted to increase the lethality of their devices by adding propane tanks or toxic chemicals to them. Reports indicate that terrorists have also discussed substituting available hazardous materials for explosives, although it is not clear whether these discussions relate exclusively to the continuing conflict in Iraq. This possibility has also been mentioned in recent U.S. threat assessments.

Recent assessments also suggest that terrorists are considering how to weaponize gasoline tankers.

- While any specific type of terrorist attack against any specific category of target remains unpredictable, although of low statistical probability, the use of vehicles carrying hazardous-materials cargos as surrogate truck bombs must be considered a plausible mode of terrorist attack.

- Although terrorists prefer truckloads of stolen or fabricated explosives, they could also turn trucks carrying flammable liquids, flammable gases, or toxic inhalants into weapons.

- Spectacular accidents involving flammable liquids and gases and evacuations resulting from spilled loads of toxic inhalants provide inspiration. Reports of tanker thefts indicate vulnerabilities. These reports indicate that a terrorist thief or hijacker could count on many hours of driving—and perhaps days, if the truck were hidden—before being discovered. There would be ample time to get the tanker to the target.

- Trucks carrying hazardous materials other than military or commercial explosives are ubiquitous and are less guarded than explosives shipments. They would appeal to terrorists with fewer resources—e.g., local conspiracies and lone operators—and especially to conspirators with insider knowledge or access to the industry.

- The federal government focuses on consequences, devoting the greatest attention and finite resources—and therefore the most-stringent security mandates—to the transport of cargos capable of causing the greatest casualties. Terrorists, driven by operational constraints, might look at things very differently, focusing their efforts on the most readily available, least protected hazardous cargos—flammable liquids.

- Gasoline tankers theoretically offer terrorists several operational attractions. They vastly outnumber all other hazardous-materials shipments combined. They operate in urban areas—target-rich environments. Their routes are predictable. They pose security challenges.

- We therefore consider gasoline tankers and, to a lesser extent, propane tankers to be the most attractive options for terrorists seeking hazardous-materials cargos.

- The principal threat from gasoline or propane tankers is fire. Without altering the tanker itself and adjusting its contents, it can be difficult to use a gasoline tanker to create an explosion; it is even more difficult to use a propane tanker. Creating an intense fire is far easier. The main limitation in creating an explosion using propane tankers is that vapors must be released to achieve exactly the right mixture of fuel and air and then ignited. Igniting propane is relatively easy, but causing propane to explode, especially at the right time and place, is technically difficult.

- Forced to choose between undertaking a complex and demanding operation to cause massive death and destruction and executing a smaller-scale attack with certainty of success, terrorists seem generally to choose the latter. Terrorists may

be willing to sacrifice their lives; they are far less willing to risk operational failure.

- Operational success tends to be defined in terms of casualties. Terrorists seek targets that have emotional or symbolic value—widely recognizable icons, targets whose destruction would significantly damage or disrupt the economy, and high body counts. In recent attacks, terrorists have been willing to forgo iconic value in favor of high body counts, for example, by bombing subways or commuter trains. The economic impact of such attacks is indirect.

- For technical reasons, it is unlikely that terrorists planning to seize a truck loaded with hazardous materials or already possessing one would choose highway infrastructure as their primary target. These are difficult attacks to carry out, with relatively little gain.

- By contrast, people are the preferred soft target, as we have seen in terrorist attacks on public transportation systems, and terrorists have demonstrated their preference for attacking vulnerable public assemblies and residential properties.

- In that regard, additional research should be conducted on the use of these materials against public transportation stations where people congregate and from which they cannot easily escape to determine the extent to which both flammable liquids and gases, explosives, and even TIH materials might be used, and to determine what security measures could be adopted to mitigate these risks at these locations. MTI strongly recommends urgent research along these lines.

- In the meantime, we recommend that the federal government, state governments, and industry collaborate to:

    a. Resolve significant jurisdictional issues between federal and state authorities

    b. Strengthen monitoring and enforcement of hazardous-materials security measures in the field; and

    c. Work to implement vehicle tracking technologies, panic alarms, and immobilization capabilities for vehicles carrying large quantities of specific hazardous materials, including gasoline. These measures offer safety and anti-crime benefits as well.

- Flammable liquids—particularly gasoline tankers—pose security threats that should not be minimized. These security threats are primarily to targets where large numbers of casualties can be created, and far less so to highway infrastructure.

- It is possible that the government's most recent threat assessments will alter current attitudes. But the authors urge a renewed look at flammable liquids and gases as a weapon of opportunity to create with relative ease an attack with enough certainty and enough causalities to make it a cause of national concern.

- A strategy is needed urgently to strengthen and sustain security measures and technologies that can reduce the risks caused by highway-borne flammable liquids, and to a lesser extent, flammable gases, used against both non-transportation, and transportation targets.

INTRODUCTION

Background

In 2008, building on research performed in 2007, the Mineta Transportation Institute's National Transportation Security Center of Excellence assembled a small team of terrorism and emergency-response experts, led by Center Director Brian Michael Jenkins, to report on the risks of terrorists using highway shipments of flammable liquids (e.g., gasoline tankers) to cause casualties anywhere, and ways to reduce those risks.

The team's first focus was on surface transportation targets, including highway infrastructure, and also public transportation stations. As a full understanding of these materials, and their use against various targets became revealed, the team shifted with urgency to the far more plentiful targets outside of surface transportation where people gather and can be killed or injured. However, the team is concerned to return to the top of the use of these materials against public transit stations and recommends it as a separate subject for urgent research

This research is being provided to DHS which has requested MTI's assistance in examining the use of highway-borne hazmat as a weapon.

The team has sanitized its previous findings to make the report appropriate for a wider audience at an unclassified level. Any material that could provide terrorists with specific information not otherwise widely available concerning vulnerabilities and how to exploit them has been eliminated.

The team included:

1. Billy Poe, a nationally recognized expert on explosives and explosive devices and a retired Louisiana State Police official. He has served as Director of the International Association of Bomb Technicians and Investigators (IABTI).

2. Douglas Reeves, an engineer by training who served for many years in the DOT's Pipeline and Hazardous Materials Safety Administration (PHMSA) and its predecessor agency. Most recently, he led the risk-management team, served as deputy director of the technology division, and served as a focal point for hazardous-materials security issues after the 9/11 attacks.

3. Karl Shrum, a former Federal Highway Administration (FHWA) hazardous-materials investigator in the state of California who also helped craft many aviation security rules and policies in the Federal Aviation Administration. He spent more than five years at TSA, where he focused on security measures for hazardous-materials shipments

4. Joseph Trella, an active duty officer in the U.S. Army during the 1990s who also served as senior policy analyst for the National Governors Association and as special assistant for homeland security to the governor of Maryland.

MTI took a broad look at terrorist thinking, targets, and operational considerations involved in weaponized hazmat to determine the relative likelihood of attacks using highway-borne hazmat against various targets across the country. The methodology used by the MTI team was an informal one that made extensive use of both current data and analyses from multiple sources and individual team specialties and experiences. The team met multiple times, both physically and by telephone. The methodology that was used is described below and is shaped by posing and answering six key questions that are listed here.

The methodology requires detailed examination of hazardous materials and hazardous materials regulations, which in turn requires the use of a number of acronyms. A list of all acronyms used in the report is provided on 51.

Hazmat Examined in this Report

- *Flammable liquids, such as gasoline*
- *Flammable gases, such as propane*
- *Truckload explosives, such as ammonium nitrate fuel oil (ANFO)*
- *Toxic-inhalation-hazard (TIH) materials (such as chlorine*)*

**Included only to help assess the likelihood of the other three materials being used and against which targets.*

Outline of This Report

The chapter titled “Commodity Flows” provides information on the overall frequency and routing of each hazardous material considered. Toxic inhalation hazard (TIH) materials are included, even though they have no effect on infrastructure, because attacks involving them must be considered in analyzing terrorist targets and weapons and in determining the probability of hazmat being used to destroy highway infrastructure.

The chapter titled “Potential Destructive Effects of Hazardous Materials Used in Acts of Terrorism” describes the average and maximum destructive effects of each of the materials considered. All potential targets are included, and are not limited to highway infrastructure.

The chapter titled “Public Information that Could Inspire and Inform Terrorists” outlines publicly available information on hazardous materials that might inspire terrorists to use them and could potentially educate them on how to acquire, deliver, and release them for maximum effect. This information includes descriptions of (1) accidents, especially spectacular accidents; (2) criminal activity; and (3) disposal operations for hazardous materials involved in derailments and other accidents.

The chapter titled “Current State of Security Regulation and Recommended Practices for the Highway Transportation of Hazardous Materials” summarizes security measures

required or recommended by the federal and state governments and by industry, and it assesses how these measures are being implemented by companies, based on the results of site visits. This section also includes observations on vehicle tracking, panic buttons, and immobilization technologies. A supplemental report on vehicle tracking has been presented to DHS separately, and is available as MTI publication 09-04, *Implementation and Development of Vehicle Tracking and Immobilization Technologies.*

The chapter titled "Analysis of the Threat and Potential Attacks" presents the core analysis of the study. We provide a general threat overview, and then consider how terrorists might consider using flammable liquids, flammable gases, and truckload explosives against all types of targets. We ask and answer five questions:

1. **How do terrorists think about targets?** We examine the words, plots, and attacks of terrorist groups in general and jihadists in particular to prioritize targets and determine how attractive highway infrastructure is to terrorists.

2. **Assuming terrorists have access to specific hazardous materials, what targets might be most attractive?** After determining this set of targets, we then assume that Jihadist groups have acquired flammable liquids, flammable gases, truckload explosives, or TIH materials, and we determine which material works best against which target.

3. **How do operational considerations influence material and target selection?** We examined several operational considerations: (1) How frequently do the materials move and how easy are those movements to predict? (2) How well are the materials protected? (3) How much might terrorists actually know about the destructive capabilities of the materials? (4) What kind of technical and operational modifications would be required to increase the chances of creating an explosion or fire? (5) What are the probabilities and consequences of a successful attack? We have sanitized the details of these considerations.

4. **How does the sophistication of the terrorist group affect material and target selection?** We place jihadist terrorists into three distinct groups: lone operators, local al Qaeda-inspired cells, and a cell centrally-funded and directed by al Qaeda with considerable resources and planning time. We consider how materials can be acquired and delivered to targets, how reconnaissance of targets might be conducted, and how the materials might have to be released. We determine the attack sequences that are most likely to be performed by the different types of terrorist groups or individuals.

5. **What kinds of attacks using highway-borne hazmat are terrorist groups most likely to conduct?** Using all of the information we developed about targets, hazardous materials, operational considerations, and terrorist groups, we consider how some of the more likely attacks would be carried out, why, and against which targets.

We conclude with some confidence that truck-borne hazardous materials are unlikely to be used to target highway infrastructure. Iconic targets such as the Brooklyn Bridge worth attacking are unlikely to be destroyed, and those that can be destroyed are not worth attacking. By contrast, the use of hazardous materials—particularly gasoline and to a

lesser degree propane tankers—against public buildings and gatherings is a cause for much greater concern. These gatherings can include large numbers of people gathered in mass transit stations, which MTI's own database suggests are targets of bombings and incendiary attacks. We also conclude that while government and industry tend to be dismissive of the security threats from flammable liquids, flammable liquids—particularly gasoline tankers—pose security threats that should not be minimized.

This key judgment, and others, predate recently issued government assessments that stress that because of the difficulty of acquiring explosives, terrorists are turning to flammable liquids and to tankers, from which the principal threat is fire used against public assemblies or residential targets, and other assessments that al Qaeda is using its engineering capabilities to consider how to best weaponize gasoline tankers.

Clearly, gasoline tankers and, to a lesser extent, propane tankers, are important weapons of opportunity. They can be used create fires tsuhat could cause significant casualties in attacks on public and residential targets, a possible threat the federal government has recently addressed. While the size of the fleet and its importance to the economy pose real challenges in terms of implementing countermeasures, this should not cause government and industry to avoid facing the risks they pose, and creating a strategy for strengthening and sustaining security measures.

It is a challenge we need to face up to.

MTI's concern about gasoline tankers predates the most recent government assessments by many months and is Appendi underscored by them. A year ago, MTI concluded that:

- *Terrorists have a continuing interest in large truck bombs—vehicle-borne improvised explosive devices (VBIEDs).*
- *Acquiring and manufacturing explosives and achieving large-scale explosions are a significant challenge to terrorist groups—especially local groups that lack access to instruction or out-of-country training.*
- *Given recent increased monitoring of sales of ammonium nitrate, the risks of acquiring this common ingredient in terrorist truck bombs have increased, and this may push terrorists toward other, more easily accessible hazmat cargos.*
- *It is known that terrorists have discussed the use of propane, gasoline, and other hazmat to enhance and/or substitute for conventional explosives.*
- *If terrorists cannot obtain explosives, they turn to the use of fire.*
- *Terrorists have considered gasoline tankers as a potential weapon for creating destructive fires.*
- *Gasoline tankers could be used with considerable lethality against buildings and public assemblies.*

COMMODITY FLOWS

Why Study Commodity Flows?

In this section, we consider four commodities: flammable liquids, flammable gases, truckload explosives, and toxic-inhalation-hazard (TIH) materials, such as chlorine, and we outline how often and where these commodities are transported in the United States. We include TIH materials because, even though they cannot be used against highway infrastructure, terrorists will consider using them in attacks.

This analysis is important because it enables us to determine the availability of the materials during their transportation and how predictably they flow (see “Public Information that Could Inspire and Inform Terrorists” beginning on page 25). Terrorists are opportunists, and a commodity that is transported in great volumes and with predictability may be more desirable than one that flows infrequently or randomly.

Composite Picture of Hazmat Flows

The quality of data on hazmat flows of interest in this study varies. Data on rail flows are typically much better than data on highway flows. The Commodity Flow Survey conducted by the Department of Transportation and the Department of Commerce is the best overall source of data; however, because of survey limitations, it includes only materials that have significant shipments.

A shipment is defined as a single movement of goods, commodities, or products from an establishment to a single customer or to another establishment owned or operated by the originating establishment (e.g., a warehouse, distribution center, or retail or wholesale outlet). Full or partial truckloads are counted as single shipments only if all commodities on the truck are destined for the same location. If a truck makes multiple deliveries on a route, the goods delivered at each stop are counted as individual shipments. For example, a gasoline tanker that picks up 8,000 gallons at a terminal and delivers it to a gasoline station would be considered one shipment; a truckload of explosives transported from a warehouse to two users at different locations would be considered two shipments. DOT has specific definitions for bulk shipments. What might be generally considered to be a large shipment varies by commodity. Highway shipments of more than a few thousand gallons or pounds of the materials of interest in this study would be considered large shipments.

To illustrate how commodity flows affect just one state, MTI looked at a very large state—California. According to the Commodity Flow Survey, approximately 9% of the total hazardous material shipped (by weight, for all classes and all modes) in the United States in 2002 went in or through California. Data from the 2002 Commodity Flow Survey for the highway shipment of hazardous materials of interest in this study are shown in Table 1 on page 10. Our ballpark estimates of the number of large shipments in California are also shown. As the table illustrates, when only the largest commodity in each category is considered, the vast majority of large shipments in California are shipments of gasoline (82.9%), followed by propane (12.1%). Shipments of anhydrous ammonia (a TIH material) constitute 3.8%, and explosives shipments constitute 1.3%. Based on a small number of

chlorine tankers nationwide, the number and percentage of chlorine shipments in California is considered very small, less than 1%.

Table 1 Selected Hazardous Materials Highway Shipments

Hazardous Material	National Highway Tons[a]	Estimate[b] of Number of Large Shipments in California	% of Large Shipments in California
Explosives—Hazard Class 1	4,361		
Division 1.5 explosives	3,972	35,000	1.3
Flammable gases—Division 2.1	44,031		
Petroleum gases (e.g., propane)	30,426	320,000	12.1
Toxic inhalation hazard TIH) materials—Division 2.3	12,574		
Anhydrous ammonia	7,691	100,000	3.8
Flammable liquids	948,619		
Gasoline	606,724	2,200,000	82.9
Total hazardous material shipment (all classes)	1,159,514		

a In thousands. Source: Department of Transportation and Department of Commerce, *Commodity Flow Survey (CFS) 2002—Hazardous Materials,* December 2004.
b Derived by dividing total national highway tons by a typical transport vehicle and scaling for California.

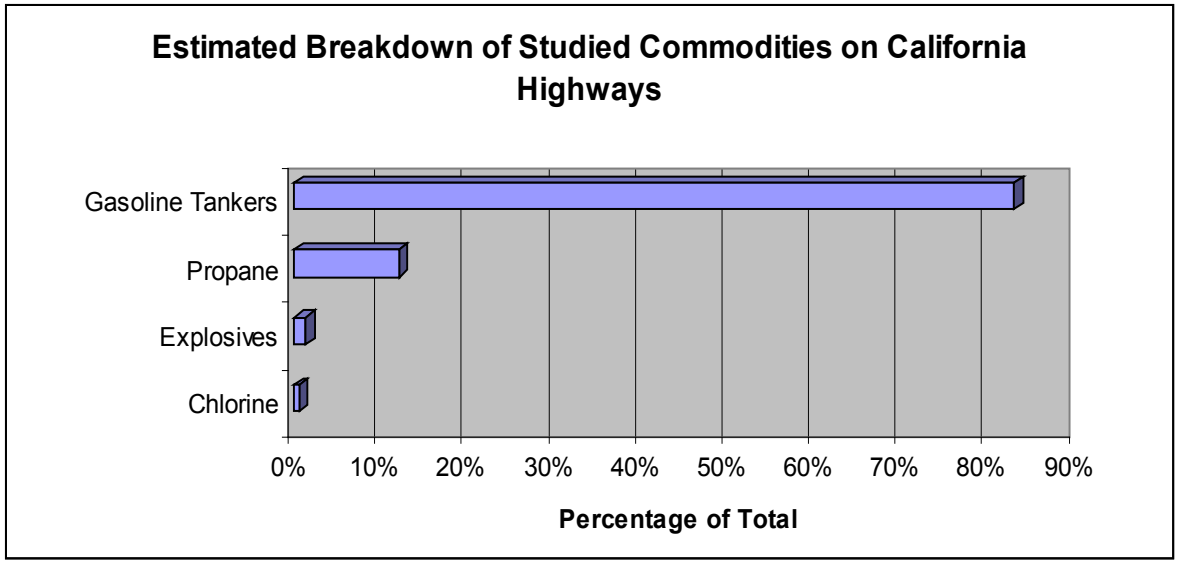

Figure 1 Estimated Breakdown of Studied Commodities on Calfornia Highways

Flammable Liquids

Given the role of the automobile in American society, it is not surprising that the vast majority of hazardous material transportation by tonnage involves gasoline. Gasoline is usually moved to storage terminals by pipeline or vessel. Tank trucks form the last transportation leg, delivering gasoline from storage terminals or tank farms to gas stations.

Gasoline is usually transported in MC 306 or MC 406 tank trucks[2] with four or five compartments and a nominal 9,000-gallon total capacity. Tank shell construction is typically of 1/5-inch aluminum. (Weight considerations are a critical factor in gasoline transportation—the tank trucks that carry flammable and TIH compressed gases under pressure typically have 5/8- to 3/4-inch steel tanks.) Gasoline trucks are unloaded from the bottom through hoses attached to lines from each of the compartments, which terminate at a central location. To discharge the gasoline, the air-pressure system must first be activated to open the valves. After that, gravity draws the gasoline out.

Annually, there are roughly 19 million truckload shipments of gasoline in the United States. The average one-way trip from tank farm to gas station covers approximately 35 miles. Shipments are most often from the source to a single gas station, where the entire content is unloaded. Gasoline tank truck operation typically runs 24 hours a day, 365 days a year. In the United States, gasoline is the only hazardous material that has to be transported by highway this frequently.

Other flammable and combustible materials transported in great quantities by highway in the United States include diesel fuel and fuel oil. The latter is used extensively in residential heating and is usually delivered by nominal 3,000-gallon straight trucks. Although these materials are somewhat more difficult to ignite (this may be of more significance from a safety standpoint than a security standpoint), they have higher heat content. Users have easy access to large quantities of these materials outside of transportation (e.g., through 600-gallon residential heating tanks).

