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A CONTEXT FOR ASSESSING THE EFFICACY OF A RADIOLOGICAL/NUCLEAR MATERIALS INTERDICTION MISSION AT BORDER CROSSINGS

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To the Graduate Council:

I am submitting herewith a dissertation written by James Dale White entitled "A CONTEXT FOR ASSESSING THE EFFICACY OF A RADIOLOGICAL/NUCLEAR MATERIALS INTERDICTION MISSION AT BORDER CROSSINGS." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Nuclear Engineering.

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A CONTEXT FOR ASSESSING THE EFFICACY OF A RADIOLOGICAL/NUCLEAR MATERIALS INTERDICTION MISSION AT BORDER CROSSINGS

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ABSTRACT

There is no widely accepted contextual framework for planning, designing, and evaluating systems of protocols and equipment for detecting, intercepting, and deterring transport of high consequence radiological and nuclear threats. A candidate framework is posited for assessment of the design and application of a security system for detection and interdiction of these threats at an international border crossing. Results from an examination of the efficacy of this framework indicate that the use of rarely considered criteria provide a promising framework for a broad community of stakeholders to use in planning, design and application of security system upgrades for high consequence threats in the flow of commerce at a border crossing. These results also indicate that discovery of these criteria can be informed by a model of the geopolitical structure in which the border crossing resides.

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CHAPTER I
INTRODUCTION

Many nations and regions are facing decisions about how to improve their abilities to deal with man-made and natural disasters like hurricanes, tornadoes, floods, levee failures, earthquakes, fires and epidemics. They establish organizations that concentrate on understanding how to predict or respond to these types of events. In addition to natural and man-made disasters, governments try to protect their citizens from criminal behavior, like burglary, violence and harassment. At the same time, these governments have other missions that are extant at international border crossings associated with immigration control, highway safety, environmental protection, customs and tariff collection.

Frequently, these additional capabilities and/or protocols must work in the same spaces as the normal security, law enforcement and compliance services already extant. In many areas of the world, limited financial resources and/or uncertain political relationships make the problem more difficult.

An architecture exists in some form to support these standing missions. Police departments, fire departments, and emergency management organizations work in some of the same spaces and share some of the same information in many regions. There may be memoranda of agreement between organizations in contiguous areas within a metropolitan area that facilitate information sharing and interoperability. This construct may allow and define the roles and responsibilities of these organizations when they need to support each other. Staffing and budget levels will be affected by these agreements. An organization can save money if they know they can rely on a neighboring organization to provide some type of support to them when needed (like fire departments and bomb squads). These relationships and understandings underpin the overall enterprise of security in a region.

In addition to improving abilities to deal with disasters, many national, regional and local organizations would like to provide improved security for their citizens. Considerable attention at the moment focuses on low probability but very high consequence events, like the detonation of an improvised nuclear device or of a radiological dispersal device. As technology is developed to detect these types of threats, and as methodologies are developed for dealing with the consequences of these events, discussions arise around how to deploy these technologies and methodologies. In some cases, the organizations that will be responsible for the utilization of the technologies are those that already have other missions that occupy their attention, like local police officers, customs officials, and emergency management officials.

When a nation or region adds the mission of protection from (or response to and recovery from) terrorism, the architecture already extant in the region may have to support the new mission. In some cases, the government may expect the same policeman who walks a beat looking for criminal behavior also to detect weapons of mass destruction. A fireman may have to deal with radioactive materials or new chemical agents in smoke. A highway patrolman may have to screen vehicles for abnormal radiation as well as looking for normal criminal behavior.

The government might assume that if they provide new equipment, protocols and training, then the responsible organizations will make a long term commitment to support the additional missions, which generally involve low probability, high consequence events. With limited financial resources and uncertain political relationships, there may be cases where organizations struggle to budget for and commit to this additional mission space for the long term. Without a long term commitment by all parties involved, it seems unlikely that the overall enterprise will succeed.

In this dissertation, three obstacles in the way of planning for and analyzing the security of a region are discussed. These obstacles are:

1) A general lack of consensus about what is meant by security;
2) A lack of consensus around metrics important to ensuring enduring mission success
3) A general lack of frameworks to support the planning and assessment of security.(McGill & Ayyub, 2009)

This planning is especially difficult for cases where: a) the threats are hard to detect; b) the occurrence of the threat is likely to be extremely rare; c) the security plan requires cooperation and coordination of multi-organizational resources (especially for the case of borders between regional constructs); d) the security system is complex; and e) the security system involves human perception and human response. This dissertation addresses this type of problem, the introduction of a mission to interdict the illicit transport of radiological and nuclear materials at an international border crossing,

There is no widely accepted contextual framework for planning, designing, evaluating systems of protocols and equipment for detecting, intercepting, and deterring infrequent transport of high consequence threats across international borders. A framework proposed in this dissertation can inform discussions and considerations around how this interdiction might be implemented. The framework will include a consideration of the relationships between organizations with missions associated with the border crossing before the radiological and nuclear threat screening mission is added, a model of the physical structure of the border crossing, and a dynamic model of the traffic flows through the border crossing station. An examination of how the addition of a RadNuc screening

mission might change the organizational relationships, the physical structure of the border crossing station and the dynamic flow of traffic through (and within) the station is conducted. To more fully characterize these effects, a set of metrics is developed that relate to high level objectives associated with long term efficacy of the endeavor.

A description of a hypothetical border crossing provides a focus point for the study. For this hypothetical border crossing, the study postulates missions of the types of organizations likely to apply there and the study discusses a likely associated concept of operations. Later in the study, what may happen when another mission (for detection and interdiction of radiological and nuclear threats) is added to the system is discussed. The model of the border crossing is useful in examining the operational effects of this radiological and nuclear (RadNuc) mission addition. Then a discussion of the hypothetical geopolitical structure is used to examine the effects of the RadNuc mission addition to the broader group of stakeholders. An examination of criteria and metrics for assessment of the efficacy of this new additional RadNuc mission system then follows.

CHAPTER II
ADDITION OF RADNUC SCREENING MISSION AT BORDER CROSSINGS

Problem Statement and Research Questions

Types of border crossings

There are many different types of border crossings, ranging from very simple to very complex. There are some border crossings which are unmanned, some which are operational only for certain periods of time, some which are at locations where only vehicle and foot traffic are allowed, some which are at locations that include sea ports as well as vehicle and foot traffic, and some locations which act like border crossings because they serve as ports of entry inland (like international airports).

The type of border crossings considered within this dissertation will be considered a location where a checkpoint is installed to monitor and control the flow of vehicles and people from one national geopolitical construct to another. For this dissertation, we will examine an international land border crossing with significant vehicular flow. An example of such a border crossing is shown in Figure 1.

The flow of people and goods from one country into another facilitates commerce and legitimate travel. Predominately, this flow is entirely legal, and is monitored and controlled at border crossings and other ports of entry to ensure that regional policies and regulations are met. Since delays in commerce have been shown to relate to economics of a value chain, then the monitoring and controlling of traffic flow can become problematic. For United Kingdom border crossings, the cost of procedures and border crossings were estimated to be from 2% to 15% of the value of the goods crossing the border.(UK KM Revenue and Customs, 2009) A photograph showing traffic backup at the U.S. San Ysidro (California) border crossing is shown in Figure 2.

Generally, there are many national policies applicable to border crossings. Several federal, state and local agencies will have missions to support the policies. These agencies will have developed regulations to support these missions. These agencies then will have developed concepts of operations to support these regulations throughout the nation. At locations like a land border crossing, these regulations and the associated concepts of operations will be applied at the same location. This confluence of policies, missions, regulations and operational constructs at the same location can be problematic. This situation can become exacerbated when additional mission spaces are laid upon

Figure 1. Laredo Port of Entry at the Gateway to the Americas International Bridge (Wikipedia)

Figure 2. San Ysidro border crossing traffic back-up (List of Mexico–United States border crossings, Wikipedia)

the border crossing and the operational construct there.

Critical issues at border crossings – growth in volume, increase in security measures, limited funding and other resources

How these layers of federal, state, county, metropolitan area, city and township missions and organizations interact varies from location to location. In some cases, there is an overall regional integrating organization that helps articulate common goals, encourages policy and operational alignment where possible and promotes overall communication and information sharing. Occasionally, the organizations may act as rigid and totally separate entities. In any case, there are certainly opportunities for development of different and possibly competing perspectives about importance of missions, training, equipment purchases, information sharing and budgets and other resources to advance initiatives. This disparity in perspectives may change radically in the face of perceived danger from immediate threats, or the need to respond to disasters or attacks.

The volume of goods and services crossing international borders has been growing significantly, and is expected to continue growing. The 2008 U.S. and global economic downturn caused some setbacks, but freight exports continue to show a long-term upward trend. According to the U.S. Department of Transportation, world merchandise freight exports nearly tripled in value from $5.4 trillion to $16 trillion from 1998 to 2008, while U.S. freight exports doubled from $682 billion to $1.3 trillion during the same period. Their report concludes that a strong interconnectedness among countries and the increased globalization of economic activities continue to generate increasing freight movements.(U.S. Department of Transportation, 2010)

At many of these borders, there have been complaints about the backup of the flow of commerce and people – at a significant economic cost. For example, in a study of the U.S. El Paso region, a study predicts that total freight flows through the area will grow by more than 76 per cent by 2035 and that if something is not done to relieve the projected congestion at the border crossings, wait times will result in a contraction of the regional economy by $54 billion (21.8 percent).(Cambridge Systematics, 2011)

At the same time, there has been significant growth in the number of security related initiatives applicable to border crossings. These security related initiatives add to the burden of the border operations staff, to the law enforcement organizations that have to deal with the violations of the regulations and the judicial systems that have to handle the cases arising from the arrests made associated with the border crossings. Several nations are struggling with the question about how best to assess the efficacy of the operational constructs to support these increasing layers of security missions.

Problem statement

The problem statement for this dissertation is to develop a useful framework for assessing the efficacy of the addition of a radiological and nuclear detection and interdiction system when it is laid onto an existing set of mission spaces and concepts of operations at a land border crossing.

Research questions

An approach for addressing this problem statement is presented. The first step in this approach is the development a set of strategic questions that will help ensure that a broad integrated perspective will be developed and examined. To develop these strategic questions, the second step was building a set of models of a hypothetical border crossing. Then an accompanying set of hypothetical stakeholders and missions associated with the border crossing was postulated. A concept of operations to support these missions at the hypothetical border crossing was developed and examined. Then these models and concepts of operations were modified to support consideration of what would happen when a radiological and nuclear materials detection and interdiction mission would be laid onto the border crossing operational construct. This examination addresses the following strategic questions:

1. What is a useful approach for eliciting strategic questions to be considered?
2. What are some strategic questions coming from the work?
3. What are some tactical questions arising from the strategic questions?
4. What are useful metrics related to these questions?
5. What is a useful methodology for evaluating these metrics?

Literature Review and Personal Experience

A literature review supported the need for a framework for assessing the efficacy of systems for detection and interdiction of radiological and nuclear threats at land border crossings. This finding aligns well with previous conclusions drawn from numerous occasions to observe and examine operations at border crossings and at ports of entry within the U.S.(White, 2011) A discussion of the literature and observations of the author is organized here as:

1. Description of border crossings
2. General missions and stakeholders for border crossings
3. Addition of security missions at border crossings
4. Need for consensus in definitions of security
5. The RadNuc mission
6. Need for consensus in metrics that relate to enduring success of this additional RadNuc mission

7. Methodologies for assessing efficacy of new missions.

Description of border crossings

An excellent summary of border crossing descriptions, international regulations associated with border crossings, and typical roles and responsibilities of government agencies at border crossings is given in the Handbook of Best Practices at Border Crossings – a Trade and Transport Facilitation Perspective published by the Organization for Security and Co-operation in Europe (OSCE) in conjunction with the United Nations Economic Commission for Europe.(Organization for Security and Co-operation in Europe, 2012) The handbook gives an overview of the existing legal framework related to international trade and border management. The handbook points out that there is an international increase in cross-border transactions supporting the growing global trade. To facilitate that trade, governments are trying to find more efficient border crossing processes.

Conway, in his “Land Port of Entry”, in the *Whole Building Design Guide* sponsored by the U.S. National Institute of Building Sciences, describes the functions occurring at a border crossing station.(Conway, 2010) These activities generally take place to meet the missions of several federal agencies. According to Conway and the previously mentioned OSCE Handbook, the types of activities include:

1. Compliance checks to ensure that activities involving the crossing of the border meet the requirements of national legislation;
2. Control of entry into or departure from the country for persons and materials arriving as commercial, non-commercial, or pedestrian traffic;
3. Collection of revenues;
4. Prevention of illegal aliens from entering the country;
5. Prevention of injurious plant, animal pests, human and animal diseases from entering the country;
6. Examination of export documents; and
7. Registration of valuable articles being temporarily taken out of the country.

Persons are essentially checked from the perspective of immigration, with the added objective of detecting and arresting criminals. These checks are carried out by immigration authorities, border police or, in some cases, by border guards or troops.

Goods are usually checked by Customs authorities. However, goods can also be examined by border police when drugs, weapons or, occasionally, undeclared or prohibited goods are suspected. Goods are sometimes also searched by animal health/agriculture officials, or by standards and consumer protection agencies. All such controls may also be delegated to Customs authorities.

Commercial vehicles are controlled by road administrations such as ministries of transport, or sometimes by border police. Immigration authorities may also choose to inspect commercial vehicles to detect illegal immigrants. Private vehicles are inspected by Customs authorities or, sometimes, by border police.

Generally, border police are in charge of controlling persons, while customs officials are in charge of controlling goods. This can lead to an important question. Can customs officers inspect traveler and identity documents or passports because, in theory, that is the responsibility of the border police or immigration authorities? We can see that some sort of agreement, supported by law, might need to be put in place.

According to the OSCE Handbook, border police frequently are not authorized to search vehicles or goods. But the identity of drivers may be an essential part of risk management for customs and, conversely, border police may have good reasons to inspect rail, road or vessel transport cargo.

Similarly, different administrations may carry out identical verifications for different purposes, such as weighing the vehicle. The traditional demarcation of the tasks undertaken by various staff members at border crossings brings with it the risk of duplication of effort, waste of resources, and lack of commitment to the areas where missions overlap.

A land border station generally includes a facility that is owned or leased by a federal agency. A border station is typically open year-round. However, there may be locations which operate seasonally due to local climate conditions, and some facilities which are not open twenty-four hours each day.(Conway, 2010)

In practice, a border is a busy area where many government organizations have a presence. Some have a physical presence, while others delegate their activities to border crossing operations staff (usually employed by a customs type organization). For instance, in its study of the UK security environment, SITPRO Ltd. (now part of the UK Department for Business, Innovation and Skills (BIS)) has identified a series of government stakeholders and divided them into two groups: those with executive authority directly responsible for controlling the cross-border environment, and others with a policy development role. Among these organizations, some have a presence at the border, such as Customs, while others are only represented at the central government level, such as the department of trade. Some are represented at both levels.

General missions and stakeholders for border crossings

According to the General Services Administration, a U.S. border station may include the following agencies and associated missions:

General Services Administration (GSA), Public Buildings Service: The GSA is responsible for the providing the land, design and construction of land ports of entry. GSA also provides general management, maintenance and repair.

U.S. Customs and Border Protection (CBP): CBP facilitates legitimate trade and travel. Generally, CBP inspects goods and people seeking entry into the U.S. at land ports of entry. Depending on the need a secondary inspection may be conducted by the CBP, Veterinary Services (VS), or the Food and Drug Administration (FDA). The U.S. Border Patrol is part of CBP, but does not participate in inspections at the land ports of entry.

The Department of Transportation's Federal Highway Administration (FHWA**)**: The FHWA works with its state, federal, and international partners to ensure the safe and efficient movement of people and goods across borders.

U.S. Food and Drug Administration (FDA**)**: FDA conducts inspections to control the import of foods, drugs, cosmetics, medical devices, biological products, animal feeds and drugs, and radiation-emitting instruments. CBP officers are trained and certified to detect and intercept shipments.

U.S. Fish and Wildlife Service (F&WS**)**: The F&WS regulates the importation of birds protected by the Convention on International Trade in Endangered Species (CITES) and the Wild Bird Conservation Act of 1992 (WBCA).

Department of Justice's Immigration and Naturalization Service (INS**):** The DOJ, whose law enforcement branches (the Federal Bureau of Investigation and Drug Enforcement Agency) coordinate with CBP and Bureau of Immigration and Customs Enforcement (ICE) agents when their investigations involve immigration violations.

Center for Disease Control (CDC): The CDC develops and implements strategies to monitor for diseases on people, animals, cargo, and conveyances arriving at the U.S.'s ports of entry. The CDC reviews operations for programs used to monitor the importation of quarantinable and other specified diseases.

Bureau of Immigrations and Customs Enforcement (ICE): ICE's mission is to detect and prevent terrorist and criminal acts by targeting the people, money, and materials that support terrorist and criminal networks. ICE is also responsible for the collection, analysis and dissemination of strategic and tactical intelligence data pertaining to homeland security, infrastructure protection, and the illegal movement of people, money, and cargo within the United States.

The Transportation Security Administration (TSA): The TSA is charged with protecting the United States' air, land, and rail transportation systems to ensure freedom of movement for people and commerce.

U.S. Border Patrol (USBP): The USBP enforces U.S. immigration law and other federal laws *between* official ports of entry along the border and in the interior of the United States. As currently comprised, the USBP is the uniformed law enforcement arm of the Department of Homeland Security. Its primary mission is to detect and prevent the entry of terrorists, weapons of mass destruction, and unauthorized aliens into the country, and to interdict drug smugglers and other criminals.

Department of Agriculture (USDA): The USDA establishes the agricultural policies that CBP Inspectors execute. Among other things, the USDA implements stray animal control policies, provides inspection services when imported animals are re-assembled after importation, and assists with notification of livestock movement to receiving states. USDA also works with Homeland Security border inspectors to train inspectors and set policy for plants, animals, and commodities entering the United States. USDA employs new Import Surveillance Liaison Inspectors, who are stationed around the nation at Import Houses and ports of entry to enhance surveillance of imported products.

Central Intelligence Agency (CIA): The CIA informs INS officers of potential terrorists, including possible operatives trying to enter the United States.(U.S. General Services Administration, 2013)

These mission spaces and the agencies responsible for them are summarized in Table 1. A similar set of mission spaces and the federal, state and local agencies supporting them for our hypothetical border crossing later will be developed and discussed later in this report.

All of these organizations operating at borders have different strategic objectives, requirements, documentation, processes and information technology systems. This potentially creates a mass of paperwork and duplication. Because these organizations have their own means of vertical reporting, they tend to work independently, thus opening up the risk of overlapping activities and operational gaps. Lack of co-ordination can also result in conflicting instructions and requirements.

Addition of security missions to border crossings

Recent years have seen a dramatic increase in security regulations. Regulatory control in trade concerns revenue collection, safety and security, environment and health, consumer protection and trade policy. In recent years, the addition of new security initiatives has added many regulatory burdens to businesses.

Table 1. Federal missions and organizations for U.S. border crossing

Mission Objective	***U.S. Agency***
Provide and maintain structures, utility interfaces	General Services Administration
Sets federal policies to facilitate cross border travel; inspects goods and people	Customs and Border Protection (CBP)
Facilitate safe and efficient movement of people and goods along federal routes	Department of Transportation Highway Administration (DOTFHWY)
Control the import of foods, drugs, cosmetics, medical devices, biological products, animal feeds and drugs, and radiation-emitting instruments	Food and Drug Administration (FDA)
Regulate the importing of birds and wildlife protected by international convention	Fish and Wildlife Service (FWS)
Federal law enforcement, criminal and terrorist threat response	Federal Bureau of Investigation (FBI)
Federal law enforcement related to drugs, smuggling	Drug Enforcement Agency (DEA)
Develop and implement strategies to monitor for diseases in people, animals, cargo, and conveyances	Center for Disease Control (CDC)
Detect and prevent criminal acts by targeting the people, money, and materials that support criminal networks	Bureau of Immigrations and Customs Enforcement (ICE)
Protecting national air, land, and rail transportation systems to ensure freedom of movement for people and commerce	Transportation Security Administration (TSA)
Detect and prevent the entry of weapons of mass destruction, unauthorized aliens, and drug smugglers and other criminals	Border Patrol (BP)
Implements animal control policies, provides inspection	Department of Agriculture (DA)

Although there are many security initiatives affecting border-crossing stations, not all are specifically relevant to Customs authorities. Other agencies also operate at borders: for example, the police, agencies for the interior or counter-terrorism agencies, and administrative bodies responsible for food, drugs, and veterinary or safety matters.

Furthermore, Customs authorities may also find themselves being required to implement security measures on behalf of other such agencies. SITPRO, for example, examined UK sea borders and supply chains and discovered that in recent years no less than 37 new and existing security-related procedures and controls had been put in place.(SITPRO, 2008) A listing of recent security initiative is given here is given here for the UK:

1. Authorized Economic Operator (AEO)
2. Container Security Initiative (CSI)
3. Secure operator
4. Known Shipper (air freight)
5. ISPS Code and SOLAS Convention (maritime)
6. ISO 28000
7. U.S. Customs and Trade Partnership Against Terrorism (C-TPAT)
8. Transport Asset Protection Association Freight Security Requirements (TAPA-FSR)
9. Multi Agency Threat and Risk Assessment (MATRA)
10. Export controls (precursor drugs)
11. Import licenses (carcinogenic substances)
12. Rough diamond certificate
13. Export controls (end use and destination)
14. Export controls (technology, dual-use and military)
15. Medical equipment licensing
16. Medicines and drugs licensing
17. Animal health controls and licensing
18. Plant health controls and certificates
19. Food and hygiene controls
20. Bio-terrorism controls for USA
21. Secure freight initiative: 100% freight screening
22. Customs pre-notifications: security
23. Using additional scanning equipment such as X-ray scanners scanning for radioactive materials and explosives and chemicals
24. Immigration passenger controls
25. Immigration vehicle operator controls

26. Financial crime and financing of terrorism; restrictions and controls
27. Pre-ship notification
28. Road operator licensing
29. Immigration outward proposed under eBorders
30. Dangerous goods declarations: air
31. Dangerous goods declarations: rail
32. Dangerous goods declarations: sea
33. Dangerous goods declarations: road
34. Compliance with specified health and safety procedures for handling goods
35. Formal co-operation agreements between businesses and executive agencies including MoUs
36. Due diligence activities such as contracts, guarantees, letters of credit, reference requests, credit checking and other
37. Commercial insurance.

Need for consensus in definitions of security

The literature indicates a lack of consensus with respect to certain terms, concepts, metrics and assessment methodologies that limits the quality of discussions around what should be done (and how much) to improve security. Clearly, the perspective of the planner/assessor produces a lens through which he perceives the quality of security in a region.

There probably will be many perspectives that need to be integrated into any enduring changes in the security posture of a region. A businessman, a police officer, and a district attorney may define security in terms of threats they deal with every day. An official within the U.S. Department of Homeland Security, the Environmental Protection Agency, the Nuclear Regulatory Commission or the Department of Defense may define security in terms that also include low probability but very high consequence events. The public at large may define security in absolute terms, wanting the government to provide total protection from any threat. Security professionals might define security in relative terms, knowing that security can never be absolute.

Furthermore, the funding available to the planner may be applicable only to a particular type of security problem. A federal organization established to support a nuclear threat mission would have funding available primarily for detection and interdicting radiological and nuclear threats, but not for recovery from a detonation of such a threat. Nor does it have funds available for dealing with chemical or biological threats or natural disasters. A federal emergency management agency might not have funding for detection and interdiction, but would have funds applicable to preparedness and response/recovery from

almost any kind of disaster. An environmental protection agency, a nuclear regulatory commission, a transportation security administration, a department of agriculture, a department of defense, and a department of justice all will have different missions that give their planners different perspectives around the definition of security.

At a regional or state level, there are still more differences in perspective. Fire departments, police departments, hospitals, bomb squads, customs officials, and judges probably all see the term security differently.

This tends to lead to a compartmentalization around the matter of security, allowing planners and analysts to deal with a smaller scope of mission space. But this compartmentalization also may crystallize perspectives, making consideration of other perspectives problematic. In many cases, these security specialists have to compete for limited resources. For example, this competitive posture might make the specialist in bomb prevention less interested in flood relief.

There is a need for a common framework (even at the highest level) to support dialogue among organizations that are compartmentalized around specific threat types (or regions). This framework should support a dialogue around how the organizations involved view security. An important part of this discussion would be how the increases in mission could be woven into the existing mission spaces of the organizations that would be touched by it.

A model frequently adds value to this type of discussion. If the mission increase were to be applied at only one bridge or tunnel, or if it included adding only a little more information to be shared, then what might have been a serious debate might instead be a quick agreement. If there are major changes in missions, then definitions of scope and specifics of implementation become very important. A model frequently can support the exploration and illumination of what is meant by otherwise vague terms.

The RadNuc mission

An additional security mission we are considering in this dissertation is screening and interdicting radiological and nuclear threats. At many border crossings throughout the world, there are radiation detection instruments used for detecting whether people or cargo have radioactive materials in excess of what is allowed. This generally is done for safety purposes. Significant quantities of radioactive material in transport generally require some sort of transportation containers approved by the federal government (and international organizations like the International Air Transport Association, or IATA, and the International Maritime Organization, or IMO), as well as placarding to alert border crossing officials and law enforcement officials that there are varying levels of radioactive material in

transit. At high enough levels, some states require official escort of vehicles carrying radioactive materials throughout their boundaries. One function of some border crossings is to detect and monitor these shipments of radioactive materials.

A high level of concern is associated with the possibility of a terrorist attack using radioactive materials in a radiological dispersal device or RDD. Generally, an RDD involves a large amount of radioactive material and a method of dispersal. In most cases, the method of dispersal involves the use of explosives that would detonate and spread the radioactive material broadly to contaminate a targeted area. Other possible methods of dispersal might involve placing the radioactive material in a water supply, spreading it from airborne platforms or in some cases just opening a container near an air intake system of a building and letting the radioactive material evaporate into the intake. For this study, we will consider only RDD threats that involve large quantities of radioactive material, emanating significant levels of radiation (which may or may not be shielded).

A nuclear threat, as considered in this dissertation, will involve special nuclear material (SNM) and will, for the purposes of this report, include a quantity of SNM sufficient that it could become weaponized in a fashion to cause a nuclear explosion. This possibility is also considered a very significant security concern. In this report, the term RadNuc will represent the threats presented by either the RDD threat or the nuclear device threat.

The shipment without authorization by the responsible authorities of radioactive materials of significant quantities and of types that could become a RadNuc threat generally is regarded as illicit. For this dissertation, the general problem of detecting and interdicting the illicit transport of RadNuc materials at border crossings is considered.

Kouzes (Kouzes et al., 2003) discusses a problem that arises from naturally occurring radioactive materials and medical isotopes at border crossings when one tries to screen for the RadNuc threat in cargo. He points out that the materials of concern for cargo are plutonium (^{239}Pu), enriched uranium (^{235}U) and ^{233}U and other special nuclear materials and any radioactive source that could be used for an RDD. All of these materials produce a gamma radiation signature.

In addition to detecting and measuring the gamma radiation coming from a person or cargo, many border crossing locations also monitor for neutron radiation, because plutonium emits neutrons as well as gamma radiation. There are not many legitimate sources of neutrons, so a detection of significant neutron flux would raise a concern. Some legitimate neutron sources include californium (^{252}Cf), americium-beryllium (AmBe), polonium-beryllium (PoBe), plutonium-beryllium (PuBe), and radium-beryllium (RaBe). These neutron sources are

commercially used for well-logging, and soil and concrete density measurements. Some neutron sources also are used for scientific research purposes.

In his paper, Kouzes discusses what he calls nuisance sources. These generally include naturally occurring radioactive material (NORM) and man-made sources like medical isotopes and commercial products containing radioactive material. Examples of man-made sources are americium (^{241}Am), barium (^{133}Ba), cesium (^{137}Cs), cobalt (^{57}CO and ^{60}Co), iridium (^{192}Ir), radium (^{226}Ra) and depleted uranium (DU). Both NORM and man-made sources can have enough radiation to trigger alarms at border crossings.

Many radioactive materials are frequently in cargo, especially the naturally-occurring ones. Commodities that contain them include fruits, vegetables, fertilizer, ceramic glazed materials, polishing compounds, fluorescent lamp starters, welding rods, propone tanks, kitty litter, road salt, ore and rock, smoke detectors, oil field pipe, and hot water heaters.

Some drivers or passengers in vehicles crossing a border will have had recent medical procedures in which radioisotopes will have been injected into their bodies. The level of gamma radiation emanating from a person injected with technetium (^{99m}Tc), for example, can be easily detected for several days after the injection. Other medical radioisotopes injected into people for diagnosis and treatments include radioactive isotopes of iodine, thallium, gallium and indium. People released from a hospital with gamma radiation measuring several thousand microR/hr can set off monitors from 100 feet away.(*Ludlum Model 3500-1000 Radiation Detector System*, 2010) Kouzes points out that about one in 2600 Americans carries a significant radioactive burden at any one time. However, this number is a gross average. If the border crossing is near a major hospital, then the number could be significantly higher. He calculated that for a typical radiation portal monitor (RPM), alarms might be generated from most medical isotopes for a period of 3 to 115 days after the medical procedure, depending upon the isotope half-life.(Kouzes et al., 2003)

The literature shows that many countries are deploying radiation detection equipment at border crossings (and at other locations not discussed in this dissertation). This equipment frequently involves the use of RPMs in the form of large polyvinyl toluene (PVT) panels sensitive to gamma radiation. When a vehicle is in the field of view of the RPM, the level of radiation coming from the vehicle can be monitored. If the level is high enough, then the vehicle may or may not be denied approval to cross the border, sent to a secondary screening station at the border crossing, detained at the primary screening station for in situ examination, or just passed on through. How the vehicle will be handled depends upon the concept of operations in use at the time at that border crossing.

One would understand that there might be considerations suggesting that the sensitivity of the detection equipment might be adjusted to manage the flow of traffic to an acceptable level. Included here is a quote from the OSCE Handbook of Best Practices at Border Crossings – a Trade and Transport Facilitation Perspective "Many countries have invested large amounts of money in radiation detection equipment and training. In the U.S., for example, virtually 100 percent of arriving sea containers are scanned by radiation portal monitors. Also each Customs and Border Protection officer is required to wear a personal radiation pager. However, such equipment is not always used effectively. At Long Beach, California, the busiest container port in the U.S., there are about 450 Customs inspectors. One third of these monitor and mitigate radioactivity alerts. The average traffic is 32,000 containers per day, generating about 600 alerts. In many countries where Customs have radiation control responsibilities, false alerts occur all the time. As a result, Customs officers often "tune down" the sensitivity of their equipment. Customs managers (or whoever has radiation control responsibilities) must make adjustments in their staffing, and assignment processes to accommodate the changes in work caused by the acquisition of new equipment. Rotterdam seaport traffic amounts to about 20,000 containers per day, with 200 alerts. However, the Customs in Rotterdam do not take action in every case. They have a list of commodities that give off high levels of radiation, such as floor tiles or cat litter. If a manifest states that such commodities are in a container, Customs lets it enter. To avert the risk of such commodities being used for smuggling – for example, surrounding a nuclear device with floor tiles – background risk management is carried out. This, however, negates the entire rationale behind having radiation detectors."(Organization for Security and Co-operation in Europe, 2012)

If we consider that 600 alerts are generated for 32,000 containers on the average at Long Beach, then we might conclude that 1.9% of the containers will have radiation levels high enough to trigger alarms. In the Ludlum manual referred to previously, they say that about 1% of the cargo will set off alarms due to NORM. Of course, this depends upon the discriminator settings used for the RPMs and the incidence of radioactive materials of all types in the stream of commerce at that point. As lower discriminator levels would be used, we would expect the number of nuisance alarms would increase, but the sensitivity to the RadNuc threat might increase.

The problem of having less than optimal detection capability if the RPM discriminator point is set high enough to limit the number of nuisance alarms is well known. There are a number of approaches being taken around the world. One approach is to just forbid any vehicle with a certain radiation level to pass over the border. A second approach is to take advantage of the fact that radioactive elements have characteristic energy spectra that are measureable by several types of detection systems. Under ideal conditions, one can certainly discriminate between different types of radioactive elements based on their

energy spectra. (Kouzes, 2005) In the United States, there has been a lot of activity around developing the Advanced Spectroscopic Panel (ASP) which was considered to show promise in this regard. Laboratory and field tests of the ASPs, cost-benefit analyses, and other activities were still under way in 2010 to inform Congress and the Administration as to its efficacy in detecting an acceptable amount of the threat space while reducing impact of RadNuc screening on commerce.(Shea, 2010) Unfortunately, the ASP Program was terminated in 2011, demonstrating that the tradeoff between detection sensitivity and impacts on commerce is a delicate balance even now.(U.S. Department of Homeland Security, 2011)

Need for consensus in metrics related to enduring success

Another difficulty in planning and assessment in the provision of security involves the question of metrics. Even with a compartmentalization to limit mission space, there does not seem to be a consensus on metrics that would indicate enduring mission success. Instead there seems to be an emphasis on measuring things that are easier to define and measure. Establishing metrics around how much funding is allocated and committed, how many pieces of equipment are procured, and how many first responders are trained to use the equipment does help at one level. But, in the view of the author, there are more important metrics related to enduring mission success. These metrics probably will have to be developed in a partnership among the national, state and local agencies whose missions (or activities) are touched by the candidate improvements in the security mission being considered. An example of this type of metric might be the commitment of the organizations that would have to execute the security improvement. These organizations might include first responders (police department, fire department, state and local emergency management personnel, National Guard personnel, customs officials) and judges and district attorneys within several contiguous municipalities. A metric that might relate to the quality of commitment among these organizations might be the presence and activity level of an integrating committee overviewing the joint mission space. Another metric might be the presence in the organizations' strategic plans of budgets to support the resource needs for the security upgrade. Another metric might be the presence of a public awareness campaign to support the changes the citizens might encounter.

According to the literature, some metrics of effectiveness used by Customs organizations include the number of times that tariffs or fines are collected. Frequently, companion metrics would be the amount of tariff and of fines collected. Other types of metrics include the amount of commodities that are processed as a function of time. The literature points out that these metrics are easy to measure.

The Trade and Transport Facilitation Southeast Europe (TTFSE) program funded by the World Bank has been exploring the use of a cost benefit analysis

approach, like the total cost of administration of customs activities to the revenue collected at a border crossing. TTFSE is a regional partnership involving the World Bank, the European Union, and the UN Economic Commission for Europe (UNECE), and the Southeast European Cooperative Initiative (SECI). Eight client countries were included – Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Macedonia, Moldova, Romania, and Serbia and Montenegro. In Southeast Europe: Improving the Climate for Trade and Transport, Dumitrescu and Moeller state that revenue collection by customs is the major single source of revenue for many governments in this region.(Dumitrescu, 2006) They point out that increase or decrease in the flow and value of trade affects the budget performance of the government agencies significantly.