Flammable Gases

Propane is the most commonly transported flammable gas. It is used to heat homes (particularly in rural areas where natural gas is unavailable), for cooking, and to power vehicles. It is usually transported as a liquefied compressed gas in tank trucks or cylinders.

Pipelines, vessels, and rail cars move propane to terminals or regional distribution centers. In addition, nominal 10,000-gallon tank trucks (the national fleet contains approximately 7,000 highway bulk transport trucks) assist in moving propane to local distributors. A national fleet of approximately 35,000 bobtails, or nominal 3,000-gallon tank trucks, move the propane to residential users, who typically have a 500-gallon on-site storage tank for heating. Bobtail deliveries are typically made to a series of customers until the tank truck is emptied. Bobtail trucks are unloaded though long hoses, using a small pump.

The MC 330 or MC 331 tank truck fleets used to transport propane often alternate between transporting flammable gases in the winter (heating) season and transporting anhydrous ammonia during the spring and summer (or agricultural) season.

Explosives

Explosives are transported for military and commercial uses. Commercial uses are predominantly in mining and construction. Explosives are transported primarily by highway.

Division 1.1 explosives (those with a mass explosion hazard) and Division 1.5 explosives (very insensitive explosives with a mass explosion hazard) are the most important from a security perspective. Most Division 1.1 explosives are transported for the military, although a small amount of Division 1.1 explosives is used commercially to initiate Division 1.5 explosives. Division 1.1 explosives account for a minimal amount (by weight) of the total explosives shipped by highway. Commercial use of Division 1.5 explosives is greater than military use.

Explosives are typically shipped from the manufacturer to a distributor or end user. Most Division 1.5 explosives are ammonium nitrate fuel oil (ANFO) mixtures or water gels, emulsions, or slurries shipped to the sites of usage, such as mining or construction sites, where they are used to break up or demolish ores or structures. Capacities of bulk trucks carrying Division 1.5 explosives range from 5 to 15 tons.

Ammonium nitrate is not classified as an explosive during transportation; it is classified as an oxidizer because of the environment and forces normally encountered during transportation. However, it causes security concerns because it can be used to create an explosion when mixed with other materials. Approximately nine million tons of ammonium nitrate are produced annually in the United States and used in agriculture as a fertilizer and in the production of explosives, such as ANFO. Ammonium nitrate is shipped by truck, rail, and vessel. The capacity of a truck carrying bulk quantities of ammonium nitrate is typically in the range of 20 tons.

Toxic-Inhalation-Hazard (TIH) Materials

Anhydrous ammonia and chlorine are the two TIH materials most commonly shipped by highway; the majority of these shipments (more than 80 percent) are of anhydrous ammonia. Other TIH materials relatively frequently shipped by highway include fuming sulfuric acid, ethylene oxide, sulfur dioxide, bromine, phosgene, hydrogen cyanide, and hydrogen fluoride.

Anhydrous ammonia is used as a fertilizer, as a feedstock for other chemical manufacturing, and as a refrigerant. Most of it by far is used as fertilizer. Anhydrous ammonia is transported in MC 330 and MC 331 tank trucks, portable tanks (nominal 200-gallon), and cylinders (nominal 20-gallon). Anhydrous ammonia nurse tanks, most with a capacity of 1,000 to 1,500 gallons, are often seen in agricultural applications.

Chlorine has a large number of industrial uses. It is also used as a disinfectant for municipal water supplies, although there are indications that this use may be decreasing.[3]

Chlorine is transported by highway in MC 330 or MC 331 tank trucks, “ton” tanks (nominal 200-gallon), or cylinders (nominal 20-gallon). Much more chlorine (in terms of tons or ton miles) is transported by rail than by highway.

POTENTIAL DESTRUCTIVE EFFECTS OF HAZARDOUS MATERIALS USED IN ACTS OF TERRORISM

Hazardous materials transportation has a good safety record. However, that record does not directly translate to the effects that could be caused by terrorists. One would expect terrorists to use hazardous materials in a manner that causes maximum destructive consequences and in ways that are not normally encountered during transportation. For example, a large quantity of gasoline placed in or close to a large building and ignited might overwhelm sprinkler systems and other control mechanisms and create a far greater fire hazard than would normally be expected in transportation. In the case of explosives, in particular, secondary hazards, such the collapse of a building, tunnel, or bridge, would exaggerate consequences.

Hazardous materials that might be used to directly attack highway infrastructure such as overpasses, bridges, or tunnels would likely be flammable liquids, flammable gases, or explosives. Use of highway infrastructure can be seriously affected by uncertainty about the effects of damage on safety. Other hazardous materials, such as TIH materials, pose significant security concerns because of the large number of fatalities or injuries that could result from their intentional release; however, they would not damage infrastructure.

Flammable liquids, flammable gases, explosives, and TIH materials form a first tier of hazardous materials to be concerned with from a security perspective when considering a broad range of targets; however, other materials also pose security risks. Poisonous materials, such as pesticides, could be used to contaminate water or food supplies. Oxidizers, such as liquid oxygen, could be used to enhance fires or explosions. Nuclear materials accumulated for medical shipments could be used in denial-of-service scenarios for key buildings or locations. Strong corrosive materials could be used to damage critical infrastructure. Flammable solids could be used to create intense fires. Although the possibilities are almost endless, there is a general consensus that flammable liquids, flammable gases, explosives, and TIH materials pose the greatest security concerns because of shipment quantities, destructive potential, immediate and dramatic impact, and the history of their use in terrorist incidents and plots, among other factors. Consequently, this study focuses on these four materials.

The effects of hazardous materials events on transportation infrastructure depend in large measure on characteristics of the infrastructure itself. For instance, vulnerabilities of an overpass or bridge to terrorism or sabotage may be magnified if the failure of critical components can be expected to result in the failure of the entire structure.

Flammable Liquids

The primary hazard posed by flammable liquids is fire, which could be used to damage infrastructure. The quantity of airline fuel in the tanks of the airplanes that brought down the World Trade Center on 9/11 was approximately the quantity carried in a large gasoline tank truck.

The ability of flammable liquids to damage infrastructure has been demonstrated by a number of spectacular incidents. For example, in October 1997, a gasoline tank truck was struck by a passenger car in Yonkers, New York, under an overpass of the New York State Thruway. The ensuing fire damaged the overpass, and the thruway remained closed for approximately six months. This incident caused DOT to consider prohibiting wetlines[5] under gasoline tank trucks.[6]

In this and other incidents, the intense heat from hazardous-materials fire caused the structural steel in an overpass to weaken or melt. Steel begins to lose its strength at temperatures as low as 800° F and melts at approximately 2,750° F. In addition, concrete can be damaged by intense heat when water trapped within its structure boils, cracks it, and breaks it into pieces (a phenomenon known as spalling).

Gasoline fires are complex events. Factors that affect consequences include burning rate, quantity of fuel available, heat of combustion, heat release rate, access to oxygen, the size of the gasoline pool, temperature, wind speed, duration of fire, features that confine or trap heat, and availability of other combustible material. Gasoline tank-truck fires of the type cited in the above incidents have several features that tend to maximize potential damage: (1) they are intense fires that persist over an extended period of time, (2) they are localized, (3) there is good access to oxygen, and (4) heat is trapped below an overhead structure.

Flammable Gases

The primary hazard posed by a flammable gas is fire. A fireball or vapor-cloud fire releases thermal energy that can damage infrastructure. It can also ignite other flammable materials to create an intense fire.

Although a fire is the most likely outcome of a successful attack using a flammable gas, such as propane, an explosion could also occur under certain circumstances. It is very difficult to create conditions that would result in an explosion, and such an occurrence would more likely be due to chance than to an intentional act. A boiling-liquid expanding-volume explosion (BLEVE) is a particularly spectacular hazardous-materials event and is described below. A fuel-air explosive is a carefully engineered military application of a vapor-cloud explosion that a terrorist might hope to emulate, as discussed later in this report, but it is very difficult to improvise. The bottom line is that igniting propane is relatively easy; causing it to explode at the right time and place is very difficult.

A BLEVE can occur when a liquefied gas is involved in a fire, particularly when flames impinge on the tank above the liquid level. Tank-shell metal weakens and the vapor pressure rapidly increases, overwhelming pressure-relief devices. Tank rupture under these conditions will violently and nearly instantaneously disperse large quantities of vapor and liquid to the atmosphere. If the liquefied gas is a flammable material and a source of ignition is present, a massive fire or explosion is possible. BLEVEs were fairly frequent in rail transportation before thermal protection, head shields, and improved shelf couplers were added to tank cars. A BLEVE is thought to have occurred in Italy in the tunnel between Palermo and Punta Raisi airport in 1996 after a tank truck carrying liquefied petroleum gas (LPG)[7] was involved in an accident and fire. The time between the

initial fire and the BLEVE allowed most of the people in the area to escape and limited the number of fatalities. The tunnel was closed for 2 1/2 days.

Tables 2 and 3 illustrate the differences between flammable liquids and flammable gases. Table 2 shows the energy content of different liquids and gases. Clearly, gasoline contains more energy than propane. Table 3 shows the relative capabilities of gasoline and propane for damaging highway infrastructure and other targets.

Table 2 Selected Hazardous Materials Highway Shipments

	Energy Content (BTUs per gallon)
Ethanol	76,000
Fuel Oil (Number 2)	139,000
Gasoline	125,000
Propane	91,600

Table 3 Comparison of Gasoline and Propane and the Characteristics that Enable Greater Damage to All Targets

	Gasoline	Propane
More intense fire based on packaging size and energy content	X	
Ability to direct heating to a specific area	X	
Capable of longer duration fire	X	
Ease of opening packaging and igniting contents	X	
Ability to ignite other combustible materials at greater distances (more diffuse effects)		X
Potential to cause an explosion		X

Explosives

The direct hazard posed by explosives is the blast overpressure created by an explosion. Debris and danger from structural collapse pose additional threats to infrastructure and people. Table 4 on page 18 provides estimates of damage caused by overpressure.

Highway infrastructure theoretically can be damaged by placing relatively small quantities of explosives at critical locations. More generalized damage could result from using very large quantities of bulk explosives in the vicinity of the infrastructure.

The power of explosives is often expressed in terms of TNT equivalency. Relative effectiveness compares effectiveness relative to TNT by weight only. Table 5 on page 18 provides relative effectiveness values for a number of explosives. Figure 2 shows distances of concern relative to the effects of overpressure.

Table 4 Explosion-Overpressure Damage Estimates[a]

Overpressure (psig)[b]	Expected Damage
0.04	Loud Noise (143 Db); Sonic Boom Glass Failure
0.15	Typical Glass Failure
0.40	Limited Minor Structure Damage
0.50–1.0	Windows Usually Chattered; Some Window Frame Damage
0.70	Minor Damage
1.0	Partial Demolition of Houses; Houses Made Uninhabitable
1.0–2.0	Corrugated Metal Panels Fail and Buckle; Housing Wood Panels Blown in
1.0–8.0	Range for Slight to Serious Lacerations From Flying Glass and other Missiles
2.0	Partial Collapse of Walls and Roofs Of Houses
2.0–3.0	Non-Reinforced Concrete Or Cinderblock Wall Shattered
2.4–12.2	Range For 1–90 Percent Eardrum Rupture Among Exposed Populations
2.5	50 Percent Destruction of Home Brickwork
3.0	Distortion of Steel Frame Building And Pulling Away From Foundation
5.0	Snapping of Wooden Utilities Poles
5.0–7.0	Nearly Complete Destruction of Houses
7.0	Overturning of Loaded Train Boxcars
9.0	Demolition of Loaded Train Boxcars
10.0	Probably Total Building Destruction
14.5–29.0	Range For The 1–99 Percent Fatalities Among Exposed Populations Due to Direct Blast Effects

a U.S. Environmental Protection Agency, Office of Emergency Management, *ALOHA User's Manual*, Washington DC, February 2007.

b Peak pressures formed in excess of normal atmospheric pressure by blast and shock wages; psig=pounds per square inch gauge.

Table 5 Relative Effectiveness of Explosives

Material	Effectiveness
Black powder	0.55
ANFO	0.80
TNT	1.00
C-4	1.34
Nitroglycerin	1.50
RDX	1.60
PETN	1.66
Semtex	1.66

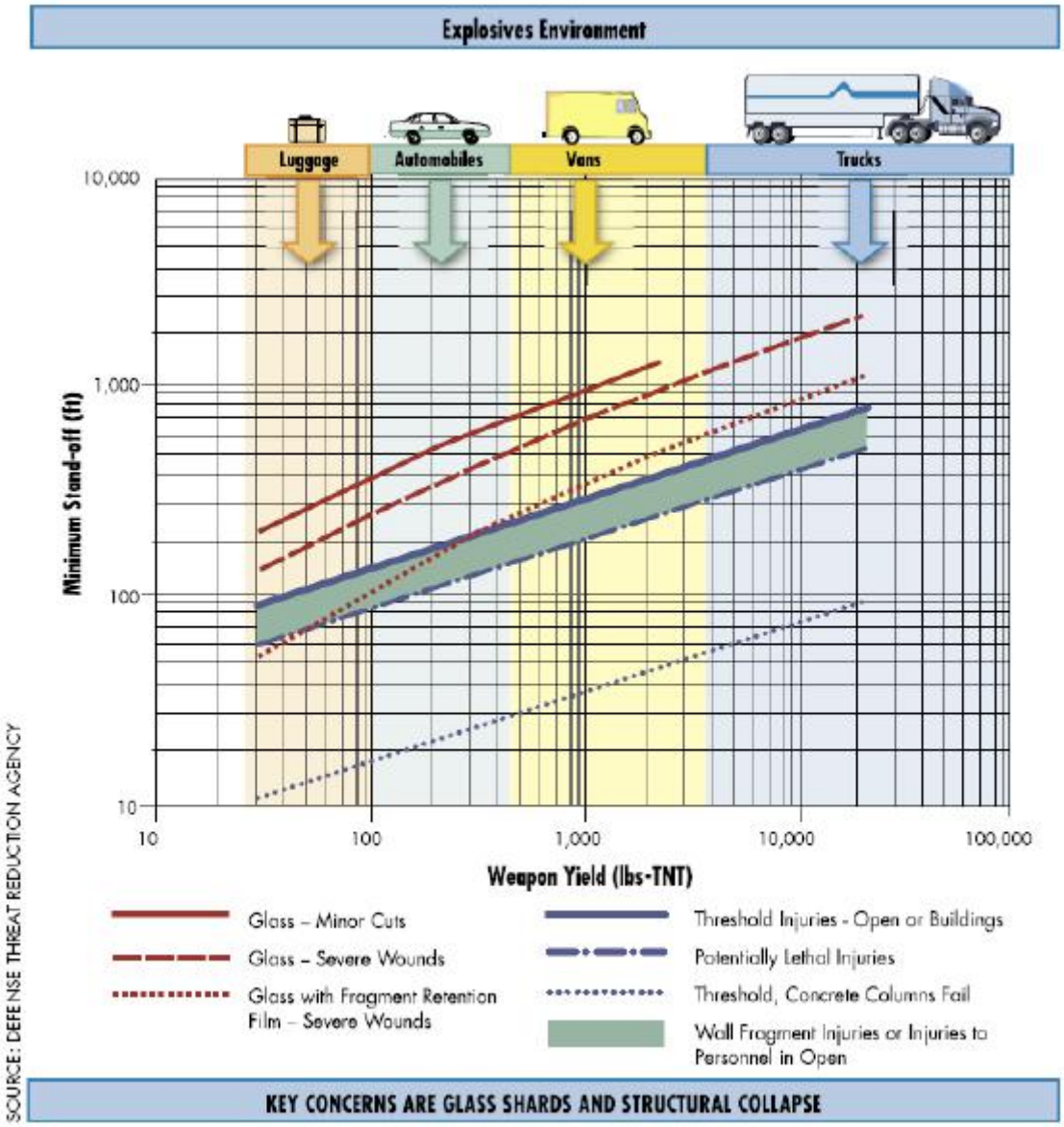

Figure 2 Distances of Concern for Explosive Overpressure

TIH Materials

In contrast to the impact of other hazardous materials considered in this study, the impact of the deliberate use of TIH materials in an act of terrorism or sabotage would be almost exclusively on people. Fatalities and injuries are the desired outcome. Casualties can occur either as a direct result of the materials or due to ensuing panic and crowd behavior (e.g., a stampede to an exit). TIH materials carry the specter of chemical warfare and weapons of mass destruction that may exaggerate their danger; however, the security concern they have generated is legitimate.

TIH materials may be gases or liquids at normal temperatures. Most TIH gases and vapors are heavier than air, which contributes to risk when they are released. TIH classification is based on toxicity for gases and a combination of vapor concentration and toxicity for liquids. Key terms and definitions applicable to TIH materials are given in Table 6 on page 22. Table 7 on page 23 lists properties of TIH materials that are most often transported by

highway.

Release of a large quantity of TIH materials in a heavily populated are a feared scenario. Rapid release of the entire contents of a tank truck carrying TIH materials would minimize the time to react, evacuate, or shelter the population or to take other protective measures. Predicting fatalities from an attack involving TIH materials in transportation is exceedingly difficult. The variables that need to be considered include:

- Amount of release
- Time over which release occurs
- Wind speed and direction
- Temperature
- Daytime or nighttime conditions
- Reaction effects of vegetation, rain, and humidity
- Population present
- Location of population
- Sheltering or evacuation and emergency response that occurs
- Susceptibility of the population to fatalities or injuries.

Models such as ALOHA, HPAC, CASRAM, and commercial models generally calculate exposure zones or numbers of people exposed to specific concentrations. Translating these to expected fatalities and injuries presents another level of difficulty. Many of the larger numbers quoted with regard to TIH materials are potential exposures or casualties. Moreover, casualties include both fatalities and injuries, which may be minor. The term casualty often gets translated to fatality in subsequent reporting or use, which exaggerates estimates of maximum damage.

Figure 3 on page 21 illustrates exposure zones to release of a TIH material. The concentration of TIH materials moves downwind and decreases over time once the release has ended. Casualties vary by level and duration of exposure. The contours in Figure 3 can be viewed as boundary levels between defined concentrations. For instance, the black portion may be considered LC50 concentrations (defined in Table 6). One would expect many fatalities among people present for a significant time within this zone. The next contour may show the boundaries of ERPG-3 exposures (defined in Table 6). Some fatalities and a substantial number of injuries might be expected in this zone. The risk increases as a person comes closer to the boundary between LC50 concentrations and ERPG-3 concentrations. It decreases as the person approaches the ERPG-2 concentration boundary. The lightest contour represents ERPG-1 concentrations, where only mild, transient health effects might be expected.

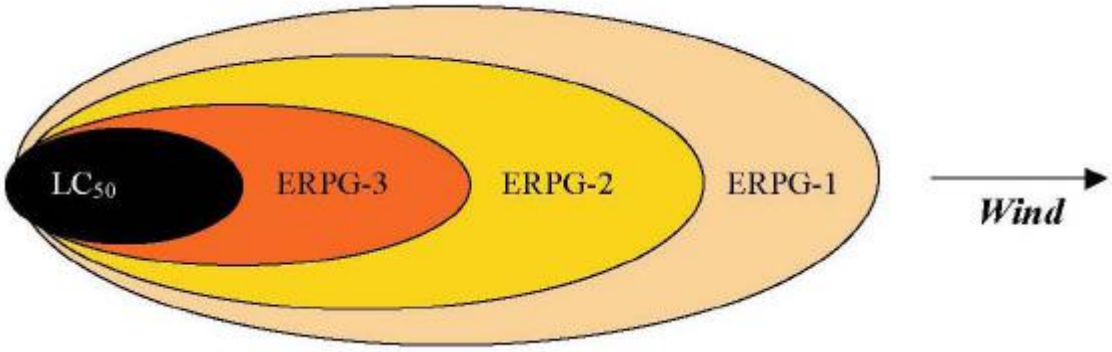

Figure 3 Exposure Zones to a TIH Material Release (shaded contours illustrate LC50 and ERPG concentrations as described in the preceding paragraph)

Modeling done in the *National Risk Assessment for Selected Hazardous Materials in Transportation*[8] suggests that fatalities from a well-executed and successful attack involving TIH materials could number in the thousands. The study estimated the number of persons who would potentially be affected in transportation accidents in ten-year periods over an extremely long period of time. Single, large events, the probabilities of which are very low, would be expected to dominate results. While the study suggests that the worst-case highway accident for the worst TIH material considered (chlorine) could result in many thousands of deaths, it did not include effects of sheltering (passive or active), which could reduce the number of fatalities on average by a factor of 7. This suggests that a few thousand may be the upper limit of fatalities that would occur as the result of a catastrophic outside release of TIH materials in highway transportation, an estimate that has been buttressed by more-recent studies.