In the same report, Dumitrescu and Moeller state that, for the more than 30 border stations and ports of entry representative of South-Eastern Europe, the TTFSE found that each of the agencies associated with operations at the border crossing wanted to be responsible only for its own procedures and associated delays, and was not prepared to take into account delays associated with the other agencies. They found little if any interest in a holistic look at the border crossing operation. There was a lot of pushback by the agencies involved against the notion of a global metric for border crossing operations. Furthermore, they found a culture in which all of the agencies involved were against the idea of measuring delays in border crossings, at least initially.

The literature points out that some performance related goals and criteria for one agency can lead to a burden on other agencies. For example, if customs organizations have targets related to the annual volume of illegal contraband detected, then that might lead to overly rigorous measures that would result in prosecuting relatively minor infractions which would increase the number of cases to be handled. That might reduce the time and resources available for more serious investigations. Even if the need to have metrics associated with quality of operations is acknowledged, the ability to focus on metrics that are easy to measure seems to result in a focus there.

Methodologies for assessing efficacy of new missions

Shattan provides an excellent discussion of a comparison between cost benefit analysis methodologies and the analytic deliberative process methodology for selection and deployment of radiation detection systems for shipping ports and border crossings.(Shattan, 2008) In his thesis, Shattan discusses how the U.S. government has insisted that any new policy decision be supported by a Cost Benefit Analysis (CBA). He explains that CBA became part of public policy decision making in 1981 when President Reagan signed an executive order 12291 mandating that “No actions by federal agencies should be taken unless they result in a net positive value to society”. In 1993, President Clinton signed

executive order 12866 which requires that a regulatory analysis be performed for all significant regulatory actions.

Shattan said that CBA is generally regarded to have its roots in the Pareto Optimum concept which results in a perspective that a policy change is an improvement if some people are better off and no one is worse off as a result of the policy. Shattan points out that in the real world almost all policy changes result in someone being worse off. According to Shattan, most CBA's today uses a revision of Pareto's original work put forth by Kaldor and Hicks in 1939.

The U.S. Environmental Policy Administration developed guidelines for performing a CBA.(U.S. Environmental Protection Agency, 2000) To perform a CBA, the analyst tries to quantify all the costs and benefits associated with a proposed change. In our case, that would mean the analyst would try to quantify all the costs and benefits of adding the RadNuc screening mission to the existing border crossing operation. The costs should include the costs of designing, procuring, installing and maintaining the equipment, as well as the costs for providing the training required for the organizations that will operate the equipment. Other types of costs that should be included are the government regulatory costs, social welfare costs, transitional costs and indirect costs. Government regulatory costs will include the costs for the government to administer, monitor and enforce the additional regulations. Social welfare costs would include losses in the cost of reduced commerce caused by slowdowns of the stream of commerce at the border crossing. A slowdown in the stream of commerce might result in increased prices of goods that have had to cross the border at our station. Transitional costs would include modifications to the border crossing station required by the new RadNuc mission. Indirect costs would include fewer companies shipping goods across the border as a result of the new mission. Some of these costs will be relatively easy to define and capture. Others may not be so easy because there will be many organizations and stakeholders affected by this additional mission.

For the CBA analysis, the benefits may be analyzed from the perspectives of the public's willingness to pay and the public's willingness to accept the changes arising from implementation of the new mission. Frequently these variables are measured by structured surveys. Another approach is to use a benefit transfer method in which results from application of another policy or another location are then applied to the new policy under consideration.

French presents a comparison of CBA and Decision Analysis.(French, Bedford, & Atherton, 2005) He points out that in CBA the analyst seeks to describe potential courses of action and to show their monetary worth to a large group of people. That means the analyst would like to show the total cost of the policy in dollars (in the U.S.) and the total benefit in dollars. French argues that it would be very difficult for two individuals to agree on the monetary values of the specific

costs and specific benefits. It would be very difficult then to produce a single objective valuation of any course of action.

There have been some recent issues in the U.S. with the application of CBA to the assessments of the efficacy of the Advanced Spectroscopic Panel for a RadNuc detection and interdiction mission. (Government Accountability Office, 2006) The criticism centered around focusing on reducing the time necessary to screen traffic at border check points and reduce the impact of any delays on commerce rather than a more complete set of objectives of the larger enterprise.

French argues that multiattribute utility methods (MAUT) provide an alternative methodology to CBA. "Through sensitivity analysis MAUT can address the perceptions of all stakeholder groups, facilitating constructive discussion and elucidating the key points of disagreement. It is also argued that by being explicitly subjective it provides an open, auditable and clear analysis in contrast to the illusory objectivity of CBA. CBA seeks to justify a decision by using a common basis for weights (prices), while MAUT recognizes that different parties may want to give different valuations. It then allows the analyst to explore the ways in which different parties might (or might not) come to the same conclusion even when weighting items differently." He points out that a key difference between CBA and MAUT is that the analyst assumes in CBA that there is some objective weight that is external to the stakeholders while the analyst using MAUT wants to consider the views of all the stakeholders separately and then compare them in the end. He argues that CBA will devolve into a subjective process rather than the objective process which is its goal.

The National Research Council published a report in 1996 proposing an analytic-deliberative process for risk characterization.(Stern, 1996) In this book, the Council points out that analysis and deliberation can be regarded as two complementary approaches. Analysis would require the use of rigorous techniques regarded as best practices by a relevant technical community. Deliberation would use formal or informal communication to raise and collectively consider issues. The Council emphasizes that the values of all the stakeholders should be captured in an evaluation.

Generally, the literature suggests that a combination of subjective surveys used jointly with quantitative surveys provides a good coverage. Subjective surveys, based on interviews, panels, and questionnaires do not require a detailed analysis, but must be collected with the use of reliable tools. Quantitative surveys, based on the collection of all available data, or a more limited sample are credible and cheap to produce, but require subsequent analysis.

Duggan points out that borders are not easily controlled nor secured at the desired level and, therefore, the enterprise can be viewed from a risk management perspective.(Duggan, 2009) She points out that it is important to

understand the traffic currently crossing the border and to examine how the traffic might change as a result of changes related to border security policies and/or protocols. She provides an interesting presentation of the relationships between goals, metrics and measures. Some metrics discussed by Duggan are captured here for consideration later within this dissertation. A high level metric mentioned by Duggan is the stability of the border. Attributes of this metric include how well the border is defined, whether the border is registered and the extent to which the border is demarcated. Duggan also, in a discussion of smuggling, introduces some metrics that might be relevant to our border crossing. They include the ability to functionally detect the threat, the number of threats detected, the amount of material seized, and the number of arrests leading to prosecution.

One approach found in the literature for assessing and planning for improving processes related to border crossing operations is benchmarking.(Organization for Security and Co-operation in Europe, 2012) Of course, one of the issues would be how to select this best in class border crossing operation, especially with a RadNuc mission among all the other missions. The steps generally will include identification of problem areas, identification of organizations (or border crossing sites) that seem to be leaders in the areas of interest, visits to them for observation of their operations, surveys of their best practices and then choice of leading edge approaches to solve some of the problems seen or expected at our hypothetical border crossing.

Need for models that support an integrated holistic view of security

The experiences of the author lead him to the conclusion that a model sometimes provides a useful framework for discussion amongst different perspectives. Frequently, analysts and planners build models that are mission specific. These models are easier to build since they are used to support limited perspectives. For security upgrades that touch several organizations, appropriate models should enable the analyst/planner to examine the effects on all these organizations. Models of this breadth can allow each organization to view the system from their own perspective. A greater benefit is that each organization can see an integrated whole view of the problem, visualize the deployment of the security upgrade, and simulate the effects of the upgrade (positive and negative). This simulation might include an integration of physical models, information sharing models, models of organizational relationships, economic models, training models, and models of the flow of goods, services and people throughout the region under consideration.

Shea points out that a country or an initiative needs an integrated layered approach to detect and interdict threats.(Shea, 2009) This type of approach is being taken by the U.S. government to protect the nation from terrorist nuclear attack. In this layered approach, the U.S. government is reaching out to other nations, assisting them in trying to limit the amount of illicit nuclear and

radiological materials leaving their borders. For our border crossing, then, it might make sense to consider the degree to which Country A and Country B have mutual agreements for the same purpose. We might view, then, the border crossing RadNuc mission to be a part of a broader strategic plan for mutually agreeable purposes between the countries. Shea goes on to say that decision makers attempting to analyze the effectiveness and efficiency of the architecture supporting the mission will likely require a methodology for establishing metrics, qualitative and quantitative, for each layer or sublayer of the architecture. He says that the appropriate metrics for evaluation might not be those most quickly considered, like outcome oriented metrics, like the number of threats found, or the number of vehicles cleared. He suggests that higher level metrics might be more appropriate although they may be more difficult to articulate.

One technique that Shea mentions for assessment is “red teaming”. He points out that the effectiveness of these tests in assessing efficacy might be limited if the tests are not designed to test the architecture for the purpose it was designed. In a red team test for our border crossing RadNuc screening mission, one might put carefully controlled and monitored amounts of nuclear or radiological material in a vehicle and determine how well the vehicle is interdicted under various conditions of traffic flow, weather, seasonal conditions, etc. In the experience of the author, this type of activity requires a great deal of planning, coordination, training, authorization (for use of radioactive materials of significant strength and for having red team personnel inside the security envelope of operations) and expense. One obvious analysis that would have to be performed is the impact of our RadNuc screening mission on traffic delays at the border.

The importance of transport and trade facilitation is becoming widely recognized, and is expected to grow. However, there are countries that are still applying outdated approaches to handling border operations, where wait times at borders sometimes last as long as a whole day.(Organization for Security and Co-operation in Europe, 2012) The Handbook states: “As we strive to eliminate common misconceptions about border operations and procedures, we should adopt a broader and more holistic approach that extends to reform for all border agencies”.

Our approach

How is one, then, to evaluate the efficacy of this type of organizational construct to take on a new initiative, like the RadNuc mission? First, we take a look at the general operating envelope at our hypothetical border crossing, examine the probable way that the missions are executed there by the organizations we have assumed, and then look at how things might change with a RadNuc mission initiative added to the mix. This examination will help us develop criteria that we predict would be important for success of the new initiative. Then we will discuss the metrics by which we might assess the criteria.

CHAPTER III
MODEL FOR HYPOTHETICAL BORDER CROSSING LAYOUT, MISSIONS AND STAKEHOLDERS

There are many possible types of organizational structures for missions associated with land border crossings, ranging from a situation in which there is a very simple land border crossing where there is one guard who mainly checks for correct documentation to an extremely busy crowded border crossing involving land, water and air transport of goods and services and pedestrians. The political structures can vary from one in which the federal government handles all of the monitoring and response to a much more complex situation in which various federal, state, county, and city organizations need to cooperate to execute all of the missions associated with movement of people, hazardous materials, other controlled materials from one country into another.

To assess the efficacy of adding a RadNuc screening mission to a border crossing station, the enterprise was examined from several perspectives, with the goal of having a more holistic view of the enterprise. At first, a diagram of an international land border crossing with only vehicular traffic was developed. That means pedestrian traffic or boat traffic did not have to be considered. In the production of the diagrammatic construct, we had to decide whether the border crossing was a small crossing with only occasional traffic or a large, complex border crossing with various types of commodities and vehicles crossing the border, or something in between. Then we had to decide whether the border crossing station was near a large metropolitan area or just a rural area, because the difference might be important with respect to resources available for handling alarm situations, as we will see later in this dissertation. Furthermore, backup of traffic at a border in a rural area might not be perceived in the same way as a backup in a large metropolitan area where traffic conditions at the border might affect traffic conditions for many people not involved with crossing the border. A modeler will need to decide what level of traffic volume will be crossing the border at our station because that will affect how many lanes of traffic will be required and how many personnel will be required to perform the necessary functions there.

This leads to the need for a model of the missions extant at the crossings and a hypothetical construct for federal organizations that will execute those missions. As this construct is developed, we will remember that the literature points out that there are several missions and several organizations at large complex border crossings. In the model used in this report, a set of missions and organizations to execute them were assumed like those seen in the literature for U.S. border crossings.

To look at the possible effects of adding a new RadNuc mission at our border crossing, a modeler would anticipate that there will be impacts on traffic flow, operational profiles and concepts of operation. To get a feel for how much impact, one will need an image of the operational area. That image will help an analyst/modeler think through the concept of operations before and after adding the new mission. One question to address is whether there is room at this border crossing for a secondary inspection station and if so how many vehicles it might hold before traffic would begin to back in the primary inspection zone because of space restrictions. [In fact, there have been some U.S. border crossings which have room for only one vehicle in secondary inspection.] Early deliberation resulted in the need for a tertiary inspection station when the RadNuc mission was added. Then a reasonable question (not contemplated before) was whether this border crossing would already have a tertiary screening station or the modeler would have to add one just because of this new mission.

Considering the problem from the perspective of impact on the flow of goods and people through the border crossing station, questions arose as to how much traffic flow the model would need to simulate, and how many lanes of traffic will cross the border. For our study, a model produced simulates a high traffic border crossing similar to what exists now at U.S. border crossings with Mexico and with Canada. The literature shows that a problem that really confounds supply chain planning and projections is the variation in time required to cross the border, not just the average time. Since we want to examine the extent to which the addition of our RadNuc mission complicates this problem, then we will need a model to support that examination. This dynamic simulation model will be discussed later in this dissertation. The model was constructed such that it can show variation in the traffic flow resulting from variations in the number of vehicles failing the primary screening and having to travel to secondary screening. In our dynamic model we also had to prescribe times allowed for screening in primary, secondary and tertiary screening.

When the RadNuc screening mission is added, then all of the models come into play. With the physical model, the modeler has to decide what types of radiation detection equipment to use and where it will be used at the station. We will decide whether to have this radiation detection equipment in some of the lanes, in all of the lanes, whether it will be repeated in secondary and tertiary screening or whether we will have different equipment. If one chooses to use different types of equipment, then there will be an increase in the training requirements for the personnel using the equipment. As one considers these types of equipment, then he is drawn to consideration of what happens if the system detects radiation levels that are above the limit (which the modeler will have to set). Does anyone have the authority to detain that vehicle because of a higher than desired radiation level? If so, who? If the radiation alarm cannot be resolved readily, then does anyone have authority to detain the person further? What if the vehicle has a suspicious radiation reading and no one at the border crossing

station is able to resolve the alarm? How will the vehicle be controlled while the alarm resolution continues? Are there resources that can be called upon for a reachback capability (national experts more familiar with radiation characteristics than the border crossing staff)? Then, if there are these resources available and there still is a question, the border crossing people might need to open the vehicle (trailer, truck or car trunk or bus undercarriage, for example). Because of a concern about a possible explosive device, frequently a bomb squad type person may be called in. These people generally come from a police department or a fire department. That is why the presence of a nearby metropolitan area or city or township can be important. If there is more than one source of this type of explosive expert, that is helpful because there might be some sort of problem (like a fire or other type emergency) that would affect one source of expert help but maybe not another in a separate location (like another precinct or township).

Since the literature shows that different types of commodities have different types of radiation levels and therefore have a different likelihood of triggering an alarm, that variation will need to be reflected in the model. Assumptions were made about how many vehicles will have various levels of radiation levels (gamma and neutron) to account for variability in commerce. A type of vehicle was added to the model to simulate the presence of a driver or passenger who has had a radioisotope-based diagnostic test or treatment that leaves them with a radioactive level strong enough to set off a primary screening monitor.

As the dynamic simulation model shows traffic backup increase as the modeler lowers the alarm trip point of the gamma and the neutron detection, he will need to consider the impact on the organizations that operate the facility. But then the question arises about how will increases in the number of vehicles stopped and sent to secondary (and maybe tertiary) affect the number of fines or arrests. As the sensitivity to radiation coming from vehicles increases, in the attempt to detect more of the threat space, more of a burden on the regional law enforcement infrastructure would result because more out of compliance situations would be detected involving the transport of radioactive materials. Since it is very unlikely that any of these detections would be from an actual RadNuc threat (because the probability of a RadNuc presence is so low), then these detections become more compliance monitoring, and, therefore would increase non-compliance detections. This point indicates the need for consideration of the effect of the RadNuc mission on the regional law enforcement and safety organizations.

As these constructs and models are built out, a broader better informed perspective is gained from which to develop goals for the RadNuc screening mission. The goal statements then can be more strategic and inclusive in nature. From these goals, a set of metrics is developed later in this study. The total set, then, of models, goals and metrics form the framework upon which several types of analysis can be performed.

Model of Hypothetical Border Crossing Layout

A hypothetical high traffic border crossing on a major highway between two hypothetical countries, Country A and Country B, as shown in the Figure 3 was considered in this study. For simplicity, this border crossing was assumed to allow only truck and automobile traffic. For the study discussion, we will assume that we are responsible for monitoring and controlling the flow of vehicles (and materials and personnel within them) traveling into Country A from Country B.

To illustrate the problem, a hypothetical regional organizational architecture was considered. The region of interest was assumed to include the major metropolitan area (MA1) around a city (CityA1), which is located in a County A1 (CNTYA1), all in a State A in Country A. The area is assumed also to include townships, Township A (TWNA) and Township B (TWNB), all in County A (CNTYA) within State A, and to include County A2 (CNTYA2) all in State A.

In our study, our responsibility is to protect metropolitan area MA1 from RadNuc threats coming down the interstate from Country B, and if, as described previously, our mission has to be supported by cooperation of several organizations within the geopolitical structure of Country A, then we should examine this structure and the relationships that should be formed to support our mission.

One important question is whether Country B organizations need to cooperate continuously with Country A organizations for our mission to have enduring success? If that does need that to happen, what would be the metric that one would use and how would one measure it? To get at these questions, a little more detail was needed. Models were developed for help in getting to these details.

Another important question is what impact do changes in what Country A does at their side of the border crossing have on Country B? In several of the methodologies discussed in our literature review, more optimal solutions were likely to be those in which there would be significant positive impacts on some or all the stakeholders but no negative impacts among the stakeholders. In the case that there were negative impacts, then some analytical approaches in the literature suggest accounting for some remuneration or tradeoff or willingness to accept these negative consequences.

For the model development, it was assumed that there would be many non RadNuc roles for the hypothetical border crossing location, typical of large, complex international border crossings.

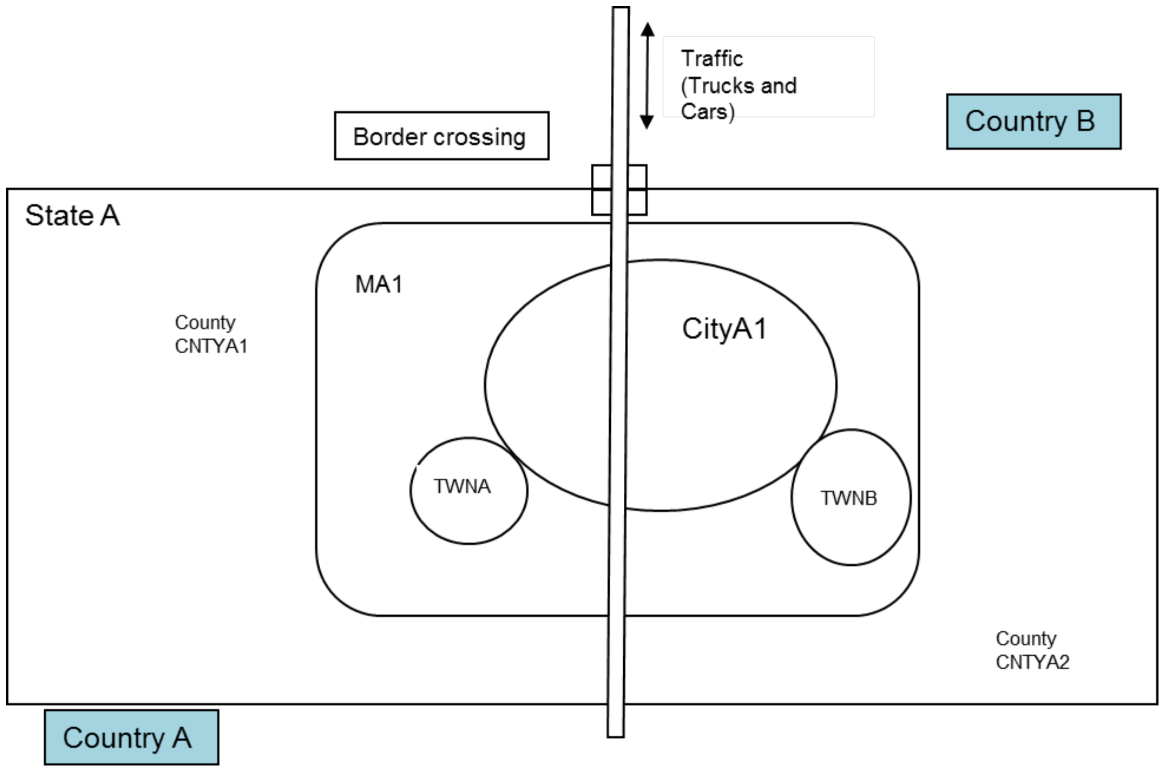

Figure 3. Hypothetical border crossing between Country A and Country B

Of course, Countries A and B will already have organizational structures in place to support their governance requirements, as codified in various laws and regulations. These laws and regulations will, in our example, include agreements concerning the flow of goods, commerce and people within them and crossing between them. These agreements may also include provisions for mutual support in certain types of law enforcement special events, and possible support for response to natural disasters. For such a border crossing, many federal organizations have policies and regulations which apply to monitoring and controlling the flow of vehicles carrying materials and people. To ensure compliance with these policies and regulations, we assume that the border crossing will have systems, protocols and operations – in alignment with the agreements mentioned above - personnel to examine the vehicles and personnel within them.

Some example federal organizational constructs for a border crossing were seen in our literature review in Chapter II. A structure similar to that for a U.S. international land border crossing was assumed, as shown in Table 2.

Table 2. Country A and country B federal missions and stakeholders for hypothetical border crossing

Mission Objective	***Country A***	***Country B***
Provide and maintain structures, utility interfaces	General Services Administration	General Services Administration
Sets federal policies to facilitate cross border travel; inspects goods and people	Customs and Border Protection (CBP-A)	Customs and Border Protection (CBP-B)
Facilitate safe and efficient movement of people and goods along federal routes	Department of Transportation Highway Administration (DOTFHWY-A)	Department of Transportation Highway Administration (DOTFHWY-B)
Control the import of foods, drugs, cosmetics, medical devices, biological products, animal feeds and drugs, and radiation-emitting instruments	Food and Drug Administration (FDA-A)	Food and Drug Administration (FDA-B)
Regulate the importing of birds and wildlife protected by international convention	Fish and Wildlife Service (FWS-A)	Fish and Wildlife Service (FWS-B)
Federal law enforcement, criminal and terrorist threat response	Federal Bureau of Investigation (FBI-A)	Federal Bureau of Investigation (FBI-B)
Federal law enforcement related to drugs, smuggling	Drug Enforcement Agency (DEA-A)	Drug Enforcement Agency (DEA-B)
Develop and implement strategies to monitor for diseases in people, animals, cargo, and conveyances	Center for Disease Control (CDC-A)	Center for Disease Control (CDC-B)
Detect and prevent criminal acts by targeting the people, money, and materials that support criminal networks	Bureau of Immigrations and Customs Enforcement (ICE-A)	Bureau of Immigrations and Customs Enforcement (ICE-B)
Protecting national air, land, and rail transportation systems to ensure freedom of movement for people and commerce	Transportation Security Administration (TSA-A)	Transportation Security Administration (TSA-B)
Detect and prevent the entry of weapons of mass destruction, unauthorized aliens, and drug smugglers and other criminals	Border Patrol (BP-A)	Border Patrol (BP-B)
Implements animal control policies, provides inspection	Department of Agriculture (DA-A)	Department of Agriculture (DA-B)

In support of these requirements, States A and B also will have structures, policies and agreements in place, especially for routine situations. Similarly, the counties in the region will have organized themselves to deal with normal situations, and may have developed mutual support agreements to deal with natural or man-made challenges like floods, hurricanes, and widespread fires. Our primary city, CityA1 (and assumed target for radiological or nuclear terrorist activity), will have, at least for the purposes of this study, developed policies and protocols for routine and many types of emergency events, and a structure for supporting them.

For the purposes of this paper, we define the regional architecture as the complete set of policies, organizational structures, personnel, equipment, protocols, agreements, training and budgets in place to meet all the known requirements for Country A, for States A and B, for the counties within the region and for our city CityA1 and the townships TWNA and TWNB all in MA1. This is an important definition because the execution of any increase in security missions within the region probably will be performed by the existing architecture or additions/modifications to it.

The diagram in Figure 4 shows a hypothetical structure for these federal organizations for Country A. For our study, we will assume that there is a parallel organizational structure for Country B.

For the states in Country A and B, there will be there will be state organizations with missions that support the federal missions. Similarly, we will assume that there are organizations at the metropolitan area, city and township levels that support these missions. An important point regarding Country A federal organizations is that they each have their own overall missions, strategic plans, internal initiatives, and budget priorities. In many cases, they compete with each other for federal resources and occasionally mission space. The quality of their relationships with their international parallels (especially Country B) and states (especially State A and State B) will affect their efficacy, to some point. For State A, we will assume the following mission and organizational structure to support the missions in alignment with the federal missions, as shown in Table 3.

Later in the dissertation, we will discuss how organizations at the county, metropolitan area, city and township levels may need to support the state and federal missions associated with our hypothetical border crossing.

How these layers of federal, state, county, metropolitan area, city and township missions and organizations interact varies from location to location. In some cases, there is an overall regional integrating organization that helps articulate common goals, encourages policy and operational alignment where possible and promotes overall communication and information sharing. In other cases, the organizations may act as rigid and totally separate entities. In any case, there

Table 3. State A organizations and missions related to border crossing

State A organization	***Mission***
Department of Transportation (DOT-SA)	Ensuring registration and licensing of movers of goods and people, protect infrastructure from overweight vehicles
Highway Patrol (HWYPAT-A)	State highway law enforcement for State A
Department of Justice (DOJ-A)	Sets and adjudicates policy for State A
Department of Safety (DOS-SA)	Ensuring safe transport of goods and people within State A
Department of Health (DOH-SA)	Control the import of foods, drugs, cosmetics, medical devices, biological products, animal feeds and drugs, and radiation-emitting instruments
Department of Agriculture (DOA-SA	Implements animal control policies, provide inspection services for imported animals, implements state policy for agricultural products
State Bureau of Investigation (SBI-A)	Sets and implements law enforcement intelligence policies
State Emergency Management Administration (SEMA-A)	Prepare for and respond to State A emergencies

are certainly opportunities for development of different and possible competing perspectives about importance of missions, training, equipment purchases, information sharing and budgets and other resources to advance initiatives. This disparity in perspectives may change radically in the face of perceived danger from immediate threats, or the need to respond to disasters or attacks.

Adding RadNuc Detection and Interdiction Mission to the Model

Many border crossings have stations which include systems of equipment, personnel and operational procedures to detect, intercept and handle many of types of dangerous materials. With the perception that terrorists might want to smuggle quantities of these dangerous materials sufficiently large to cause catastrophic damage, there has been a growing interest in expanding the application of these systems and in improving the systems already deployed. Two types of threats getting a lot of attention are radiological and nuclear.

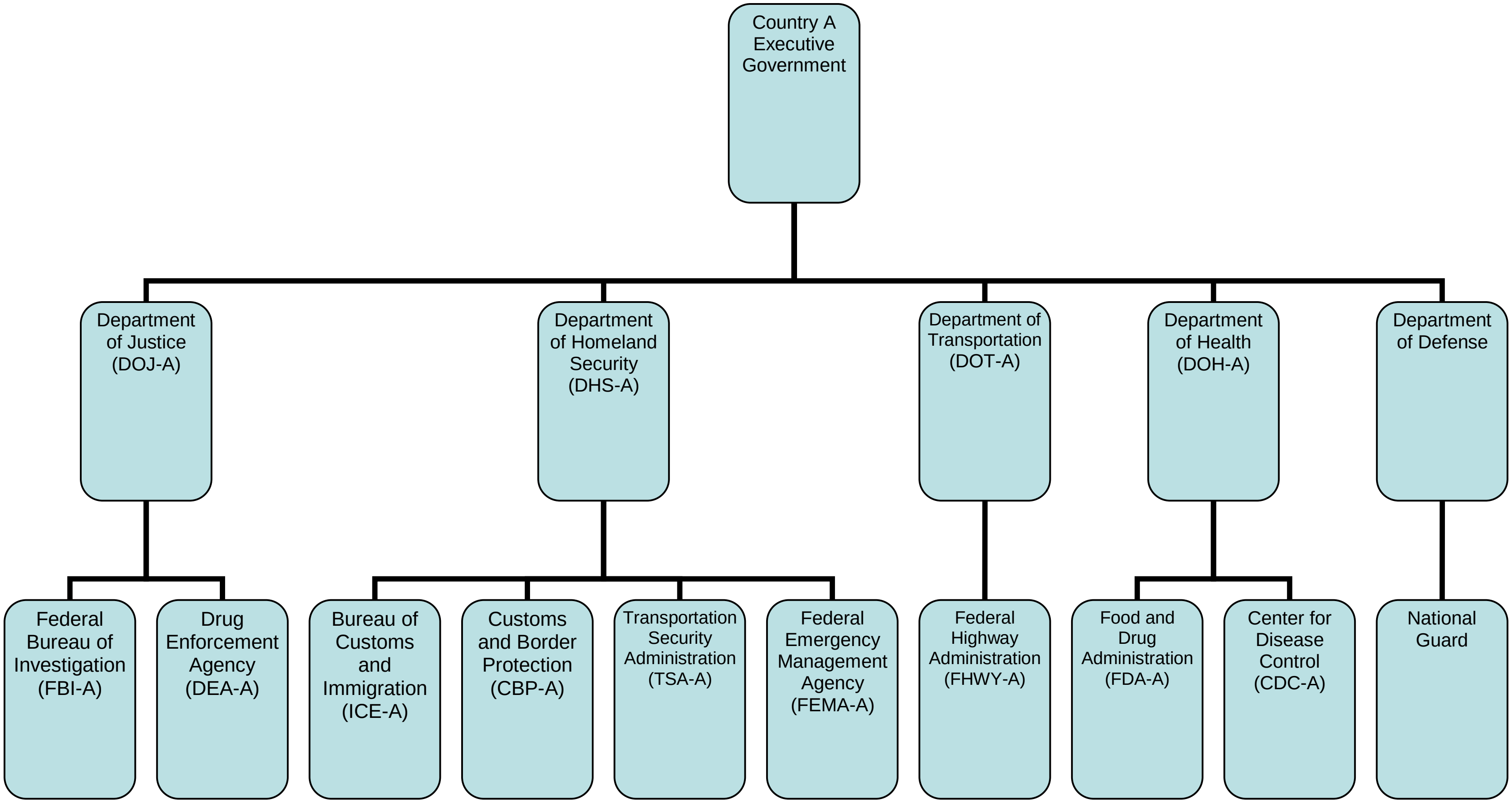

Figure 4. Hypothetical structure for federal organizations in Country A for border crossings

A nuclear threat generally is considered to be a weaponized assemblage of a significant quantity of nuclear materials in a fashion such that a nuclear chain reaction will cause a very dramatic release of energy in a short period of time, like in a nuclear bomb. The nuclear materials most often discussed are highly enriched uranium (HEU) or plutonium-239. Neither the exact quantity, chemical form nor the choice of nuclear material is important for this dissertation.

A radiological threat generally is considered to be a weaponized assemblage of a sufficient quantity of materials that emit ionizing radiation in a fashion such that they could be released in a manner to cause significant radiation damage or contamination to people or property. The exact type of material and quantity are not important for this dissertation.

In our example, we want to develop an enduring mission around the threats from radiological or nuclear terrorist activities. In our city CityA1, and in the counties in which it is located, and in the contiguous counties in State A in Country A and in State B in Country B, a broad range of organizations will be impacted. The border and customs officials who generally are policing against smuggling, illegal aliens, and other criminal activity may now have to add detection and interdiction of illicit radiological and nuclear materials to their mission spaces. This probably will include the purchase and maintenance of new equipment, development of new concepts of operations of the new equipment within the existing operational requirements, development of new information sharing and fusion agreements, development of new training programs, development of new protocols for prosecution, development of new agreements between contiguous jurisdictions to support tracking and interdiction of the threat, the development of public and private business awareness around the changes in policies and procedures, and finally the development of budgets within all of the impacted organizations to support the additions. All of these changes will need to fit into the existing architectural construct. The fact that the probability of this type of terrorist activity is low (relative to fires, floods, storms, other criminal activities) may engender a lack of enduring commitment to the increased mission by some of the organizations involved.

According to a report from the U.S. Government Accountability Office, the U.S. Customs and Border Patrol (CBP) standard procedures direct vehicles, containers, and people coming into the country to pass through portal monitors to screen for the presence of radiation. Most RPMs use technology—known as “plastic scintillators” (PVT) – that detect the presence of radiation but cannot distinguish between harmless and dangerous nuclear or radiological materials. This results in the need for “secondary inspections”. To confirm and identify the presence of radiation, this secondary inspection includes CBP officers using Radiation Isotope Identifier Devices (RIIDs) to localize the source of radiation, determine whether the radiation being emitted is from a harmless source, such as kitty litter, or a dangerous source, such as weapons-grade nuclear material.

Typically, completing a secondary inspection takes about 15 minutes but can take much longer.(Government Accountability Office, 2006)

In this dissertation, the assumption is made that either of these two types of threats could be carried across the border between Country A and Country B in a truck, van or automobile. The implications of adding the mission to detect, interdict or deter nuclear and radiological (RadNuc) threats to the mission space already existing at our hypothetical border are examined. The types of equipment to be used at the border crossing are typical for detection and characterization of radiological and nuclear materials. The equipment types will include:

1. Fixed instruments - Radiation Portal Monitors (RPMs) – capable of scanning most sizes of vehicles crossing the border at our station. These RPMS are very sensitive to gamma radiation, partially because of their large size, but do not give spectrum information that would be helpful in determining the nature of the material emitting the gamma radiation. They also will contain neutron detectors. We will assume that these RPMS will be at each lane located at the Primary Screening Station (hereafter called Primary), and also one set will be located in the Secondary Screening Station (hereafter called Secondary).
2. Portable radiation detection equipment, including handheld radioisotope identifiers (RIIDs). These will be present at the Secondary Inspection Station.
3. Portable gamma radiation detection equipment, including radiation pagers. These are useful because they give a sensitivity that enables the officer in Secondary to be able to separate the vehicle with gamma radiation from the others. They can also help identify whether the driver or passengers or vehicle are emitting the highest levels of gamma radiation.
4. Portable neutron search detectors (NSD) will be used in secondary Screening to help localize neutron sources in the vehicles.
5. Whole vehicle x-ray machines that will be gamma through transmission or gamma backscatter devices that will produce radiographic images of the vehicle as the vehicle drives by or the machine itself can drive by the vehicle. In our case, these systems will be placed in Tertiary screening (hereafter called Tertiary) – unless the border crossing station already has them in Secondary for non-RadNuc screening purposes.