Achieving this level of fatalities would be difficult. The ability to control a plume and the unpredictability of results make TIH materials a less-than-ideal choice as a weapon of mass destruction. A credible attack using truckload quantities of TIH materials in which everything went as planned (a highly successful attack) could be expected to result in perhaps as many as a few hundred fatalities; a typical successful attack might produce dozens of fatalities. Introduction of a TIH material into a building with many people present, although requiring a greater degree of operational sophistication, is another scenario that potentially could produce a significant number of fatalities.

The most significant transportation accident involving chlorine occurred near Graniteville, South Carolina, in January 2002. A rail car carrying approximately 90 tons of chlorine was breached after an accident caused by a switching error. A substantial proportion of the chlorine was released from the rail car, resulting in the evacuation of 5,400 people within one mile of the accident, including the town of Graniteville. Nine people were killed, including the engineer and a number of employees at the Avondale Mills plant near the accident location. Given the nature of the accident and the population nearby, more fatalities might have been expected.

Table 6 Terms and Definitions Applicable to TIH Materials

Term	Definition
TIH	Toxic inhalation hazard, a term used to describe gases and volatile liquids that are toxic when inhaled. The term is used synonymously with poison inhalation hazard (PIH).
Hazard Zone	One of four levels of hazard (A thought D) assigned by hazardous materials transportation regulations to gases and one of two levels of hazard (Aand B) assigned to liquids that are toxic when inhaled.
Hazard Zone A	Gases: LC50 less than or equal to 200 ppm. Liquids: V equal to or greater than 500 LC50, and LC50 less than or equal to 00 ppm.
Hazard Zone B	Gases: LC50 creater than 200 ppm and less than or equal to 1000 ppm. Liquids: V equal to or greater than 10 LC50, and LC50 less than or equal to 1000 ppm; criteria for Hazard Zone A are not met.
Hazard Zone C	LC50 greater than 1000 ppm and less than or equal to 3000 ppm.
Hazard Zone D	LC50 greater than 3000 ppm and less than or equal to 5000 ppm.
ERPGs	Emergency response planning guidelines, values intended to provide estimates of concentration ranges above which one could reasonably anticipate observing adverse health effects.
ERPG-2	The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair an individual's ability to take protective action.
ERPG-3	The maximum concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing live-threatening health effects.
LC50	The concentration of a material administered by inhalation that is expected to cause the death of 50 percent of an experimental animal population within a specified time.
V	Saturated vapor concentration in air of a material in mL/m^3 (volatility) at 20°C and standard atmospheric pressure.
ERG Protective Action Distance	Emergency Response Guidebook (ERG) Protective Action Distances are estimates that have been developed based on historical transportation incidents. Factors considered include quantities of materials released, rates at which the materials were released, and meteorological conditions. Guidebook distances are 90 percent values based on ERPG-2 distances (i.e., in 90% of the incidents, distances are less than the ERG value).

Note: ppm=parts per million; mL/m^3=millimeters per cubic meter

Table 7 Properties of Select TIH Materials

Chemical	Hazard Zone	LC50 (ppm)	ERPG-2 (ppm)	ERPG-3 (ppm)	Boiling Point (°F)	ERG Protective Action Distance (in miles, large spill,[a] at night)
Ammonia, anhydrous	D	4000	150	750	-28.03	1.4
Bromine	A	113	0.5	5	137.80	4.6
Chlorine	B	293	3	20	-30.23	4.6
Ethylene oxide	D	4350	50	500	51.26	1.5
Hydrogen chloride	C	2810	20	150	-118.66	6.5
Hydrogen cyanide	B	40	10	25	78.80	2.3
Hydrogen fluoride, anhydrous	C	1300	20	50	66.92	2.7
Phosgene	A	5	0.2	1	46.94	7.0+
Sulfur dioxide	C	2520	3	15	14	3.9
Sulfuric acid, fuming	B	347	10 mg/m^3	30 mg/m^3	625	4

[a] A large spill could be from a tank truck, a rail car, or a number of smaller packagings.

Conclusions

Flammable liquids, flammable gases, explosives, and TIH materials are all potential terrorist weapons; they all allow terrorists to meet threshold levels of average consequence, but with varying likelihood of success. However, explosives and flammable liquids would seem to be the most likely highway-borne hazmat weapons. Experience with explosives, the instantaneous nature of associated damage, and the potentially devastating consequences of an explosion favor their use.

Nevertheless, flammable liquids, particularly gasoline, are widely available in large quantities in transportation, as discussed in “Commodity Flows” beginning on page 9. Equally important, they could easily be used against an array of potential soft targets.

PUBLIC INFORMATION THAT COULD INSPIRE AND INFORM TERRORISTS

Terrorists and terrorist groups often use public, "open" sources to gain information about potential targets and weapons. The 9/11 conspirators studied aviation security by examining public reports of security measures, conducting reconnaissance, and observing security measures in dry runs.

We explore in later sections the ways terrorists might conduct surveillance. In this section, we discuss the information terrorists could gain from the open literature about the effects of the hazardous materials considered in this study.

We believe that three types of data in particular could inspire and instruct terrorist thinking about the use of hazardous materials: (1) how the materials behave in accidents, including spectacular, newsworthy events; (2) how the materials are acquired in publicized non-terrorist crimes; and (3) how materials involved in accidents behave in publicly known disposal operations.

ACCIDENT HISTORIES

Information on hazardous materials involved in highway accidents indicates how the materials behave when they are released in an accident, how many casualties they can cause, and how much damage they can inflict on highway infrastructure. This information may be studied by terrorist groups seeking to understand the advantages of weaponizing different types of hazmat.

Two distinct "sets" of information are available to terrorists: (1) analytical studies and official data analyses that identify trends and averages, and (2) histories of individual accidents, especially spectacular accidents that generate publicity.

Analytical Studies and Data Analyses

The most authoritative data on hazardous materials reside in the Hazardous Materials Information Reporting System (HMIRS) maintained by DOT's Pipeline and Hazardous Materials Safety Administration (PHMSA). The National Transportation Safety Board (NTSB) also studies high-consequence accidents (or, defined more narrowly for highway purposes, crashes) and conducts special studies to identify risk trends and problems. While a large quantity of data is available, we did not find any study focused narrowly on the consequences for highway infrastructure of fires and explosions caused by gasoline or propane tankers.

The available data must be carefully understood. For example, the higher casualty figures for commodities such as gasoline tankers may reflect the relatively large share of hazardous-materials highway shipments (estimated to be between 35% and 50%, depending on location, time of day, and time of year) they represent.

Also, there is no separate category of damage to highway infrastructure. Further, because carriers filling out reports may wish to understate damages, damage levels are probably underreported. MTI's analysis indicated that only ten accidents between 1997 and 2007 resulted in more than $1 million in property damage, and only five of these ten accidents created property damage of more than $2 million (between $2.5 and $4 million). These figures are questionable because accidents studied by the NTSB during this period resulted in high levels of damage. For example, property damage caused by an October 19, 1997, gasoline tanker accident near an overpass on the New York State Thruway totaled $7 million.

Still, the data tend to suggest that even the classes or divisions of materials that cause the highest percentages of incidents, fires, property damage, and deaths in highway transportation accidents generate only modest amounts of damage. According to HMIRS data, the average amount of property damage would be well under $250,000, which is certainly modest compared with that created by explosives ($1 million).

However, we have examined the HMIRS data for the ten years between 1997 and 2007, which contained roughly 50,000 incident reports involving highway transportation, the vast majority of which took place during loading and offloading and included even small releases. MTI selected for more in-depth analysis 206 accidents,[9] including some that involved more than one class or division of material, that (1) occurred in transit (as opposed to during unloading or loading, for example); (2) resulted in a fire, explosion, or gas dispersion; and (3) caused either one or more deaths, at least $85,000 in damage to the carrier,[10] or at least $100,000 in damage to public property or to private parties other than the carrier.[11] Of these 206 accidents, 96% resulted in fires, 33% resulted in explosions, 14% resulted in gas dispersion, 42% resulted in at least one fatality, and 5% resulted in more than $1 million in damages.

This set of 206 accidents resulted in a total of 105 deaths, $34,487,939 in property damage, 194 fires, 68 explosions, and 28 gas dispersions. The average death per accident was 0.509, and the average property damage per accident was $167,417.

We examined the hazardous materials involved in these 206 accidents and found the five classes or divisions that were involved in the largest number of accidents. They together constituted 90% of the accidents, 95% of the deaths, 97% of the property damage, 91% of the fires, 94% of the explosions, and 86% of the gas dispersions. We also found a small set of accidents (nine) that involved more than one class or division (and in these, flammable-combustible liquids were very often involved) and another small set (nine) that involved other classes or divisions.

The distribution of accidents, deaths, property damage, fires, explosions, and gas dispersions, along with the average deaths and property damage per incident, are displayed in the chart below. As the chart reveals, the reported deaths per accident are low, as is the reported (and probably underreported) property damage.

Table 8 Summary of 1997–2007 Hazardous Materials Incident Reporting System (HMIRS) Highway Crash Data: Five Most Lethal Classes or Divisions

Class	Accidents	Deaths	Property Damage	Fires	Explosions	Gas Dispersion	Avg. Deaths	Average Loss
Flammable/ combustible liquids	170 (83%)	94 (90%)	$30,861,443 (89%)	161 (83%)	60 (88%)	18 (64%)	0.553	$ 181,538
Flammable Gases	7 (3.4%)	2 (1.9%)	$160,500 (.5%)	7 (3.6%)	0 (0%)	3 (10.7%)	0.286	$ 22,928
Corrosive materials	6 (2.9%)	2 (1.9%)	$239,000 (.7%)	3 (1.5%)	2 (2.9%)	3 (10.7%)	0.333	$ 39,833
Oxidizers	3 (1.5%)	2 (1.9%)	$105,000 (.3%)	3 (1.5%)	-	-	0.667	$ 35,000
Explosives	2 (.9%)	-	$2,000,000 (5.8%)	2 (1%)	2 (2.9%)	-	0	$1,000,000
Total of 5 leading classes	**188 (90%)**	**100 (95%)**	**$33,365,943 (97%)**	**176 (91%)**	**64 (94%)**	**24 (86%)**	**0.532**	**$ 180,123**
Multiple Classes per incident	9 (4.4%)	3 (2.9%)	$314,996 (.9%)	9 (4.6%)	2 (2.9%)	2 (7.1%)	0.333	$ 34,999
All other classes	9 (4.4%)	2 (1.9%)	$807,000 (2.3%)	9 (4.6%)	2 (2.9%)	2 (7.1%)	0.222	$ 89,666
TOTAL 100%	**206**	**105**	**$34,487,939**	**194**	**68**	**28**	**0.509**	**$ 167,417**

The data on the five most classes or divisions most frequently involved in these 206 serious accidents are discussed below:

1. *Flammable liquids* (the combustible-flammable class), including gasoline, gas oil, aviation gas, fuel oil, and ethanol, accounted for 83% of the accidents, 90% of the deaths, 89% of the property damage, 83% of the fires, 88% of the explosions, and 64% of the gas dispersions. There was an average of 0.533 death per incident, and the average damage amounted to $181,538.

2. *Flammable gases*, particularly propane, accounted for 3.4% of the accidents, 1.9% of the deaths, 0.5% of the property damage, 3.6% of the fires, none of the explosions, and 10.7% of the gas dispersions. There was an average of 0.236 death per incident, and the average damage amounted to $22,928.

3. *Corrosive materials,* including boron tribromide, amine and polamine liquids, and

batteries, accounted for 2.9% of the accidents, 1.9% of the deaths, 0.7% of the property damage, 1.5% of the fires, 2.9% of the explosions, and 10.7% of the gas dispersions. There was an average of 0.333 death per incident, and the average damage amounted to $39,833.

4. *Oxidizers,* such as potassium permanganate, accounted for 1.5% of the accidents, 1.9% of the deaths, 0.3% of the property damage, 1.5% of the fires, and none of the explosions and gas dispersions. There was an average of 0.667 death per incident, and the average damage amounted to $35,000.

5. *Explosives,* such as detonation fuses and boosters, accounted for 0.9% of the accidents, none of the deaths, 5.8% of the property damage, 1% of the fires, 2.9% of the explosions, and none of the gas dispersions. There were no deaths, and the average damage amounted to $1,000,000.

The 22 accidents of the 206 in these years in which there was either more than one death or more than $1 million in property damage (only 11% of the total) accounted for 72% of the property damage and 32% of the deaths. Of these 22 serious accidents, flammable liquids accounted for all but two of the 34 deaths (94%) and $22,724,500 of the $24,729,50 in property damage (92%).
Several rather simple but important observations could be drawn from these data by individuals seeking to weaponize flammable liquids, flammable gases, truckload explosives, or TIH materials.

First, there are no highway incidents involving TIH or chlorine in the database that resulted

From accident data, terrorists might learn that:

1. ***Flammable liquids create fires that can engulf people and motorists and have the potential of killing large groups of people if the people are trapped.***

2. ***Flammable gases can create spectacular fireballs and blasts that are intense and deadly and potentially able to kill large numbers of people, but explosions are difficult to create with flammable gases.***

3. ***Explosives have huge destructive forces but are stable in the normal transportation environment.***

4. ***TIH materials such as chlorine can kill large numbers of people, but only if evacuation is not possible. Also, the safety record of these materials is good. Media and government attention to TIH materials may be more significant for a terrorist than actual accidents are.***

in damage to highway infrastructure. There was, in fact, only one incident involving TIH that caused a fire and property damage above the threshold established for this set of incidents.[12] This may suggest that there are relatively few shipments of these materials and/or that safety controls and route restrictions are particularly effective.

Second, few accidents were caused by explosives, which may again be the result of

relatively low levels of transportation, a relatively high level of safety and route controls, or the relative stability of many explosives unless intentionally discharged. The property damage per accident, however, is very high—by far the highest of any class.

Third, given the significant trade in propane, the fact that no accidents resulted in an explosion and only a few resulted in a fire suggests that the structure of the propane tanks is more robust than that of a gasoline tanker and that it is more difficult to create a fire or an explosion with propane than might be assumed.

Finally, flammable liquids such as gasoline—which constitute a large percentage of the hazmat being transported by road—are responsible for the highest percentage of deaths and property damage. Also, when normalized per incident, gasoline tanker accidents are roughly twice as lethal as other classes, with the sole exception of oxidizers.

This may lead terrorists to make the following observations: A great deal of flammable liquid such as gasoline is being transported by road, and crashes involving flammable liquids often result in fires. The fatality rate is low, especially considering that most of the casualties are the drivers, but this could simply be a function of where the gasoline is released.

Studies and Coverage of Spectacular Accidents

Although the average destruction resulting from hazmat accidents is low, some of these accidents can be spectacular, particularly those involving propane, as indicated by excerpts from NTSB accident summaries. Some of these are listed below along with our own short summaries of more-recent accidents that meet the NTSB's thresholds but have not yet been formally studied by NTSB and accidents that took place outside the United States and are therefore outside of NTSB's jurisdiction. All of the accidents had significant news coverage, both locally and nationally. Information that would be particularly relevant for terrorists is italicized.

In these accidents, certain things would be understood by terrorists:

1. The fires created by flammable liquids can engulf motorists, bystanders, and residences at some distance from the actual release. The potential to cause large numbers of casualties is clear.

2. The fireball and blast created by flammable gas can be intense and deadly. The strength of the blast is determined by the size of the explosion and the distance that pieces of the vehicle travel after the explosion. Once again, the potential to cause large numbers of casualties is clear.

3. Explosives have significant force but are, in fact, stable.

4. TIH materials can, if directed properly, cause a significant number of deaths. (Far more information is available from rail tank car accidents than from highway accidents.) However, if the population at risk is alerted, evacuation is possible and major casualties

can be avoided.

Accidents Involving Flammable Liquids

June 6, 2008: Atlanta, Georgia. A tanker truck accident closed I-85 near Atlanta. The fuel spilled, but there was no fire.

June 4, 2008: **Tampa, Florida.** A tanker on fire shut down traffic in both directions on I-75 and 301 near Tampa. The fire caused significant damage to an overpass, which will be closed for weeks.

January 18, 2008: Providence, Rhode Island. A tanker truck exploded, showering surrounding buildings and houses with debris.

July 27, 2007: Register-Guard, Oregon. A gasoline tanker (a tractor towing two tanker trailers) exploded after catching fire. The cargo was 10,000 gallons of gasoline. Both tanks exploded. There were no injuries. Highway 58 was closed for six hours.

August 9, 1998: Biloxi, Mississippi. At about 12:53 a.m., a Premium Tank Lines, Inc., truck driver was transferring gasoline from a cargo tank to underground storage tanks at a Fast Lane gasoline station-convenience store in Biloxi, Mississippi, when an underground storage tank containing gasoline overflowed. An estimated 550 gallons of gasoline flowed from the storage tank, across the station lot into the adjacent highway, through an intersection, and into a storm drain. The gasoline ignited, and fire engulfed three vehicles near the intersection, which ultimately resulted in the deaths of five occupants and the serious injury of one. Damages were estimated at $55,000.[13]

October 9, 1997: Yonkers, New York. At about 12:10 a.m., a truck tractor pulling a cargo tank semi trailer was going under an overpass of the New York State Thruway when it was struck by a sedan. The car hit the right side of the cargo tank in the area of the tank's external loading/unloading lines, releasing the gasoline they contained. The ensuing fire destroyed both vehicles and the overpass; the thruway remained closed for approximately 6 months. The driver of the car was killed; the driver of the truck was not injured. Property damage was estimated at $7 million.[14]

March 17, 1993: Fort Lauderdale, Florida. About 3:13 p.m. on a Wednesday, an Amerada Hess (Hess) tractor-semi trailer hauling gasoline was struck by National Railroad Passenger Corporation (Amtrak) train 91. The truck driver was attempting to cross a railroad/highway grade crossing on Cypress Creek Road in Fort Lauderdale, Florida. Traffic in the area of the crossing was congested because the left and center lanes were closed just over the crossing. Traffic was being channeled into the right lane and later shifted into a right-turn lane. The truck, which was loaded with 8,500 gallons of gasoline, was punctured when it was struck. A fire erupted, engulfing the truck and nine other vehicles. The fire killed the truck driver and five occupants of three stopped vehicles.[15]

February 13, 1991: Carmichael, California. About 3 a.m. Pacific Standard Time, a tractor-semi trailer (cargo tank) overturned as the vehicle was traveling on a main urban

roadway in Carmichael, California.... At the time of the accident, the truck was being used for the intrastate delivery of gasoline to service stations; the cargo tank contained about 8,800 gallons of automotive gasoline. The driver lost control of the vehicle in a curve. The vehicle overturned onto its side and struck the embankment of a drainage ditch located in a dirt field beside the road. The cargo tank bounced and came to rest in the dirt field and adjacent to the drainage ditch. The rear end of the cargo tank landed on an unoccupied car parked in the field. Gasoline from the cargo tank spilled into the drainage ditch, which extended under the roadway and behind private residences nearby. About 15 minutes after the overturn, the gasoline ignited behind a residence. The fire flashed back and engulfed the overturned cargo tank, and the car under the cargo tank. A second unoccupied car parked near the overturned tank truck also caught fire. Gasoline runoff in the drainage ditch entered the underground drainage system and was also ignited. In addition to the total loss of the tank truck, its cargo, and the two parked cars, four homes and their contents were destroyed or heavily damaged by fire, and the residents from a 2-mile-square area were evacuated.[16]

December 4, 1975: Seattle, Washington. About 1 a.m., a 1975 Peterbilt tank truck and a 1970 Peerless full trailer (tank), owned by Union Oil Company of California, went out of control on the Alaskan Way Viaduct in Seattle, Washington, as the driver attempted to negotiate a curve on the traffic-polished concrete roadway at 52 mph and during a rainstorm. The combination vehicle jackknifed and the trailer struck a viaduct support column. The trailer's tank ruptured and its cargo of gasoline spilled. Fire ensued, spread along the viaduct, and spilled to the ground below, where it ignited 4 railroad freight cars, 30 motor vehicles, and adjacent buildings. The accident caused property damage estimated at $750,000. Two firemen were injured while fighting the fire.[17]

Accidents Involving Liquefied Petroleum Gas (Including but Not Limited to Propane)

July 11, 2008: Tarragona, Spain. A large LPG truck exploded close to a campsite near Tarragona. The campsite was crowded with campers in tents and trailers at the time. The blast and fireball left a 5-foot deep, 65-foot wide crater and destruction within a 1,000-foot radius. More than 200 people were killed. The exact events surrounding the accident are subject to debate. The tank truck was not equipped with emergency pressure-relief devices and may have been overloaded and subject to thermal expansion from the sunshine, may have been in a vehicle crash, or may have been engulfed in fire, subsequently causing a BLEVE.