There are difficulties with this type of mission (RadNuc) in a complex border crossing situation, like the one assumed in this study. One of the difficulties is that the border crossing is a location where a great deal of activity may be taking place. As the literature search showed, there may be opportunities for overlap of missions resulting in duplication of measurements,

Another difficulty is that the frequency of detecting an actual radiological or nuclear threat is very, very low but the frequency of detecting radiological or

nuclear material is not low. Many types of commodities carried across borders have enough radioactive materials within them that resultant gamma emissions might be intense enough to trigger alarms at screening stations. Furthermore, drivers or passengers occasionally have medical treatments that result in a sufficient amount of radioisotopes within their bodies that radiation detection equipment will alarm within considerable distances.

The possibility of illicit transport of dangerous materials across borders and into highly populated areas has been recognized as a significant threat to most industrialized countries – especially the United States of America.(Shea, 2009) There are many types of dangerous materials transported across borders of countries every day. Types of materials include: radiological materials, explosive materials, hazardous chemicals, ammunition.(Kouzes et al., 2003)

The postulate made earlier was that the development of a set of models can facilitate the discussion of how much security is reasonable for a government/regional citizenry because it can provide a framework for that discussion. The existence of the model set would be useful in the articulation of requirements for security and the metrics that might be used in the tradeoff discussions around how much security is reasonable. The model set should support deliberation around:

1) Political constructs (as shown in the organization type charts) that would facilitate/limit the actions required to provide/improve security;
2) Metrics/measures that would frame discussions around how much security is reasonable for the financial resources required, and/or the impacts on the citizens of the region, and/or the impacts on other aspects affecting the economics of the region;
3) Amount and types of capabilities that are needed and their geographical deployment;
4) Resources needed to operate and maintain any equipment needed;
5) Roles and responsibilities of private and public organizations regarding deterrence, detection, interdiction, response, recovery; and
6) Methodologies for assessing the quality of security provided.

In this chapter, we have seen that in Country A there are more than ten federal organizations and at least eight state organizations which have missions at the hypothetical border crossing. An introduction of a new mission at the border crossing should be examined from the perspectives of each organization which might be affected. We also have raised the question about how a new mission for Country A might affect Country B. There is also the likelihood that other new security or trade facilitation initiatives will be introduced into the border crossing enterprise. The analyst should consider how changes in operation borne through those initiatives might affect the efficacy of the RadNuc mission. A further consideration is that changes in Country B border operations might affect the operations for Country A.

These points demonstrate that a simple set of diagrams of physical layout and a set of organization type charts (with articulated missions) can provide a perspective from which considerable insight could be developed. It becomes obvious that the introduction of new missions into existing border operations might be better informed by consideration of a broader, complete set of organizations associated with the border crossing.

CHAPTER IV
OPERATIONAL MODEL OF HYPOTHETICAL BORDER CROSSING

Approach

This chapter discusses the development and use of an operational model for a hypothetical, high traffic, complex land international border crossing. The model is used to examine the likely operations of the border crossing, the effects of the missions at the border crossing on traffic flow, including the necessity for secondary screening. We also discuss likely relevant regional geopolitical constructs around the border crossing.

To the hypothetical international border crossing mission space, the mission of interdicting and/or deterring radiological and nuclear threats is added. This mission addition requires the addition of radiation portal monitors in the Primary location, and radiation portal monitors and portable radiation detectors in the Secondary inspection station. We also add a Tertiary inspection station for the cases where additional inspections might be required for further adjudication of alarms. An emphasis is placed on estimating the necessary resources needed to maintain security and functionality at the site.

For this simulation, a computational model approach known as agent-based modeling (ABM) is used. ABMs (also known as multi-agent systems or multi-agent simulations) use a computational model to simulate the actions and interactions of autonomous agents to see their effects on the system as a whole. The model discussed in this report was created using an agent-based programming language and integrated modeling environment known as NetLogo. A 3 dimensional model of the international border crossing was also created using a 3D modeling program (Google SketchUp)

The development of the operational model supported a consideration of how agencies associated with the border crossing would have to work together to implement the new RadNuc detection and interdiction mission. The expectation was that this model would help us better articulate goals, develop strategic questions and discover metrics which we will use later in our framework for assessing mission efficacy.

Before designing the model for the hypothetical international border crossing, descriptions of typical international border crossings were considered to get a sense of layout, traffic routing, numbers of lanes, and general operational profiles.(Organization for Security and Co-operation in Europe, 2012) This

author also has had experience observing operations at border crossings and, with others, prepared a restricted distribution report on the application of RadNuc screening missions in regions containing border crossings and ports of entry.(White, 2011) From these considerations, preliminary models were developed to examine operations before implementation of the RadNuc mission.

Overall Preliminary Model Description

Border crossing model without a RadNuc mission

The model was developed in a way to support the examination, highlighting and demonstration of some aspects of border crossing operations that would be impacted by introduction of an initiative around a RadNuc mission. The first aspect of the model is a three dimensional sketch showing the layout of the hypothetical border crossing for this work. This sketch is described in a way that demonstrates how the border crossing might be laid out and operated spatially. A second aspect of the modeling is a consideration of how some of the relevant organizations would have to work together, before and after the RadNuc mission begins. This can be viewed as the geopolitical aspect of the border crossing. The third part of the model is a dynamic simulation of the traffic flow through the border crossing, including a Secondary inspection area. This dynamic model shows how traffic might back up along the highway crossing the border and how the number of vehicles sent to Secondary screening might vary as screening parameters change. The need for a Tertiary Screening Station is discovered and discussed.

For simplicity, the model will only take into account an interstate and no other crossings such as railways, river crossings, air traffic, or other highways. The interstate at the border station will consist of six lanes of traffic traveling in opposite directions, for a total of twelve lanes of traffic. Our responsibility (in this research) is to consider the traffic coming from Country B into Country A. We have chosen, however, to include traffic going from Country A into Country B in the model to be able to investigate any requirements for cooperation between Country A and Country B organizations.

The diagram in Figure 5 was developed using Google SketchUp. [Licenses for SketchUp are available to the public at no cost, but are explicitly limited to non-commercial use]. It shows six lanes of traffic crossing the border from Country B into Country A and six lanes of traffic crossing the border from Country A into Country B.

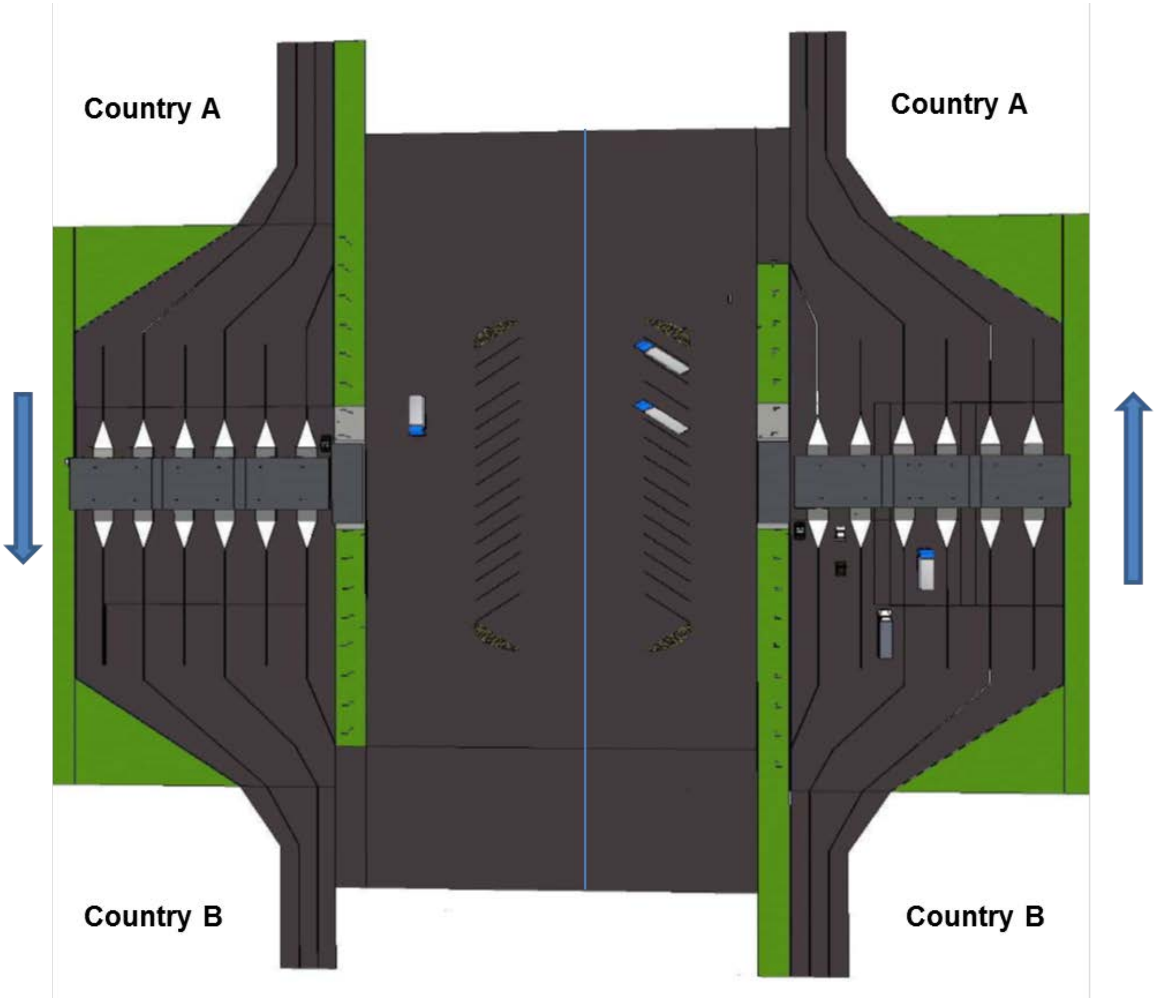

Figure 5. Top view of model of hypothetical border crossing using Google SketchUp

The six lanes of inbound and outbound traffic will each be equipped with normal equipment for a border crossing station. They will have a Primary inspection station booth in which works a border crossing guard. This guard in a booth in each lane is responsible for screening for all the types of parameters described previously. He will follow the Concept of Operations developed by the State A Customs and Border Control organization to ensure that the vehicles have the required labels, DOT numbers, manifests for cargo, licenses, and identity paperwork as described previously in Chapter II. In some cases, the documentation will not be complete and the driver will be directed to Secondary screening locations as shown in the diagram. Other reasons for sending vehicles to Secondary include suspicious behavior of the driver or passengers, presence of alcoholic beverages, and overweight vehicles. Occasionally, a vehicle may be directed to secondary screening on a random basis. A good description of

general operations at a U.S./Canada border crossing is given in the “Border Crossing Guide for Commercial Truck Drivers”.(United States Department of Transportation, 2008) The officials in Primary will represent many of the requirements and regulations from the missions of several agencies, shown previously in Table 2. State organizations shown previously in Table 3 also will have some impact on or be impacted by operations at the border crossing.

There frequently will be law enforcement vehicles at the border crossing as shown in Figure 6. These law enforcement vehicles may be used to: a) escort the vehicles from Primary to Secondary screening under positive control; and b) to chase down vehicles that cross the border in a way that violates the protocols. This on-site law enforcement presence in our model will be provided by the State A Highway Patrol under a Memorandum of Understanding (MOU) between the Highway Patrol and the Country A Department of Homeland Security. The MOU will specify the number of this type of law enforcement vehicle that will be at the border crossing, the number of hours during the day for each day of the week, and the manner in which the law enforcement officers will be notified which vehicles need to be escorted or chased down.

The legal basis for the State A Highway Patrol officers to chase down the vehicles that have violated some protocol at the crossing will be the responsibility of the State A Department of Transportation. The DOT-A will work with state, regional and local district attorneys and judges to develop a consensus that the concept of operations for detaining these drivers and vehicles is well considered.

As the vehicles are escorted to Secondary, they will follow the escort vehicle until they are parked. In our construct, the drivers will be met in Secondary by officers from the Country A Customs and Border Protection (CBP-A). These officers will have a range of inspection protocols for paperwork associated with the driver and other occupants of the vehicles and protocols for determining whether proper decals are in place, for examination of registrations and for authorization for transport of hazardous materials.

In addition to federal and state agencies, some local agencies will be involved in activities that support or will be affected by the border crossing station. The sheriff’s department and police department may be involved in interdiction on roads or streets near the border crossing. Police and fire departments frequently have roles associated with controlling vehicles carrying hazardous materials. They also provide explosives experts who support the opening of suspicious vehicles or containers within them.

2-Dimensional dynamic simulation model description

The purpose of this model is to help discover and understand operational features important to the success of the missions at the border crossing. For

clarity and to help visualize the 2 dimensional dynamic simulation model used to simulate traffic flow through an international border crossing, an additional model perspective includes an isometric view of the crossing station, shown in Figure 6. The model consists of 6 lanes of traffic on both the incoming and outgoing sides with a secondary inspection location situated between the incoming (right side) and outgoing lanes of traffic. The law enforcement vehicle is shown in the innermost lane.

In Figure 7 is another isometric view. For convenience, the model has a construct for the border crossing laid out in a way that there is a contiguous arrangement for vehicles coming into Country A and those coming into Country B whereas they normally would be separated. This allowed a little broader perspective than just considering flow in one direction.

This dynamic model will simulate the traffic flow through and within the border crossing station before and after implementation of the RadNuc screening mission. Before and after this mission implementation, there is interest in the backup of vehicles trying to cross the border and the impact of screening operations in Secondary on resource requirements there.

Before the addition of the RadNuc mission, normal screening for compliance, security and immigration will affect the traffic flow. The first phase of modeling simulates this effect. But since our focus is on the effects of the RadNuc screening mission, we will assume that all of the relevant agencies have worked out acceptable fractions of traffic flow sent to secondary inspection, acceptable backups at the border and the concepts of operations and supporting agreements to enable the enterprise to run smoothly.

In this first phase, the assumption is made that there is a detection system that looks over the entire mission space and detects noncompliance, safety concerns, immigration issues, and suspicious behavior. There will also be random selection of vehicles for examination. The model assumes a probabilistic nature of the traffic and persons passing through this detection system, resulting in a stochastic nature of the number of vehicles failing the Primary detection discriminator and consequently sent to Secondary. After this model simulation represents what seems to be a reasonable operating envelope, RadNuc screening operational elements are added to the model in the next phase.

Simulation using agent-based modeling

The dynamic simulation model was built using NetLogo. [NetLogo is free and open source software, under a GPL license. It is written in Scala and Java.]

Figure 6. View of the 6 incoming lanes of the border crossing model

Figure 7. Alternate view of the border crossing model showing the incoming and outgoing lanes of traffic as well as the secondary inspection location

Figure 8 below shows an image of the two-dimensional model designed. Just as in the three-dimensional model, the two-dimensional model consists of 6 lanes of traffic on both the incoming and outgoing sides, giving a total of 12 lanes. The incoming side is denoted by red vehicles while the outgoing side has blue vehicles. Each of the 12 lanes has a toll booth which serves as a security checkpoint and the primary inspection location. This is denoted by the vertical red bars in the center of the figure. During the agent-based model simulation, vehicles are assigned probabilities by a random number generator. If the number assigned exceeds the discriminator threshold then the vehicle is required to go to Secondary. The incoming side is shown at the bottom of the figure while the outgoing is shown at the top of the figure. The Secondary is located in the middle of the figure between the incoming and outgoing lanes of traffic.

This phase of model development has the purpose of simulating the operation of the border crossing without a RadNuc screening mission. As a simplification, we assume that there is one detection system that will look at all of the reasons that might require a vehicle to be sent to a Secondary Screening station. The goal is to simulate the number of vehicles coming into Primary, a stochastic variation in the number being sent to Secondary and then released from Secondary. We want the model to show that the border crossing operation before the addition of RadNuc screening runs efficiently, with a fraction of vehicles going to Secondary that is non-zero, but does not overwhelm the officers' ability to clear the cars from Secondary before there is a significant backup in Secondary. Then In the next phase of the model, the RadNuc screening mission will be added to examine the effects of this additional mission on the border crossing operation.

For the general detection system (representing the totality of screening due to non RadNuc causes), discriminator levels will be varied to get about the right level of Primary and Secondary activity to use as a base case before adding RadNuc screening. In this agent-based model, vehicles are assigned probabilities by a random number generator. If the number assigned exceeds the discriminator threshold then the vehicle is required to go to Secondary. It can be seen from the figure that if the discriminator levels are lowered (increased sensitivity) then there is a higher probability of a vehicle exceeding the threshold level. Increasing the sensitivity of a detector would therefore increase the number of vehicles that set off alarms. This would lead to a higher volume of vehicles required to receive a secondary screening.

A computational model using agent-based modeling is used to simulate the actions and interactions of autonomous agents to see their effects on the system as a whole. For this study an emphasis is placed on determining how varying the inputs of traffic volume and discriminator level affect the wait times of vehicles crossing the border, the security and functionality of the border crossing, and the resources needed to maintain this security and functionality (both manpower and equipment). Three distinct test cases were run.

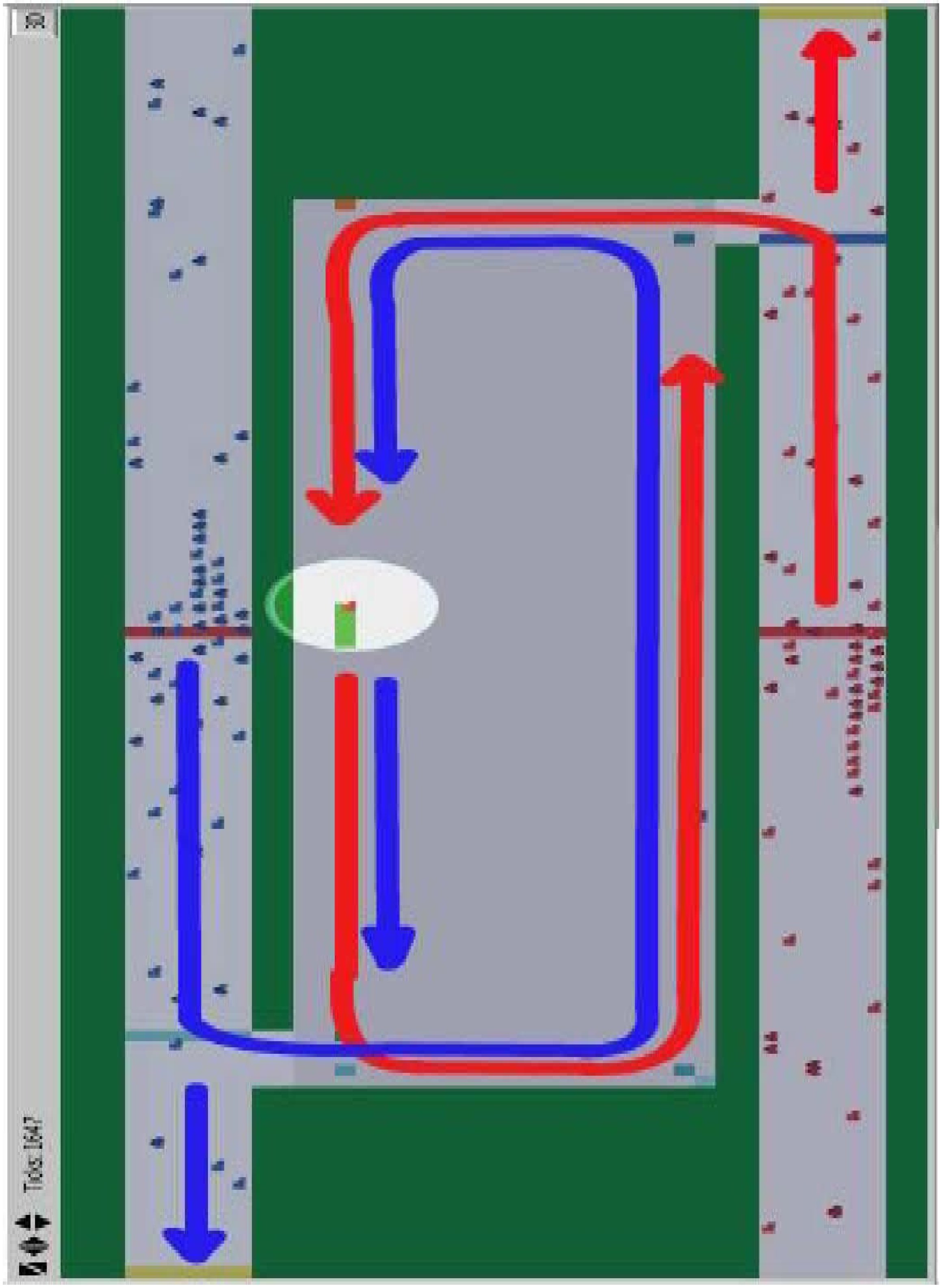

Figure 8. Border crossing model during the beginning of the simulation

Before the model is started some major initial inputs are required such as the number of cars and trucks to be placed in each lane, the maximum speed the vehicles can obtain, and most importantly the discriminator level of the Primary Screening operation. The discriminator level is modeled by assigning a random value reading to each vehicle that enters the Primary Screening Station. This is accomplished by assigning a different random number from 0 to 1 to each vehicle and comparing it to the current Primary discriminator alarm value to determine which vehicles will be required to go to the Secondary inspection location. The equation below represents the mathematical form of this.

Sec. Insp. Requirement = ifRandom(0−1) > Current Discriminator Level

The probability distribution of the randomly generated numbers is generated by NetLogo. We used settings in the code to get the general shape we felt reasonable. A typical distribution from the model is given in Figure 9. The data for Figure 9 was obtained by running the model for 35,075 iterations,

Once a discriminator level is chosen the random number of the vehicle is compared to the discriminator level. If the random number is larger than the discriminator level the vehicle is treated as if it alarmed a detector in the Primary Inspection Area and is required to go to the secondary inspection location. The discriminator alarm levels are chosen through the use of slider bars on the main graphic user interface and can be changed at any time throughout the simulation. Thus, any probability (detector discriminator level) of being required to go to secondary screening can easily be applied. This is a good feature because it allows easy manipulation of the model to see the effects.

It is possible to change the number of cars and trucks to be placed in each lane in the model. For example, choosing a number of 3 for incoming trucks and 3 for incoming cars will place 3 trucks and 3 cars in each lane on the incoming side (bottom), for a total of 36 vehicles on the incoming side. A typical case for a sample vehicle on the incoming side will be examined in detail to describe the process flow of the rest of the model.

During the simulation the vehicles are asked certain questions such as the color of the patch that they are on (NetLogo uses patches to describe where the vehicles are located on a grid) to determine if an action needs to take place or not. For example, in the beginning of the simulation (as well as throughout the rest of the simulation) vehicles are asked if the color of the patch they are on is red, the color designating the toll booths. If so, then the vehicles are required to slow down to a speed of nearly 0 to model the time spent at the RPM being scanned. If not, then they continue on their normal path and speed.

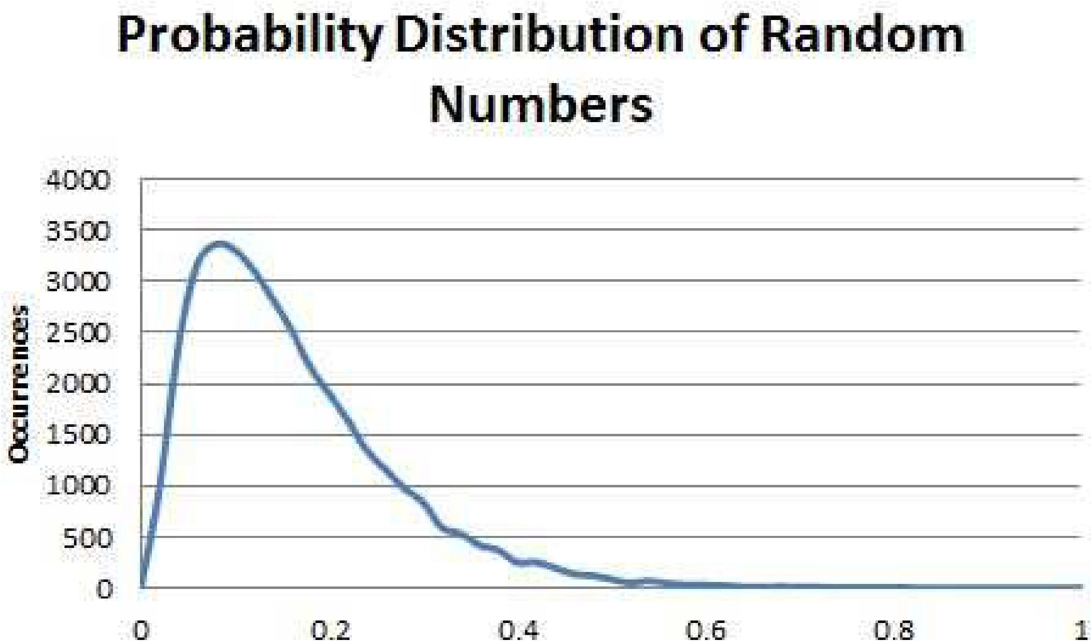

Figure 9. Probability distribution obtained from the NetLogo model using a random number generator for a log-normal distribution

Once the vehicles progress through the red region they move until they reach the vertical blue bar. At this point probabilities are assigned to determine if the vehicle is required to go to secondary screening or not. If so, the vehicle is re-routed to the secondary inspection location. If not the vehicle continues to the end of the map at which point it wraps back around and starts the process again. The process of wrapping the vehicles around to the beginning of the model introduces artificiality into the model that is not ideal. More realism could be added to the model by using a text file to input traffic flow data as a function of time.

If the vehicle is required to go to secondary screening it is re-routed and sent to the secondary portion of the model. If there are no vehicles in the secondary inspection station then the vehicle will undergo a second screening to validate the first "alarm". If a vehicle is already present in Secondary then, just as in real life, the second vehicle is required to wait in line until the secondary inspection screening process becomes available. The secondary screening takes longer (approximately 10 total minutes in this model phase) and is reflected in the model by requiring the vehicles to pass slowly through an extended zone larger than the primary screening zone. In this first phase of the model (without the addition of a RadNuc screening mission) we assume that all vehicles pass the secondary screening and are allowed to pass through the border crossing. To model this,

the vehicles are simply looped around the secondary portion of the model until they reach the entrance once again. At this point a random number is chosen to distribute the vehicle back to one of the 6 initial lanes. After being placed randomly onto one of the 6 lanes the vehicle will continue forward until it reaches the end of the model and wraps back around to start the process again.

Throughout the simulation the vehicles are required to follow certain rules such as a speed limit, maximum acceleration and deceleration, and to stop when they reach the vehicle in front of them. Assumptions made in the simulation include the following:

1. That all vehicles passing through the primary and secondary inspection zones do so in the same amount of time. This assumption deviates from actual border crossing operations. More variation will occur more during the secondary screening process than during the primary due to the thoroughness of examination of paperwork and physical inspection amount done during the secondary screening process. Reviews of documentation, vehicle weight, decaling, licensing or safety permit information are generally required at this time.

2. That all vehicles pass the secondary screening process. In the rare event that a vehicle does not pass the secondary screening, extra time must be taken to log the event and to notify the proper authorities. In real life, this process can take up to a day in some countries. But we are assuming we have a relatively modern well-functioning border crossing with well-established protocols and well trained officers.

3. Any dependent relationship between vehicles in line or in adjacent inspection booths was neglected. It is possible that a group of vehicles with similar problems (like lack of proper documentation or decaling) could show up at nearly the same time. This would require the vehicles in any of the Primary Screening area that had been alarmed to be escorted to the secondary inspection location for further screening. This type of situation is possible and might cause a temporary backup.

Test Cases for Phase 1 model

Test cases were designed to address the following questions:

• What probability of detection in primary would cause the security organization to have to add one more set of officers (assuming a set equals 3 shifts and 1 back-up)?
– Security personnel are only capable of monitoring a certain amount of vehicles in the secondary inspection location. We have made this threshold level of secondary screening capability a variable. It can be set using the slider bar in the main graphic user interface. It represents the maximum number of vehicles that can be in the secondary inspection before another trained and certified

officer would need to be brought to the station.

– Because of the added length of time that it takes for a secondary inspection it is possible for secondary to back up. Therefore it would be beneficial to determine how varying the inspection time in secondary would affect the flow of vehicles through secondary and the subsequent requirement of security officers.

Test Case I – Effects of detection rates in primary screening

If the threshold is exceeded then the Secondary Screening operations will be required to add more security officers. In Test Case 1, we address the following questions:

• What flow rate in primary begins to have deleterious effects on wait times and number of officers required in secondary?

– Increased flow rates through the primary inspection systems increase the probability of alarming a primary detector, causing a subsequent increase in the number of vehicles required to go to the secondary inspection location. It is possible that this increase in vehicles could overwhelm the security personnel causing a back-up of vehicles in primary.

• How does improving the speed of resolution of alarms in secondary affect the retardation of flow through secondary as well as the resources (officers) required?

To setup the simulation, 5 cars and 5 trucks were chosen to be placed in each of the 6 lanes on both the incoming and outgoing sides. Therefore a total of 120 vehicles are present in this simulation at all times. We have set a criterion that more than 5 vehicles in the secondary inspection location will result in the additional costs of adding one more set of officers (a set being 4 to cover 3 eight hour shifts plus a backup). This is assumed to be the maximum number of vehicles that can be present in the secondary inspection location before the security officers become overwhelmed. The test case was run multiple times (different simulations) with different primary inspection station discriminator levels to determine which level overwhelms the security personnel. Each simulation was run for a maximum of 30,000 ticks (we have chosen a tick to be one second). If the simulation was run for 30,000 ticks without exceeding the threshold level it was considered to pass the criterion and a lower discriminator level was chosen for the next simulation. A simulation was considered complete and cut short if the threshold level was exceeded. Also, if a simulation exceeded the threshold level it was run again to confirm the validity of the previous simulation. If a simulation was run 3 consecutive times, with all 3 simulations exceeding the threshold level, then the simulation with the current inputs was confirmed and the result for the minimum detection probability for primary was considered determined found.

The first simulation (simulation 1) was run with an alarm discriminator level of 0.85 for both the incoming and outgoing flows of traffic. Vehicles with a random number greater than 0.85 were required to go to Secondary for additional screening. With a discriminator level of 0.85 the simulation ran for the full 30,000 ticks without the secondary inspection location exceeding 5 vehicles. The maximum number of vehicles to be in the secondary inspection location at one time was found to be 1. This is shown in Figure 10 below.

Simulation 2 was run with an alarm discriminator level of 0.65. The simulation was able to complete a full 30,000 ticks without exceeding the secondary inspection threshold level. Figure 11 shows that secondary met the threshold level twice throughout the simulation but never exceeded the level at which the Secondary is at capacity.

With these current inputs the security organization would be required to add one more set of security officers. Figures 11 through 13 reflect simulations 3, 3-a, and 3-b respectively. It should be noted that in Figures 12 and 13 the total number of vehicles did not fully reach the threshold level on the plot before the simulation was stopped. This is due to the way vehicles are counted in the secondary inspection location. Because of the probability of the random numbers generated it is possible that a simulation can be run for a higher discriminator level in which the simulation will pass. Therefore a range of discriminator levels should be recorded as the lowest detection probability for primary. Thus, a range of 0.63 to 0.65 was chosen as the minimum detection probability in primary without exceeding the threshold level requiring the security organization to add another set of security officers.

Test Case II - Effects of primary flow rate

We examined the effect that the primary flow rate has on the wait times and security officers required in secondary. In this test case simulations were run by varying the initial number of vehicles in the model. Three simulations were run for this test case: low, medium, and high volume traffic flows. Each simulation was run for a total of 30,000 ticks. A secondary inspection location threshold level of 5 vehicles was used to determine the effect of the traffic flow on secondary. The discriminator alarm levels for both flows of traffic were set to 0.65 for each simulation.

Simulation 4 was run with 5 cars and 5 trucks in each lane on both the incoming and outgoing sides. This simulation serves as the low volume traffic flow simulation. It was determined that the average wait time experienced by vehicles waiting to cross the border was in the range of 75 to 140 ticks. This is reflected by the red (incoming) and blue (outgoing) curves in Figure 14 given below.