July 27, 1994: White Plains, New York. About 12:30 a.m., a tractor cargo-tank semi trailer loaded with 9,200 gallons of propane (a liquefied petroleum gas) and operated by Suburban Paraco Corporation was traveling east on Interstate 287 in White Plains, New York. The truck drifted across the left lane onto the left shoulder and struck the guardrail; the tank hit a column of the Grant Avenue overpass. The tractor and the semi trailer separated, and the front head of the tank fractured, releasing the propane, which vaporized into gas. The resulting vapor cloud expanded until it found a source of ignition. When it

ignited, according to an eyewitness, a fireball rose 200 or 300 feet in the air. The tank was propelled northward about 300 feet and landed on a frame house, engulfing it in flames. The driver was killed, 23 people were injured, and an area with a radius of approximately 400 feet was engulfed by fire.[18]

April 29, 1975: Eagle Pass, Texas. At 4:20 p.m., a Surtigas, S.A., tractor-tank-semi trailer, westbound on U.S. Route 277 near Eagle Pass, Texas, swerved to avoid an automobile ahead which was slowing for a turn. The tank-semi trailer separated from the tractor, struck a concrete headwall, and ruptured; vaporized LPG was released. The ensuing fire and explosion destroyed a building and 51 vehicles. The 51 persons who were in the area were burned and 16 persons, including the truck driver, were killed. The National Transportation Safety Board determined the cause of the fatalities and injuries to persons in the vicinity was the explosive force and fire, from which they had no time to escape. The rapid development of the explosive force and fire was caused by the gross rupture of the tank.[19]

September 21, 1972: New Jersey Turnpike. At 8:25 p.m., a tractor-semi trailer (tank) carrying propylene liquid petroleum gas sideswiped a Greyhound bus (carrying no passengers) in the southbound lanes of the New Jersey Turnpike about one mile north of Exit 8. After impact, the bus, while rotating clockwise and sliding across the highway, was struck by a southbound automobile. The tractor-semi trailer scraped, then straddled the turnpike's median guardrail, jackknifed, spun into the northbound lanes, and overturned. Before overturning, the tractor-semi trailer was struck by a northbound automobile. Fire, which had erupted at the tractor as it scraped the median guardrail, spread to propylene which was leaking from the cargo tank's damaged plumbing. After the fire had burned for about 25 minutes, the cargo tank exploded in a ball of flame; segments of the tank rocketed more than 1,300 feet northeast and 500 feet southwest of the tractor-semi trailer.[20]

March 9, 1972: Lynchburg, Virginia. At 2:30 p.m., a tractor-semi trailer (tank) carrying liquid propane under pressure was traveling north on U.S. Route 501 at approximately 25 m.p.h. At a point 7.1 miles north of Lynchburg, Va., the truck…slid along the shoulder on its right side and struck a rock outcropping, which ruptured the tank and permitted the liquid propane to escape. On exposure to the atmosphere, the propane vaporized into a cloud, which spread rapidly throughout the area. Within 1 or 2 minutes a fire erupted in the propane-air mixture. The truck driver, apparently not injured in the rollover, fled on foot north from the overturned vehicle. When the propane-air mixture ignited, the truck driver was enveloped in the fire and was killed. Two southbound motorists, who had stopped their cars north of the overturned truck, and a passenger of one of the motorists were severely burned when the vapor cloud ignited. The occupants of a house located in a hollow below and west of the highway heard the crash and ran from the house, but were caught in the propane-air vapor flash and were severely burned. One of these victims died as a result of his burns. The house, outbuildings, and about 12 acres of woodland were destroyed in the ensuing fire.[21]

Accidents Involving Explosives

June 4, 1971: Waco, Georgia. At about 8:00 p.m., a 1961 Volkswagen two-door sedan, traveling west on U. S. Highway 78 (Old Georgia Route 8), crossed over the centerline of

the two-lane highway and collided head on with an eastbound tractor semitrailer transporting a 25,414-pound cargo of explosives. Both vehicles were traveling at about 40 mph before impact. Fire broke out immediately along the left side of the tractor and in front of the trailer. Firemen arrived at the scene shortly thereafter and tried to put out the fire while the truck driver tried to persuade bystanders to move from the burning wreckage. The cargo detonated about 10 or 15 minutes after the collision. The automobile driver apparently was fatally injured in the collision. The truck driver was not injured. Both drivers were alone in their vehicles. Two firemen, a wrecker driver, and two bystanders died as a result of the explosion. Thirty-three people were injured and property damage was estimated in excess of one million dollars…the cause of the explosion was localized heat on the nitroglycerin-based dynamite. The explosion caused extensive property damage.

Accidents Involving TIH Materials

August 22, 2003: Middletown, Ohio. At 7:17 a.m., an Amerigas Corporation (Amerigas) cargo tank semi trailer arrived at the AK Steel Corporation (AK Steel) facility in Middletown, Ohio. The driver pulled the vehicle up to the fill location and helped an AK Steel employee hook up to the fittings for a plant storage tank. According to the driver, about 7:40 a.m., the AK Steel employee began transferring anhydrous ammonia, a poisonous and corrosive gas, from the storage tank to the cargo tank. The driver said that it took about 30 minutes to equalize the pressure between the storage tank and the cargo tank. He said that once the pressure was equalized, the internal pressure in the cargo tank was 130 pounds per square inch gauge (psig). About 8:20 a.m., while the cargo tank was still being loaded, its front head cracked open, releasing vapor. The driver, who had been resting in the tractor, got out and saw the escaping vapor. He said that he activated the emergency shut off device for the cargo tank and that according to the gauges, the cargo tank was a little less than half full, the internal pressure was about 170 psig, and the temperature of the anhydrous ammonia was 80 degrees F. *About 100 employees and contract workers were evacuated from the buildings downwind of the cargo tank and moved to safer locations*. Five people were treated for inhalation injuries and released. The cost of repairing and replacing damaged equipment was about $25,000.

May 11, 1976: Houston, Texas. About 11:08 a.m., a Transport Company of Texas tractor-semi trailer (tank) transporting 7,509 gallons of *anhydrous ammonia* struck and penetrated a bridge rail on a ramp connecting I-610 with the Southwest Freeway (U.S. 59) in Houston, Texas. The tractor and trailer left the ramp, struck a support column of an overpass, and fell onto the Southwest Freeway, approximately 15 feet below. The anhydrous ammonia was released from the damaged tank semi trailer. Six persons died as a result of the accident, 78 persons were hospitalized, and approximately 100 other persons were treated for injuries.... The cause of 5 of the 6 fatalities and all of the 178 injuries was the inhalation of anhydrous ammonia. [23]

CRIMINAL THEFTS OF FUEL AND FUEL TANKERS

Terrorists are opportunists; they maximize gain and minimize risk. Therefore, they look for easy, proven ways to increase the chances of obtaining materials and reaching their objectives. Purely criminal operations can inspire and instruct terrorist attacks on both counts. Airline hijackings gained prominence as a criminal activity, and ransom kidnappings

were purely criminal operations. Both tactics were subsequently adopted by terrorists. Publicized accounts of criminal activity assist a terrorist operation in several ways. First, for terrorists considering attacks using hazardous materials, they illustrate methods of purchasing or obtaining the materials, or obtaining a hazmat cargo vehicle itself. Second, accounts of criminal activity may illustrate ways of delivering a weapon to the target. By observing news accounts or perhaps connecting with or recruiting criminals, a terrorist operative can become familiar with the ways others surreptitiously achieve an end that is similar to theirs and can then make adjustments to fit the technique to their objectives.

In January 2008 alone, multiple thefts of tankers occurred. In examining these and other attacks, several observations arise:

1. The theft of fuel oil appears to be a significant crime, requiring some level of organization. In other words, it is the act not of a single criminal, but of a conspiracy—probably an informal, local one. This suggests that terrorists who seek knowledge of how fuel can be stolen can obtain it.

2. The theft of fuel appears to be related to fuel costs, if fuel prices increase, criminal thefts will also increase. Thus, the motivation for and sophistication of the thefts will increase, and so will the knowledge of successful techniques. Most of the thefts have occurred where fuel oil is needed and transported the most: on the mid-Atlantic seaboard and in the Northeast, areas that account for nearly 80% of the fuel oil used in the United States.[24]

3. The fact that many thefts of tankers take place at night and from unguarded sites, some of them by hot-wiring or using keys left in the trucks, suggests that security measures could be strengthened with relatively little effort.

4. Some of the thefts are simple hijackings at gunpoint with the driver in the rig, or thefts of vehicles left unattended at a truck stop. Site visits performed by the authors of this report confirmed that there is a concern about common crime, including theft and non-terrorist employee sabotage, and a general sense that the chances of hijacking are likely to grow when the price of fuel increases.

5. Smaller companies appear to experience more thefts, although whether the loss per shipment is greater than that incurred by large companies cannot be determined with current data. It may also be that security measures used by smaller companies are more easily circumvented, but this is subject to verification.

6. The relatively few incidents in which the truck rig is damaged suggest that thieves and hijackers are familiar with trucks and that they have at least minimal driving skills, as well as basic insider knowledge of the trade. Site visits confirm that while a complete novice might have difficulty driving a stolen tanker truck, the level of sophistication needed to drive a rig and discharge the fuel is hardly insurmountable and could be achieved in a few days; some newer tractors have automatic transmissions, which makes them easier to drive.

7. There are indications of insider collusion. Such collusion could be unwittingly provided

to a terrorist operation by a person who believes he is involved only in a criminal theft. In harder economic times, the incentive for employees to engage in what they perceive to be a "black market" will increase.

8. The fact that a storage or hiding area for the stolen fuel is often already arranged suggests that fuel could be stolen and later placed into either an underground facility, a fuel tanker, or a surrogate tanker for use in a terrorist operation.

9. Law enforcement response to hijackings is a challenge.

HAZMAT DISPOSAL OPERATIONS

The transportation of hazardous materials by rail and highway often creates a need for special disposal operations. These operations, which involve releasing, burning, or containing the material, can provide inspiration and information on how certain materials behave and what is needed to release and ignite them for maximum effect. Some of the information is publicly available and easily accessible by terrorists.

Disposal operations for flammable liquids focus on cleanup and containment. Liquid flammables are generally released and ignited quickly. If they are not, the disposal operation involves transferring the liquid from a damaged container to another container. When liquid flammables do burn, the fire lasts less than 10 minutes and is extremely intense, generating heat of more than 2,000°F.

TIH materials dissipate quickly if the containing structure is compromised. Casualties downwind and downhill from a release, under the right conditions, could be significant. But once TIH material is vented, there is little to do other than wait for it to dissipate through normal pressure and wind. Terrorists would learn little from disposal operations other than reconfirmation of the toxicity of the material if it can be directed to a concentrated population.

Explosives experts face situations in which truckload explosives have either detonated through an accident and caused a blast or have to be isolated and removed from sources of further detonation. Explosive materials may remain stable despite an accident, thus emphasizing the need for detonation. It should be pointed out that when explosive that is contained and intact is exposed to fire, significant explosions can result. The most recent accident involving highway transportation of high explosives occurred in Spanish Fork, Utah, on August 10, 2005. The truck carrying the explosives caught fire, and the cargo—35,500 pounds of cast boosters (Penolite)—detonated, creating a crater three stories deep.

Finally, disposal operations for flammable gases, in which carefully managed explosives are often used, provide valuable information on how destructive flammable gases can be, but also information on how difficult it can be to unleash that force. For terrorists, the destructive force would be known from information on rail accidents, which are more spectacular, as will be seen.

A procedure referred to as "vent and burn" has been used successfully more than 15

times in the past 20 years to dispose of flammable gases and liquids. It is an emergency technique that is used as a last resort to mitigate the danger from containers—such as tank cars—involved in an accident. In these situations, the tank car usually has considerable damage and cannot be moved or offloaded.

The charges used in a vent-and-burn operation are designed to puncture small holes in the tank car in a careful sequence of events, in which the tank is opened, then the material is released and safely ignited and burned. When this is successful, a rail tank car of propane will burn out quickly in cold weather. Vent and burn techniques have been improved over the years.

The explosive force of the material itself has been seen in unsuccessful operations of this kind. After a derailment in Molina, Florida, in 1979, the disposal operation was unsuccessful and three rail cars detonated and were blown more than a mile away. In a February 2003 accident in Lonsdale, Ontario, Canada, five LPG tank cars were involved in a derailment, and three of them experienced a BLEVE. While vent-and-burn operations were successful on two of the three tank cars, the third operation was not successful and that tank car was found a mile from the derailment site.

As indicated, the key technical challenge is that of releasing, venting, and then igniting the material, especially at a time and place chosen by the terrorist. The timing and the amount and shape of explosive needed to create an explosion—and even more so, vented burns—are critical and difficult to achieve. If these efforts were directed at creating a large fuel-air explosion in a populated area, the fatalities from blast, heat, and damage from rocketing pieces of the tanker could be considerable. But there are many technical problems that must be overcome with considerable sophistication. This is not therefore considered as significant a threat as others.

CONCLUSION

Terrorists reviewing publicly available material would draw several conclusions. From accident data and spectacular accidents, they would see that (a) flammable liquids create tremendous fires; (b) flammable gases can create spectacular fireballs and blasts, but timed explosions are difficult to achieve; (c) explosives have huge destructive force but are stable in the normal transportation environment; and (d) TIH materials such as chlorine—despite alarmist media attention—can kill large numbers of people only if effective emergency response is not possible. They could also gain inspiration from thefts of tankers, and from public knowledge about hazardous materials disposal operations, understand both the explosive force of detonating flammable gases and also the difficulty of creating and directing such an explosion.

CURRENT STATE OF SECURITY REGULATION AND RECOMMENDED PRACTICES

This section examines security regulations and recommendations for highway transportation of hazardous materials from the standpoint of the issuing authority, i.e., the federal government, and industry associations. It then summarizes all of these regulations and recommendations by the phase of security they cover: personnel, terminal, and en route. Finally, it assesses the general adequacy of regulations as recommended and as implemented. It does not treat state authorities however, which are significant players in the regulatory framework

Background and Framework of Federal Regulation and Inspection

Regulatory responsibility for the security of highway transportation is currently shared by TSA, the Federal Motor Carrier Safety Administration (FMCSA), and PHMSA. In the period following 9/11, TSA was new and was concerned primarily with standing up a large federal workforce for aviation security. As the agencies responsible for the regulation of trucking and hazardous materials, FMCSA and PHMSA issued security rules until TSA was appropriately organized and staffed to take on this function, after which any security countermeasures issued in response to threat conditions would be issued by TSA. In 2006, TSA and PHMSA executed a formal memorandum of understanding that delineates their agencies' respective authorities and commits those agencies to coordinating their programs and activities in advance under multiyear action plans.

Inspection and enforcement is also divided between FMCSA and TSA. FMCSA has identified approximately 38,000 carriers of hazardous materials of the types and quantities that could be used as weapons. Nearly all have been contacted regarding a security sensitivity visit. FMCSA conducts about 3,000 compliance reviews of hazardous materials carriers annually. A more in-depth program to visit carriers transporting certain explosives, radioactive materials, and highly toxic substances is under way. TSA had a workforce of 100 surface-transportation security inspectors in FY 2007 and plans to increase the number to 200 by FY 2010. However, those inspectors are primarily responsible for rail and public transit rather than the security of highway transportation of hazardous materials.

Current security regulations focus on security threat assessments (STAs) for drivers who have a hazardous-material endorsement to their commercial driver's license; operating rules for transporting hazardous materials; security plans for companies transporting hazardous materials; and safety permits required for carriers of certain hazardous materials.

FEDERAL SECURITY REGULATIONS

Security Threat Assessments to Prevent Insider Incidents

Title 49 CFR 1572.3 identifies drivers who hold a commercial driver's license under 49 CFR 383 and 384 and are applying to obtain, renew, or transfer a hazardous-materials endorsement (HME) to that license. These drivers are subject to an STA conducted in

accordance with the standards in CFR 1572.5. Those standards include disqualifying criminal offenses described in CFR 1572.103, immigration status requirements described in CFR 1572.105, an analysis described in CFR 1572.107 that determines that an applicant is a security threat, and a finding of mental incapacity under CFR 1572.109. The detailed information the applicant must provide is prescribed in CFR 1572.9. Applicants must provide fingerprints for an FBI/CJIS (Criminal Justice Information Services) criminal-history records check. TSA conducts the STA through its Transportation Threat and Credentialing Office. The finding that an applicant is a security risk is based on an "intelligence-related background check." No state may issue or renew an HME without a TSA determination of no security threat and a state must revoke the HME if notified that the individual is a security threat.

Federal Operating Rules for General Security Purposes

Title 49 CFR Part 397 contains the rules for driving and parking when transporting hazardous materials. Regulations intended for safety purposes may also be significant security countermeasures.

Section 397.5 requires that vehicles carrying Division 1.1, 1.2, or 1.3 explosives must be attended at all times by the driver or a qualified representative of the motor carrier. A vehicle is attended when that person is on it or is within 100 feet and has an unobstructed view of it. Vehicles carrying explosives are not required to be attended when they are in a government-approved safe haven. Vehicles containing other hazardous materials must also be attended unless the driver is "performing duties that are incident and necessary to [his] duties as the operator." A vehicle carrying Division 1.1, 1.2, or 1.3 explosives may not be parked within 300 feet of a bridge, tunnel, or place where people congregate, unless there is no practicable alternative. Drivers of such vehicles must also be provided with the names and phone numbers of persons to be contacted in an emergency.

States must follow CFR 397.61 et seq when establishing and maintaining routing designations for nonradioactive hazardous material in quantities that require placarding. Routing designations must be provided to the public under CFR 397.73.

Public Law 110-53, the 9/11 Commission Act, provides that the Secretary of Transportation, in consultation with the Secretary of Homeland Security, shall document, assess, and analyze routes for transporting radioactive and nonradioactive hazardous materials and shall identify criteria for selecting routes based upon safety and security concerns within one year.

There is also a general provision in CFR 397.67 stating that even if no state routing designations apply, vehicles transporting hazardous materials should not be operated over routes that go through or near heavily populated areas, tunnels, etc., unless there is no practicable alternative or the driver is required to detour. The driver must be given a written route plan if the vehicle is transporting Division 1.1, 1.2, or 1.3 explosives.

FMCSA Safety Permits

FMCSA requires that motor carriers file a Motor Carrier Identification Report and HM

Permit Application (Form MCS-150B) per CFR 390.19 to transport either 25 kg (55 lb.) of Division 1.1, 1.2, or 1.3 explosives, PIH materials (the quantity varies by hazard zone), or compressed or liquefied methane or natural gas in containers larger than 3,500 gallons. The motor carrier must certify, among other things, that it has:

- A satisfactory security plan per Part 172 of CFR49, cited above
- A communications plan meeting the periodic contact requirements of Section 385.415
- Successful completion of the security training required by Section 172.804.

The information required on Form MCS-150B includes a detailed identification of hazardous materials carried and the number of vehicles (specifically, hazmat cargo tank trucks and trailers) used for this purpose.

The operational requirements for a hazardous materials permit under Section 385.415 include a requirement that the motor carrier provide a telephone number to be carried on the vehicle that can be used to verify by a motor-carrier employee or representative that the shipment "is within the general area for the expected route for the permitted material."

PHMSA Security Plan Requirement

Title 49 CFR 172.800 requires that any person transporting more than 25 kg (55 pounds) of a Division 1.1, 1.2, or 1.3 explosive or 3,500 gallons or more of bulk hazardous materials must have a security plan.