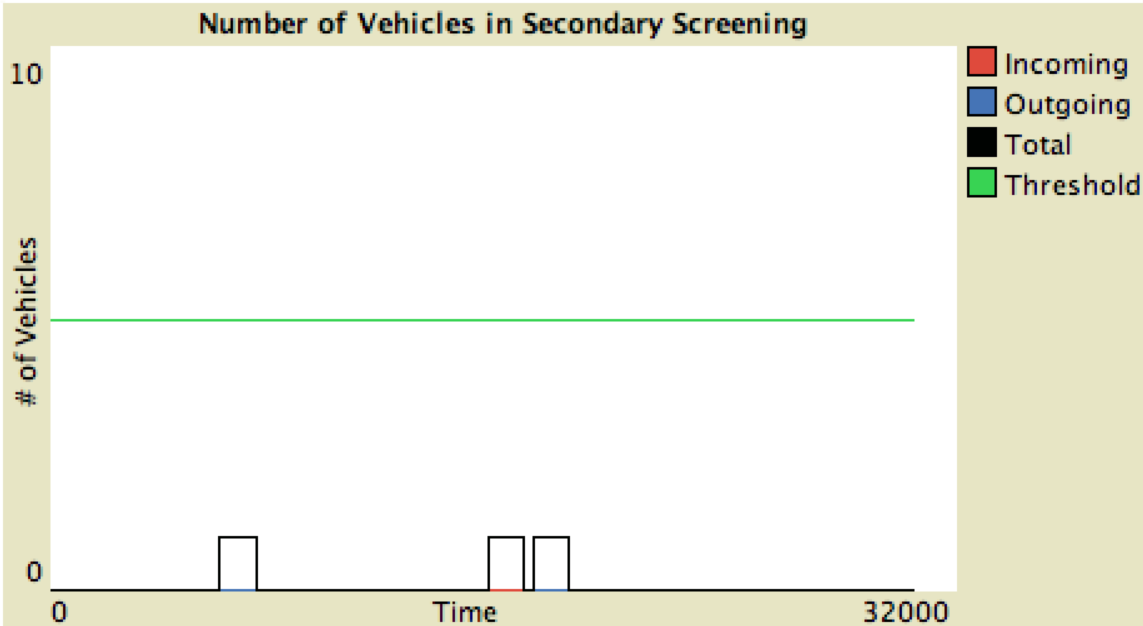

Figure 10. Number of vehicles in secondary screening as a function of time for simulation 1 obtained from the NetLogo model

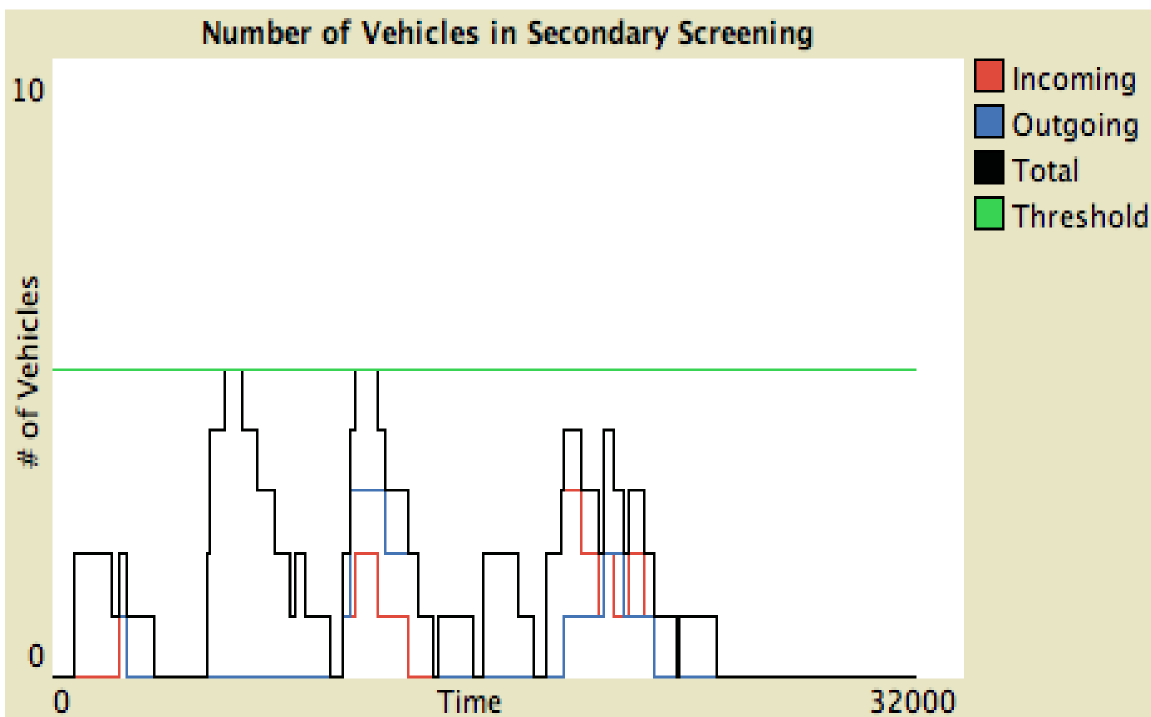

Figure 11. Number of vehicles in secondary screening as a function of time for simulation 2 obtained from the NetLogo model

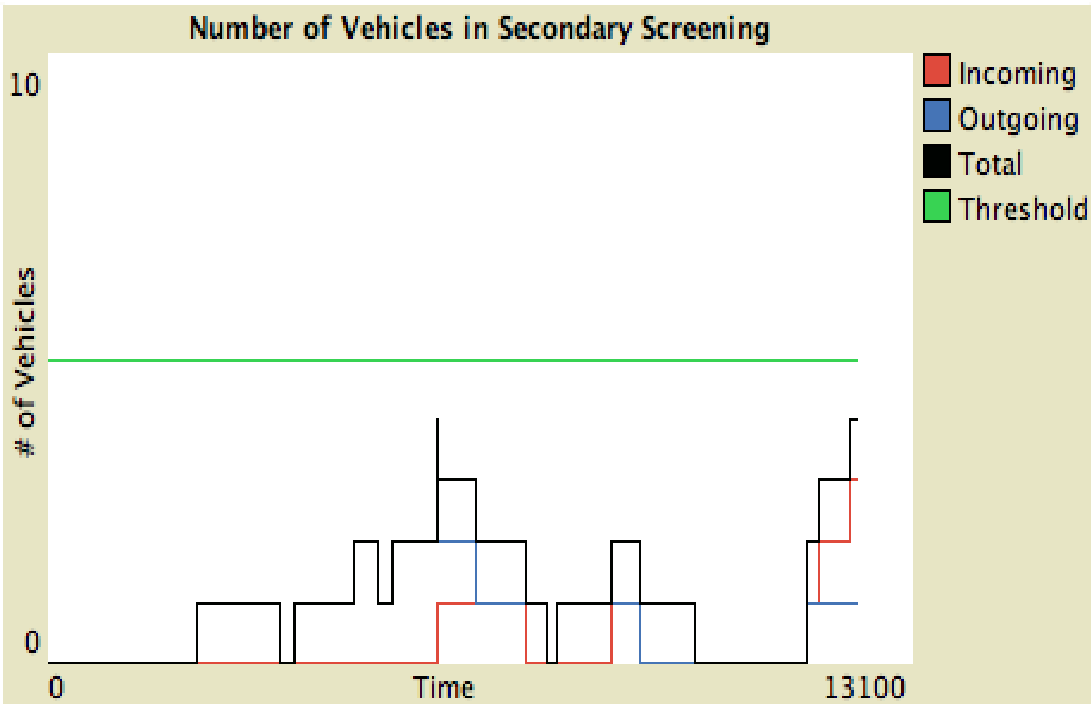

Figure 12. Number of vehicles in secondary screening as a function of time for simulation 3-a obtained from the NetLogo model

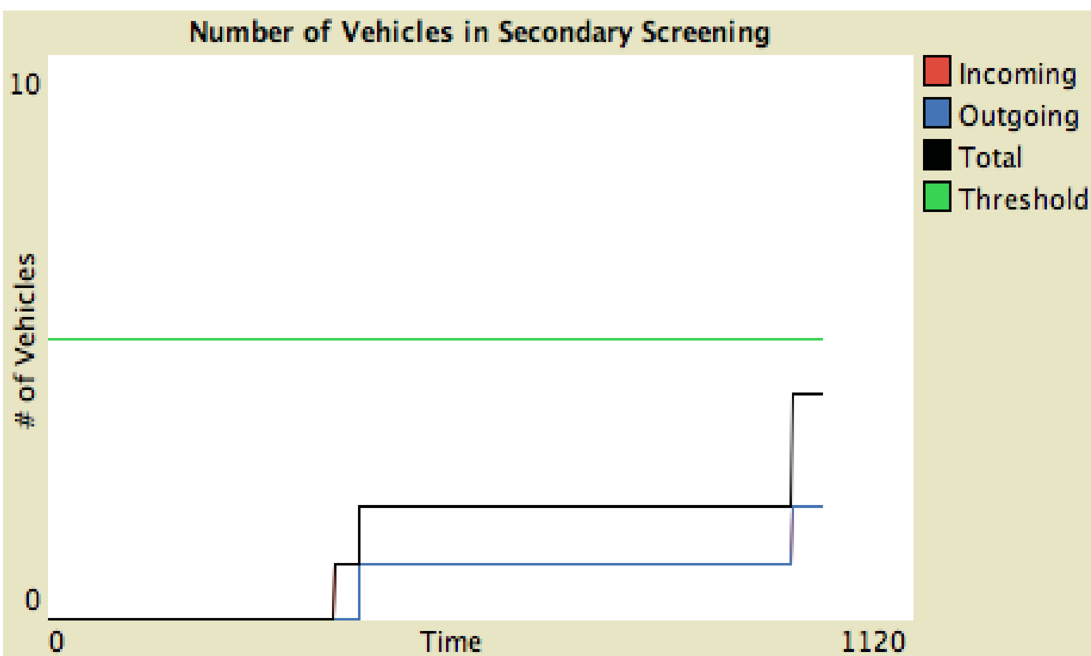

Figure 13. Number of vehicles in secondary screening as a function of time for simulation 3-b obtained from the NetLogo model

The maximum wait time experienced by a vehicle is shown by the green curve in Figure 14. Figure 15 shows the number of vehicles in secondary screening as a function of time. It can be seen from the figure that the threshold level is exceeded for most of the simulation. Therefore with the current density of traffic and discriminator alarm level the security organization would be required to add at least one more set of security officers or increase the discriminator level temporarily. Because the maximum number of vehicles in secondary at any one time during the simulation was 14 the security organization would be required to add two additional sets of security officers, assuming that one new set of officers would be required for each increase of 5 vehicles in the Secondary Inspection station.

Simulation 5 was run with 15 cars and 15 trucks in each lane of the incoming and outgoing lanes of traffic. This simulation serves as the medium volume traffic flow simulation. From this simulation it was determined that the average wait time experienced by all vehicles waiting to cross the border ranged from 250 to 455 ticks. This is a longer wait time than the vehicles in simulation 4 experienced. Figure 16 gives the wait times of the vehicles waiting to cross the border as a function of time, while Figure 17 gives the number of vehicles in secondary as a function of time. It can be seen from Figure 18 that the wait times of the incoming vehicles were higher than the outgoing for a portion of the simulation. This was due to the random placement of the vehicles as they are wrapped back around the model to start the process again. On occasion, one lane will become longer than the rest resulting in longer wait times for vehicles in that lane. As seen in Figure 19 the maximum number of vehicles in secondary was 12.

Therefore using the assumption of a maximum of 5 vehicles with the current number of officers, the security organization would be required to add two additional sets of officers to operate without becoming overwhelmed.
Simulation 6 was the same as simulation 5 except that 20 cars and 20 trucks were placed in each lane of the incoming and outgoing traffic flows. This simulation serves as the high volume traffic flow simulation. Figure 18 gives the wait times of the vehicles waiting to cross the border as a function of time. The average wait time of vehicles ranged from 350 ticks to 570 ticks. Figure 19 shows the number of vehicles in secondary as a function of time. It can be seen from the figure that the threshold level was exceeded once again. However in this simulation the maximum number of vehicles in secondary was 8. This would require the security organization to add only one more set of officers to operate without becoming overwhelmed. Just as was the case for simulation 5, the vehicles in simulation 6 experienced longer wait times than those in simulation 4. The highest average wait time in simulation 6 (570 ticks) is over 4 times the highest average wait time of vehicles in simulation 4 (140 ticks).

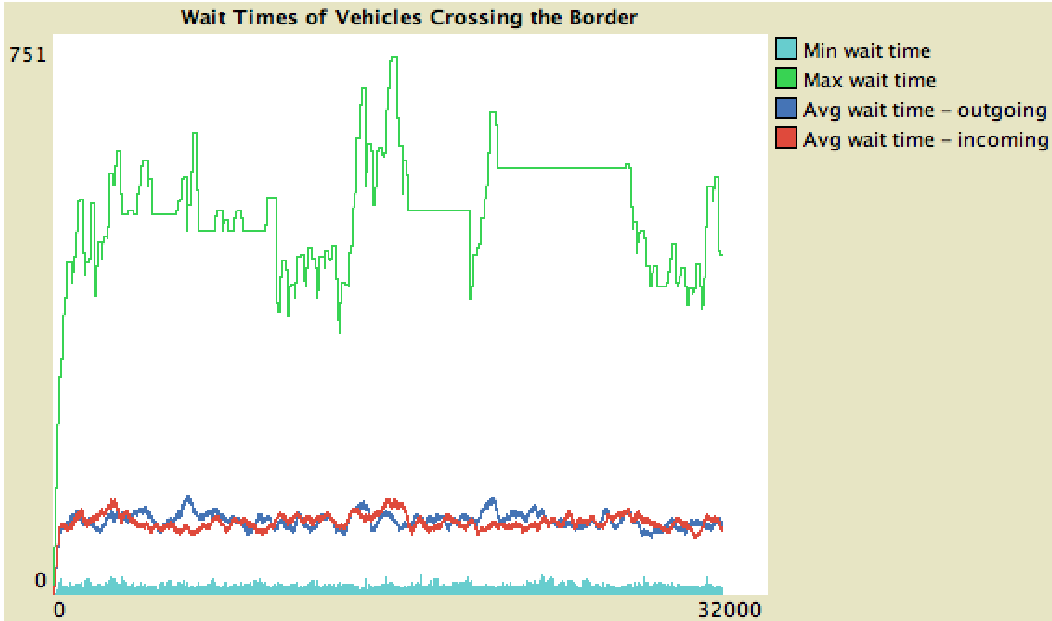

Figure 14. Wait times of vehicles waiting to cross the border as a function of time for simulation 4 obtained from the NetLogo model

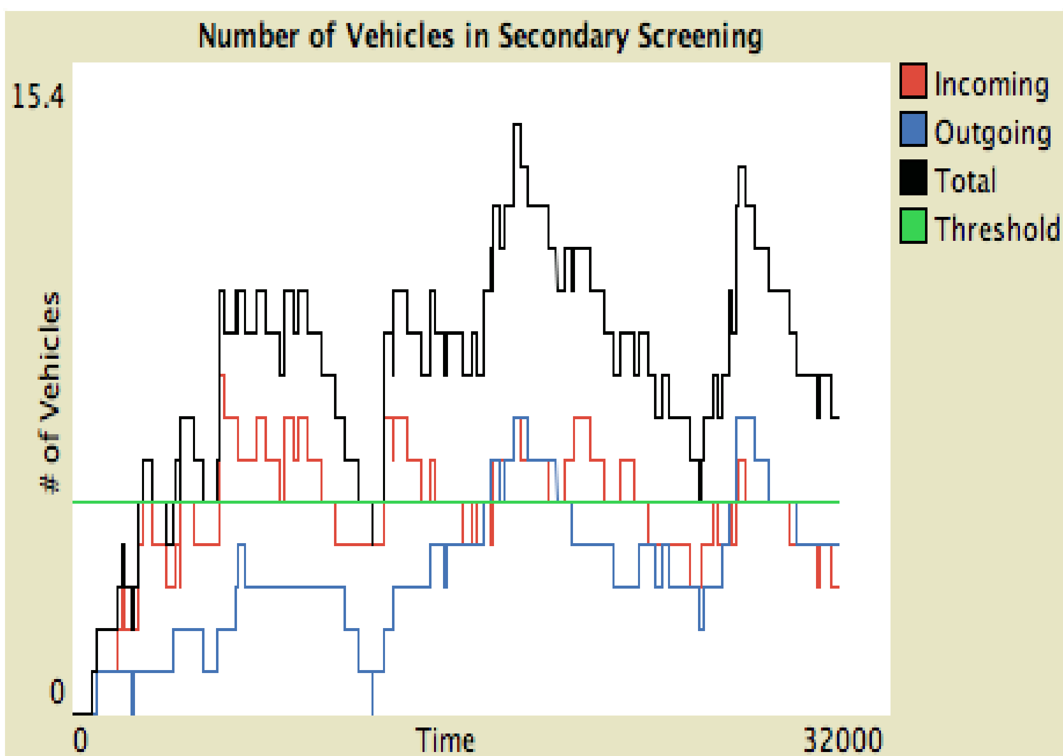

Figure 15. Number of vehicles in secondary screening as a function of time for simulation 4 obtained from the NetLogo model

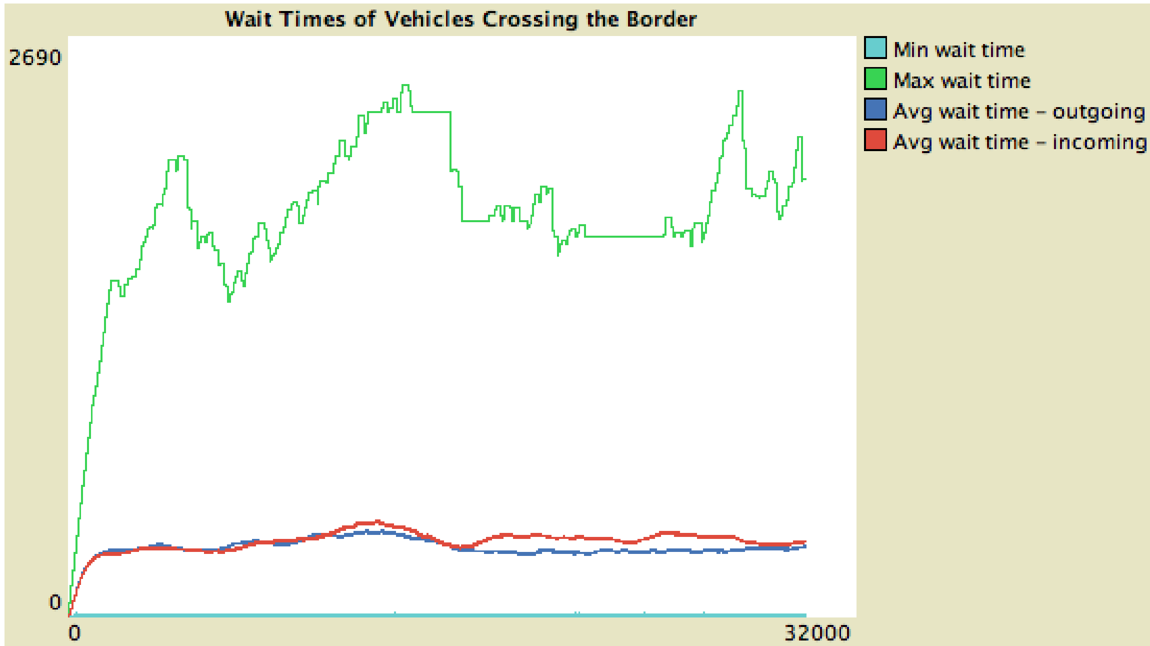

Figure 16. Wait times of vehicles waiting to cross the border as a function of time for simulation 5 obtained from the NetLogo model

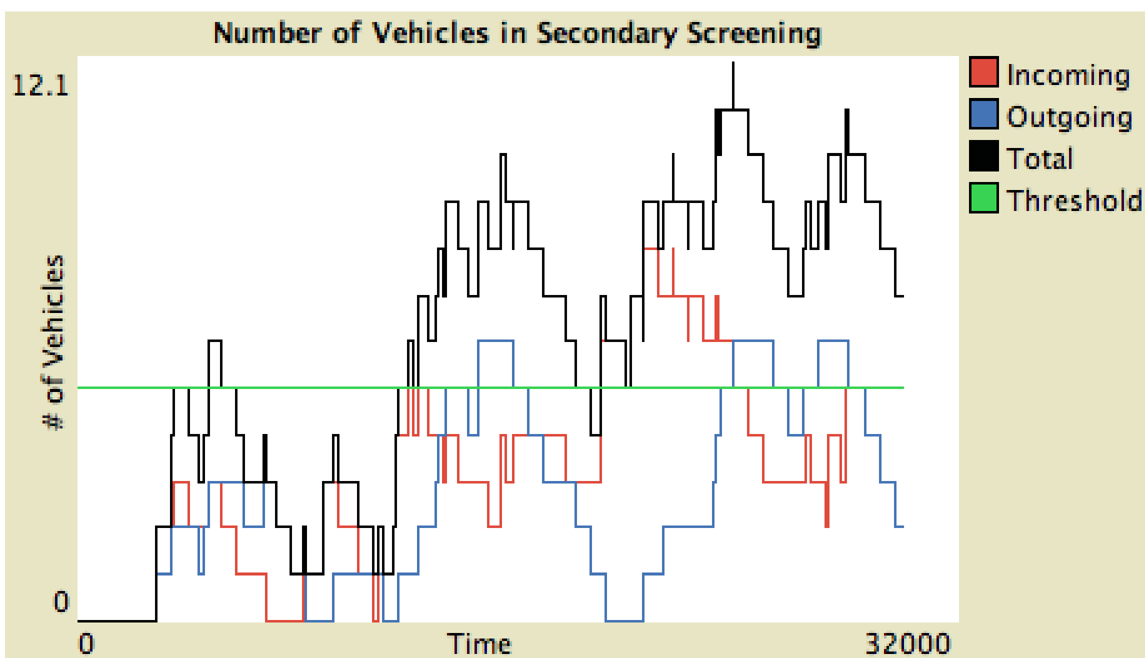

Figure 17. Number of vehicles in secondary screening as a function of time for simulation 5 obtained from the NetLogo model

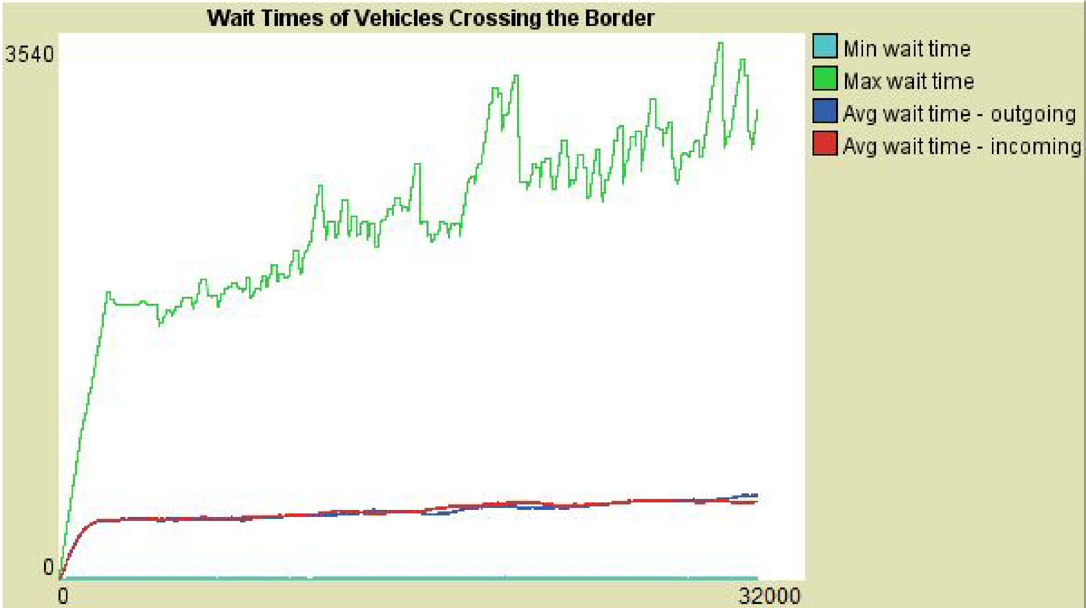

Figure 18. Wait times of vehicles waiting to cross the border as a function of time for simulation 6 obtained from the NetLogo model

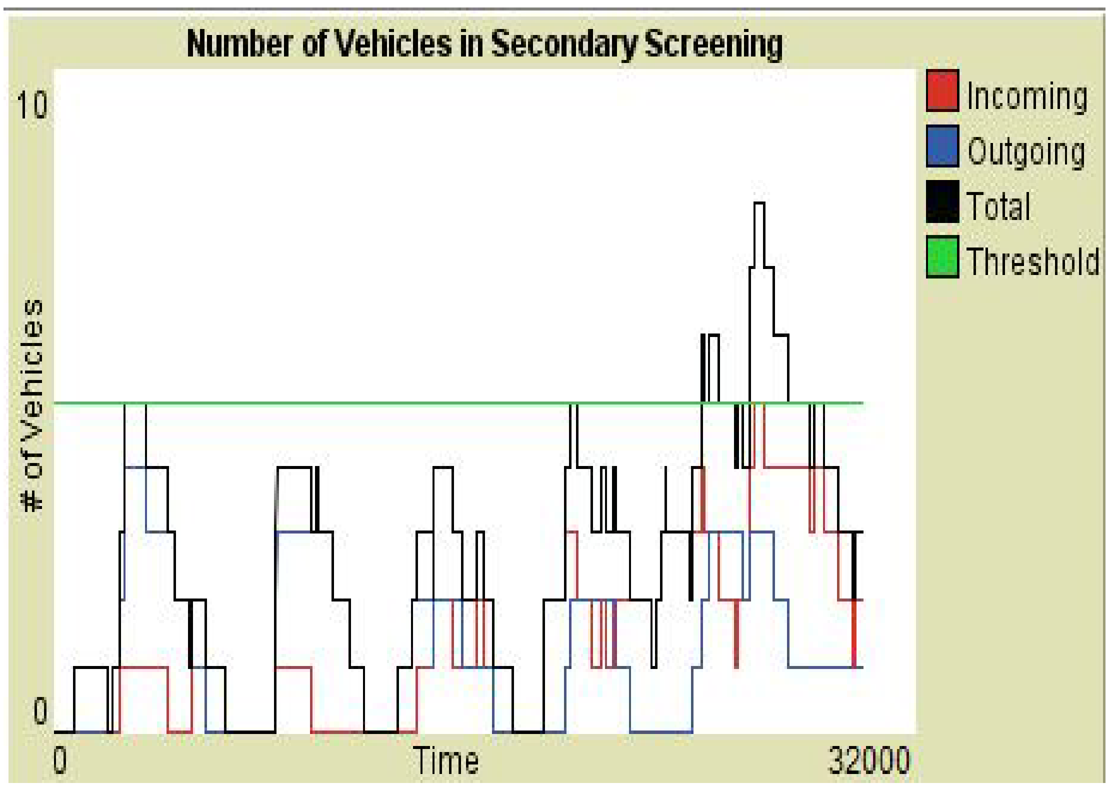

Figure 19. Number of vehicles in secondary screening as a function of time for simulation 6 obtained from the NetLogo model.

The results obtained from the simulations run for this test case show that an increase in traffic flow leads to an increase in the wait times experienced by vehicles waiting to cross the border. This effect was expected. The increase in the number of vehicles means that more vehicles will be screened in primary. It is possible at very low traffic flow rates that a small increase in the traffic flow will not significantly increase the wait times experienced. However, for the 3 simulations run here, increases in the traffic flow rate led to significant increases in the wait times of the vehicles.

A result that was not expected was the number of vehicles that were required to go to secondary screening. In simulation 4 the maximum number of vehicles in secondary was 14. In simulations 5 and 6 the traffic flow was increased but the maximum number of vehicles in secondary was found to decrease to 12 and 9 respectively. Reasons for this unexpected nature could be simply due to the fact that the vehicles required to go to secondary screening are chosen by probabilities assigned from a random number generator. It is also possible that the maximum rate at which vehicles can pass through the primary screening was met in simulations 4, 5, and 6. Therefore the rate at which probabilities are assigned to vehicles passing through the crossing is the same in these 3 simulations. The only difference in the simulations is that the increased flow rate results in longer lines of vehicles backing up behind the primary screening.

Test Case III - Effects of secondary inspection times

Secondary inspections take an extended amount of time when compared to primary inspections. This extended amount of time could have negative effects on the traffic flow through secondary. Therefore it is desirable to determine how improving the speed of resolution of alarms in secondary affects the retardation of flow through secondary as well as the required resources (officers). This test case builds upon the two previous test cases in which detection probability and traffic flow were varied to determine the effects. Therefore 3 simulations will be given: high, medium, and low speed of resolution. The 3 simulations will be run by varying the amount of time that it takes to clear a secondary inspection. Simulation 7 was run with 5 cars and 5 trucks in each lane. Both the incoming and outgoing discriminator levels were set to 0.65 while the average inspection time for a vehicle in secondary was 545 ticks. Just as in other simulations the model was run for 30,000 ticks. This simulation serves as the high speed of resolution simulation. Figure 20 gives the number of vehicles in secondary as a function of time.

Just as in simulation 7, simulation 8 was run with 5 cars and 5 trucks in each lane. The simulation was also run for 30,000 ticks. The only difference between the simulations is that simulation 8 was run with an average secondary inspection time of 770 ticks. Figure 21 gives the number of vehicles in secondary as a function of time.

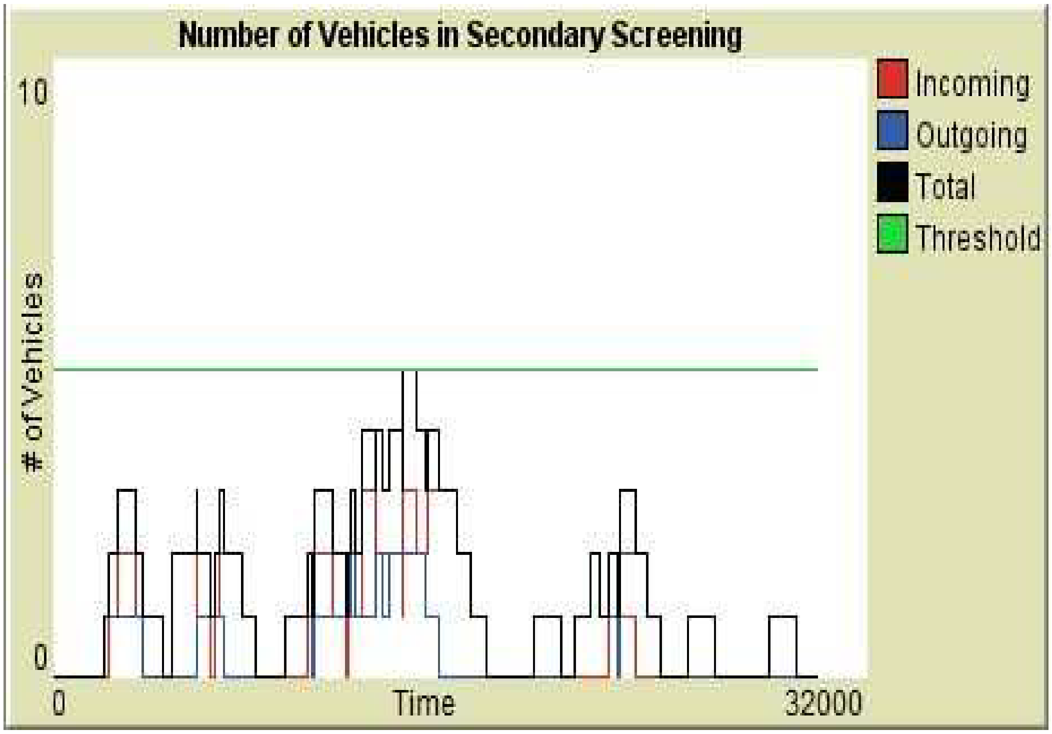

Figure 20. Number of vehicles in secondary screening as a function of time for simulation 7 obtained from the NetLogo model

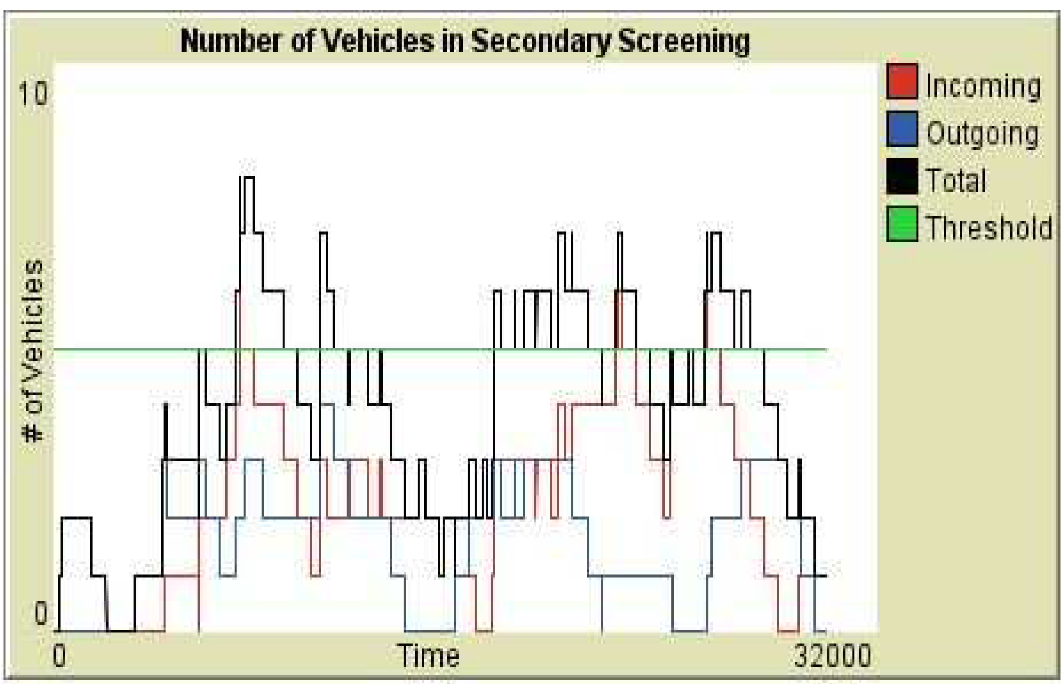

Figure 21. Number of vehicles in secondary screening as a function of time for simulation 8 obtained from the NetLogo model

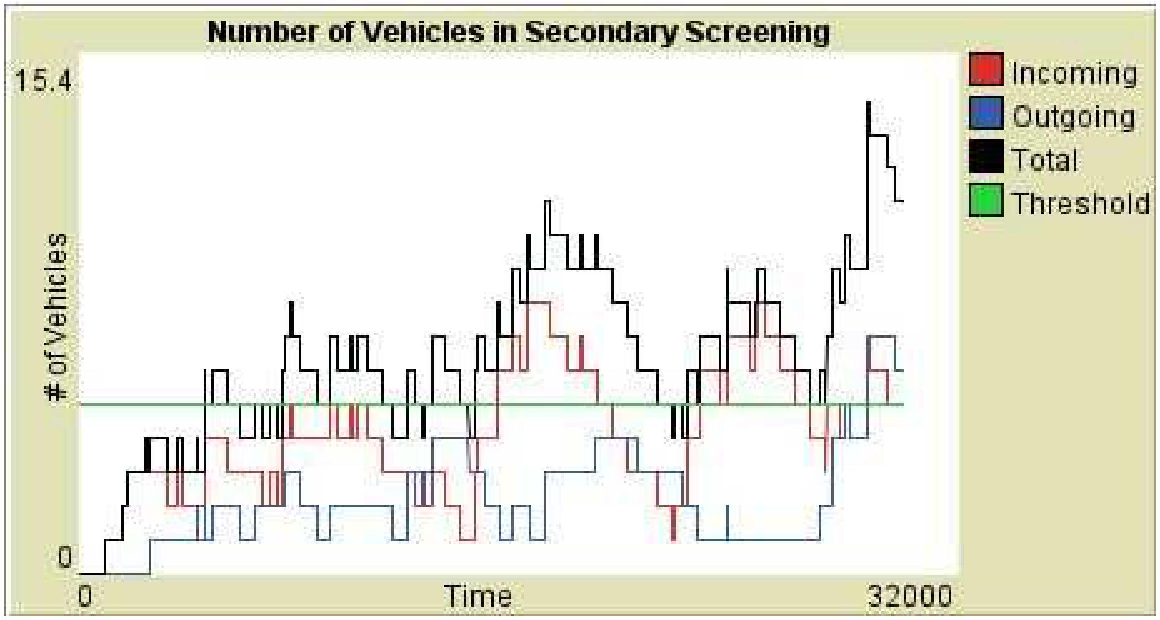

Figure 22. Number of vehicles in secondary screening as a function of time for simulation 9 obtained from the NetLogo model.

For simulation 9, the average secondary inspection time was 1100 ticks. The simulation was run with 5 cars and 5 trucks in each lane, and was run for 30,000 ticks.

It can be seen from simulations 7 through 9, and their supporting figures, that as the average secondary inspection time per vehicle increases, the number of vehicles in secondary increases. This effect is expected. Because of the extended screening times vehicles begin to backup.

Results

3 major test cases were run to determine the effects that varying major inputs have on the wait times on vehicles crossing the border as well as the resources required by the security organization. Test Case I was used to determine the probability of detection in the primary inspection location that would cause the security organization to add one more set of security officers. Discriminator levels of 0.85, 0.65, and 0.63 were used in simulations of this test case. From these simulations it was found that as the discriminator level is lowered the probability of detection of a vehicle with some characteristic requiring Secondary Screening increases. This can be seen in Figure 15. As the discriminator level is lowered the location on the curve is lowered (moved left). This leads to a larger area being above the discriminator threshold level, thus leading to a higher

probability of a vehicle alarming a primary detector. As Figures 18 through 20 show as the discriminator level is lowered the number of vehicles in secondary increases. When a discriminator level of 0.63 was used it was found that the simulation was not able to pass and exceeded the secondary threshold level. Two additional simulations were run to verify the same result using the 0.63 discriminator level. From this it was determined that the lowest possible discriminator level that could be used with the current traffic flow and security officers was in the range of 0.63 to 0.65. Any discriminator level lower than this would require the security organization to add another set of security officers.

Test Case II was used to determine the effects of the primary flow rate on wait times of vehicles and security officers required in secondary. Simulations were run by varying the initial number of vehicles in the model. Figures 18 through 21 show the results of these simulations. It was found that an increase in traffic flow leads to an increase in the wait times experienced by vehicles waiting to cross the border. An unexpected result however was that the number of vehicles required to go to secondary screening did not increase with increasing initial traffic flow. A reason for this could be that the maximum rate at which vehicles can pass through the primary portals was met in simulations 4, 5, and 6. This means that the number of vehicles required to go to secondary in these simulations was strictly dependent upon probability and the numbers generated randomly.

Test Case III helped to determine the effects that varying secondary inspection times have on the vehicles required to go to secondary. Three simulations were run in which the average inspection time per vehicle in secondary was changed. The simulations covered average times of 545, 770, and 1100 ticks. As Figures 21 through 22 show, an increase in the average inspection time causes an increase in the vehicles in secondary.

Conclusions/Future Directions

The results obtained led to a richer overall understanding of border crossings, traffic flow models, and agent-based modeling. As expected, the model showed that increasing the traffic flow through the crossing ultimately requires the security organization to hire additional sets of security officers. This can be rather expensive due to the fact that if one additional security officer is needed for a shift, three more officers on top of the initial one are required. This is assuming three 8-hour shifts as well as a backup. Since we would expect overall traffic flow to vary from hour to hour and from day to day, follow-on work should take those variations into account.

Results also showed that other inputs to the model such as discriminator alarm levels and secondary inspection times have an impact on the system as a whole, as expected. Delays experienced by vehicles waiting to cross the border as well

as the number of vehicles required to go to secondary screening all hinge on these inputs. Therefore it is important to understand how these inputs affect the system. This is why an agent-based model was designed and developed. The model enables the user to change inputs with relative ease to see the effects visually.

Some of the assumptions made when designing this model could be added in future revisions to add more realism to the model and the subsequent simulations. Currently the number of desired vehicles is chosen through the use of a graphic user interface and slider bars. Once the number of vehicles is chosen the vehicles are placed randomly throughout the model as described before. A nice addition would be to improve the code so that a text file could be created as an input to the model. The test file would contain data on the traffic flow rate as a function of time. This would allow an added complexity, such as rush-hour traffic in the morning and evening, to be added to the simulations to see the effects.

Another assumption made was that all vehicles that are required to be screened in the secondary inspection location always pass this secondary inspection. In real life this is not the case. There will be occurrences in which the problem causing the primary alarm cannot be resolved with the personnel or equipment on site. There is also the possibility that a more serious situation would be suspected, like an explosive or a chemical or biological hazard. In either case the event must be logged and the proper authorities must be notified. Therefore the addition of these scenarios would allow yet another set of effects to be viewed that are not possible with the current model.

We have assumed that all primary inspections take the same amount of time. We also assumed that for the secondary inspections except the secondary inspections were given a longer length of time. In reality there will be a distribution of times that it takes for vehicles to pass through the primary and secondary inspections. Using probability distributions, ranges of times could be assigned to all vehicles passing through primary and secondary inspections.

Dynamic Simulation Model for Addition of RadNuc Mission

Addition of RadNuc mission to hypothetical border crossing

For this next phase, we will assume that Country A has decided to add the RadNuc mission to the operations around the border crossing. The following assumptions also are made:

1. Country B will also add a RadNuc mission to its border crossing
2. The sponsoring organization for this initiative is Country A Department of Homeland Security (DHS-A).

3. Instrumentation will be added to the border crossing to help detect the presence of radiological and nuclear materials.
4. DHS-A will specify the operating parameters of the equipment
5. DHS-A will provide funding for the initial purchase of the equipment.
6. These RPMs will include measurements of gamma and neutron radiation as the vehicles slow down and then stop for Primary Inspection.

Equipment involved

In our model, there will be a radiation portal monitor (RPM) at each Primary Inspection Station. This will serve as the primary detection location for radiation detection. The RPMs at each toll booth will be equipped with both gamma and neutron detection capabilities. The secondary inspection location will be utilized to examine further any vehicles that alarm a detector in the primary inspection location. The secondary inspection location will be comprised of: a second RPM to verify the first hit, handheld detectors equipped with an radioisotope identifier, and radiography equipment (e.g., to scan a whole truck spatially, etc.)

Typical operating procedure

In this section an example is used to show the typical RadNuc screening process flow of a vehicle through our hypothetical international border crossing. As a vehicle enters the primary inspection location primary screening begins. At this time the monitor will begin a gross neutron and gamma count. During primary screening official documents such as passports, driver's licenses, shipment manifests, etc. are verified. Once the vehicle has passed any toll requirements, the gross gamma and gross neutron counts recorded will be compared to the normal background count. Depending on the outcome of the count the vehicle is either allowed to proceed through the crossing or is required to go to the secondary inspection location for further screening.

If the vehicle is required to go to the secondary inspection location, it is escorted to a monitoring station where it will first go through another RPM monitoring system much like that in Primary to see if the readings that lead to the alarm are repeated. The next step would involve inspectors doing visual inspections as well as using a hand-held monitor to determine the location of the radioactive materials in the vehicle. Inspectors will also review any licensing or permit information. If the radioactive material is identified and is found to be an innocent source, the occurrence is logged and the individual is released. If the source is identified as not consistent with the list of innocent radiation sources, the occurrence is logged and technical assistance is contacted for further guidance. If the source cannot be identified then the personnel associated with the vehicle as well as the vehicle itself are examined further. If the cause of the alarm is judged to meet requirements and no danger is discovered, the occurrence is documented and the individual is released.

The following assumptions were made about the radiation portal monitors (RPMS), neutron detectors and the level of radioactivity in the trucks and cars. Radiation Portal Monitors (RPMs) will include gamma radiation detectors and neutron detectors. The outputs of the RPMs will be gamma and neutron readings as a function of time as the vehicle travels by the RPMs. The discriminator settings for gamma alarms and for neutron alarms can be set at whatever level we choose. But there will be consequences for setting the alarms at a particular level. If the discriminator level for gamma radiation is set to zero, any gamma reading above zero will trigger an alarm. If any gamma alarm results in a decision to send the vehicle to Secondary, then it might be possible that vehicles would be sent to Secondary frequently enough that the capability of the existing officers to resolve the alarms would be overcome.

Since one of the new mission spaces for Secondary Inspection will be for adjudication of alarms that occur in the Primary lanes, the Secondary station will also have more radiation detection equipment that has some isotopic identification capabilities and is portable so that hot spots of radioactivity can be determined.

Occasionally there will be cases where the Secondary Inspection area will not have the capability to resolve the question about whether the radioactive material is only normally occurring radioactive material (NORM).

For those cases, we assume the border crossing will have another area called Tertiary. In this area, the drivers and other occupants of the vehicles will be separated from the vehicles, the vehicles will be placed under stricter administrative controls, and additional assets will be called in to help resolve the radiation readings. In some of these cases, specialized capabilities will be called upon to ensure that the vehicles can be inspected manually. This might involve the use of bomb squads from regional police or fire departments. This Tertiary Inspection Area is not shown in the Google SketchUp diagrams but is shown in the user interface of the two dimensional dynamic simulation model. The large space between the incoming and outgoing lanes of traffic is the secondary inspection location and serves to be a further (second) screening location in the event that the primary inspection location detector alarms. The actual location of the secondary screening is the horizontal green bar located in the center at the top of the secondary inspection location. If a primary inspection location detector alarms vehicles are escorted to the secondary inspection location by a security officer so that a second screening can be done to confirm the validity of the first alarm. Figure 23 below shows an image of the model with the simulation in progress. It can be seen how traffic backs up at the Primary Inspection Areas. Also shown in Figure 23 is an incoming (red) vehicle in the secondary inspection location.

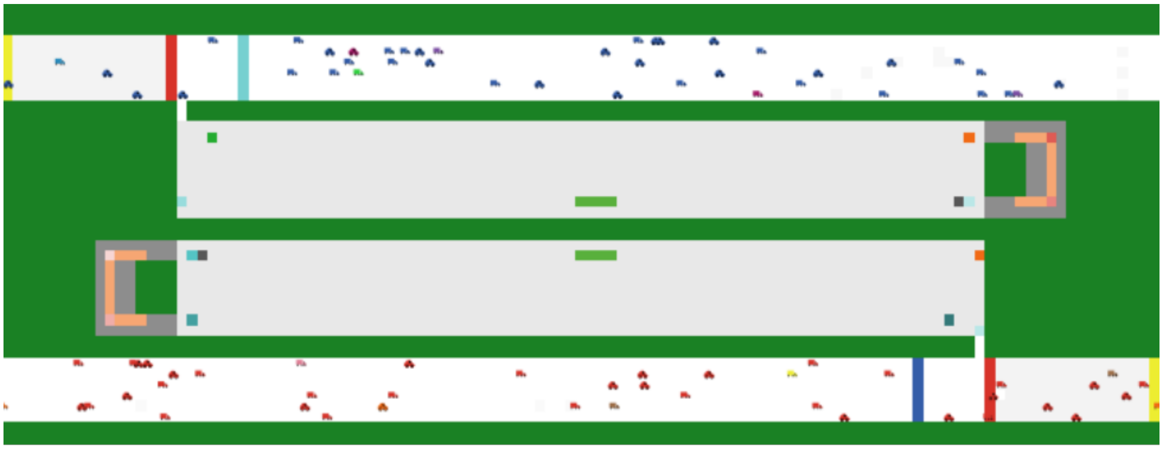

Figure 23. Two dimensional simulation model layout of border crossing

Assumptions for vehicle radioactivity (incoming/outgoing colors)

To screen for the RadNuc threat, the system will measure gamma and/or neutron radiation emanated from a vehicle in the field of view of the RPM in Primary Screening. In truck traffic, there will be a broad range of commodities, most of which will not emanate any radiation (detectable by our RPMs). Some of these, however, will still fail some of the screening done in Primary Screening and will be sent to Secondary for resolution of the problem. Possible causes include improper paperwork, improper decaling, and vehicle weight different than expected and suspicious behavior of the driver or passengers. At some border locations, vehicles are occasionally selected on a random basis for Secondary Screening.(Organization for Security and Co-operation in Europe, 2012)

The adapted model will continue to simulate the stochastic variation in the rate at which these vehicles are sent to Secondary for reasons not associated with the RadNuc screening mission – and then add the impact of vehicles failing the radiation screening system in Primary Screening.

In this adapted model, there are six types of vehicles, with differing levels of radioactivity either in the commodities carried by the trucks, the luggage in the cars, or radioactive medical burdens in the people in the vehicles as a result of medical treatments or diagnostic tests. The types of radiation detected by the RPMs and the portable radiation detectors only include gammas and neutrons, as is normally the case in border crossings.(International Atomic Energy Agency, 2013) In this model, most vehicles (85.6%) do not contain enough gamma or neutron radiation to trigger an alarm even at the lowest setting on the RPMs. Actual levels of radioactivity in vehicles going across border crossing will vary from location to location and occasionally from season to season. In the dynamic

simulation model, trucks or cars with no measurable radiation are called Non RadNuc. They will show up as red for vehicles coming from Country B into Country A and as blue going from Country A into Country B. [For our model, we were constrained by the icons we could assume at one time. The model uses a total of 6 types of vehicles having different types and levels of radioactivity, leaving 36 non RadNuc vehicles for a ratio of 85.6%.]

For radioactive classes of trucks and cars, the model uses arbitrary units for the expected levels of gamma and neutron radiation. This approach stays well away from any classification issues. There is a great deal of sensitivity around the levels of radiation emanating from vehicles, how well it could be detected by RPMs (and more advanced sensors), and the level of radiation given off by different types of commodities in different types of packaging in different types of vehicles. These details about radiation levels and energy spectra associated with the radiation are really not very relevant to the strategic questions addressed in this dissertation.

However, we do want to examine how RadNuc screening at different discriminator levels will impact throughput, backups in Secondary and other operational considerations. To give some detail in these operational considerations, the model includes various classifications, reflecting broad levels of radiation (gamma and neutron) that we might expect to be emanated from the vehicles. The broad categories are named in terms of low or high gamma radiation emanations and low or high neutron emanation levels.

Two in 42 (4.8%) of the vehicles will be trucks with a low level of gamma radiation and no neutron radiation. Truck cargo occasionally does have some gamma radiation coming from potassium-40 bearing materials taken from the earth. Examples are bricks, stones and plants. Generally, this type of cargo has no neutron radiation. In the model, these are called Lowgamma trucks. They will show up as brown for vehicles coming from Country B into Country A and as violet going from Country A into Country B. The gamma radiation level was set arbitrarily at 5 and the neutron radiation level was set to 0 (since this type of cargo has typically has no neutron radiation measureable in our border crossing scenario).

One in 42 (2.4%) of the vehicles will be a truck with a medium level of gamma radiation and no neutron radiation. In our model, this type of truck cargo would have some more gamma radiation than that coming from potassium-40 bearing materials taken from the earth. Examples are small to medium commercial, scientific and medical radioisotopes.(Kouzes, 2009) Generally, this type of cargo has no neutron radiation. In the model, these trucks are called Medgamma trucks. They will show up as pink for vehicles coming from Country B into Country A and as sky blue going from Country A into Country B. The gamma radiation level was arbitrarily set at 10 and the neutron radiation level to 0 (since

this type of cargo has typically has no neutron radiation measureable in our border crossing scenario).

One in 42 of the vehicles (2.4%) will be a truck with a high level of gamma radiation and no neutron radiation. This type of truck cargo would have significantly more gamma radiation than that coming from potassium-40 bearing materials taken from the earth. Examples are large commercial and scientific radioisotopes, as well as drivers or passengers who have had recent medical treatments. These are called Highgamma trucks in our model. They will show up as orange for vehicles coming from Country B into Country A and as magenta going from Country A into Country B. The gamma radiation level was arbitrarily set at 100 and the neutron radiation level to 0 (since this type of cargo has typically has no neutron radiation measureable in our border crossing scenario).

One in 42 (2.4%) of the vehicles will be a truck with a medium level of gamma radiation and some detectable neutron radiation. This type of truck cargo would have somewhat more gamma radiation than that coming from potassium-40 bearing materials taken from the earth. But in this class of vehicles, there will be neutron emanation at a level high enough to be detected in Primary Screening. Examples are commercial items like moisture gauges and scientific radioisotopes. Other examples would include trucks carrying significant quantities of nuclear reactor fuel (UO_2 or UF_6). Another type of neutron alarm can be generated when a shower of cosmic ray particles strike high-Z materials and generate neutrons. This occasional spike in neutron levels around materials in cargo generates nuisance alarms. Since plutonium emits neutrons and since plutonium is an element of concern for nuclear weapons, any significant neutron detection would likely cause a vehicle to be stopped and sent to a Secondary for alarm resolution. We assume that will be the operational concept our model. These are called Neutron trucks in the model. They will show up as yellow for vehicles coming from Country B into Country A and as lime going from Country A into Country B. The gamma radiation level was arbitrarily set at 10 and the neutron radiation level to 5 (since this type of cargo typically will have neutron radiation measureable in our border crossing scenario).

One in 42 (2.4%) of our vehicles will be a car with a high level of gamma radiation and no neutron radiation. In the model, for this case the drivers or passengers in the cars will have had recent medical treatments. These are called Cargammas in our model. They will show up as orange for vehicles coming from Country B into Country A and as magenta going from Country A into Country B. The gamma radiation level was arbitrarily set at 100 and neutron radiation level to 0 (since people generally have no neutron radiation measureable in our border crossing scenario).

A summary of these types of vehicles, their distribution and the color code for incoming and outgoing vehicles is shown in Table 4.

Table 4. Radioactivity types and levels for vehicles in the dynamic simulation model

Turtle Name	Type	Fraction	Gamma	Neutron	Incoming	Outgoing
Non RadNuc	Truck and Car	85.6%	0	0	Red	Blue
Lowgamma	Truck	4.8%	5	0	Brown	Violet
Medgamma	Truck	2.4%	10	0	Pink	Sky
Highgamma	Truck	2.4%	100	0	Orange	Magenta
Neutron	Truck	2.4%	10	5	Yellow	Lime
Cargamma	Car	2.4%	100	0	Orange	Magenta

This means that 14.4% of the vehicles in our model contain radioactive materials of a quantity to have gamma or neutron emanations to be detectable by RPMs at Primary Screening.

The dynamic simulation model will show the movement of the trucks as cars as a function of time. By observing the shapes (truck icons look like trucks and car icons look like cars) and the colors, one can watch how the various classes of cars and trucks move through the system, including Secondary.

Developing the concept of operations resulted in questions about how to handle a truck with a neutron signature (yellow color for incoming or lime for outgoing). Neutron alarms are frequently resolved by a quick scan of the vehicle to see if there are still neutrons detected near the vehicle. In some occasions the neutrons emanations were caused by the “ship effect” and, therefore, the new measurement will not detect neutrons.(Kouzes, Siciliano, Ely, Keller, & McConn, 2008) But in our case, the Neutron Truck actually will have neutron sources on board. The screening official will not know a priori whether it was a ship effect measurement. But when an official measures in Secondary, he will also continue to detect neutrons. This can cause a significant concern. The author has observed border crossing personnel escorting vehicles in this type of situation to a separate part of the station, which we will call the Tertiary Screening Station, where the vehicle is kept under strict administrative control until the neutron alarm is resolved. In the model analyst interface, the Tertiary Screening Station is shown within the large dark gray lot with a peach colored stopping strip. In the model, Neutron Trucks would be held in Tertiary for considerably longer times than would be expected for Secondary. In our model, the officials will stop vehicles for about an hour in Tertiary as opposed to 20 minutes in Secondary stopping strip.

As we set up the model, there are a number of obvious questions which spring up. Where would Tertiary Screening actually take place? What would really happen in Tertiary screening? What organizations would need to be involved?

How could we be assured that those organizations are committed to support Tertiary Screening, especially if they have simultaneous demands on their time elsewhere?

The first question about where Tertiary screening would take place points out that the Country A General Services Administration, GSA-A, will have to make a special place available for Tertiary Screening at the border crossing station. That might require allocation of already limited space at the station. It might require special fencing or other physical boundaries to help secure the vehicle. It might also require a low background radiation site. A correlated question would be whether there already was a Tertiary Screening Area at the station because of a similar need for Non-RadNuc reasons. Some border stations already have large x-ray stations that can radiograph an entire tractor trailer to nonintrusively produce an image of the cargo inside the vehicle. In that situation, provision of the space might be simple. But for the case where there is limited space available, this might be an obstacle.

The second question addresses the concept of operations for Tertiary Screening for RadNuc threats. Possibilities include further examination of the information related to the manifest, the driver, the vehicle and the shipper. Other possibilities include slower, more complete scanning of the vehicle for better characterization of any radiation hot spots, using higher resolution gamma detectors to look for radioisotopes that have gamma and neutron emanations. Another possibility is a reachback capability in which a group of experts with more advanced knowledge of radiological and nuclear threats would review the information and provide advice. A related question then would be which organization would provide this reachback capability and how would we know they had an enduring commitment to provide it? A possibility is that some official would decide that the inside of the vehicle and its cargo should be examined physically. This would require legal standing to open a car trunk or to open the trailer behind a truck. But that decision would probably require first that the vehicle be examined to ensure there was an acceptable risk that opening the trunk or trailer would result in catastrophic results. For example, a bomb squad would travel to the border crossing station from some nearby authority to examine the vehicle for some sort of explosive device. We have observed that some police organizations and some fire organizations have this capability. That possibility then raises another set of questions. Which organization would have the responsibility (and with what liability) to certify the vehicle safe to open? What set of agreements would need to be in place to provide this service on a timely basis? Our assumption is that this capability would not be needed frequently at the station and, therefore, would not reside at the facility. But if there were situations in which this capability would be required for three hours a day, which would be problematic. It is possible, then, that this capability might be offered by more than one organization in the region. In that situation, there would be a more complicated, but maybe more reliable, set of relationships and agreements required.

These questions add to our list of discovered questions and metrics for consideration later in the dissertation.

Cases Investigated

Four cases were examined. The first case, Case A, represents the situation at the border crossing before the RadNuc mission is introduced. The dynamic situation model was made to correspond to this case by setting the discriminator alarm levels for gammas and for neutron above any radiation level exhibited by the trucks and cars. The model should show that traffic will flow along readily, with some vehicles sent to Secondary to resolve paperwork or other issues not associated with the RadNuc mission. The buildup of vehicles in Secondary should be on the average below 5 vehicles because we have designed our protocols to be manageable with the number of Secondary screeners on site to handle up to 5 vehicles at one time.

The second case, Case B, shows the impacts of adding a RadNuc screening mission onto the existing framework of mission screenings (law enforcement, immigration, vehicle safety, vehicle registration, etc.). For Case B, the RPM discriminators at set a level where some vehicles would set off radiation alarms in Primary and then be sent to Secondary for resolution of RadNuc alarms. For this case, the secondary screeners will have to be trained to use a set of specialized equipment and to use additional protocol steps beyond those already in place for non-RadNuc mission space. For this and other RadNuc cases, the model has to include a Tertiary for the situations where the Secondary screeners cannot resolve the alarms. This might occur if the instrumentation indicates the gamma radiation profiles or neutron presence that seem out of character from the vehicle manifests or the explanations of the drivers of the vehicles. These situations can be difficult to adjudicate. In some cases, radiographic images of the entire vehicle can be performed with specialized equipment and specially trained operators. These images can help the officer to understand the configuration of the cargo and verify it agrees with the description in the manifest and/or the explanation given by the driver. Sometimes off site support may be required from reachback specialists in characteristics of RadNuc threats. In Tertiary, there may be a requirement for opening the vehicles and performing manual inspection of the cargo. But if the vehicles and their cargo in Tertiary are considered possible RadNuc threats, other specialists might be required to determine whether it would be safe to open the vehicles (trailers, trucks or trunks of cars, for example). These specialized skills generally are found in local police or fire departments. The time to resolve alarms in Tertiary Screening can vary widely. Our model assumes a resolution time of one hour.

The third case, Case C, examines the impact of a more aggressive application of RadNuc screening. The discriminator settings for gamma and neutron radiation

are set to only alarm for pretty significant gamma levels and for pretty low neutron levels. The model should show that more vehicles would be sent to Secondary and occasionally to Tertiary.

The fourth case, Case D, examines the effect of very aggressive application of RadNuc screening. The discriminator settings for gammas and neutrons will be set so that any detection of gammas or neutrons will cause the vehicles to be sent to Secondary Inspection. We would expect enough vehicles to be sent to Secondary to overwhelm the capacity for Secondary screeners to resolve the alarms in reasonable time frames. The model should show that the number of vehicles sent to Tertiary might overwhelm the capacity of the specialized teams to adjudicate the alarms.

The summary of the conditions in Cases A through D is given in Table 5. The results of these dynamic simulations for each of these cases will be discussed first. Then the impacts of these results on the geopolitical constructs will be considered. This will support our discussion of metrics for predicting the long term efficacy of applying the RadNuc mission into this border crossing construct.

For the user interface of our updated dynamic model, we use the color coding shown in Table 6. This will make it possible to see which types of vehicles are at what positions at various times during the simulation. In fact, one can watch individual vehicles as they move throughout the system during the simulation, observing whether they pass through Primary without significant delay, have to go to Secondary or even have to go to Tertiary Screening, as shown in Figure 23. The analyst can see how long each vehicle stays within the screening areas. This allows us to determine the effects of changing discriminator levels of various types of vehicles during the simulation.

We show in Figure 24 a more complete view of the analyst interface for this updated model. On the left side of the analyst interface to the dynamic simulation model, we have located 15 slider bars. The sliders can be moved to change the values of fifteen parameters. The first parameter is the number of nonradioactive trucks in the simulation set up. The second slider bar is to set the number of nonradioactive cars. The third is the number of Lowgamma trucks (which we have described as having the radiation levels of gamma reading of 5 for gammas, and 0 for neutrons). The fourth is the number of Medgamma trucks (gamma reading of 10, neutron 0), and the fifth is the number of Highgamma trucks (gamma reading of 100, neutron 0). The sixth is the number of Cargammas (gamma reading of 100, neutron 0), and the seventh is the number of neutron trucks (gamma reading 10, neutron 5). The eighth is the discriminator level we use for normal screening (regulatory compliance, immigration, safety, etc.) for traffic coming into Country A, the ninth slider bar is the discriminator level we use for normal screening for traffic traveling from Country A into Country B.

Table 5. Cases represent different levels of screening for RadNuc threats

Case	Gamma discriminator level	Neutron discriminator level	Represents
A	143 (>100)	7 (>5)	Case where no RadNuc screening is carried out
B	41(>10)	1	Lower level of RadNuc mission screening
C	8 (>5)	1	Medium level of RadNuc mission screening
D	0	0	Very aggressive screening; any radioactive material would result in alarm

Table 6. Color coding for dynamic simulation model layout

Feature	Description	Color on model graphic
Border Crossing	Hypothetical border crossing	Red
Radiation Detector	Radiation portal monitor station (RPM)	(Blue/Sky Blue)
Secondary	Secondary inspection zone	Light Gray
Secondary Stopping Strip	Location where secondary screening occurs	Light Green
Tertiary	Area where suspect vehicles failing secondary screening are examined	Dark Gray
Tertiary Stopping Strip	Strip where model counts vehicles as being in tertiary screening	Peach

The tenth is for the discriminator level for neutrons, the eleventh is the discriminator level for gammas. The twelfth sets the criterion for the allowable number of vehicles in tertiary screening, the slider bar next to that is to set the criterion for the acceptable number of vehicles in secondary screening. The two bottom slider bars are to set the acceleration and deceleration values for the vehicles in our simulation.

Results for Case A

In Case A, we set the discriminator levels for gammas and neutrons so high that none of our vehicles trigger an alarm. This case could represent the situation before the RadNuc mission would be applied to the border crossing. Since there

will be no alarms, then the only vehicles that would be sent to Secondary would be those that are sent there because of some other issues for which the border crossing officers in Primary are not satisfied. The actual model settings for this case have the discriminator setting for gamma counts at 143 and the neutron count rate set at 7. Since in our model the highest gamma reading for any truck or car is 100 and the highest neutron reading is 5, it is clear that there would be no situation for which a truck or car would be sent to secondary for a RadNuc mission for Case A. These settings are shown in the slider bar section of the analyst interface in Figure 24.

A larger view of the part of the analyst interface showing simulated traffic at 10800 seconds is shown in Figure 25. The model shows that there are two trucks in the outgoing Secondary, one of which is in the way out. In Figure 26, the model shows that the number of vehicles that are in secondary screening for incoming and outgoing both reach 3 but remain below the threshold of 5 vehicles above which we are assuming that additional secondary screening officers would be required. Therefore, no extra secondary screening personnel or additional secondary space is necessary. In Figure 27, results show 4 vehicles in incoming secondary at about 7500 seconds, but they are cleared out of Secondary by the end of the simulation.

As we also would expect, there are no cars or trucks sent to Tertiary because this is the case for which there is no RadNuc mission screening. It remains empty at the highest discriminator level because the RPMs are essentially turned off. The plot in Figure 28 below shows a value of zero for the number of vehicles sent to Tertiary.

The number of vehicles waiting to cross the border during the simulation for Case A is about 30 to 35 for both incoming and outgoing (for a total of 70-72), as shown in Figure 29, or about 6 per lane for the 12 lanes. We will assume that this level of backup is acceptable to the Customs and Border Patrol of Country A and Country B. This seems like a reasonable assumption for a border crossing operation that is very efficient.

In Figure 30, model results show that around 1050 incoming and 1050 outgoing vehicles (for a total of 2100) have crossed the border in the 10,800 seconds of simulated time (3 hours). This means that an average of about 59 vehicles per hour will cross the border in each lane. This rate of vehicles passing through each lane would indicate that our border crossing process is reasonably efficient and that the concept of operations for dealing with all of the missions before RadNuc screening is introduced does not lead to a significant delay in traffic.