Title 49 CFR 172.802 states that the security plan must include an assessment of security risks and appropriate measures to address those risks. At a minimum, the plan must contain:

- Measures to confirm information provided by applicants hired for positions involving access to and handling of hazardous material
- Measures to address the assessed risk of unauthorized access to hazardous materials or conveyances
- Measures to address assessed security risks en route from origin to destination.

Title 49 CFR 172.704 (commonly referred to as the HM-232 Security Awareness Program) requires that each employee with access to hazmat "receive training that provides an awareness of security risks associated with hazardous-materials transportation and methods designed to enhance transportation security. The training must include a component covering how to recognize and respond to possible security threats."

FEDERAL RECOMMENDED SECURITY MEASURES FOR SECURITY PLANS

PHMSA and TSA Guidelines

PHMSA has issued regulations and guidelines for developing and implementing security plans. On June 26, 2008, TSA issued extensive guidance to implement the PHMSA regulations. The measures are indexed to DHS security threat conditions green, blue,

yellow, orange, and red, indicating the prevailing threat assessment. TSA, the lead federal agency for hazmat security issues, has also instituted a program of corporate security reviews (CSRs) (see below for further discussion).[25]

A training program designed to provide the necessary knowledge and tools to conduct an effective security assessment of a motor carrier's operations was developed as a cooperative effort by PHMSA, FMCSA, and TSA. The centerpiece of the program, called Hazmat Motor Carrier Security Self Assessment Training, is the "Guide for Developing an Effective Security Plan for the Highway Transportation of Hazardous Materials" developed by Battelle and TotalSecurity.US for FMCSA. The guide is designed to provide motor carriers with sufficient background to understand the threats involving hazardous materials, the means to identify the vulnerabilities to those threats, and an approach to addressing those vulnerabilities. The guide includes the vulnerability assessment, the components to be included in a security plan, the components of a training program, and the administration of a security plan.

TSA has also developed the "Hazmat Motor Carrier Security Self-Assessment" for managers and another version for drivers. These guides have a question-and-answer format, with questions such as: "Do you verify that your drivers meet all state and federal commercial drivers licensing requirements, including verifying that they are authorized to handle and transport hazardous materials?" A "yes" answer is followed by security reminders; a "no" answer is followed by a complete checklist of security actions needed to meet all applicable requirements. A contact list of all concerned federal agencies is appended.

According to two TSA reports,[26] TSA also conducts CSRs in various modes of transportation, including highway infrastructure and freight motor carriers. In 2004, TSA began management interviews and site visits to assess security policies and practices of organizations that operate critical highway infrastructure such as large bridges and long tunnels. By 2006, TSA reported that it had completed CSRs for 38 state governments and four other operational authorities.

Similarly, TSA targeted motor carriers that transport hazardous materials for CSRs. By the end of 2006 (the most recently available report), TSA had completed 15 CSRs at motor carriers. At that time, TSA did not believe that the "small amount of data gathered lends itself to rigorous statistical analysis."

The CSRs used a framework of 73 standard questions to interview infrastructure operators and a modified framework of 76 questions for motor carriers. The questions covered ten functional areas:

1. Threat assessment
2. Vulnerability assessment
3. Critical infrastructure
4. Management and oversight
5. Personnel security
6. Training
7. Secure areas

8. Physical security countermeasures
9. Cyber security
10. Exercises

The results of the CSRs are considered Security Sensitive Information and are restricted on a need-to-know basis. In published reports, TSA uses numerical scores that are not "an absolute measure of how well an organization has implemented security practices" for comparative purposes.

TSA conducted a pilot program in Missouri that trained 40 state investigators to perform CSRs in partnership with FMCSA. TSA is now training compliance inspectors and safety auditors in Michigan and Colorado, as well as its own Transportation Security Inspectors to perform CSRs.

TSA works with the DHS Infrastructure Protection (IP) office, which is charged with coordinating with state and local governments and implementing grant and training programs to protect all types of infrastructure. TSA experts have accompanied IP contractors on site assist visits to bridges and tunnels. IP's protective security advisors have in turn participated in CSRs.

INDUSTRY RECOMMENDED SECURITY MEASURES

American Chemistry Council Motor Carrier Security Guidance

The American Chemistry Council Guide was "solely intended to stimulate thinking," but it is more detailed and specific in its recommendations than any other guidance produced for similar purposes. It contains guidance not only for carriers of hazardous materials, but also for shippers, to provide complete supply-chain security. It is therefore considered to be an exemplar of such industry guidance. The guide was published in 2003 and has been superseded by new regulatory requirements in some areas, particularly in driver surety.

Institute of Makers of Explosives (IME) Guidelines

The recommendations in IME Safety Library Publication 14, *Handbook for the Transportation and Distribution of Explosives Materials*, updated in 2007, do not go beyond federal regulatory requirements with respect to any practice that could be considered a security countermeasure.

Highway Watch and Successor Programs

The Highway Watch program had four major components:

1. Training and outreach
2. A 24/7 call center
3. The Highway Watch Information Sharing and Analysis Center (ISAC)
4. The Emergency Warning and Education Center (EWEC)

The Highway Watch program conducted security-awareness training for highway

professionals such as truck drivers and infrastructure construction, maintenance, and operations personnel. The training provided instruction in how to recognize potential security threats, to avoid becoming the target of terrorists, and to accurately and rapidly report concerns to the authorities. Training was presented in English and Spanish, both in person and electronically. About 800,000 persons have received the training.

The Highway Watch program was replaced by the Trucking Security Program known as "Eyes on the Road." Subsequently, in September 2008, it evolved to another program known as "First Observer."[27]

ISAC shares and analyzes information collected from its members and works collaboratively with law enforcement, intelligence agencies, and transportation-industry leaders to validate and verify the information and to identify trends, patterns, and potential threats. It disseminates its findings to the surface transportation industry and law enforcement.

TSA has also produced a series of foldout brochures on reporting suspicious activities and threat indicators.

SUMMARY OF REQUIRED AND RECOMMENDED SECURITY MEASURES

Security Measures for Vetting Personnel

Drivers must have a valid commercial driver's license with an HME based upon an STA. Other measures to vet personnel are an employment background check; verification of citizenship or immigration status, perhaps with a social security number; and criminal background checks for employees other than drivers through a private security company.

Security Measures for Access Control

Facilities should be fenced, with locked gates and doors. Parked vehicles should be locked when unattended. Lighting and clear zones around fences and buildings may be combined with CCTV, alarm systems, or security guards to spot intruders. A photo ID system should also be used to determine if persons are authorized to be in the area.

En Route Security Measures

Each driver's identity and shipment information should be confirmed before departure. Access to information about shipments should be limited to essential personnel. Vehicles should be attended in transit, and those transporting explosives or TIH in many states must follow designated routes and use designated safe stopping and parking places. These routes and stopping or parking places are public information, which may also present vulnerability (discussed later). Vehicles should be inspected for tampering with locks or seals applied to valves and cargo doors. A co-driver or escort can provide additional security. Communications must be maintained with the driver and an alert notification must be made if a shipment does not arrive when and where expected. Drivers may be provided with a panic-button type of alarm for use in emergency situations. A vehicle tracking system is also recommended.

Vehicle tracking and disabling systems are discussed in MTI publication 09-04 and are briefly referenced again in the "Analysis of the Threat" section of this report. In short, vehicle tracking is required for DOD explosives shipments and is recommended—and probably increasingly implemented—for commercial TIH and truckload explosives shipments by TSA specifically (in its Security Action Items) and also by PHMSA generally. Technologies that enable local or remote immobilization of vehicles are being implemented for high-value shipments (such as cigarettes), and while neither DOD nor TSA pilot programs include immobilization for TIH and explosives shipments, they may do so in the future.

The situation is significantly different for gasoline and propane tankers. While vehicle tracking and some panic alarms have been implemented for economic reason in large tanker fleets, they are not used by smaller carriers and are unlikely to be implemented soon. More important, there are no indications that the industry is going to implement either

Current Security Measures in Brief

Personnel vetting
- *TSA fingerprint-based security threat assessment for hazmat drivers*
- *Employment background check, verification of citizenship or immigration status*
- *Possible criminal background checks*

Access control
- *Fenced facilities*
- *Locked gates, doors, and unattended parked vehicles*
- *CCTV, alarm systems, or security guards*
- *Photo ID system for authorized personnel*

En Route Security
- *Confirm driver's identity and shipment information*
- *Attend vehicles in transit*
- *Maintain communications with driver*
- *Alert law enforcement if driver gives an alarm or shipment doesn't arrive*
- *Panic button or vehicle tracking system, especially for explosives or TIH shipments*

local or remote immobilization voluntarily, nor are there any federal mandates to do so. FMCSA, which as been at the forefront of piloting technologies, has recognized the dual-use benefits of these technologies for improving operational efficiency as well as improving security and reducing cargo theft if they are implemented by motor carriers, including gasoline and propane carriers. PHMSA has also issued general recommendations for tracking. However, TSA's recommendations for tracking and immobilization do not apply to carriers of flammable liquids and gases.

Evaluation of Security Measures

The MTI team applied its regulatory and analytical experience and the results of two May 2008 site visits in evaluating the adequacy of the general framework of security measures and some specific security countermeasures. The evaluation of security countermeasures to be implemented is based on their estimated effectiveness, which varies with two key factors: (1) the assumptions made regarding the capabilities of an attacker and the plausible attack scenarios, and (2) an estimate of the probable level of compliance and diligence in

implementing the countermeasures.

The assumptions made regarding the capabilities of an attacker and the plausible attack scenarios are outlined in the chapter titled “Analysis of the Threat and Potential Attacks” beginning on page 47. The operational planning involved for these scenarios is highly influenced by the presence or absence of insiders who can provide information or actually operate a tank truck. The probable level of compliance and diligence in implementing the countermeasures is important, because countermeasures that are deemed effective but not actually carried out only create a false sense of security.
Countermeasures are needed for each phase of an attempted attack. Those phases and our preliminary evaluation regarding propane and gasoline tankers (where site visits helped us) and explosives and TIH carriers are as follows:

1. **Gathering information and selecting a target.** The large numbers of flammable liquid and gas vehicles and facilities make gathering general information about this industry relatively easy, but selecting particular vulnerable targets in this haystack can be a matter of either opportunity or deliberate effort. A lone operator would be able to act only on his own experience, but a target might easily present itself. A local cell could take the time and trouble to identify and select particular targets based on a broad reconnaissance of its area. Gathering information about shipments of explosives and TIH material is more difficult because they are relatively infrequent and knowledge of their locations can be more closely controlled, although required routes and stopping places are public information. A terrorist acting alone would almost have to be an insider. A local cell would probably need an insider as well. STAs for drivers and background checks for other personnel provide information and target security by limiting inside access to vetted persons. Compliance with TSA- and DMV-administered STAs is assured. However, operators will *not* do background checks unless they intend to restrict persons who do not meet their standards, although most will at least check employment application references. A sophisticated conspiracy could probably persuade or coerce vetted persons to become involved in an operation.

2. **Surveillance and identification of the vehicle(s) to be used in the attack**. The particular vehicle or vehicles to seize are selected on the basis of a combination of vehicle condition (loaded or unloaded), location, and vulnerability. Vehicle and facility security measures have a direct correlation to the capabilities of a potential attacker. A lone operator is likely to be deterred by the mere appearance of security and to seek an unprotected target, such as an unattended vehicle. A local cell will look for a more vulnerable target to improve its chances of success. A sophisticated conspiracy will choose its preferred target and will then work to defeat whatever security measures are in place. Facilities and the vehicles at them can be well protected by the measures described in this section if those measures are fully implemented and diligently carried out. That is reasonably assured for vehicles carrying explosives and TIH materials but will vary for those carrying flammable liquids and gases.

3. **Seizing vehicle(s).** The countermeasures described in this section are designed primarily to prevent surreptitious seizure, not armed hijacking. However, the countermeasures would be effective against *theft* if they are diligently implemented. The relative infrequency and high risk of explosive

and TIH-material shipments give greater assurance of compliance with those measures. A sophisticated conspiracy would be needed to reliably defeat them.

4. **Driving seized vehicle(s) to the target.** Once the vehicle has been seized and a capable driver is behind the wheel, alert and response are needed to interdict it before it reaches its intended target. The relevant countermeasures are effective communications with or without a vehicle tracking or disabling system. An insider driver with little knowledge could simply drive on to the target without generating an alarm but probably could not defeat a tracking or disabling system. A sophisticated conspiracy at both ends of the communications link would be needed to override an alarm generated by a vehicle tracking and/or disabling system. It would have to involve an inside driver with full knowledge of any tracking or disabling system, someone who could mimic a normal driver (and even a driver with a legitimate temporary problem) until he reaches

> ***Terrorists are not mirror images of our own planning, and we must focus on how terrorists operate, not on how we plan.***
>
> ***Terrorists are not bound by the analytical models used by government authorities to mitigate the consequences of the expected next attack. They are interested in mounting a successful attack with high loss of life by whatever means available. Hazardous materials that are not highly secured, such as flammable liquids and gases, are weapons of opportunity and can provide that means.***

his target. However, few of the many motor carriers transporting hazardous materials, particularly carriers of gasoline and propane, presently utilize disabling systems.

5. **Igniting flammables, detonating explosives, or releasing TIH materials.** Once in possession of the vehicle and in proximity to the target, the attacker would have to deal with locking mechanisms or breach the compartment directly.

Key Observations from the Evaluation of Security Measures

Some of the security measures described in this section were already in place as safety measures prior to 9/11. The initial response to the threat of attacks using hazmat transported by highway was undertaken by the agencies with safety responsibility for the highway mode, FMCSA and PHMSA. In 2002, TSA was still a new agency, and its first priority was to federalize and deploy the people and equipment needed for the aviation security system. In short, the security measures adopted and recommended by FMCSA and PHMSA were common-sense best practices designed to increase security awareness and be reasonably implemented in the near term; they were not necessarily derived from a threat analysis.

As TSA acquired the headquarters staff to address security in non-aviation modes of transportation, it adopted a more analytical approach based on risk management according to the consequences of an attack. This philosophy gives priority to those materials that are seen as most hazardous to life or the environment or are disruptive to transportation or the economy overall. Radioactive materials, high explosives, and TIH hazards are defined as more dangerous “Tier I” Highway Security-Sensitive Materials (HSSM); flammable liquids and (such as gasoline) and gases (such as propane) are considered less dangerous “Tier II” HSSM. TSA has developed a comprehensive set of security action items for HSSM that

were released to the industry on June 26, 2008. However, Tier I HSSM are transported by a relatively small and specialized segment of the industry that is much easier to manage than the large number of motor carriers transporting flammable liquids and gases, which are Tier II HSSM. In short, the strength of the measures appears to be based on worst-case consequences of sophisticated, high-risk attacks envisioned by the government, not on the average consequences of the low-risk attacks terrorists most often attempt.

TSA was not authorized to have any non-aviation inspectors in the field until after the 2004 attacks on the trains in Madrid and has been slow to exercise direct regulatory authority in non-aviation modes. The institution of CSRs may be a step in the right direction if it is aimed at creating better understanding and enforcement of rules, rather than collecting data for analysis.

However, there is still confusion between federal agencies and between federal and state authorities about the overall approach to the security of highway-transported hazmat. We encountered this confusion about roles and responsibilities in our investigations and field visits, finding conflicting statements between state, federal, and industry authorities about who inspected the industry for compliance with federal regulations and recommended practices. Security regulation and inspection, where it is undertaken at all, appears to be an add-on to safety-related activities by personnel who are not specialized for the task. This environment has left motor carriers largely on their own initiative to adopt and comply with the recommended measures described in this section. In short, security regulation and inspection jurisdiction is confused and is also weak. We would hope that TSA will address this problem, since it is the lead federal agency.

Key Observations on Security Regulations

1. ***The security measures adopted and recommended by FMCSA and PHMSA were common-sense best practices designed to increase security awareness and be reasonably implemented in the near term; they were not necessarily derived from a threat analysis.***
2. ***The strength of the measures appears to be based on worst-case consequences of sophisticated, high-risk attacks envisioned by the government, not on the average consequences of the low-risk attacks terrorists most often attempt.***
3. ***Inspectional jurisdiction is confused, and security inspections are weak.***

Terrorists are not bound by the analytical models used by government authorities to mitigate the consequences of the expected next attack. They are most interested in mounting a successful attack with high loss of life by whatever means available. Many hazardous materials that are not Tier I HSSM, such as flammable liquids and gases, might provide the means. Security measures must be considered in the context of an actual attack scenario and evaluated for their effectiveness against the capabilities of an attacker. We turn to this evaluation in the next section.

ANALYSIS OF THE THREAT AND POTENTIAL ATTACKS

Introduction

We have outlined the destructive effects of flammable liquids, flammable gases, explosives, and TIH and how these materials are transported and secured. We have also summarized the information about these materials that might be available to terrorists, based on reports of criminal thefts, accidents, and disposal methods.

We now analyze in depth how and whether terrorists might use these highway-borne hazardous materials to conduct attacks, and how and whether they might use them to destroy highway infrastructure, or instead to attempt to destroy other targets.

To make this determination, we examined targets, materials, operational and technical complexities, and terrorist sophistication from different angles. We started with broad questions and then drilled down to details.

This section begins with a review of terrorist objectives, statements, and actions. This provides the general context for understanding the likelihood of terrorist attacks on highway infrastructure in the United States. We then ask six questions:

First, ***how do terrorists think about targets?*** Irrespective of the weapons or materials they may have access to, what kind of targets do terrorists find more desirable, and why? What have terrorists said? What have they plotted? What have they done? The answers give us some clues about how terrorists may view *highway infrastructure as potential targets.*

Second, ***assuming terrorists have access to specific hazardous materials, what targets might be most attractive?*** Here we *assume* that terrorists have acquired one of the four highway-borne hazardous materials that, carried in bulk, can cause the greatest loss of life or damage. We then determine which of these materials (without overwhelming technical modification) may be best suited for attacking which targets.

Third, ***what operational considerations influence the selection of material and target?*** These considerations are derived from our understanding of how terrorists actually operate and how the materials might have to be altered to be used effectively. They include various factors, including how often and how predictably the material is shipped, how well the material is protected, and how easy it might be for a terrorist group to understand its destructive effects. We then ask whether and what specific technical and operational modifications might be needed to increase the chances of creating an explosion or a devastating fire. Because the anticipated consequences of the attack—and *even more* important, the probability of success—are important to the terrorists, we have attempted to define a narrower set of attacks and materials that might be considered comparatively more likely to succeed in meeting the terrorists' objectives. *This allows us to make further judgments about the likelihood of hazardous materials actually being used successfully against various targets.*

Fourth, ***how does the sophistication of the terrorist group affect material and target selection?*** Not all terrorists have the same level of organization, technical sophistication, resources, or determination We subdivide terrorists groups into three categories: lone operators; local al Qaeda–inspired cells; and cells centrally funded and supported by al Qaeda, that is, organized, funded, and directed with considerable resources and long planning horizons. We ask which probable attacks each type of terrorist group might be most likely to carry out using hazardous materials (but also taking into account the availability of other materials to achieve the same objective). We assess the likelihood that hazardous materials might be used by these specific terrorist groups and against which targets, *which allows us to further refine our conclusions about attacks against various targets*

Fifth, ***given the findings from the previous questions, which attacks are terrorist groups most likely to conduct using highway-borne hazmat?*** We provide some general observations on how such attacks might be carried out.

This, in turn, will set the stage for some concluding observations about additional measures and countermeasure that should be taken to lower the probability of the most likely attacks.

Overview of the Threat

Key Questions in Analyzing Potential Hazmat Attacks

1. ***How do terrorists think about targets?***
2. ***Assuming terrorists have access to specific hazardous materials, what targets might be most attractive?***
3. ***What operational considerations influence the selection of material and target?***
4. ***How does the level of sophistication of the terrorist group affect material and target selection?***
5. ***What are the most likely attacks terrorist groups might conduct using highway-borne hazmat?***

Before addressing the specific question of how likely terrorists in the United States are to employ hazardous materials in attacks against any target, we review what is known about terrorist planning in general.