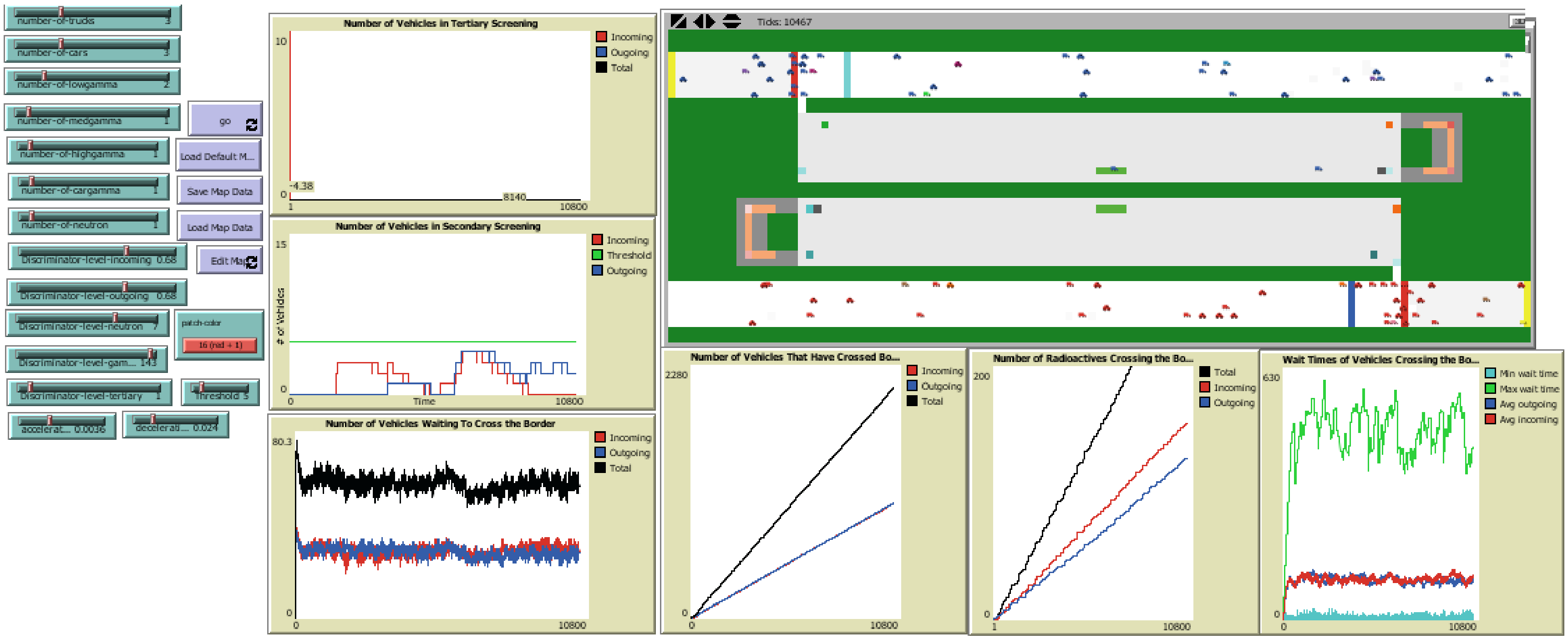

Figure 24. Analyst interface for two-dimensional dynamic simulation model for Case A

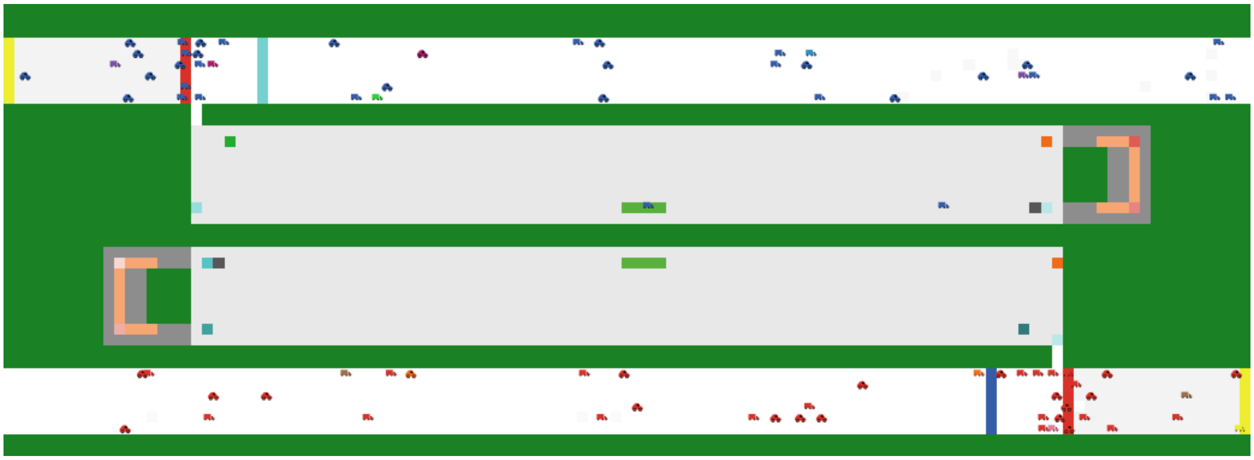

Figure 25. Enlargement of operator interface showing traffic flow for Case A

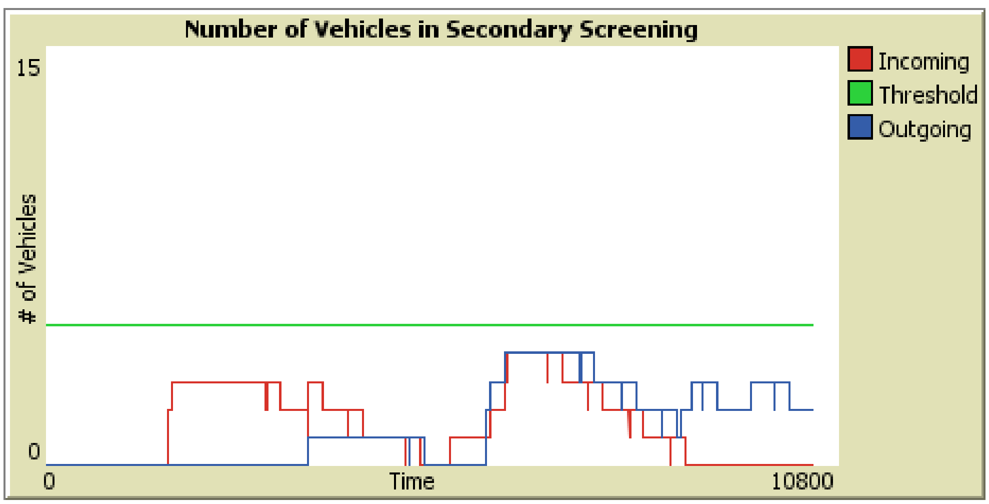

Figure 26. Number of vehicles in secondary screening for Case A

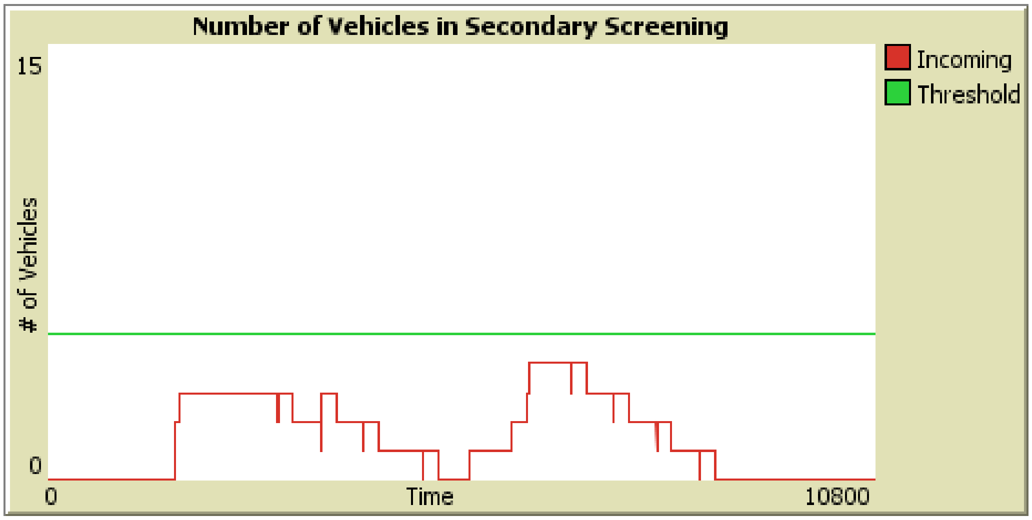

Figure 27. Number of incoming vehicles in secondary screening for Case A

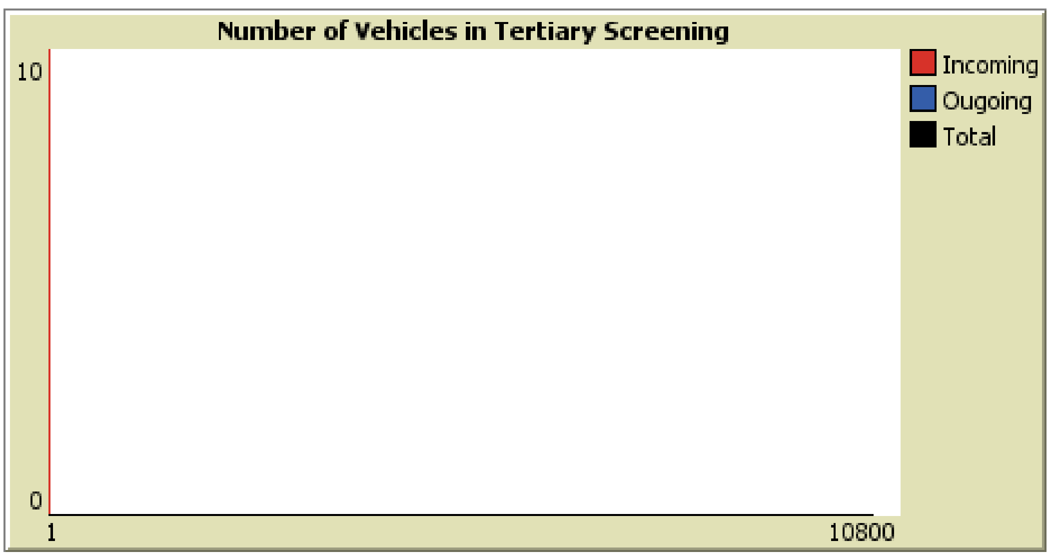

Figure 28. Number of vehicles sent to tertiary for Case A

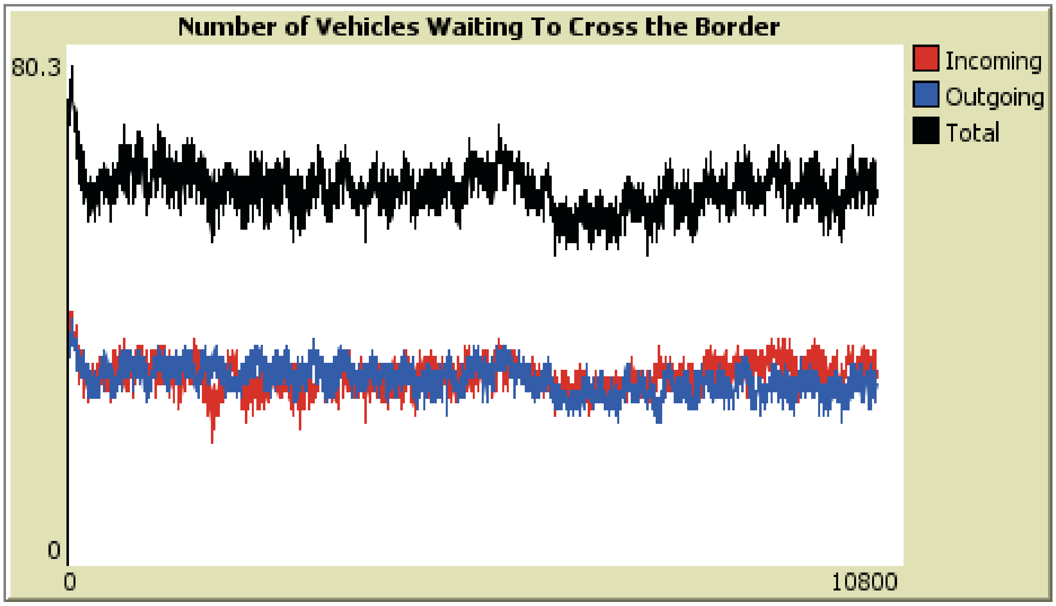

Figure 29. Number of vehicles waiting to cross the border for Case A

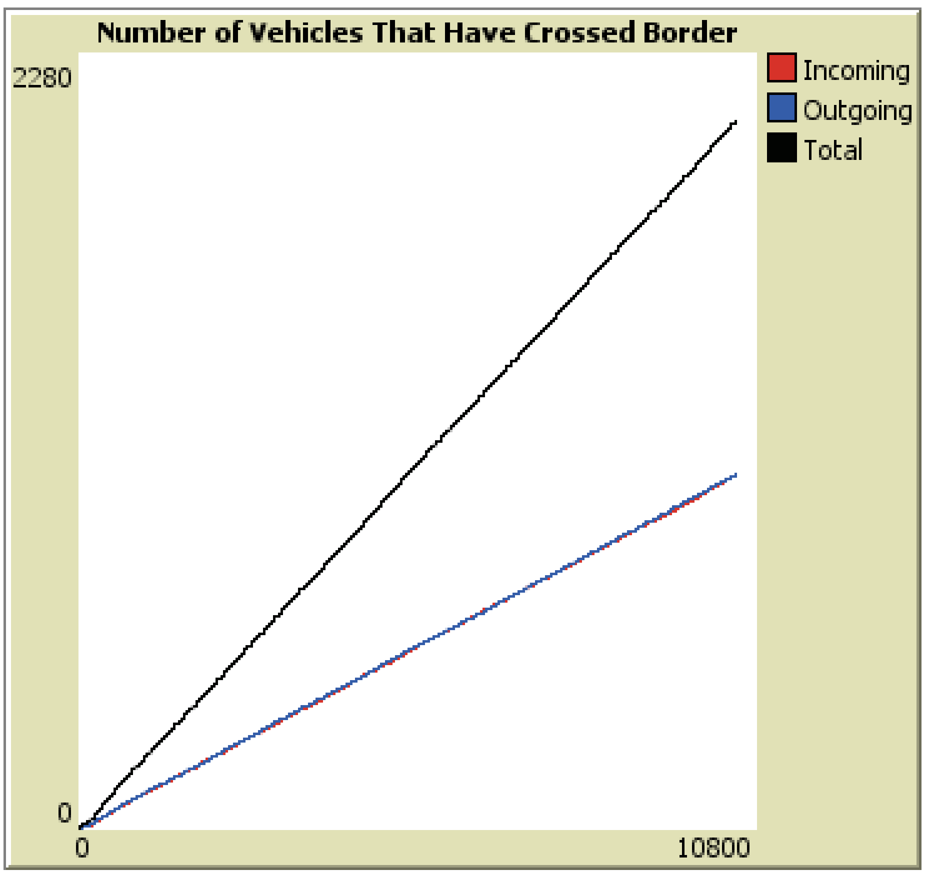

Figure 30. Number of vehicles that have crossed the border for Case A

For reference, according to the U.S. GSA, the world's busiest Land Port of Entry (LPOE), the San Ysidro LPOE supports 24 northbound vehicle lanes into the United States serving more than 50,000 northbound vehicles daily. That means they have an average of 2083 per hour crossing the border going north per hour in each of 24 lanes, or 86 vehicles per hour per lane. According to their website, they expect traffic to increase by 87% by 2030.(U.S. General Services Adminstration, 2013)

In Figure 31, the model shows that 155 vehicles which have radioactive materials in their cargo, luggage or persons have crossed the border from Country B into Country A, and that 145 vehicles that have radioactive materials have crossed from Country A into Country B in the 10,800 second run. That means that a total of 300 vehicles carrying radioactive materials have crossed the border in one direction or the other out of a total of 2120 vehicles, or about 14.15% which is consistent with the 14.3% shown in Table 4. This indicates that our simulation model is working well. There is a difference in the number of incoming and outgoing radioactive vehicles. This is because of the randomness in our model probability distribution function for the non-radioactive vehicles.

The wait times for vehicles to cross the border are shown in Figure 32. The maximum wait times seem to be 600 to 700 seconds.

A pictorial view of the traffic showing back up in the Primary Inspections Areas and the number of vehicles in Secondary Inspection is given in Figure 33. In the screen shot of the model shown in Figure 33, the number of cars backing up in the lanes is shown to vary from lane to lane. The interface shows that are only 2 vehicles remaining in the incoming secondary after 3 hours. One is a car and the other is a truck.

As expected, there are no vehicles in Tertiary screening, as shown in Figure 34. Figure 35 shows the number of vehicles in Secondary Screening for vehicles coming into Country A from Country B as a function of time for Case A. Only trucks and cars with verification issues are screened in secondary. The total reaches 3 incoming vehicles at 10000 seconds. Since we have set our threshold at 5 vehicles in Secondary before additional manpower would be required, our model indicates that the screening protocols are adequate up to this point.

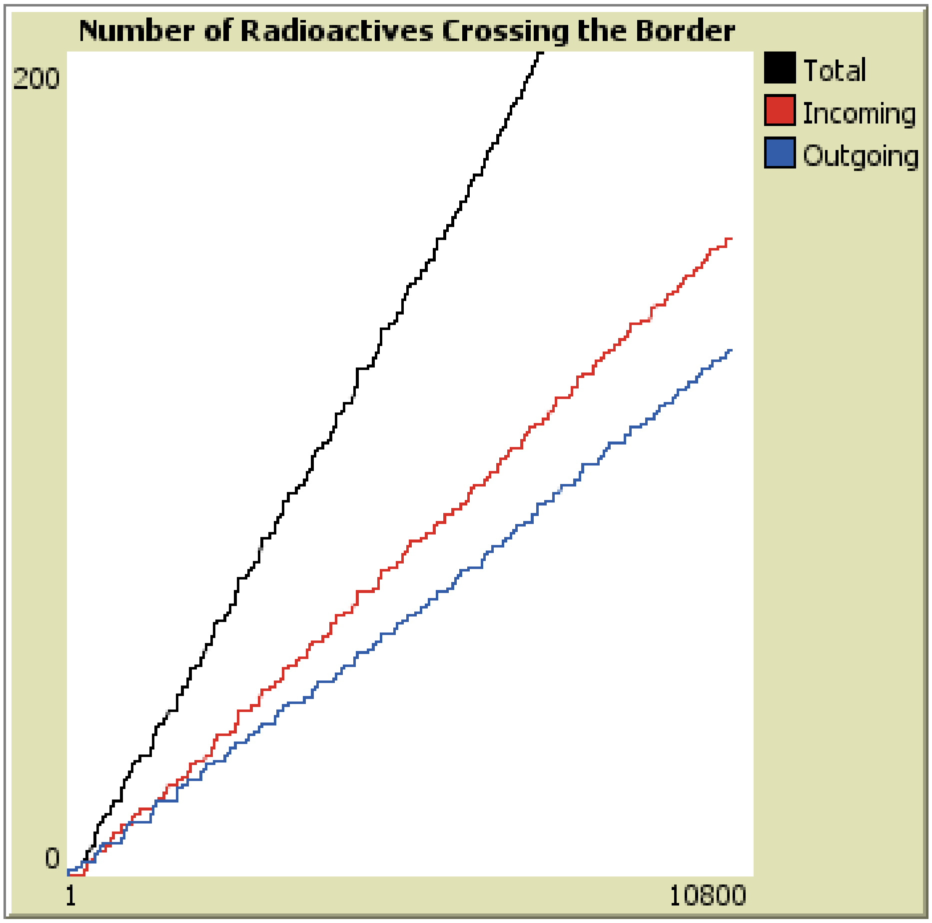

Figure 31. Number of radioactive vehicles that have crossed the border for Case A

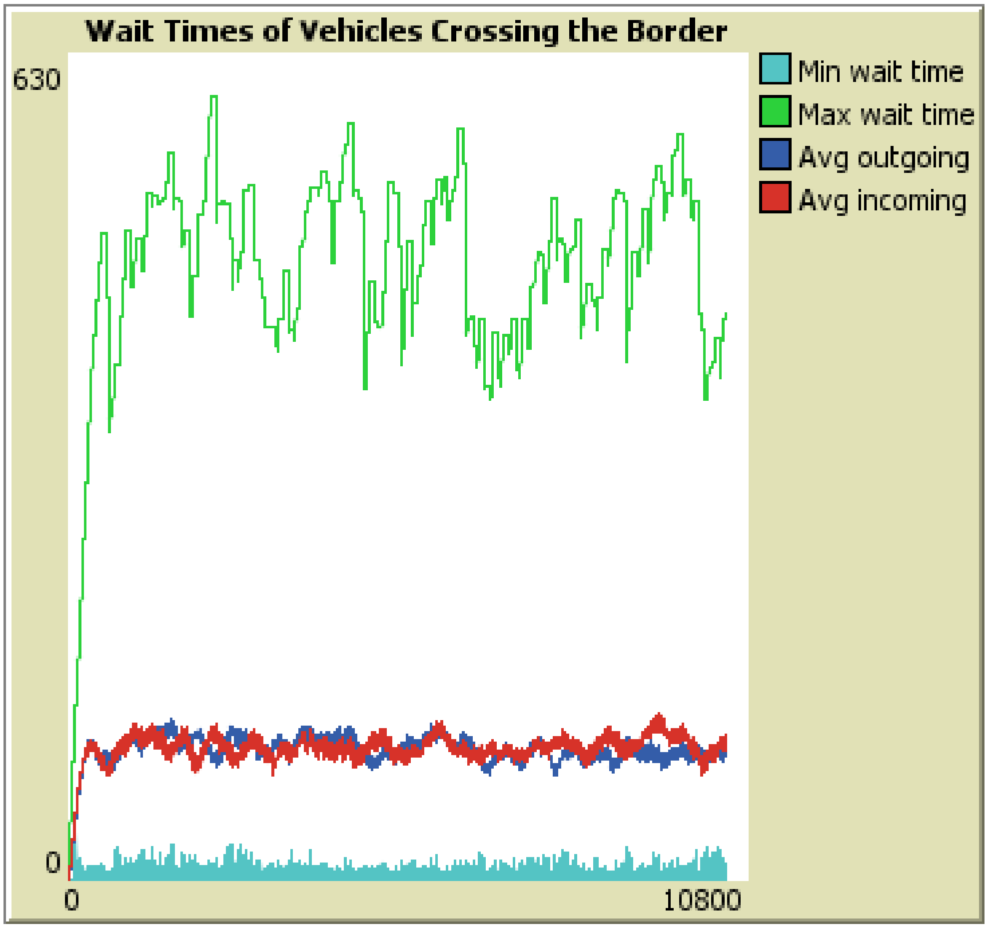

Figure 32. Wait time of vehicles crossing the border for Case A

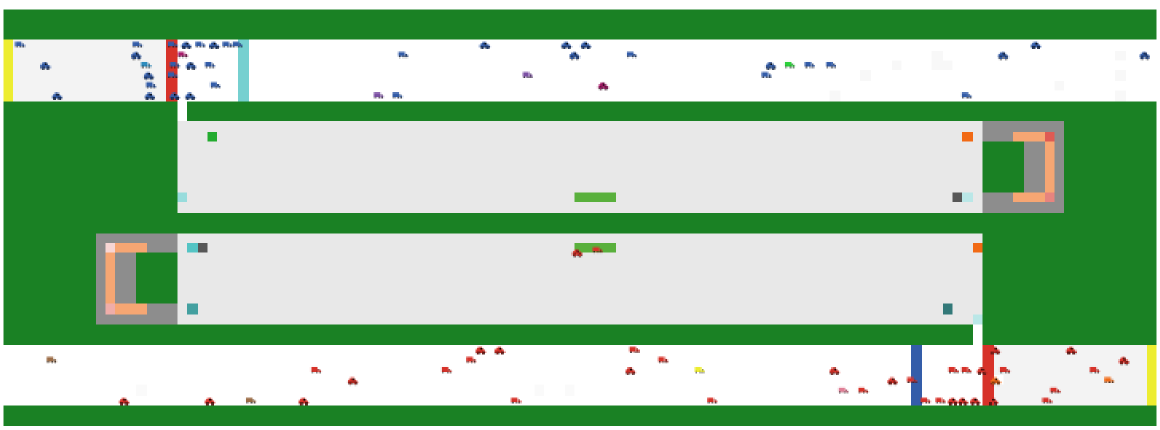

Figure 33. Expanded view of screen shot for Case A showing traffic flows

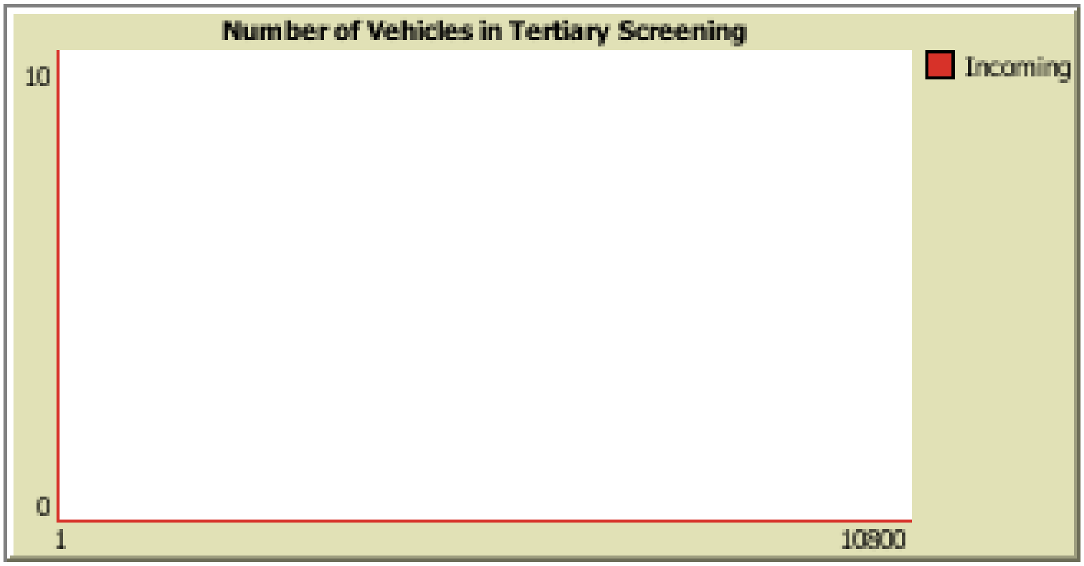

Figure 34. Number of vehicles in Tertiary Screening for Case A.

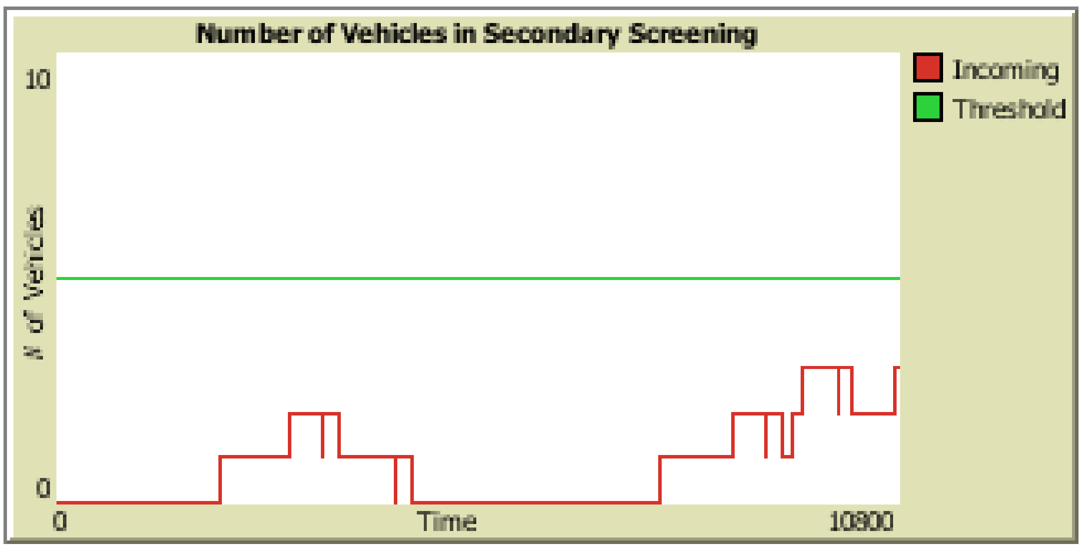

Figure 35. Number of vehicles in Secondary Screening for Case A

Results for Case B

In this second case, Case B, the impacts of adding a RadNuc screening mission onto the existing framework of mission screenings (law enforcement, immigration, vehicle safety, vehicle registration, etc.) will be examined. For Case B, the RPM discriminators are set at a level where we would expect to see that some vehicles would set off radiation alarms in Primary and then be sent to

Secondary for resolution of RadNuc alarms. The gamma discriminator level was set at 41 and the neutron discriminator level at 1, as shown in the analyst operator interface in Figure 36. At these settings, the Highgamma trucks (gamma level set at 100) and Neutron trucks (neutron level set at 5) would be detected, interdicted and sent to the Secondary. For this case, the secondary screeners will have to be trained to use a set of specialized equipment and to use additional protocol steps beyond those already in place for non-RadNuc mission space.

The model may now begin to show what happens when the Secondary screeners cannot resolve the alarms. This might occur if the instrumentation indicates gamma radiation profiles or neutron presence that seem out of character from the vehicle manifests or the explanations of the drivers of the vehicles. These situations can be difficult to adjudicate. They may require specialists in RadNuc threats understanding and characterization. In Tertiary, there may be a requirement for opening the vehicles and performing manual inspection of the cargo. But if the vehicles and their cargo in Tertiary are considered possible RadNuc threats, other specialists might be required to determine whether it would be safe to open the vehicles (trailers, trucks or trunks of cars, for example). These specialized skills generally are found in local police or fire departments. The time to resolve alarms in Tertiary Screening can vary widely. For our model, we assume a resolution time of one hour.

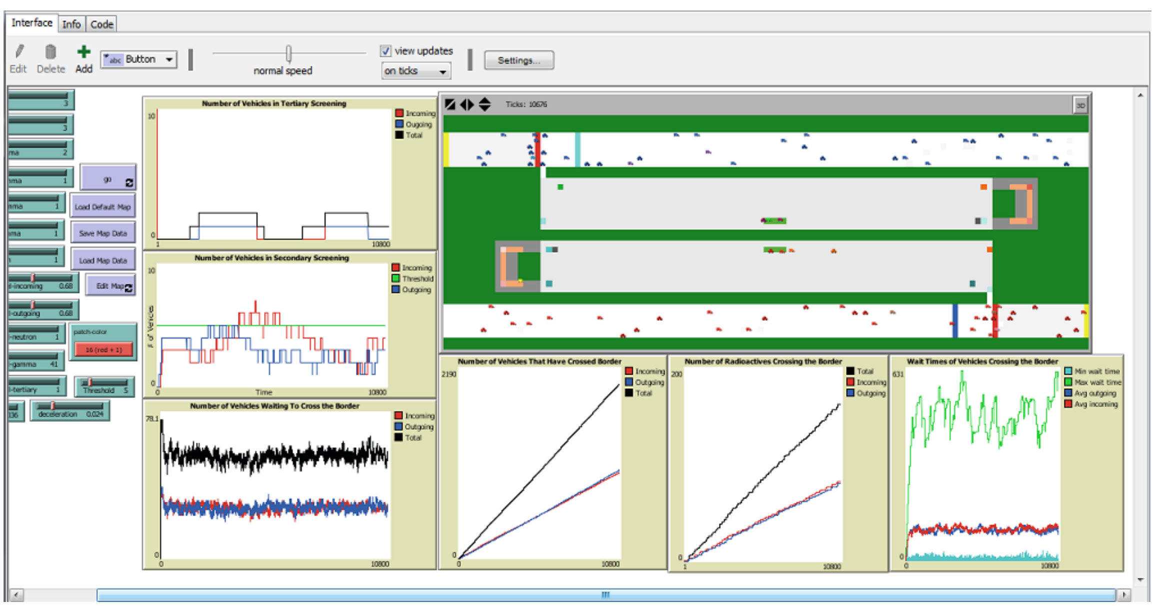

Figure 36. Analyst interface for two-dimensional dynamic simulation model for Case B

In Figure 37, the model results show that in this case, Case B, even though we have set the discriminators for gammas at 41 and for neutrons at 1, the number of vehicles coming from Country B into Country A sent to Secondary (Incoming only shown in the figure 38), reaches 7 and the number for traffic going from Country A to Country B reaches 4. The graph shows that the dynamic model calculates that the Outgoing secondary never reaches the threshold of 5 vehicles and the Incoming surpasses that threshold criterion at 1200 seconds. In our model, the criterion is that once there are 5 vehicles in secondary screening, then Secondary has reached the limit of the capability to resolve the alarms. Therefore, the model will assume that another secondary screening officer will have to be brought on board for each shift. If we assume that the border operates 24 hours per day, then that would mean adding at least three screening officers, each of which would have to have training on RadNuc missions. This training would have to be provided and financed by the geopolitical structure. In our model, we assume the CBP-A (and corresponding CBP-B) would provide the officers, the initial training and provide refreshed training over the foreseeable future.

In Figures 39 and 40 results show that some vehicles are sent to the Tertiary area. They are present there from 2000 – 4000 seconds and 6000 – 10800 seconds. Within our geopolitical construct the model assumptions are that the Tertiary Inspection Screening area is where:

a. vehicles will be held under tighter administrative control by CBP-A,
b. special inspection capabilities like full vehicle radiography might be used by CBP-A,
c. specialists (like bomb squad technicians from CityA1 police department or Township A or Township B or fire department) will determine whether the truck or car can be inspected manually,
d. those manual inspections would occur by CBP-A or perhaps the FBI-A (requiring opening of truck or trailer containers) and opening of car trunks, opening of packages, and
e. further manual inspections might occur by CBP-A or perhaps the FBI-A.

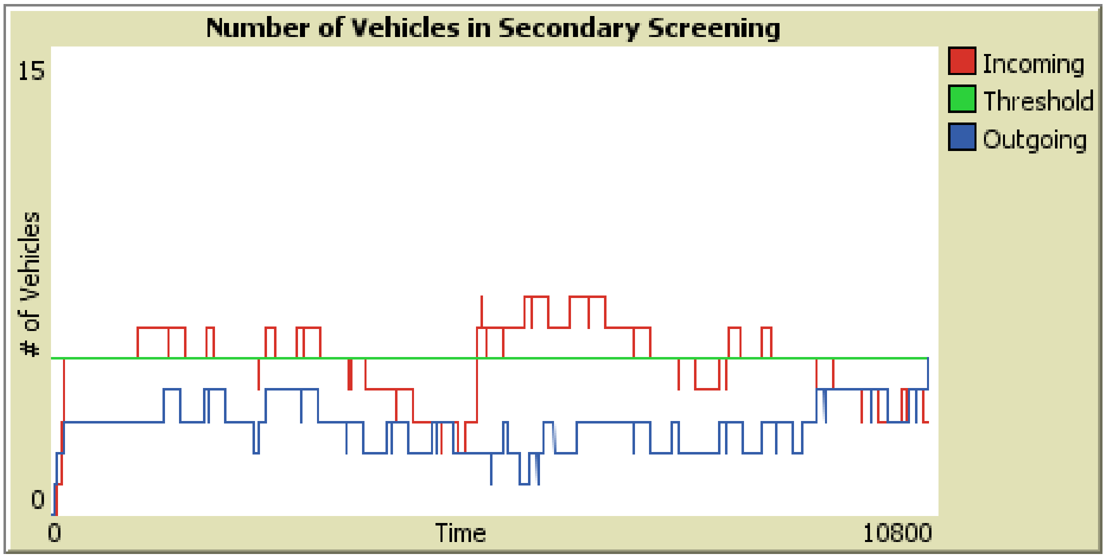

Figure 37. Number of vehicles in secondary screening for Case B

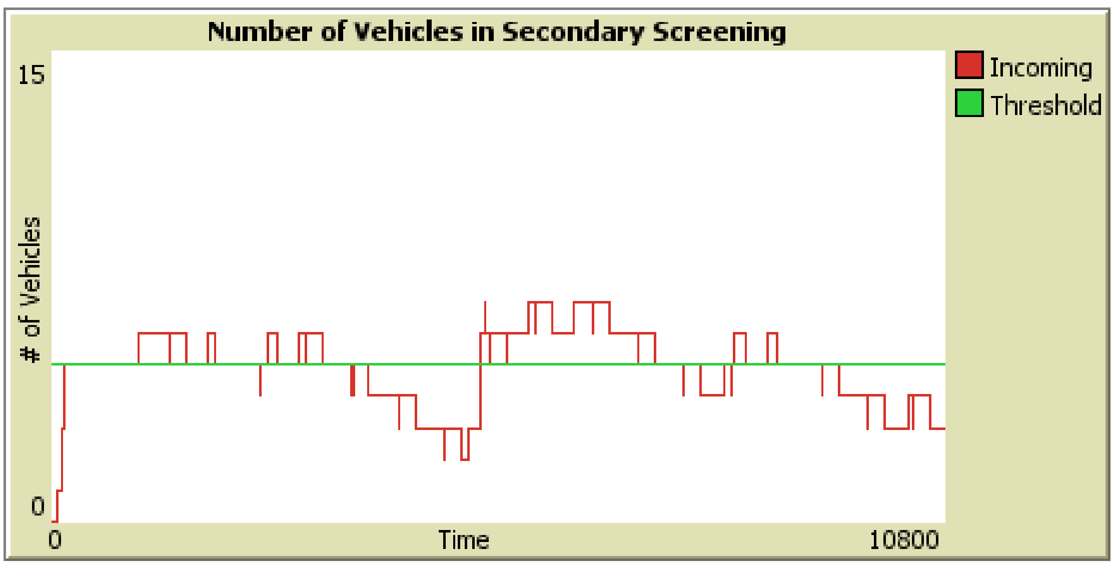

Figure 38. Number of incoming vehicles in secondary screening for Case B

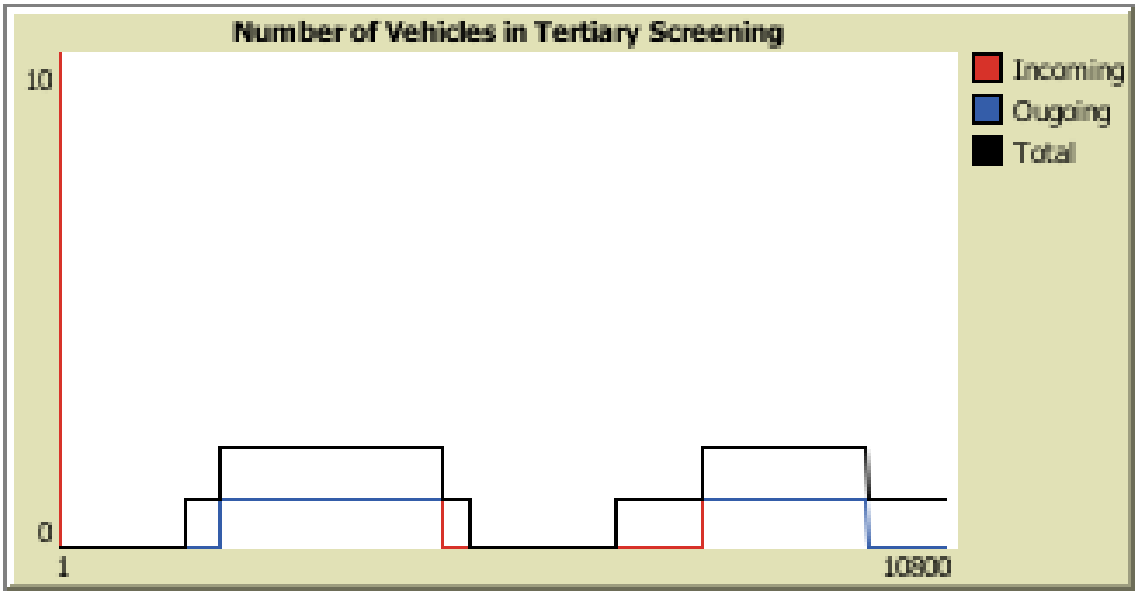

Figure 39. Number of vehicles in tertiary screening for Case B

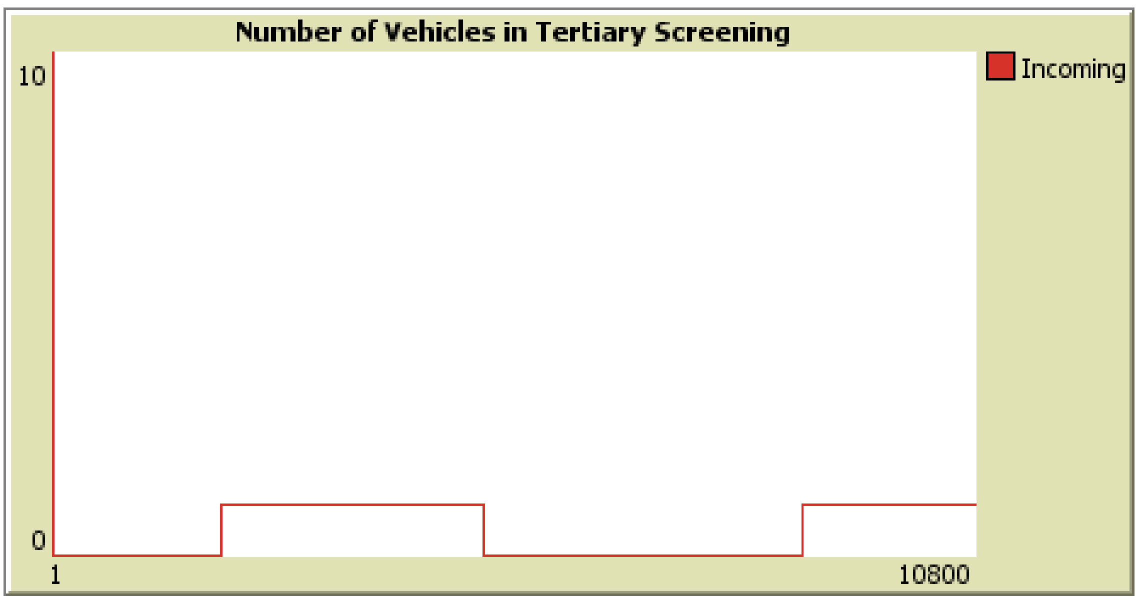

Figure 40. Number of vehicles in incoming tertiary screening for Case B

Figure 41 shows that the number of vehicles waiting to cross the border during the simulation for Case B is about 30 to 35 for both incoming an outgoing, or about 6 per lane for the 12 lanes, much like in Case A. We will assume that this level of backup is acceptable to the Customs and Border Patrol of Country A and Country B. This seems like a reasonable assumption.

In Figure 42 the model shows that about 2050 vehicles cross the border, a little bit less than for Case A (2100), in which we did not screen for vehicles with radioactive materials, because fewer vehicles are sent to Secondary. This means that if we only look for vehicles with very high rates of gamma emissions and/or any measurable neutron emissions, we would not expect to see much effect on the total number of vehicles crossing the border. But we would need need to add some space and skills to resolve alarms in a Tertiary.

Results shown in Figure 43 are that around 170 radioactive vehicles cross the border in Case B because of the high gamma and neutron discriminator settings. Figure 44 shows that the wait times for vehicles crossing the border reaches a maximum of about 630 seconds, but on the average is about 100 seconds for both incoming and outgoing vehicles. Results indicate that this least aggressive level of screening for radioactive materials does have some effect on wait times in our model, especially for the maximum wait time.

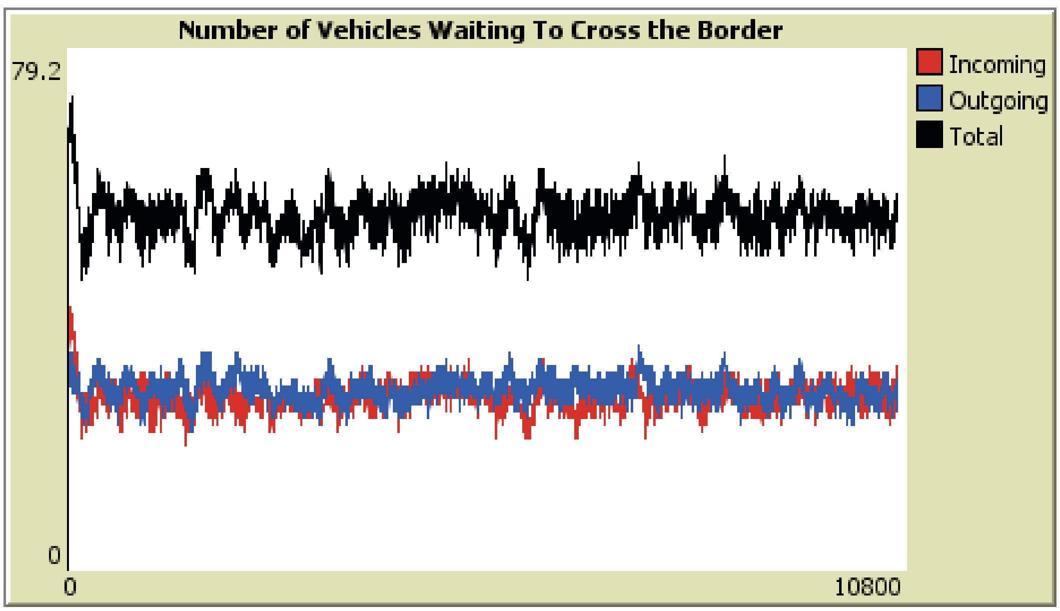

Figure 41. Number of vehicles waiting to cross the border in Case

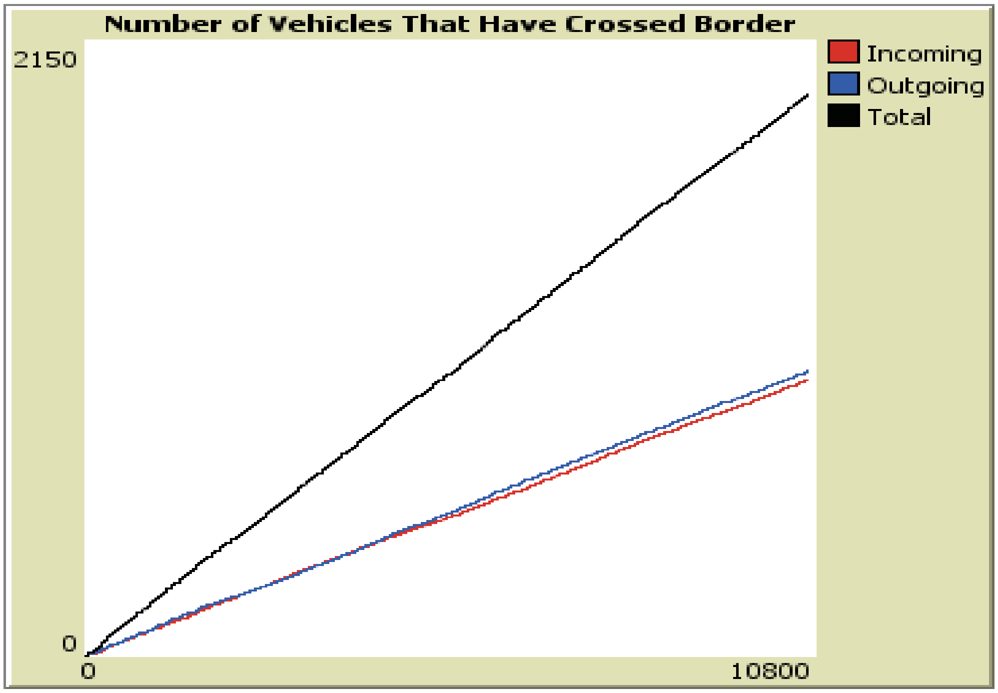

Figure 42. Number of vehicles that have crossed the border in Case B

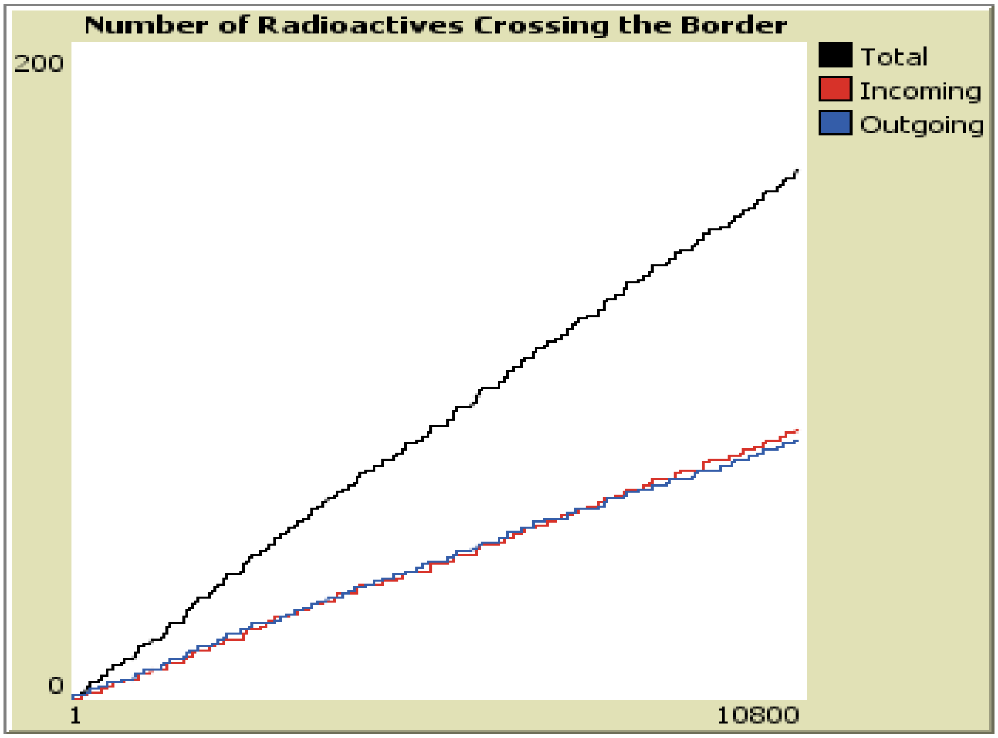

Figure 43. Number of radioactive vehicles that have crossed the border for Case B

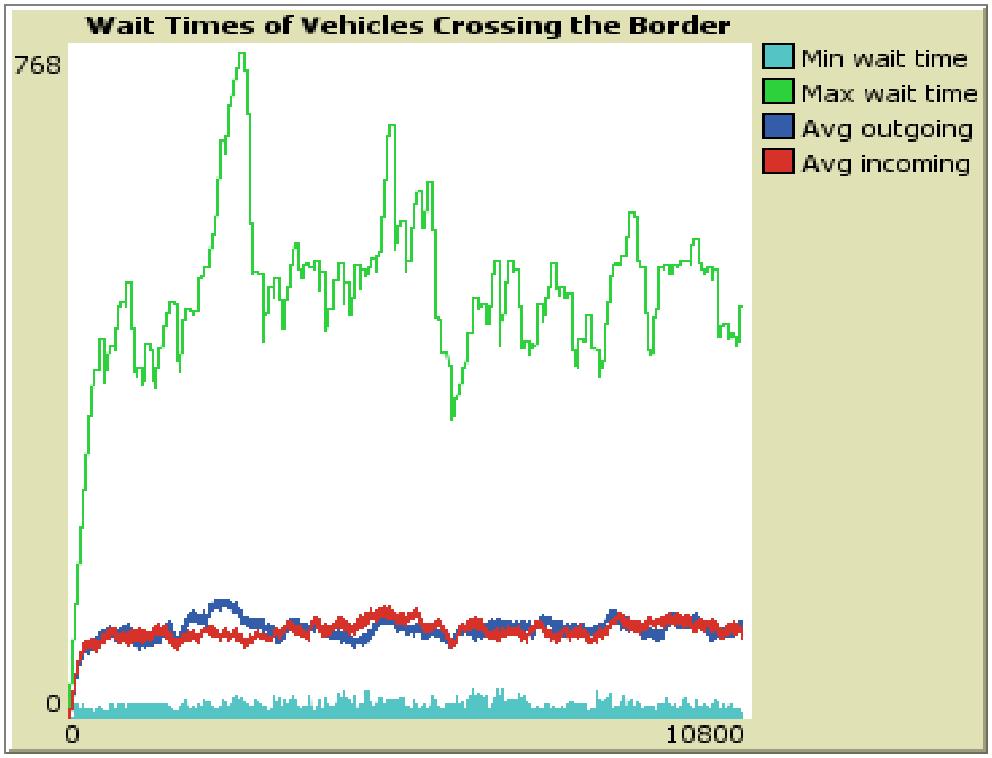

Figure 44. Wait times of vehicles crossing the border for Case B

Results for Case C

The third case, Case C, models the impact of a more aggressive application of RadNuc screening. The discriminator settings for gamma and neutron radiation are set to only alarm for pretty significant gamma levels and any of our vehicles emitting neutrons. We would expect that more vehicles would be sent to Secondary Inspection and occasionally to Tertiary Inspection.

The analyst interface for the two-dimensional simulation model for Case C is shown in Figure 45. Results in Figure 46 are that the number of vehicles sent to Secondary exceeds our criterion of 5 quickly. In Figure 47, the model shows that the number of vehicles in incoming Secondary first exceeds the threshold around 800 seconds. The number varies from 3 to 7 during the simulation.

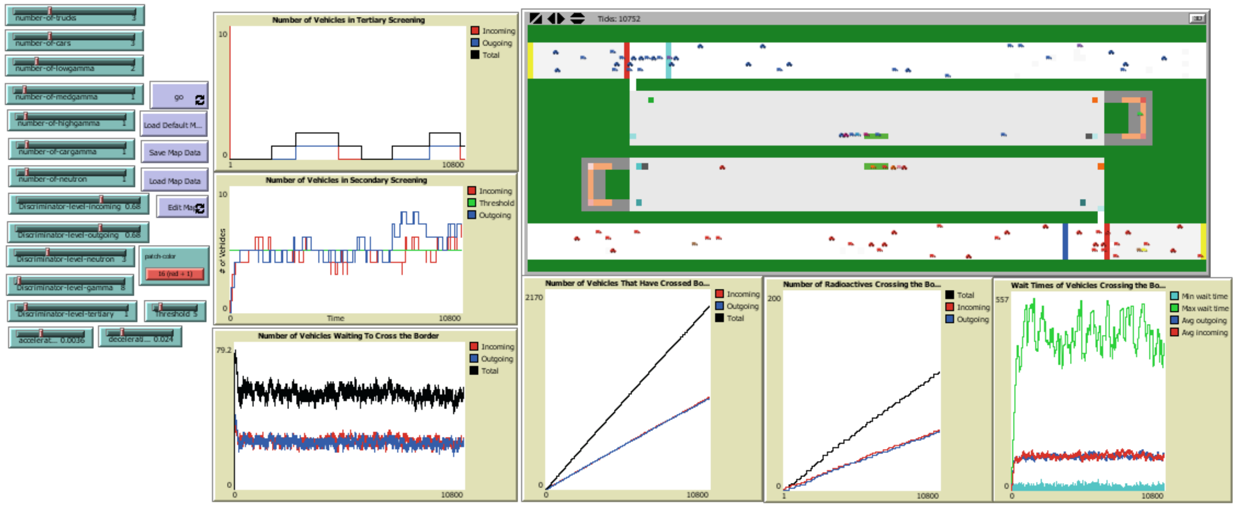

Figure 45. Analyst interface for two-dimensional dynamic simulation model for Case C

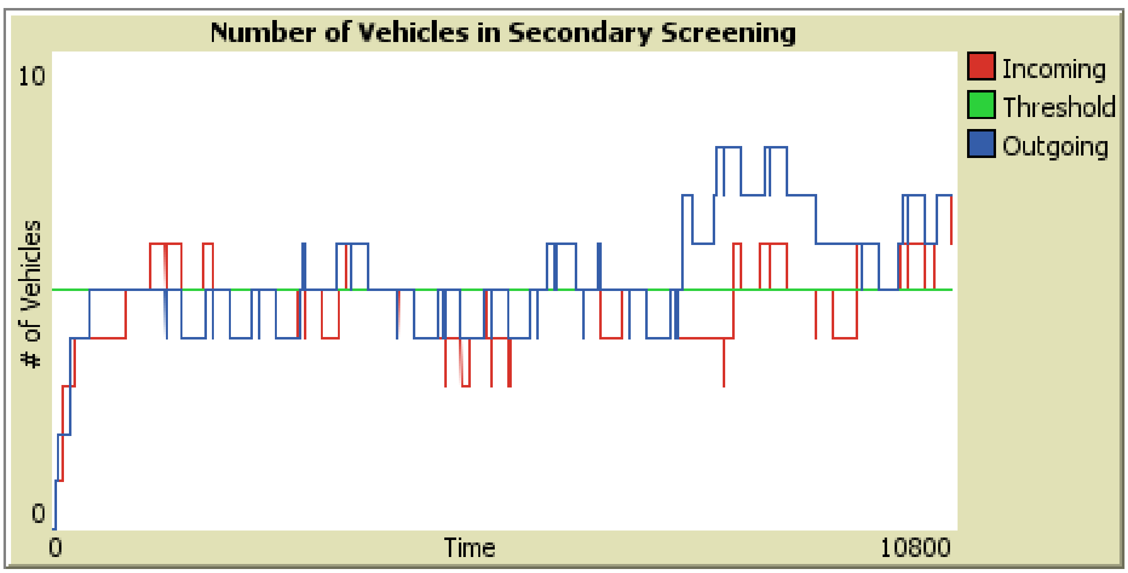

Figure 46. Number of vehicles in secondary screening for Case C

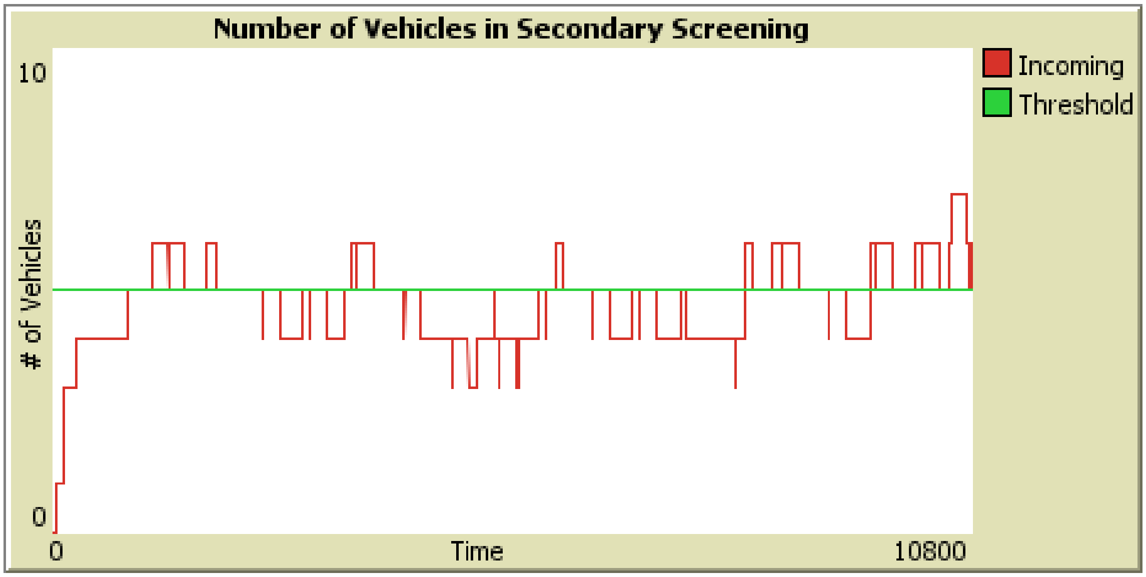

Figure 47. Number of incoming vehicles in secondary screening for Case C

The number of vehicles in tertiary screening is shown in Figure 48. Generally the number in incoming tertiary varies from 0 to 1, as does the number in outgoing tertiary. In Figure 49 there is no more than one vehicle in incoming tertiary screening.

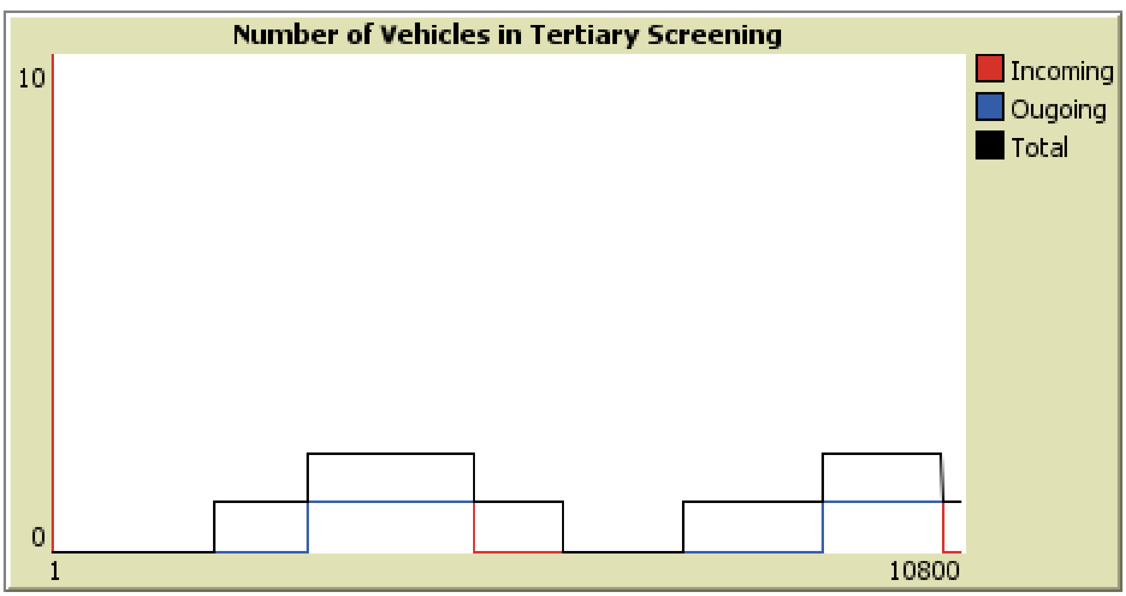

Figure 48. Number of vehicles in tertiary screening for Case C

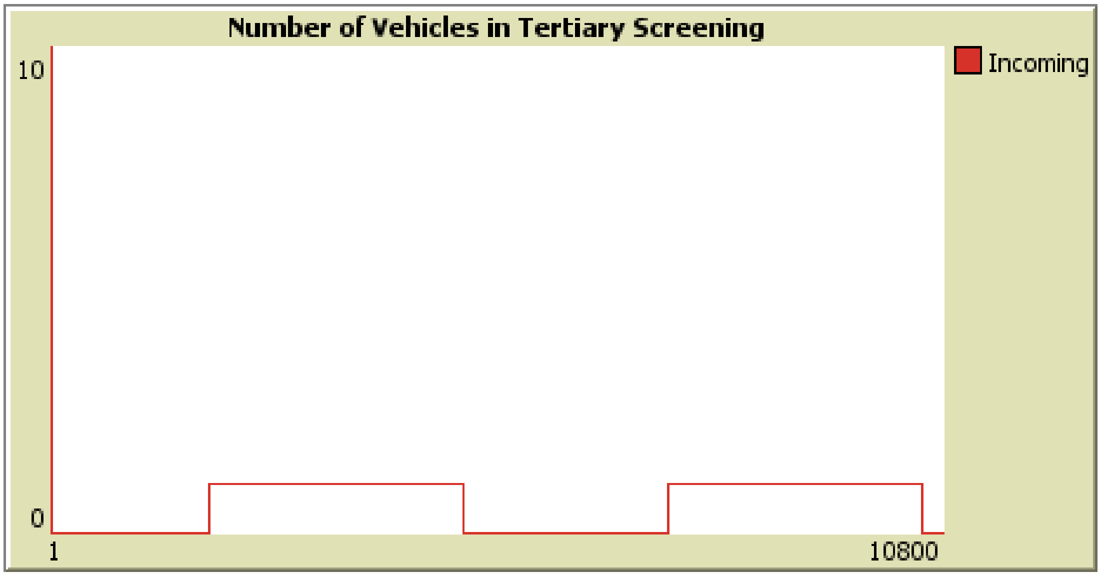

Figure 49. Number of incoming vehicles in tertiary screening for Case C

The number of vehicles waiting to cross the border is about 30 in each of the outgoing and incoming cases, as shown in Figure 50. The number of vehicles crossing the border is about 2000 cars in Case C, with about the same number of incoming and outgoing, as shown in Figure 51

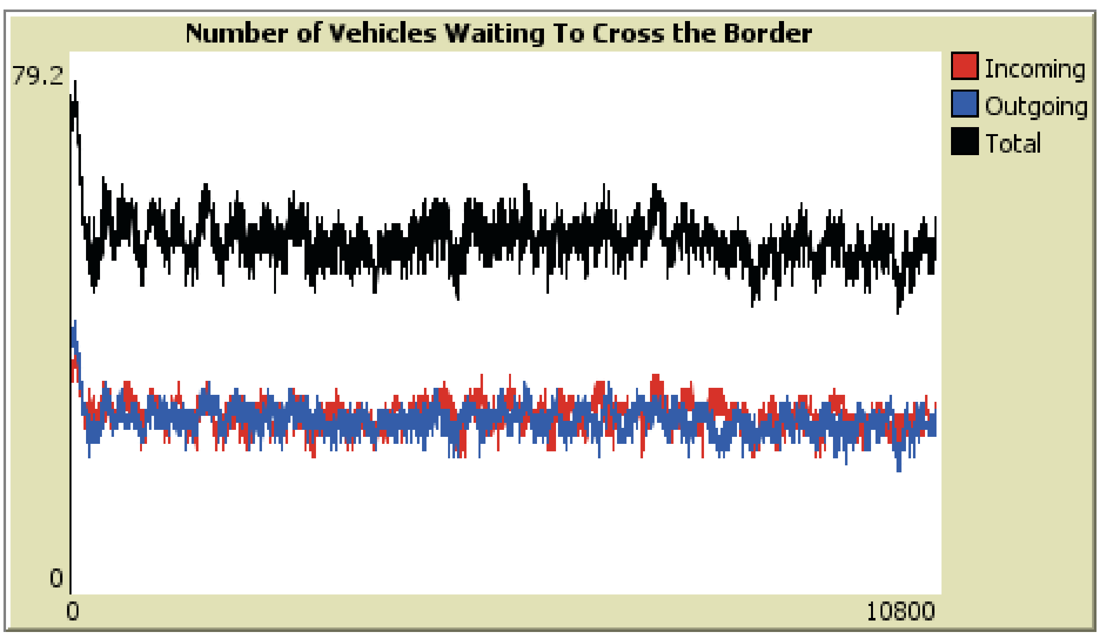

Figure 50. Number of vehicles waiting to cross the border in Case C

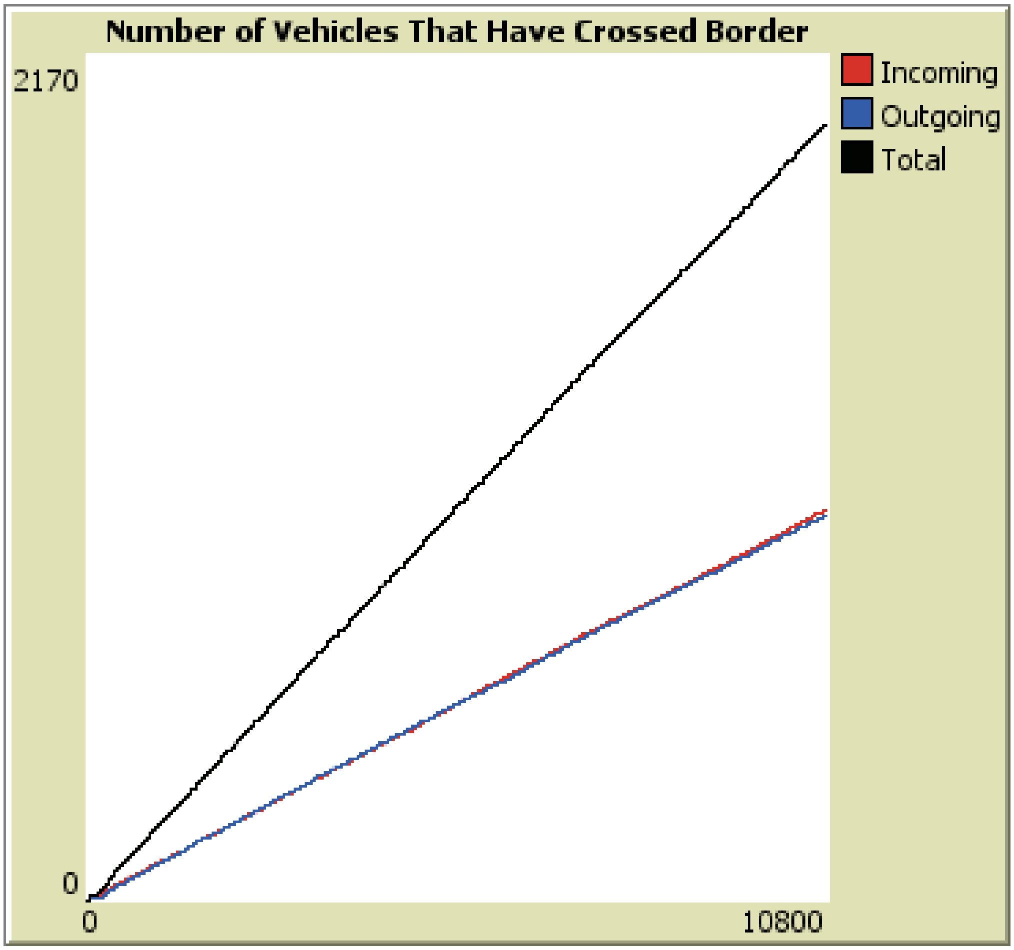

Figure 51. Number of vehicles that have crossed the border in Case C

Figure 52 shows that around 100 total radioactive vehicles crossed the border in this case. All low gammas crossed without being screened to Secondary (two incoming and two outgoing), plus around 10 medium or high gammas as well as any neutrons that cleared secondary in time to cross the border.

The average wait time to cross the border for case C is about 150 seconds, with a maximum of about 550 seconds, as shown in Figure 53.