Currently, al Qaeda, its affiliated organizations, and individuals or small groups inspired by its ideology, which together comprise the jihadist universe, represent the principal terrorist threat in the United States. There are other sources of threat—e.g., white supremacists, animal-rights and environmental extremists who have carried out acts of violence—but with the exception of white supremacists, they have shown little inclination toward large-scale violence. Right-wing extremists in the United States have carried out large-scale

operations (e.g., the 1995 Oklahoma City bombing) and have contemplated ambitious schemes that would have resulted in large numbers of casualties (e.g., blowing up propane tanks near Sacramento in 1999). Nevertheless, our threat assessment focuses on the jihadist enterprise, the highest-level terrorist threat.

Based on their own declarations and plots that have been uncovered, it is clear that al Qaeda's central leadership remains committed to spectacular acts of terrorism, acts that would come close to or exceed 9/11 in terms of casualties, emotional impact, and economic damage.

"Al Qaeda central," however, is only part of the threat. Since 9/11, terrorists inspired, and in some cases assisted by al Qaeda, have carried out numerous lower-level operations, and many more small-scale terrorist plots have been uncovered and thwarted. The deadliest of these attacks (those in Bali, Madrid, and Mumbai) produced around 200 fatalities each. But most of the attacks have produced fewer casualties. Bombings that are directed against transportation targets simply because they offer concentrations of people in confined environments are giving terrorists a "return" of about 20 fatalities per bomb on the major successful attacks, something easily achievable with flammable gas and flammable liquids. In other words, we cannot dismiss attacks using certain hazmat because of our assumptions about al Qaeda's ambitions to replicate 9/11-scale attacks. Single operatives and local cells operate within a different framework of opportunities and objectives.

In its media campaign, al Qaeda continues to exhort its followers to violence, to take action on their own—tacit recognition that al Qaeda cannot provide them with direct assistance. Although there have been anecdotal reports of American volunteers being directed toward operations abroad rather than in the United States and there is indirect evidence of constraints imposed on terrorist "wannabes" by local Muslim communities, radicalization and recruitment to violence continue in the United States, and certainly there is no evidence that American could-be jihadists are receiving instructions *not* to carry out attacks in the United States. The absence of attacks and the paucity of sophisticated plots, compared with the situation in Europe, may reflect good luck and a lack of constituency, rather than centrally imposed constraints.

The few plots uncovered in the United States thus far reveal a low level of capability and competence. Therefore, local terrorist planning should be viewed as distinct from the more grandiose ambitions of al Qaeda's central leadership. While surprises are always possible, elaborate, multi-component, combined attacks like those in Egypt, Turkey, Jordan, Saudi Arabia, Morocco, Mumbai, and Madrid are not very likely in the United States.

Terrorists everywhere draw inspiration from various sources, but most of the inspiration comes from other terrorist incidents. Repeated modes of attack become part of the terrorist playbooks to be replicated locally. For example, the 2004 Madrid commuter train bombings inspired the 2005 London subway bombings, which together inspired the 2006 Mumbai train bombings. They also draw inspiration from Internet discussions and available instruction.

Terrorists listen to what we say. Government reports identifying certain vulnerabilities, reports that terrorists may be planning certain kinds of attacks, or mere speculation that they might do so prompt terrorists to ask themselves whether they could, in fact, do what

is being discussed. Our concerns drive their conversations.

Finally, terrorists may draw inspiration from spectacular accidents, reports of criminal thefts, or other newsworthy events which, in the post-9/11 world, almost invariably lead to official or media speculation on whether terrorists might attempt to repeat them. As our review of accidents ("Public Information that Could Inspire and Inform Terrorists" beginning on page 25) indicates, there have been a number of spectacular highway accidents. The 2007 MacArthur Maze crash of a gasoline tanker and the resulting fire destroyed a key freeway ramp, but far more deadly highway crashes have happened, crashes involving gasoline tankers (Biloxi in 1998, Yonkers in 1997), propane tankers (Spain in 1978, where over 200 people were killed at a tourist camp site, and White Plains, New York in 1994), and TIH rail tank cars (Graniteville, South Carolina in 2005). A number of criminal thefts of fuel oil tankers have occurred since 2006, including multiple thefts of fuel oil tankers in Lancaster County, Pennsylvania, and Suffolk County, New Jersey; the 2007 hijacking of a fuel tanker in Baltimore; and the May 2008 hijacking of a fuel tanker in Houston.

The chronology of terrorist plots, threats, and concerns expressed by the authorities shown in Table 9 indicates the extent to which plots and attacks have involved gasoline tankers. The accounts of these schemes may reflect actual plots that have been uncovered; fables spun by captured terrorists to entertain, impress, or mislead their interrogators; the fertile imaginations of informants determined to deliver information to eager handlers; or hypothetical scenarios conjured up by "red teams" assigned to think as terrorists. But it is nonetheless clear that the idea of using hazardous materials as a weapon is by now well established in the mind of the public, and almost certainly in the minds of terrorists.

Factors Influencing Weapon Choice

It is important to understand the factors that may drive terrorists away from explosives and toward other hazardous materials. Explosives certainly remain the principal weapons of contemporary terrorists—bombings comprise the majority of their attacks. But terrorists also have used fire as a substitute for explosives or to enhance the effect of their bombs. These fires range from simple arson—a tactic favored by environmentalist extremists as the easiest way to destroy property—to Molotov cocktails, a substitute for hand grenades, to the tiny incendiary devices used by animal-rights fanatics to start fires in retail fur departments, to the addition of propane tanks to increase the power of explosives. Terrorists on at least one occasion also added toxic chemicals to conventional explosives to increase their lethality. Reportedly, those responsible for the 1993 bombing of the World Trade Center in New York laced their explosives with cyanide.

Just as large quantities of explosives can be concealed and brought to a variety of targets in vehicles, so large quantities of flammable liquids or gases, or of toxic inhalants, can be brought to a variety of suitable targets only in highway tankers or surrogate tankers.

Flammable liquids and gases have also been used as a substitute for explosives, for example, in the 2007 terrorist attacks in London. Terrorists filled two vehicles with gasoline and propane tanks and parked them near nightclubs in London's busiest area, hoping to create a gigantic explosion and a fireball that, had their devices worked, might have killed scores of nighttime revelers. The following day, the same terrorists crashed their gasoline-

drenched vehicle into the terminal of the Glasgow airport, presumably seeking martyrdom in a massive fiery explosion. They did manage to set the car on fire, and the fire engulfed a small part of the terminal but caused no explosion—in large measure, because the terrorists were unable to achieve the right mixture of fuel and air inside the automobile. This event is the closest one we have to one of the scenarios envisioned in this report—an attack using a suicide tanker. (It was erroneously reported that the tanker driven by a suicidal terrorist into a crowd of tourists in Tunisia, killing 21 at a historic synagogue, was filled with liquefied natural gas. The tanker actually contained conventional explosives.)

Following terrorist attacks in Saudi Arabia and Morocco in 2003, there were reports that known al Qaeda operatives have discussed pre-operational screening and acts of intelligence involving fuel stations, fuel lorries, and underground fuel storage locations. Authorities went on the alert in both the United Kingdom and the United States.

In another plot uncovered in the United Kingdom, terrorists were considering driving limousines filled with flammable gases such as propane into underground garages of buildings in London.

A recent review of terrorist chatter about weapons and tactics yields no mention of tankers or trucks carrying other hazardous materials as weapons. However, authorities have identified highway trailer hijacking as a possible new method of fund-raising by terrorists. This conclusion appears to be based upon surmise, and it refers to hijackings of readily salable cargos (such as cigarettes), not hazardous materials.

Nonetheless, as outlined in “Public Information that Could Inspire and Inform Terrorists,” tanker thefts resulting from the rising cost of fuel can be viewed as a possible inspiration to terrorists, although none of the thefts thus far has had any nexus with terrorism.

From a terrorist perspective, vehicles containing thousands of gallons of flammable liquids or gases would seem to offer an attractive target that can be turned into a destructive weapon. However, those with detailed knowledge inside the trucking industry apparently see little threat. According to our field interviews, they base their view largely on the assumption that terrorists would prefer explosives, which they could easily manufacture, and the fact that it is not easy to “detonate” a cargo of gasoline.

Increased government monitoring of large-quantity sales of chemicals that can be used to make explosives (e.g., ammonium nitrate fertilizer) and the technical difficulties of detonating a large quantity of homemade explosives have created some challenges to bombmaking. Less expertise is needed to seize a gasoline tanker, drive it to a target, release the fuel, and ignite it to achieve considerable damage. However, significantly greater sophistication is needed to achieve a similar level of destruction using propane tankers.

In addition, ideas for operations may arise from personal experiences of the planners themselves—special knowledge, work experience, or access. And given the large number of companies, especially independent contractors and private owners involved in the carriage of propane and gasoline, the chances of an idea forming and the level of knowledge necessary to carry out a successful attack being acquired are increasing. Terrorists are opportunists, as mentioned before, and the opportunities are significant, including the

opportunities that hijacked gasoline tankers create

The terrorists we are talking about are lethal and destructive. Purely symbolic violence does not suffice. They want very high body counts and massive destruction. But they also want their attacks to succeed, even if they themselves are willing to die in the attempt—indeed, they are especially concerned about success in such cases, since they get only one try. For religiously inspired terrorists, success is evidence of God's favor. A yield of 100 or 200 casualties is evidence enough.

This pushes terrorists toward soft targets, tested tactics, *and* accessible weapons. Availability, ease of access, and knowledge requirements drive terrorist planning. When high-consequence results are weighed against certainty of success, certainty of success wins. From the standpoint of availability, ease of access, and knowledge requirements, flammable materials, such gasoline and, to a lesser extent propane, should be reevaluated as possible terrorist weapons for use against soft targets that can yield significant but not catastrophic numbers of casualties in the United States.

KEY QUESTIONS

1. How do terrorists think about targets?

We can best answer this question by looking at the statements, plots, and attacks carried out by (1) all terrorists and (2) jihadists such as al Qaeda. In this analysis, we consider the entire spectrum of weapons, not just weaponized hazardous materials transported by highway, and the entire spectrum of targets. We establish a general priority of targets for Jihadists and for other terrorists. However, we exclude terrorist attacks conducted as part of an active insurgency in an area of active operations.

Categories of Targets

While there are probably an infinite number of possible terrorist target categories, the history of terrorist attacks suggests that the following may be a useful categorization of potential targets *in the United States*:

1. Prominent government, political, and financial figures, such as the president and vice president, cabinet officers, and prominent CEOs. Over the years, terrorists have assassinated the prime minister of Spain and the former prime minister of Italy, and they have attempted to assassinate the prime minister of the United Kingdom. Prominent business executives have been targets primarily of kidnappings in Europe and Latin America; there are no cases of such kidnappings in the United States (although the daughter of the prominent Hearst family was kidnapped by domestic terrorists in 1974).

2. Government buildings, particularly iconic structures such as the White House, the Department of State, the Pentagon, and CIA headquarters. The 1995 Bojinka plot included reference to crashing a plane into CIA headquarters, and the U.S. Capitol was bombed in 1983.

Table 9 Selected Attacks Involving Gasoline Tankers and Official Concerns About the Threat

January 1982: IRA terrorists ditch a hijacked gasoline tanker under a rail bridge, halting all trains from Belfast to Dublin until authorities can determine that the rig is not booby-trapped and can be safely removed.
June 1996: Terrorists launch a suicide attack on Khobar Towers, an American military housing site in Saudi Arabia, killing 19. The vehicle employed was a tanker truck loaded with explosives, not flammables.
April 2002: A suicide attacker drives a tanker truck into a group of tourists at a synagogue in Djerba, Tunisia, killing 21. The tanker was filled with explosives, not flammables; nevertheless, it is often reported as a fuel tanker attack.
May 2002: Terrorists in Israel secretly attach a remotely detonated bomb to a gasoline fuel tanker and set it off when the truck is at a fuel terminal.
June 2002: The FBI warns that fuel tankers may be used to attack synagogues, although it says that it has no evidence of such a plot.
September 2002: Afghan authorities intercept a booby-trapped tanker loaded with jet fuel, preventing it from entering the U.S. air base at Bagram.
February 2003: The first of a series of reports of al Qaeda plots to attack gas stations with stolen or hijacked tankers appears. The report indicates that terrorists are also targeting bridges.
April 2003: More detailed reports of terrorist plots are released, based upon decoding of captured al Qaeda chief operational planner Khalid Sheikh Mohammed's disc drive. Authorities find "evidence of several potential al Qaeda plots involving tanker trucks," including plans for "hijacking fuel tankers on the highways, modifying milk carriers to hold gasoline, attaching remote control bombs to unsuspecting propane trucks." Further intelligence indicates that a terrorist operative posed as a potential buyer of a gas station in the United States to collect information on tanker routes, fuel delivery schedules, and tank filling procedures.
January 2004: Japanese authorities envision hijacked tanker trucks used as bombs in Tokyo.
April 2004: The report of a stolen tanker truck in New Jersey raises concerns about terrorism.
June 2004: Reports of tanker trucks stolen and hijacked in Iraq to be used in truck bombings appear.
August 2004: In a widely publicized report, a captured operative reveals that al Qaeda plotters had questioned "whether a hijacked oil tanker truck could serve as an effective weapon."
June 2005: A report on hazardous materials reveals that a Pakistani ordered out of the country in 1996 was still driving gasoline tanker trucks for various oil companies eight years later.
August 2005: A report indicates that jihadists were talking about using suicide drivers to drive hijacked fuel tankers into gas stations to cause mass casualties. The discussions considered using water trucks filled with gasoline. New York, Chicago, and Los Angeles were mentioned specifically as targets. Although the discussion parallels earlier revelations, the source in this case is considered to be of questionable reliability.

3. Commercial property, especially financial institutions, and corporate headquarters The New York Stock Exchange (NYSE) was reconnoitered as a target, along with financial institutions in New York and Washington. Corporate headquarters were frequent targets of symbolic terrorist bombings in the 1960s and 1970s.

4. Critical infrastructure, such as nodes of telecommunications, transportation (including highways), water, and power. Within transportation, there are categories of targets that have been repeatedly attacked (commercial airliners) and more recently attacked (mass surface transportation). The airliner has long been a symbol of U.S. sovereignty, and flying accidents, from which most people consider no escape possible, have always attracted intense public fear and attention. Surface transportation provides concentrations of people in situations where it is difficult to protect families.

5. Iconic symbols of the United States, or of a particular region. Internationally recognized national icons include the Statue of Liberty in New York; and the Lincoln, Washington, and Jefferson Memorials in Washington DC. The financial engine of the United States is probably best symbolized in the Wall Street Stock Exchange in New York. So-called "sub-iconic symbols," which represent a city or a region include various other bridges or buildings in cities.

6. Public gatherings outside of buildings (e.g., open-air celebrations that occur regularly throughout the year, but particularly on national holidays).

7. Large numbers of civilians inside public venues (such as at stadiums during sporting events, in crowded shopping malls, in hotel lobbies, in crowded cafes and restaurants, or in train stations or airports). These have been the principal targets of al Qaeda since 9/11.

8. Large numbers of civilians inside multiunit residential buildings. Residential compounds were attacked in Saudi Arabia because they housed large numbers of foreigners.

Al Qaeda and Other Jihadist Groups

The threat posed by al Qaeda and groups associated with it is somewhat easier to analyze than that of other groups because al Qaeda's declarations, plots, and attacks are fairly consistent and suggest a distinct prioritization of targets.

Al Qaeda urges its followers to carry out attacks that will produce high body counts and will have symbolic value—in jihadist language, attacks on targets that have "emotional" value (iconic targets)—and attacks that will cause serious economic damage. The iconic component can refer either to the destruction of an internationally recognized icon or to an iconic venue. In the latter case, the destruction of the target would not necessarily be the goal. The venue would merely be a dramatic backdrop that would increase the psychological impact of the attack.

In fact, however, few of the jihadist attacks and plots since 9/11 have included iconic targets or venues, although diplomatic facilities and even nightclubs the jihadists consider sinful do have symbolic content. And despite the continued drumbeat about economic warfare in al Qaeda communications, the economic impact of the terrorist attacks since 9/11 has been incidental—for example, attacks on hotels do adversely impact tourism.

Almost all of the jihadist attacks since 9/11 have been directed against soft targets—that is, unprotected or lightly protected targets such as hotels (Indonesia, Kenya, Jordan, Egypt, Pakistan), restaurants and nightclubs (Indonesia, Morocco, United Kingdom), public surface transportation (Spain, United Kingdom, Philippines, India), residential compounds (Saudi Arabia), and high-profile individuals. Terrorist attacks on embassies, consulates, and commercial buildings (Indonesia, Pakistan, and Turkey) have used vehicle bombs on the street; in other words, they have not attempted to penetrate security. Only in a couple of instances have terrorists attacked government buildings or, in one case, a refinery (Saudi Arabia), which are likely to have higher levels of security. This again suggests a low tolerance for risk of failure. The detonation of the terrorist devices, even beyond any

security perimeter, still resulted in casualties and destruction. The avoidance of security does not mean that the terrorists were averse to personal risk, since many of these were suicide attacks. We are talking about operational risks.

A review of the terrorist plots that were uncovered during the same period reveals greater operational ambition (use of exotic substances, multipart operations) to attack more diverse but still similar targets. Most of the plots involved attacks on public surface transportation—the killing fields of terrorists bent upon slaughter. Embassies figured in several plots, along with other government buildings and military headquarters. Several plots involved attacks on naval or civilian vessels, like the attacks on the U.S.S. *Cole* or the French supertanker *Limburg*. However, soft targets predominate.

Bridges were cited as targets in a few plots, but these plots were uncovered at the "thinking about" or reconnaissance stage, before any operational planning. There is no evidence that terrorists had or could easily have acquired the means to successfully carry out attacks against inherently robust targets in the transportation sector.

On the basis of this analysis and the list of targets we started with, certain priorities emerge.

The most valuable targets are those that promise the highest body counts. In addition to public transportation, these include outside public assemblies and large numbers of people inside residential or public buildings. The terror effects increase if: (1) attacks yield deaths that are hard to avoid (hitting the public in areas that were previously thought safe), (2) they happen nearly simultaneously in different places, and (3) they can generate horrific deaths, for example, trapping and burning people in closed buildings. If such attacks can take place against the backdrop of an internationally recognized U.S. icon, their value increases even more.

The second-most valuable targets (or at least venues) are national icons. However, the value of these targets would increase significantly if attacks also caused both substantial numbers of casualties and economic harm. The paradigm for such attacks is, of course, the 9/11 attacks on the World Trade Center.

The third most valuable targets would be key nodes of infrastructure that, if attacked, might yield sustained economic harm. These include oil refineries or terminals, port facilities, pipelines, and energy facilities. Again, attacks that coincidentally create large numbers of casualties are of higher value.

Other Terrorists in the United States

Other sources of terrorist attacks in the United States range from the Animal Liberation Front and violent environmental activists to right-wing extremists and white supremacists. For these groups, the priority of targets is primarily dictated by the specific objective of the attack, because these groups are motivated by narrowly defined issues. While the Oklahoma City bombing resulted in a significant number of casualties, it is important to realize that in the mind of the bomber, Timothy McVeigh, the objective was to destroy a federal government building with government employees, not civilian bystanders. In

another case, authorities arrested right-wing extremists who plotted in 1999 to blow up huge propane storage tanks in Elk Grove, near Sacramento, California. Had the attack been carried out, it could have caused fatalities among nearby residents.[28]

It is difficult to define precisely the ranking of targets for such a large range of groups. However, certain trends do emerge. Declarations, plots, and actions show that these attackers tend to:

1. Focus on targets (individuals, infrastructure, or buildings) that are specifically associated, as part of the government or as part of a company, with the specific policies or entity being targeted. Two examples are the bombings of IRS offices and the assaults on laboratories or individuals engaged in animal research.

2. Focus on controlling economic damage and on limiting collateral casualties. For example, recent environmental fires set in housing developments by environmental extremists specifically excluded occupied buildings. Attacks on animal testing labs have similarly avoided human casualties, although some animal-rights extremists have targeted individuals.

3. Make no mention of transportation infrastructure.

4. Almost never target bystanders, either in open-air public gatherings or inside residential or other public buildings.

In summary, then, non-jihadist target selection tends to favor acts against individuals, symbols of the U.S. government, or a particular policy, project, or practice. It does *not* tend to favor critical infrastructure, including highway infrastructure, and, except in the case of right-wing extremists, it does not favor attacks that create large numbers of fatalities. In fact, when we look beyond contemporary jihadist terrorists outside the United States, we see that bridges have figured as targets in a very small fraction of terrorist attacks on surface transportation in recent decades. Moreover, these attacks were against small structures, and more important, they occurred in conflict zones where guerrilla armies were engaged in sustained systematic campaigns of sabotage to undermine local economies. In the more developed countries, serious assaults on bridges and tunnels are generally confined to wartime sabotage.

2. Assuming terrorists have access to specific hazardous materials, what targets might be most attractive?

In the discussion above, we assumed that planning starts with target selection and proceeds to acquiring hazardous materials with which to attack. Another approach would be to assume that terrorists have acquired or can easily acquire a specific hazardous material and then examine the targets they might select to attack with that material. Here, target selection is the driven by the particular hazardous material involved.

We shall attempt to rank or describe the most attractive targets for an individual, cell, or group that has acquired or has easy access to one of the following materials:

1. A truckload quantity of flammable liquids, such as gasoline
2. A truckload quantity of a flammable gas, such as propane
3. A truckload quantity of a Division 1.5 commercial explosive, such as ANFO
4. A truckload quantity of a TIH material, such as chlorine.

The authors have examined categories of targets and assessed those that are most attractive for each hazardous materials, although targets may be opportunistic—that is, much depends on what is available within the general vicinity of the hazardous material that has been acquired, and the target characteristics itself. Those results are too sensitive to be presented in a public report. The one conclusion from this analysis that can be conveyed is that there are many more-attractive targets than highway infrastructure that could be attacked with these materials, such as office and residential buildings, along with shopping malls.

The discussion following Question 3 (page 58) addresses operational considerations that vary by hazardous material and targets. When terrorists have already obtained the hazardous materials, the likelihood of success of an attack or the extent of the damage that could be caused by it may vary considerably, depending on the target. Also, some targets may be vulnerable to specific hazardous materials, but not to others.

Target vulnerabilities may limit the suitability of a specific hazardous material for attacking it. For instance, a flammable liquid such as gasoline is best suited for attacking structures susceptible to fire. The ability to get the flammable material to a critical location is also a factor. As a general rule, physical structures are most vulnerable to explosives, because of the “reach” of these materials and the wide array of structures they could be used to attack.

Highway infrastructure would present difficult targets for terrorists, particularly if damage to the infrastructure is the only objective of an attack. Destruction of overpasses whose steel supports are vulnerable to fire (the type of structure most readily damaged) simply would not have the economic effects sought by terrorists, nor would their destruction cause significant casualties. Tunnels bored through hard rock might be difficult to collapse even with significant quantities of explosive, although their support structures could be temporarily compromised. Even if successfully attacked, they may have limited impact due to the existence of alternative transportation routes—although tunnels, because they are used often as a last resort in transportation planning, may create more economic dislocation than the loss of other highway points.

Only when coupled with the possibility of causing significant numbers of fatalities and injuries do these targets really become more attractive.

The type of highway infrastructure most likely to be a potential target of terrorism is probably iconic suspension bridges. Certainly, carefully engineered attacks using explosives could pose risks to such bridges. In theory, flammable liquids and flammable gases could damage support structure, but the operational complications present significant impediments to an attack using these materials.

3. How do operational considerations influence material and target selection?

Several factors affect the choice of hazardous materials for conducting an attack and the targets that might be selected. Accessibility of the hazardous material, vulnerability of targets, and a sense of the likelihood of a successful attack are the most important operational considerations. These considerations also vary with the sophistication of the individual terrorist or group, discussed below.

Accessibility of the Hazardous Material

One of the most critical considerations in any attack is to the difficulty of obtaining a hazardous material capable of causing significant damage to people or structures. Characteristics of hazardous-materials transportation play important roles in these considerations, along with how well the materials are secured. Key transportation characteristics for the four types of hazmat of interest in this study are as follows:

1. *Flammable liquids*. Gasoline is the hazardous material most frequently transported in large quantities by truck. They would be relatively easy to observe, with points of origin and destination well known: Gasoline is delivered in public venues that have open access and little security. Opportunity exists for insiders to acquire truckload quantities of these materials, both as vehicle drivers and as operators or employees at the delivery location.

2. *Flammable gases.* Although not as accessible as gasoline, propane is still an easily identifiable hazardous material whose shipment patterns are observable.

   Security countermeasures for flammable liquids and gases are the same as those for other bulk hazardous materials. If all or most of the recommended countermeasures are implemented, a facility will be reasonably secure from intruders. En route security depends largely on attending or locking or sealing the vehicle.

3. *Explosives.* Bulk quantities of commercial explosives are delivered by truck infrequently, and security can be expected to be higher than security for the other hazardous materials considered in this study. Specialized or insider knowledge would be almost essential to acquiring these materials for a terrorist attack.

4. *TIH Materials.* Highway shipments in bulk quantities of the TIH materials that pose the greatest security risks, such as chlorine, are very infrequent. Specialized or insider knowledge would be required to acquire and use these weapons. And while anhydrous ammonia is frequently shipped, it is a Zone D TIH material, the least lethal type, and is of limited value in terrorist scenarios.

Security countermeasures for explosives and TIH materials are similar, and because of the high risk posed by shipments of these materials, operator diligence in implementing the measures is more assured. Drivers are thoroughly vetted. Facility security for explosives operations is generally high. The high level of attention given to TIH materials

by authorities and the public is also a factor in compliance. Shipments of explosives or TIH materials occur relatively infrequently

As stated earlier, it is also important to remember that terrorists learn from reports of accidents and thefts and from some hazardous-materials disposal operations. They can, with reasonable effort, learn that flammable liquids (particularly gasoline) are transported frequently; that these materials ignite easily, that they can create very intense fires; and that they can be hijacked and brought to a large array of targets.

Terrorists can understand from reports of both rail and highway tanker accidents that flammable gas, such as propane, can, under just the right circumstances, explode and create a fireball and blast damage that is as great as that from a large amount of explosives, with the potential of killing many people if they can be found in high concentrations. But they might not understand just how difficult it is to achieve such an effect, especially the difficulty of directing energy at a particular piece of a target.

Terrorists would know that explosives are not transported as frequently as flammable liquids and flammable gases, and that they are stable during normal transportation conditions. However, they would also know that explosives, if detonated, can cause significant damage.

Finally, terrorists might observe that under the right conditions, casualties resulting from release of TIH materials can be catastrophic; however, they could also see from accident reports that if victims are not placed in precisely the right position, surprisingly little damage may occur. They would also rightly infer that most TIH material shipments are by rail car.

Vulnerabilities of Targets

Specific vulnerabilities of specific targets make certain types of hazardous materials better suited to attack them and may alter the way a material is used (or whether it can be used) in an attack. The effects of target vulnerabilities on operational considerations for the hazardous materials considered in this study are discussed below.

1. *Flammable liquids*. Releasing and igniting the contents of a gasoline tanker does not pose significant technical difficulties. The ability to position a gasoline tanker inside or under a target would be the most critical operational consideration. There are many targets with a large number of occupants where this may not pose significant difficulties.
2. *Flammable gases.* A flammable gas is far more difficult to release and ignite than a flammable liquid. The pressurized gas tanks are more robust and releasing and directing the gas requires fairly good timing skills. Even more important creating an explosion (especially one that is timed, placed, and well directed) rather than simply a fire is very difficult.
3. *Explosives.* Perhaps the greatest operational complexity in the use of bulk quantities of commercial explosives would be in knowing how to place a detonator and booster charge to detonate a significant portion of the explosives shipment. The types of commercial explosives transport vehicles are more varied than the types of vehicles for flammable liquids and gases. Thus, more expertise and

specialized capabilities are necessary to plan an attack using explosives in transportation. In addition, some commercial explosives are shipped as oxidizers and must be sensitized before use. Again, specialized knowledge and expertise are required. Explosives do have the advantage of being able to affect targets at great distances, and a near-instantaneous explosion offers less time to prevent or mitigate consequences.

4. *TIH materials*. The only potential targets of TIH materials are people. For an attack to be successful, it would be necessary to release the entire contents of a bulk highway shipment of TIH material as quickly as possible in close proximity to large numbers of people. The robust nature of the packaging acts as a deterrent, as does the presence of structures where sheltering is possible. A terrorist would also need to be concerned with complex meteorological considerations (temperature, wind direction, wind speed) in planning an attack using TIH materials.

Likelihood of a Successful Attack

1. While most terrorists desire the greatest possible amount of fatalities or destruction, a terrorist planning an attack would place a premium on the surety of achieving results above a threshold level, rather than achieving maximum consequences. Uncertainty of results using the hazardous materials of interest in this study is evaluated below.

2. *Flammable liquids*. Hazardous materials such as gasoline offer a relatively easy path to achieving an event with at least moderate consequences.

3. *Flammable gases.* Achieving a fire of a certain magnitude is within the capability of many terrorists. The ability to produce an explosion might be considered as a bonus, though it is very difficult to do. Operational difficulties are much higher than those with gasoline for most targets, which reduces the likelihood of a successful attack.
4. *Explosives.* Predictability of outcomes from conventional attacks with explosives is the standard by which other terrorist events must be evaluated. Terrorists attempting to obtain explosives from transportation risk detection, and there are steps where things can go wrong; explosives have the potential to produce high numbers of fatalities and significant damage to structures.
5. *TIH materials.* Consequences from using this category of materials are the most variable or uncertain. Lack of everyday experience with the materials; potential difficulties obtaining, opening, and controlling releases from highway shipments; and unreliability in obtaining predictable levels of casualties make these materials less-than-ideal weapons for terrorists. Maximum possible casualties may be very high if everything in an attack goes correctly; however, variability is still high, and the median or average for any event is likely to be low in comparison with that of other hazardous materials.

It is important to note that potential lack of knowledge about the actual probability of success of a terrorist attack plays a complex role in planning such attacks or developing strategies to counter them. For example, a terrorist may be drawn to attempting an attack

with a low probability of success based on dramatic but infrequent images of accidental hazardous-material events. The difficulties of creating an explosion using propane may be countered by the visual effects of spectacular events that have occurred. We may be surprised when a successful attack occurs, since both attacker and defender are operating with many unknowns and an experience base that is incomplete.

Figure 4 shows a rough correlation of the probability of a successful attack and a reasonable upper limit of achievable consequences for the hazardous materials of interest in this study. It is based on the study team's judgment concerning real-world operational constraints and history, rather than a worst-case model. It does not consider access and vulnerability issues. It was arrived at by consensus, but without using formal techniques or methods. Fatalities can be thought of as a reasonable higher-level total (but not worst case) that might be expected from a successful attack. Probability can be thought of as the likelihood of achieving a successful attack with significant numbers of fatalities, given that an attack occurs. Full contours are not shown on the graph in order to simplify understanding (i.e., it is possible for each of the materials to obtain "up to" lower numbers of fatalities with increasing probability). The purpose of the figure is to provide a general sense of the potential risks (consequence and probability) of terrorist attacks using these hazardous materials.

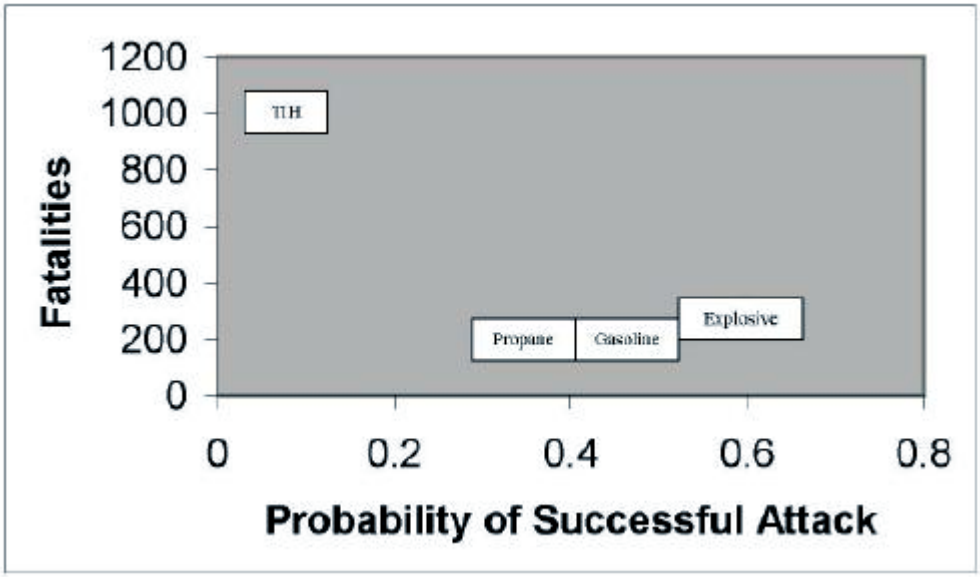

Figure 4 Estimated Correlations of Probability of Success of an Attack a potential consequences

4. How does the sophistication of the terrorist group affect material and target selection?

The ability to obtain hazardous material depends on the terrorist's available planning and funding. Even once the material has been obtained, the terrorist and/or terrorist cell needs to have a certain level of sophistication to take down a specific target. Each of the subgroups (the lone operator, locally inspired jihadist cells, and groups funded and supported by al Qaeda central) has a unique set of operational assumptions that limit its ability to acquire material or select targets. Before determining plausible attack scenarios, we need to consider the operational assumptions and the capability limits of each subgroup.

The Lone Operator. The lone operator may be one who turns to a Jihadist ideology because of a personal loss or sense of alienation. As they become indoctrinated, lone operators may decide to strike at society for perceived personal insults or assaults to Islam that are spread through Jihadist literature. Depending on circumstances, a lone operator may become the catalyst who starts a local jihadist cell.

Obviously, a lone operator will have limited funding, because there is no organization to bankroll his operation. Lacking an organization, a lone operator may resort to petty crime to obtain funds. But this risks greater exposure to law enforcement and possible detection and incarceration. Most likely, lone operators will fund their own operations. They thus must maintain a low profile that limits their possible attack scenarios.

The level of planning of lone operators will vary, depending on such factors as access to information, prior knowledge of intended target sets or hazardous material, access to material, and overall mindset, e.g., focus on detail versus impulsive action, determination, quickness to act, and temperament. We assume that a lone operator's level of planning detail will be limited due to personnel and resource constraints, so materials and targets will be chosen because of the convenience of access. Except for suicide bombers, lone operators are inclined not to martyr themselves.

Local Al Qaeda-Inspired Cells

The local al Qaeda-inspired cell may consist of first- or second-generation immigrants or converts to Islam who are knowledgeable about local customs and culture. They are integrated into the society and have the rights and benefits afforded to all of the countries' citizens. Usually, a catalyst organizes the local al Qaeda-inspired cell. Members may be usually radicalized through jihadist or Salafi websites, in the prison system, or in radical meeting places.

Local cells are connected by ideology and personal ties, not through a hierarchical structure. Members gravitate to each other based on that ideology and personal relationships. Some of these groups may be amorphous and temporary, but others may establish longer-term partnerships in a sustained campaign directed by a central figure.

Due to the nature of local cells, funding is more of a necessity for them than for the lone operator. Funding comes from sources such as criminal activity (e.g., the baby-formula black market, cigarette smuggling, and distribution of counterfeit items) or local

sympathizers. Criminal activity increases a cell's exposure to local law enforcement and detection through intelligence-based policing. Foreign intelligence sources are of very little value in detecting these cells beyond providing trend analysis of increased local Jihadist cells in other countries.

A local cell's planning for a possible attack is more in-depth and involved than that of the lone operator. Since the cell obviously has more than one member, individuals can be tasked with specific assignments, and tailored research can be done. Cell members may also be recruited for a specialty they possess. Planning is still at a rudimentary level because: (1) local cells cannot take advantage of the resources and knowledge that comes from a central and presumably more professional and well-financed authority; (2) the members have uneven training, mostly through websites, videos, printed manuals, etc., and very little hands-on practical experience; and (3) cell members are from the local community and have very little operational experience.

Cells Funded and Supported by al Qaeda Central. Such cells may consist of "foreign" Islamists or a mix of foreign Islamists and radicalized local members under the direction of the foreign Islamists. At least some members are likely to have received training and operational experience in either Bosnia, Iraq, Afghanistan, or Pakistan. They have hands-on experience and specialties in explosives, munitions, weapons, etc. Many may have been involved in operations against foreign targets, most likely in Bosnia or Iraq.

Al Qaeda centrally funded and supported cells are not dependent on local funding. Money is funneled to them from al Qaeda "headquarters," through the use of hawala[29] or an informal banking system built on trust. These cells are better financed and therefore freer to develop more-sophisticated operations.

The centrally funded and supported cells are not constrained by time. Operatives can be infiltrated into a country through various methods (student visas, border crossings, tourist visas, etc.) and can integrate into society, although actual cases suggest that operatives tend to hit the ground running. Planning is highly sophisticated, because the objectives of these cells are to inflict significant casualties and to hit high-priority targets. They are more likely to engage in reconnaissance to maximize the effect of an attack, while minimizing their losses. As part of the planning process, they will probe and test security measures to find a target's weaknesses or a softer target. They are constrained not by time but by operational success.

The centrally funded and supported cells also possess greater expertise. As noted before, their members most likely have practical training and operational experience. Depending on the nature of a planned operation, the cell members may be specialists in either the type of target or the weapons to be used, or they may go through the training necessary to gain access to possible assets. Finally, these cells have more sophisticated knowledge in tradecraft, and members are more apt to engage in reconnaissance over a period of time to determine routines and routes of prospective targets.

Acquisition of Hazardous Materials

The level of sophistication of a terrorist group or individual is not the only determining

factor in hazardous material acquisition. The ease of acquisition of the material plays a significant part in the planning process. Another significant factor is the patience of the group. If a group does not have an impulsive desire to strike quickly, it may be inclined to either recruit a legitimate driver to its cause (to deliver the material to either an operative or a target site) or become certified to transport hazardous material. Characteristics of hazardous materials transportation play important roles in these considerations.
Conceivably, a lone operative could obtain any hazardous material except military explosives. Frequency of transport and less than adequate security countermeasures provide an opportunity for terrorists to obtain flammable liquids. Materials in the other three categories could also conceivably be obtained; however, the need for more information on movement and on ways to "weaponize," along with the need for reconnaissance of delivery routes, makes obtaining these materials more difficult unless the group has an insider as part of the operation.

Vehicle Acquisition

There are a number of ways to acquire a hazardous material vehicle: stealing/hijacking, turning an insider, or through legal means. Groups with limited funding will require more drastic and impulsive methods of acquisition, such as stealing/hijacking; as the terrorists' level of sophistication and patience increases, the method of acquisition is more likely to be through legal means or through turning an insider to either deliver the vehicle to an operative or conduct the operation.

While hijacking a tanker may be the easiest method of acquiring one, there are others. The next possibility is turning an insider. This is more complicated and can range from duping an insider into thinking that he is participating in a simple theft to radicalizing one who will do what he can for the cause. The insider is a particularly dangerous factor; he or she has every reason to keep the operation secret but has no reason to hesitate or not go ahead, either because of money (if he has no knowledge of terrorist ties) or subscription to a jihadist ideology. The third method of acquisition is through legal means. This is by far the most time-consuming method, but it is not overly complicated. The process to become a legally certified hazardous-material driver is not difficult or expensive.

A lone operator may not be able to meet the security thresholds the state and federal governments have established for obtaining a CDL which, absent getting a hazardous materials endorsement, does not prompt TSA to conduct an STA against various databases. A lone operator may or may not have a clean record, which will be relevant if he wishes to obtain a legal CDL. Also, a lone operator may be more impulsive and may opt for a quick and simple illegal method. Terrorist cells may be more inclined to have members obtain a legal CDL license. To circumvent the background checks, members who have clean records and have been radicalized within the United States will be most likely to go through the CDL certification process.

Delivery Methods

Delivery and execution of an operation will vary among terrorist groups, but the success of the operation is the most important factor for all three subgroups, and success is measured by body count, not by the destruction of infrastructure.

A lone operative is most likely to hijack a vehicle and use it on a target of opportunity, such as a crowded outside area or a building from which escape is not easy.

Local cells might use hijacking, coercion of drivers, or legal certification of a driver to conduct an operation. However, the attack scenario will vary, depending on the level of sophistication of the members. A locally inspired jihadist cell is more likely to create a multi-event, rather than an attack on a single target of opportunity.

The level of sophistication of an al Qaeda centrally funded and supported cell reduces the need to resort to hijacking; instead, coercion and legal certification of operatives are highly probable. Alternatively, the cell might establish a legitimate hazmat carrier company, especially a fuel-carrier company, as a front.

5. What are the most likely attacks that terrorist groups might conduct using highway-borne hazmat?

A number of factors go into determining the most likely use of highway-borne hazardous materials by terrorists. In the following, we recap some of our previous conclusions and apply them.

A. Terrorists' primary objective is to achieve a significant number of deaths—say, 100 or more—with as much certainty as possible. They are not inclined to take significant risks in order to achieve thousands of fatalities.

B. To the extent that multiple attacks can be conducted, the net effect is greater than the number of fatalities. Two or three attacks on the same day have a greater impact than three attacks separated by many weeks or months.

C. The ability to acquire a hazardous material, deliver it, and properly release it for destructive effect is key. Knowledge and access are important because:

    1. Patterns of gasoline and propane shipments are often predictable, the technical knowledge needed to drive a truck is not extensive and there are many experienced truck drivers, procedural and technical security measures need improvement, and there is a pattern of non-terrorist criminal thefts of tankers.

    2. Security measures for explosives and TIH materials are higher than those for flammable liquids and gases, and there are plans to increase them. These materials are also transported less frequently.

D. The ability to achieve hundreds of fatalities at different targets without significant technical complication is important. In this respect, we note that:

    1. There are many buildings and other crowded environments, including long tunnels, in which truckload explosives could kill hundreds. However, even though truckload explosives are the weapon of choice for attacking such targets, explosives are transported less frequently and they have more security; also, it is becoming more difficult to create homemade explosives.

2. There are also many environments in which a gasoline tanker could be used to create an intense fire that could result in a high number of casualties, including many public or residential buildings, as terrorists have discussed, or possibly long tunnels. Public transportation stations, if not properly guarded from penetration by vehicle-borne materials, represent another target.

3. Although spectacular accidents may create the impression that propane tankers can create an even larger number of fatalities, the technical sophistication required to ignite propane is greater than that which is required to ignite gasoline, and even more technical knowledge is needed to cause it to explode.

4. When there are numerous unmonitored targets, reconnaissance and planning become easier, allowing for the planning of multiple attacks without detection.

Given all of these considerations, we do not believe that terrorists—particularly lone operators or local jihadist cells, but even a well-organized al Qaeda operation—would use hazardous materials to attempt to destroy highway infrastructure. Those targets that can be brought down easily do not have sufficient value to be attractive, and those that do have value cannot easily be destroyed with hazardous materials.

Second, there are many targets that are far more likely to achieve terrorist objectives. We believe the most likely use of highway-borne hazardous materials by terrorists would involve targets other than highway infrastructure. These include, most importantly, public and residential buildings, and public assemblies

Countermeasures for Consideration

There are a number of general countermeasures that should be considered.

General Security Procedures and Technologies.

State and federal authorities should work together to:

1. Along with industry associations, *increase the required and recommended security measures that apply to the gasoline tanker and propane tanker fleets.* Clearly, the federal government considers gasoline and propane to be “lower-consequence” materials. MTI considers them to be higher-probability materials for attacks with average, yet lethal, consequences.

2. Urgently *resolve jurisdictional issues and increase the strength of inspection of hazardous materials security measures implemented in the field. It is critical that federal or state inspectors ensure that required measures are implemented and that recommended measures are understood and encouraged.*

3. Attempt to find ways to encourage the implementation of *vehicle tracking and immobilization* and to apply these technologies to the gasoline and propane tanker fleets (see last section below).

4. Encourage the highest possible degree of coordination between the federal and state authorities and centers that will be involved in responding to a terrorist threat or actual attack involving highway-borne hazmat used against highway infrastructure. There are many such authorities and centers, and their power relative to each other will no doubt continue to evolve over time. This suggests that state authorities should maintain a *current* understanding of how these authorities and centers would *actually* respond to threats and attacks, by studying them thoroughly and by participating wherever possible in exercises to gain this insight. The federal authorities and centers that can be involved are many; they include the long-standing FBI-led Joint Terrorism Task Force (JTTF) and the newer Fusion Centers; the Federal Inter-Agency Group (FIG); the DHS led National Infrastructure Coordination Center (NICC) and the National Operations Center (NOC); TSA's Terrorist Screening Center; and FEMA's field office and command center.

Encourage Vehicle Tracking and Immobilization.

Finally, we turn to the topic of vehicle tracking and immobilization. In additional research provided in MTI report 09-04, we concluded that there is an increasing trend—driven primarily by perceived gains in economic efficiency and safety—toward implementing vehicle and, more recently, trailer tracking. In addition, efforts are being formed, by Qualcomm and MAGTEC, for example, to develop safe and reliable ways to immobilize trucks that unauthorized drivers have attempted to start or that hijackers have attempted to take over. These techniques include relatively sophisticated and layered levels of required authentication, depending on the event. For example, with immobilization and tracking technology implemented, even if a vehicle is idling—as it can be if a driver is attending the vehicle but not in it—it cannot be driven, and it will essentially experience an engine kill if the driver does not input a unique access code. And even if a hijacker is able to drive the vehicle, a driver or someone else who observes the hijacking can ask that a tracking center remotely disable the vehicle, which is done safely in 12 steps as the vehicle loses accelerating power. Apparently driven by the need to prevent theft of high-value cargo, such as cigarettes, some motor carriers are deploying this technology, which the most recent FMCSA pilot program demonstrated to be safe and developed a set of best practices for. Vehicle tracking is also being implemented by some of the larger tanker companies. One company, which MTI visited, uses tracking to monitor its fleet and drivers, and the system includes a panic alarm.

However, there seems to be little federal interest or industry incentive to implement vehicle tracking and immobilization technologies for gasoline or propane tankers. While PHMSA and FMCSA have broadly recommended consideration of these technologies (and FMCSA has repeatedly piloted these technologies), TSA—which has the regulatory lead for hazardous materials security—has not recommended either tracking or immobilization for gasoline or propane tankers.

The objective of merely protecting a small number of infrastructure targets is highly unlikely to justify the cost of mandating fleetwide tracking and remote (as opposed to local) immobilization, which would also be technically difficult to implement. However, a number of lower-tech procedures can be implemented by state authorities to respond to threats,

such as additional guards, CCTV cameras, and even the intentional the use of traffic signals to create traffic jams that would make it far more difficult for a truck to reach its target, assuming there is some warning. There are very few highway transportation infrastructure targets that terrorists would likely attack and this therefore buttresses this conclusion.

However, the possibility of terrorists using gasoline tankers to attack targets other than highway infrastructure suggests that tracking and local and remote immobilization could have value, particularly when combined with the safety and efficiency benefits these technologies would provide for the industry and the state.

Therefore, state authorities, the federal government, and industry associations should reexamine the decision to exclude gasoline tankers from tracking, panic alarms, and immobilization recommendations, and to find ways to encourage tanker companies to implement these technologies.

ENDNOTES

1. We are aware that U.S. Department of Homeland Security Secretary Michael Chertoff said on May 29, 2008, that Hezbollah "makes al Qaeda look like a minor league team" and "poses the greatest threat to national security." However, the United States is not actively engaged in combat against Hezbollah, as it is against al Qaeda insurgents in Iraq or Taliban/al Qaeda insurgents in Afghanistan; and while elements of Hezbollah have in the past attacked American targets elsewhere, there have been no Hezbollah terrorist attacks on American soil, nor to our knowledge, has Hezbollah called for such attacks. In contrast, al Qaeda, which carried out the 9/11 attacks, continues to exhort its followers to carry out attacks on American targets and in the United States. However, operationally it makes little difference whether al Qaeda or Hezbollah occupies first place among terrorist foes, as both entities have carried out large-scale truck bombings.

2. MC 330, MC 331, MC 306, and DOT 406 refer to tank trucks meeting specifications established by DOT for transportation of authorized hazardous materials. MC 330 and MC 331 tank trucks carry liquefied or pressurized gases. MC 306 and DOT 406 are gasoline tank trucks. MC refers to motor carrier designation for trucks manufactured to basic specifications issued prior to 1995.

3. For safety and environmental reasons, some municipalities have moved away from chlorine to other, less hazardous or non-hazardous materials and techniques. According to a study released in 2007, since 1999, 25 water utilities, particularly those treating wastewater, have switched to liquid bleach or ultraviolet light. See Paul Orum, *The Terrorist Threat: How Water Utilities Can Get Chlorine Off the Rails and Out of American Communities*, Center for American Progress, April 2007.

4. "Ton Tank" is a generic hazmat term that refers to portable tanks often transported by trucks that carry about a ton of hazardous materials.

5. Wetlines are pipelines underneath a gasoline tank truck through which gasoline flows.

6. See "Public Information that Could Inspire and Inform Terrorists" beginning on page 25 for a more detailed account of this incident.

7. LPG (Liquefied Petroleum Gas) is a mixture of gases usually derived from fossil fuel sources. It is a mixture of propane, butane, and other flammable gases. Propane is a product of natural gas processing or refining. Propane shipments constitute the majority of highway shipments of flammable gases.

8. Argonne National Laboratory, Decision and Information Sciences Division, *A National Risk Analysis for Selected Materials in Transportation*, Report #ANL/DIS 01-01, December 2002.

9. Although the system records "incidents," we are calling them "accidents" because one of the threshold requirements is carrier damage of at least $85,000, thus highly suggesting a single of multivehicle crash or accident.

10. $85,000 is a conservative figure, since the cost of replacing a gasoline tanker ranges from $75,000 to $150,000.

11. We did not include cleanup and response costs because of the reporting focus on actual damage to infrastructure.

12. The incident took place in Delano, California on July 2, 2007, and involved the release of 4,789 gallons of organophosphorus, a liquid pesticide.

13. "Hazardous Materials Accident Summary Report: Overflow of Gasoline and Fire at a Service Station-Convenience Store, Biloxi, Mississippi, August 9, 1998," National Transportation Safety Board, NTSB Number HZM-98/02; NTIS Number PB99-917007, http://www.ntsb.gov/publictn/1999/HZM9902.htm, accessed January 6, 2010.

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24. See http://www.eia.doe.gov/pub/oil_gas/petroleum/analysis_publications/heating_brochure/heatbro.htm.

25. The TSA guidance can be found at http://www.tsa.gov/what_we_do/tsnm/highway/hssm_sai.shtm.

26. See "2006 Corporate Security Review Summary: Motor Carrier, Motor Coach, and School Bus," Transportation Security Administration, Washington DC: 2006, and "Assessment of Highway Mode Security: Corporate Security Review Results," Highway and Motor Carrier Division, TSA Transportation Sector Network Management Office, Washington DC: May 2006, http://www.transportation.org/sites/security/docs/CSR%20Highway%20Infrastructure%20Results%2011-06%20-%20final.pdf, accessed January 6, 2010.

27. See TSA web announcement at http:www.firstobserver.com.

28. "2 Men Plead Not Guilty to Gun, Bomb Plot Charges," *Los Angeles Times*, December 21, 1999, p. 3.

29. Hawala: A system for remitting money, primarily in Islamic societies, in which a financial obligation between two parties is settled by transferring it to a third party, as when money owed by a debtor to a creditor is paid by a person who owes the debtor money. Hawala transactions are usually based on trust and leave no written record. Definition from http://www.thefreedictionary.com/hawala.

ABBREVIATIONS AND ACRONYMS

ALOHA	Areal Locations of Hazardous Atmospheres
ANFO	Ammonia Nitrite Fuel Oil
ATF	Bureau of Alcohol, Tobacco and Firearms
BLEVE	Boiling Liquid Expanding-Volume Explosion
CASRAM	Chemical Accident Statistical Risk Assessment Model
CCTV	Closed Circuit Television
CDL	Commercial Drivers License
CFR	Code of Federal Regulations
CIA	Central Intelligence Agency
CJIS	Criminal Justice Information Services
CSR	Corporate Security Review
DHS	Department of Homeland Security
DMV	Department of Motor Vehicles
DOD	Department of Defense
DOT	United States Department of Transportation
EFP	Explosively Formed Projectiles
ERG	Emergency Response Guidebook
ERPG	Emergency Response Planning Guidelines
EWEC	Emergency Warning and Education Center
FBI	Federal Bureau of Investigation
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FOUO	For Official Use Only
FTA	Federal Transit Administration
FY	Fiscal Year
GPS	Global Positioning System
GVWR	Gross Vehicle Weight Rating
Hazmat, HM	Hazardous Materials
HME	Hazardous Materials Endorsement
HMIRS	Hazardous Materials Information Reporting System
HMX	Cyclotetramethlene-Tetranitramine (An Explosive)
HPAC	Hazard Prediction and Assessment Capability
IABTI	International Association of Bomb Technicians and Investigators
IME	Institute of Makers of Explosives
IP	Infrastructure Protection
IRS	Internal Revenue Service
ISAC	Information Sharing & Analysis Center
JTTF	Joint Terrorism Task Force
LC 50	Lethal Concentration 50

LCV	Longer Combination Vehicle
LPG	Liquefied Petroleum Gas
MC	Motor Carrier
MCS	Motor Carrier Safety
MG/M3	Milligrams Per Cubic Meter
MTI	Mineta Transportation Institute
NICC	National Infrastructure Coordination Center
NTSB	National Transportation Safety Board
NTSCOE	National Transportation Security Center of Excellence
NYSE	New York Stock Exchange
OSD-ATL	Office of The Secretary of Defense
PETN	Pentaerythritol Tetranitrate (Explosive also Known as Pentrite)
PHMSA	Pipeline and Hazardous Materials Safety Administration
PIH	Poison Inhalation Hazard
PPM	Parts Per Million
PTDI	Professional Truck Driver Institute
RDX	Cyclotrimethylenetrinitrammine (an Explosive)
RICO	Racketeer Influenced and Corrupt Organizations Act
SAIC	Science Applications International Corporations
SDDC	Surface Deployment and Distribution Command
SSI	Sensitive Security Information
STA	Security Threat Assessments
TIH	Toxic Inhalation Hazard
TNT	Trinitrotoluene (an Explosive)
TRB	Transportation Research Board
TSA	Transportation Security Administration
VBIED	Vehicle-Borne Improvised Explosive Device

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Brian Michael Jenkins is the director of the National Transportation Security Center of Excellence (NTSCOE) and one of the world's leading authorities on terrorism and sophisticated crime. He works with government agencies, international organizations, and multinational corporations as an analyst, investigator, and crisis-management consultant. From 1989 to 1998, Mr. Jenkins was the Deputy Chairman of Kroll Associates, an international investigative and consulting firm. Before that, he was chairman of the RAND Political Science Department, where, from 1972 to 1989, he also directed RAND research on political violence.

Mr. Jenkins obtained his bachelor of arts degree in fine arts and his master of arts degree in history from the University of California, Los Angeles. He has also studied at the University of Guanajuato in Mexico and the University of San Carlos in Guatemala, where he was a Fulbright Fellow and the recipient of a second fellowship from the Organization of American States.

Commissioned in the infantry at the age of 19, Mr. Jenkins became a paratrooper and, ultimately, a captain in the Green Berets. He is a decorated combat veteran, having served in the Seventh Special Forces Group in the Dominican Republic during the American intervention and later as a member of the Fifth Special Forces Group in Vietnam (1966–1967). He returned to Vietnam on a special assignment in 1968 to serve as a civilian member of the Long Range Planning Task Group; he remained with the group until the end of 1969, receiving the Department of the Army's highest award for his service. Mr. Jenkins returned to Vietnam again in 1971 on another special assignment.

In 1996, President Clinton appointed Mr. Jenkins to the White House Commission on Aviation Safety and Security. From 1999 to 2000, Mr. Jenkins served as an advisor to the National Commission on Terrorism, and in 2000 he was appointed to the U.S. Comptroller General's International Chamber of Commerce and became a member of the board of directors of ICC Commercial Crime Services. Mr. Jenkins was also a member of the Transportation Research Board/National Research Council Panel on Transportation: Science and Technology for Countering Terrorism 2002.

Mr. Jenkins has been the counterterrorism research team leader and a research associate with the Mineta Transportation Institute since 1996. He is the author or co-author of the following MTI reports:

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- *Executive Overview of MTI Terrorism Reports,* October 2001.
- *Saving City Lifelines: Lessons Learned in the 9-11 Terrorist Attacks,* September 2003.
- *Selective Screening of Rail Passengers,* March 2007

Mr. Jenkins is also a senior advisor to the President of the RAND Corporation and a counterterrorism advisor to NYC Police Commissioner Ray Kelly. Over the years, Mr. Jenkins has also served as a consultant to or carried out assignments for a number of government agencies.

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Bruce Butterworth, MTI NTSCOE Research Associate, has had a distinguished government career, working at congressional, senior policy, and operational levels. Between 1975 and 1980, as a professional staff member of the House Government Operations Committee, he ran investigations and hearings on many transportation safety issues, particularly in aviation. He spent 11 years in the Department of Transportation, eight of them in the Office of the Secretary. He managed negotiations on the inclusion of air and maritime services in the GATT (now WTO), chaired U.S. delegations to United Nations Committees, dealt with transport and aviation issues related to border inspections, and was part of the response to the bombing of Pan Am 103.

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He served as an associate director of the United States Holocaust Memorial Museum (2000–January 2003), responsible for security and building operations. He designed and implemented a "best practice" procedure for dealing with mail possibly containing anthrax powder and developed and conducted new, comprehensive emergency planning and exercises. Between January 2003 and September 2007, he was one of two deputy directors in a 1,300-person Engineering Directorate at NASA's Goddard Space Flight Center, managing workforce planning, budgeting, and all aspects of human capital management for complex robotics space missions, substantially reducing overhead and improving workplace safety there. He currently works for TKC Communications Corporation as a strategic planner in DHS's Information Sharing and Analysis Branch and is also active as a research associate with the Mineta Transportation Institute.

With Brian Michael Jenkins he co-authored *Selective Screening of Rail Passengers* (MTI Report 06-07), published by the Mineta Transportation Institute in February 2007. He also co-authored a May 2007 study, *Keeping Bombs Off Planes: Securing Air Cargo, Aviation's Soft Underbelly* with P.J. Crowley, senior fellow and director of Homeland Security at the Center for American Progress.

Mr. Butterworth was awarded a master of science degree from the London School of Economics in 1974 and a bachelor of arts degree from the University of the Pacific in 1972 (magna cum laude). He was a California State Scholar and a Rotary Foundation Fellow. He also received numerous special achievement and performance awards.

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An engineer by training, Mr. Reeves served for many years in DOT's Pipeline and Hazardous Materials Safety Administration (PHMSA) and its predecessor agency prior to retirement in 2007. As a supervisory general engineer, he led the risk-management team, functioned as deputy director of the technology division, and acted as a focal point for hazardous-materials security issues after the 9/11 attacks. In 2004, he received the Secretary of Transportation's Award for Meritorious Achievement for significant accomplishments supporting the department's safety and security goals. Prior to joining PHMSA, Mr. Reeves worked for the Office of the Secretary of Defense in the areas of acquisition policy, industrial productivity, and quality. Mr. Reeves has a bachelors degree in electrical engineering from the University of Michigan and a masters degree in industrial engineering from Texas A&M University

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Mr. Trella has extensive experience in homeland security at the state level. He served for three years as special assistant to Maryland's governor for homeland security, public safety, emergency management, military affairs, and veteran's affairs. While serving in this capacity, Mr. Trella was the governor's liaison with the state's public safety agencies on September 11, 2001, and the subsequent anthrax attacks in Washington DC. In 2003, Mr. Trella began working for the National Governors Association as a senior policy analyst in homeland security, specializing in homeland defense/National Guard issues, intelligence, information sharing, and interoperable communications. Prior to joining the governor's staff, Mr. Trella served as an officer in the U.S. Army for six years, with international experience in strategic and tactical planning, negotiations, security, counterterrorism planning and operations, and disaster relief. Mr. Trella has a Bachelor of Business Administration degree in business economics from Loyola College in Maryland and a Masters degree in international negotiations and conflict resolution from the University of Baltimore and School of Advanced International Studies.

PEER REVIEW

San José State University, of the California State University system, and the MTI Board of Trustees have agreed upon a peer review process required for all research published by MTI. The purpose of the review process is to ensure that the results presented are based upon a professionally acceptable research protocol.

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