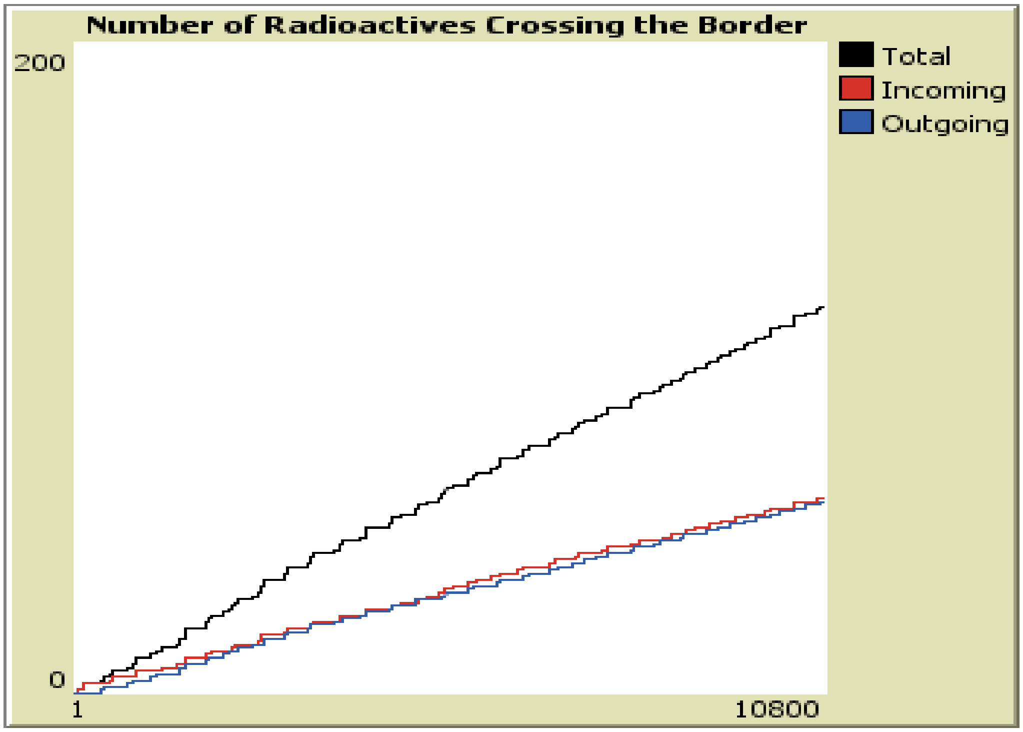

Figure 52. Number of radioactive vehicles that have crossed the border in Case C

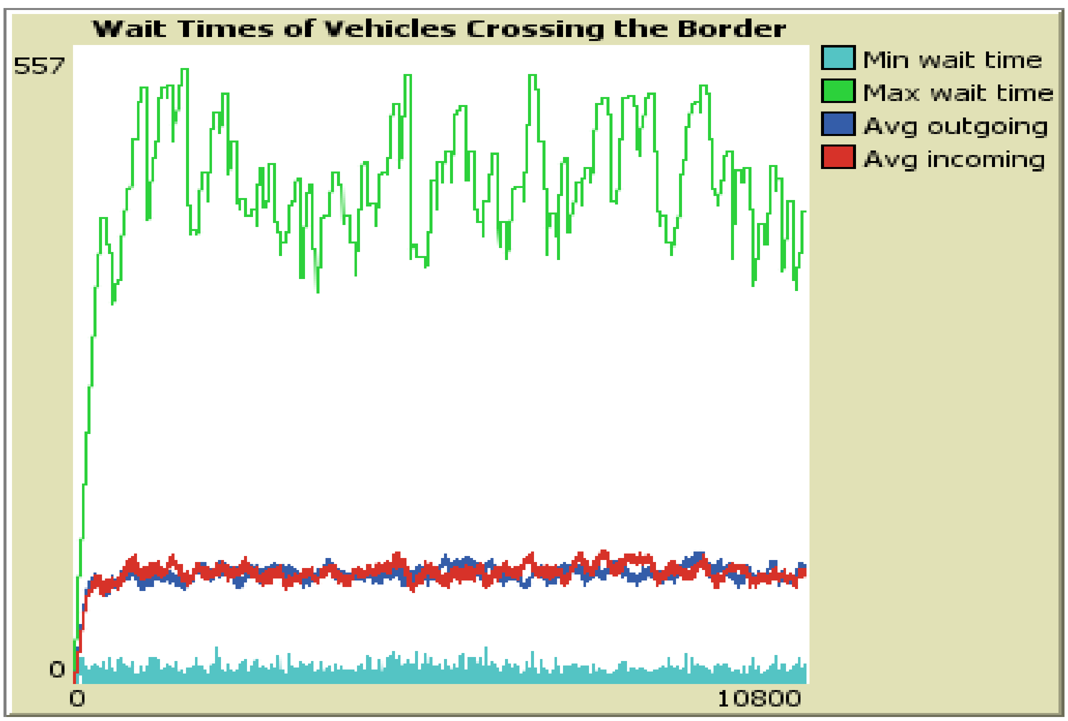

Figure 53. Wait times of vehicles crossing the border for Case C

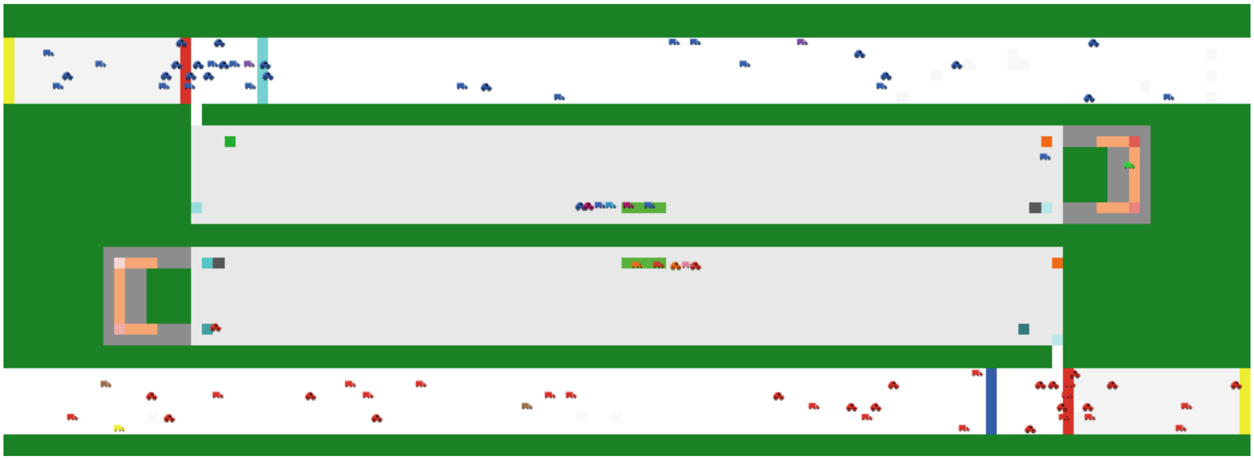

Figure 54. Expanded view of screen shot for Case C showing traffic flows

The analyst interface, shown Figure 54 above, displays an enlarged view of the traffic simulation. At 10800 seconds, there are 5 vehicles in the incoming Secondary and 6 in the outgoing Secondary. There is one truck in the outgoing Tertiary and one car just leaving the incoming Tertiary.

Results for Case D

The fourth case, Case D, models the impact of very aggressive application of RadNuc screening. The discriminator settings for gammas and neutrons were set so that any detection of gammas or neutrons will cause the vehicles to be sent to Secondary. Expectations are that enough vehicles would be sent to Secondary to overwhelm the capacity for Secondary screeners to resolve the alarms in reasonable time frames. The number of vehicles sent to Tertiary would be expected to overwhelm the capacity of the specialized teams to adjudicate the alarms. The analyst interface for the two-dimensional simulation model for Case D is shown in Figure 55.

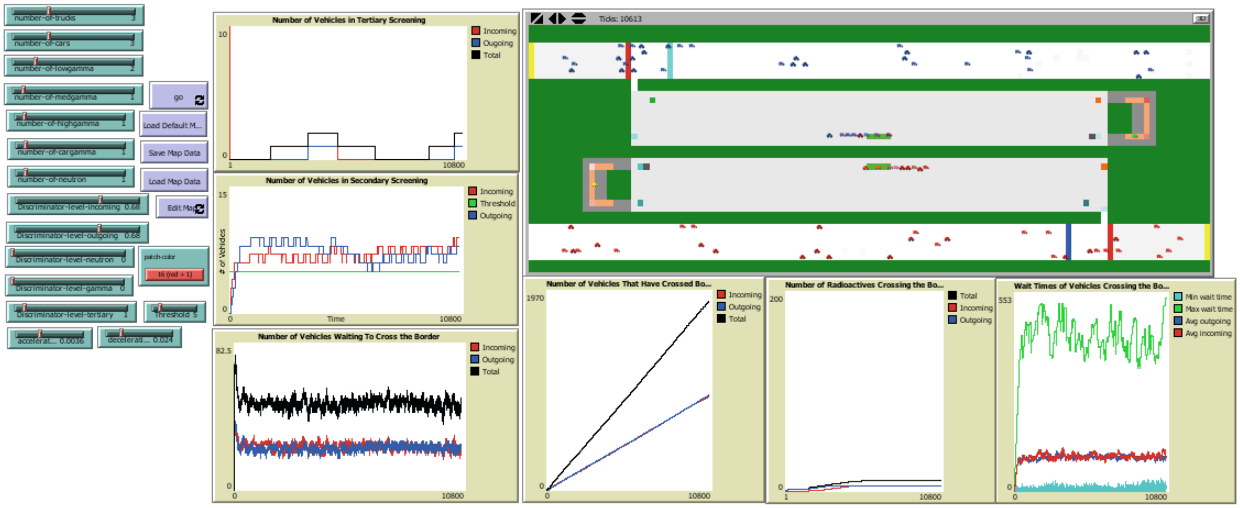

Figure 55. Analyst interface for two-dimensional dynamic simulation model for Case D

An enlargement of the operator interface to show visually the backup of vehicles at 10800 seconds is shown in Figure 56. We can see here there are 9 vehicles in the incoming Secondary and 8 vehicles in the outgoing Secondary.

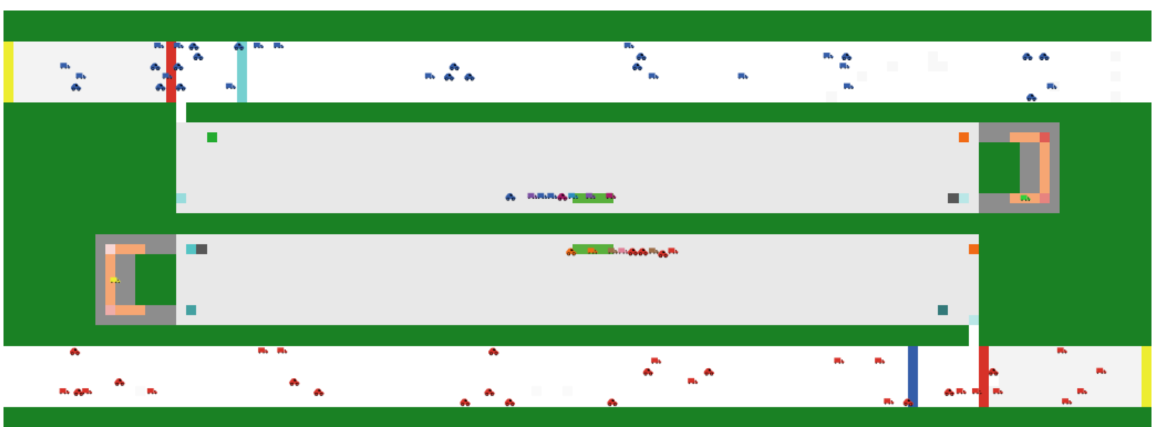

Figure 56 Dynamic simulation model of traffic backup for Case D

In Figure 57, the graph shows that extra personnel would become necessary almost immediately. Both incoming and outgoing traffic piled up in Secondary and the issue would not resolve for several hours even if no more cars entered secondary.

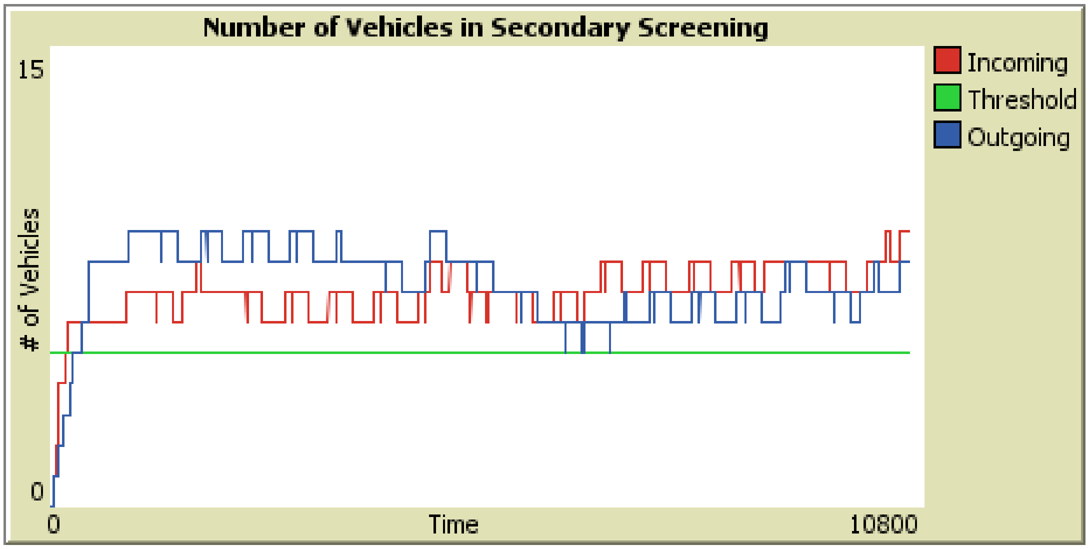

Figure 57. Number of vehicles waiting in secondary for Case D

A view of the number of vehicles in the incoming Secondary only is shown in Figure 58. The number of vehicles in Secondary will overwhelm the screening resources beginning at about 300 seconds and continue to do so.

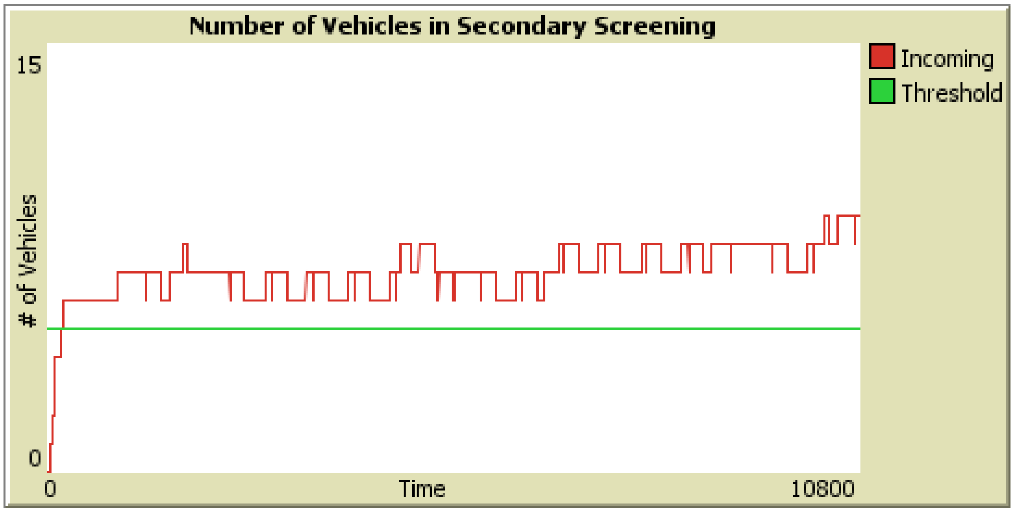

Figure 58. Number of incoming vehicles in secondary screening

Figure 59 and Figure 60 show that the number of vehicles in Tertiary screening is 1 for incoming and outgoing vehicles. The number of vehicles waiting to cross the border is shown in Figure 61.

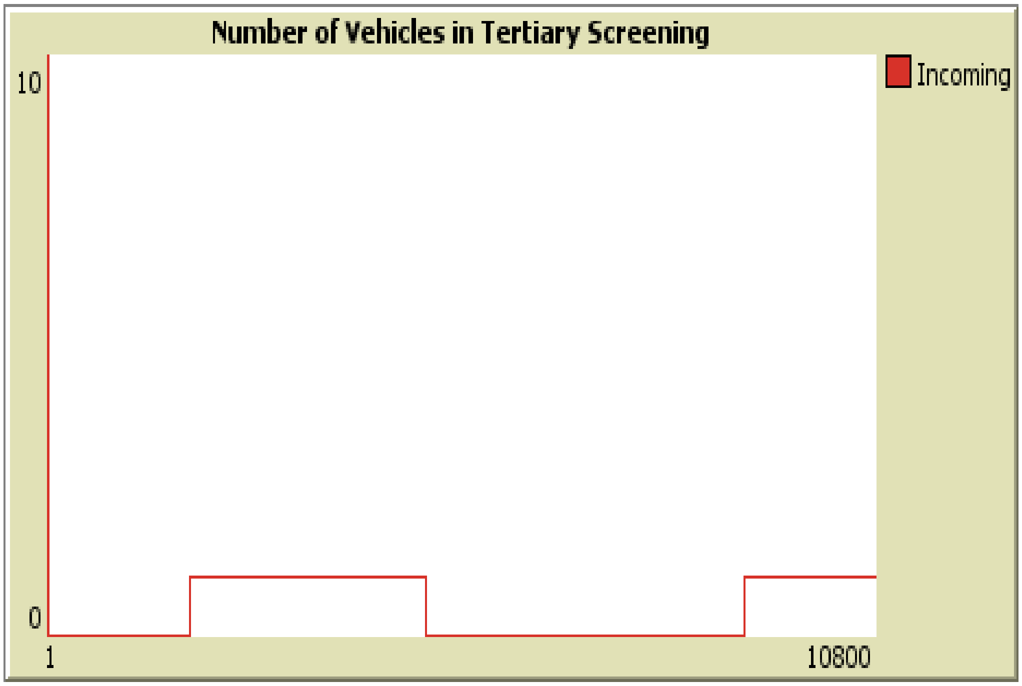

Figure 59. Number of vehicles in tertiary screening for Case D

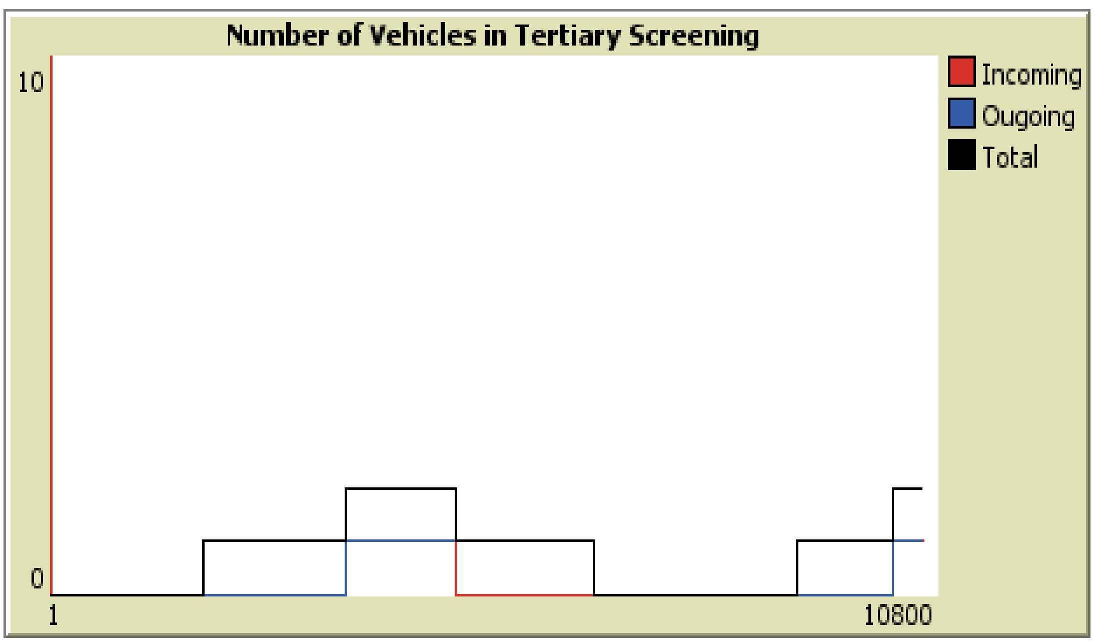

Figure 60. Total number of vehicles in tertiary screening for Case D

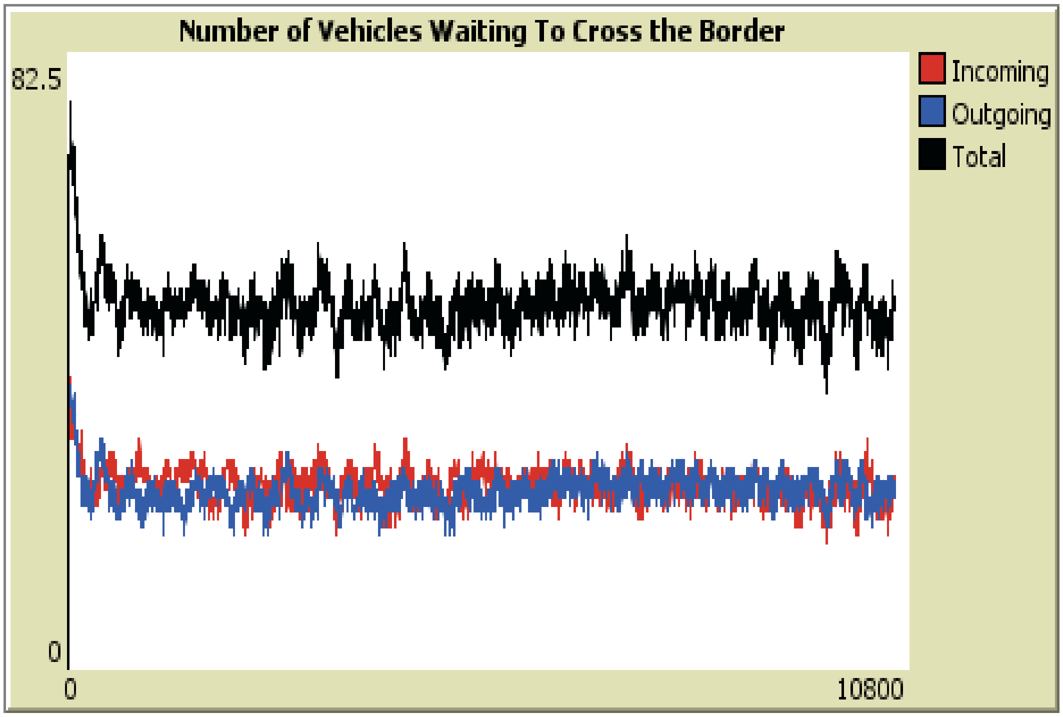

Figure 61. Number of vehicles waiting to cross the border in Case D

The total number of vehicles that have crossed the border in 3 hours is around 1900 or 633/hr, as shown in Figure 62. Figure 63 shows that almost no radioactive vehicles cross the border. Around 10 vehicles were able to clear secondary in time to cross the border in three hours (10800 seconds).

The maximum wait times reached 553 seconds for vehicles that did not go through secondary, as shown in Figure 64. The average wait time was around 150 seconds.

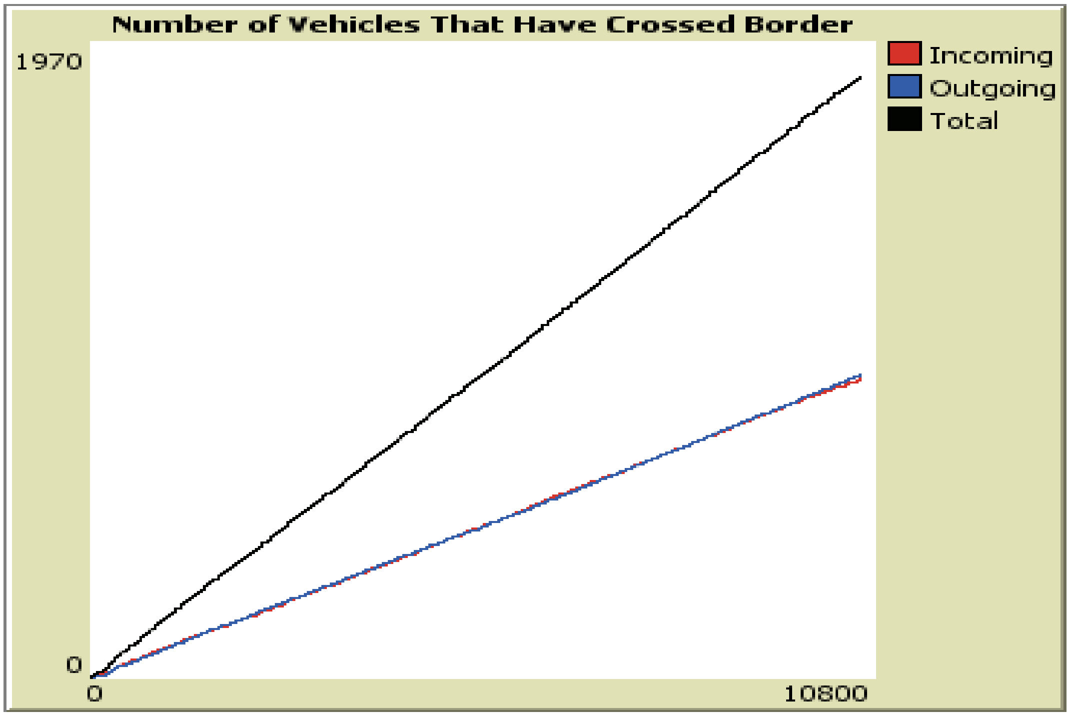

Figure 62. Number of vehicles that have crossed the border in Case D

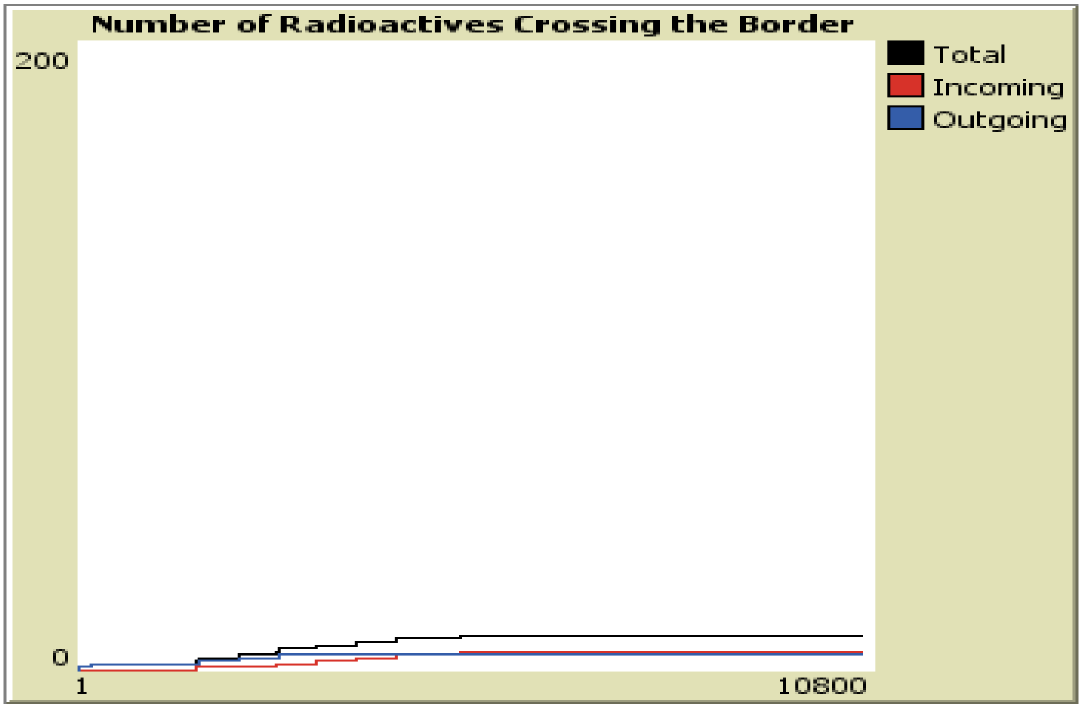

Figure 63. Number of radioactive vehicles that have crossed the border in Case D

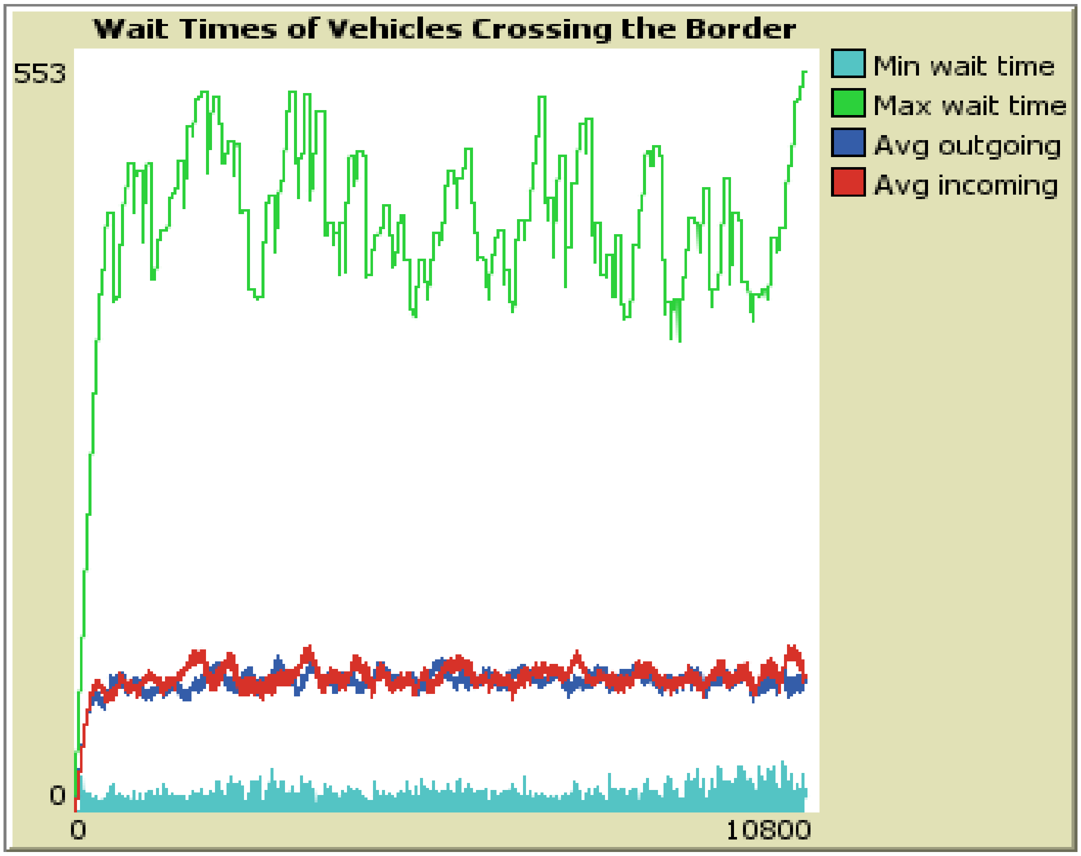

Figure 64. Wait times of vehicles crossing the border for Case D

Developed Model of Geopolitical Structure and Examined Effects of RadNuc Mission Addition

The construction of the hypothetical concept of operations for the border crossing showed that there would be state, regional and local organizations on which the mission would depend. There would be a need for the State A Highway Patrol to agree to chase down vehicles that might run through the border crossing after an alarm at the Primary Screening Station. It is reasonable to assume that this provision already is made under an existing memorandum of agreement for other situations involving a driver that would refuse to stop at the border. This situation, however, would be more complicated because the vehicle might contain a radiological or nuclear threat. There might need to be a provision in the memorandum about how to handle that concern. We would expect to see sections in any memorandum of agreement and in the concept of operations covering this situation.

It is also possible that the local Sheriff Department or Police Department would get involved in the interdiction and arrest. In our isometric model of the border crossing station, there is an icon to represent the presence of a local police car. The icon could represent the Highway Patrol, Sheriff's Department or Police Department presence. For the situation in which there is criminal activity related to radiological or nuclear materials at our hypothetical border crossing, the Metropolitan Area MA1 police department (in our case) will be responsible for escorting the driver, passengers and/or vehicle to their headquarters – unless a threat is suspected or found in the vehicle. In the case of a found threat, then the vehicle may be escorted by an FBI or military representative to a secure location removed from populations centers. There would need to be a memorandum of agreement among these organizations articulating which of them will be responsible for these special cases. These cases also should be covered in a regional concept of operations.

In the case of criminal behavior, the local District Attorney's office would be involved. For the case of radiological and nuclear materials, a District Attorney with the most relevant capability might have agreed to take the case. If a radiological or nuclear weapon was found or suspected, federal assets would be called in after the local officials had secured the situation. In our large metropolitan area, an Information Fusion Center will have been established and will communicate with the State A Information Fusion Center about the vehicle, driver and cargo to see if there is any more information relevant to the situation that might help the border crossing officials or the local law enforcement officials assess the situation. These considerations are reflected in Table 7 below.

Table 7. Additional stakeholders derived from analysis of model

	Highway Patrol	Sheriff	Police Dept.	Fire Dept.	Safety Dept.	District Attorney	Military Guard	Information Fusion Center
State A	X				X			X
Metro Area MA1			X	X	X	X		X
City A1			X	X	X	X		
County A1		X		X	X	X		
County A2		X		X	X	X		
Township A		X	X	X	X			
Township B		X	X	X	X			
National Guard							X	

CHAPTER V
DISCUSSION OF METRICS

Systems Engineering, Requirements and Metrics for Enduring Mission Success

If we assume that there is a for need continuing participation by all of the relevant organizations in all of the relevant jurisdictions throughout the region, then there would be a need to develop enduring consensus and commitments around goals, objectives, requirements and expectations. However, these attributes are not stand alone, but rather they will exist in a pool of other previous agreements and commitments. Furthermore, consensus may erode due to changing perspectives and/or pressures on resources. Our system for detection, interdiction and response to radiological and nuclear threats will need to blend into the existing system of systems in the region. This is a typical systems engineering problem in which interface requirements become very important. For example, the systems engineer will need to determine how much of what kind of information can be shared at what speed under what conditions between the systems within the information fusion centers of Country A and B, States A1 and B1, and the city CYA1.

Techniques for development of consensus goals, objectives and requirements are well known by systems engineers, especially for new systems. At this level the focus generally is on increasing the probability of threat detection and interdiction assuming certain levels of efficacy for the equipment to be provided. Plans and budgets are built around providing enough equipment to provide coverage of likely pathways for threat introduction and for the training of the personnel who would man the equipment and respond to threat indications.

For this case of adding functionality to an existing system of systems, the basic systems engineering constructs still seem applicable. More emphasis needs to be placed on interface requirements and on impacts on the existing infrastructure, like power requirements, data storage capabilities, information fusion capabilities, space availability for equipment, manpower ceilings of state and local organizations, modifications to training modules, and modifications to existing concepts of operations.

When the additional mission cuts across multiple state, local, and federal jurisdictions, the problem is more complicated. There will be many competing priorities. The outlying counties in State A1 may not feel as threatened as

City CYA1, and, therefore, feel that less priority should be put on low probability high consequence events. The systems engineer cannot force a commitment from these partners, but will need to understand and plan for what the partners will pledge to provide.

When an additional mission execution requires international coordination (as in our example), then another level of complexity is introduced. Country B may be more interested in protecting its citizens from threats traveling into their country from Country A than they are interested in detecting threats moving into Country A. Agreements will need to be in place to support building of plans, protocols and budgets for effective partnering between Countries A and B.

The metrics to support planning of a program to add or increase a radiological and nuclear threat mission of a region should include those factors that are important to enduring mission success. Another factor that should be considered is the degree to which this mission and the activities necessary to support it are symbiotic with other missions at the international, national, regional and local levels. If the new mission is viewed as part of an larger set of missions important to the security of a broad base of stakeholders as well as providing benefits locally, then the prospects for continuing willingness to accept this mission probably will increase. This chapter discusses the types of metrics that will be helpful in planning and assessing this type of program.

Different perceptions around increase in security from radiological and nuclear threats

Development of requirements for an integrated system should take into account all the perspectives of the partners in the enterprise. Many partners are more interested in increasing overall security from every day threats than low probability high consequence events. Examples might be businessmen, police officers, district attorneys. An official within the Country A Department of Homeland Security, the Country A Environmental Protection Agency, the Country A Department of Health or the Country A Environmental Protection agency may define security in terms that also include low probability but very high consequence events. The public at large may define security in absolute terms, wanting the government to provide total protection from any threat. Security professionals might define security in relative terms, knowing that security may never be absolute.

The funding available to the planner may be applicable only to a particular type of security problem. The Country A Department of Homeland Security mission has funding available primarily for detection and interdicting radiological and nuclear threats, but not for recovery from a detonation of such a threat. Nor does it have funds available for dealing with chemical or biological threats or natural disasters. The Country A Federal Emergency Management Agency does not have funding

for detection and interdiction, but has funds applicable to preparedness and response/recovery from almost any kind of disaster. The Country A Environmental Protection Agency, the Country A Transportation Security Administration, the Country A Department of Agriculture, and the Country A Department of Justice all have different missions that give their planners different perspectives around the definition of security.

These differences in perspective and restrictions within the appropriations and budget processes frequently lead to a compartmentalization of security missions. With this compartmentalization may come a compartmentalization of goals, objectives, and requirements. Especially in the example where multinational, multi-state and multi-jurisdictional authorities will be involved in execution of the mission, there is a need to establish requirements and metrics that meet the new mission needs while also continuing to meet the pre-existing mission needs of all the partners. There may be two opposing forces, then. One force is the drive to keep planning simple, controllable and easy to measure (compartmentalized). Another possible competing force is to develop systems that support the existing missions within the region while enabling the new functionalities of the radiological and nuclear missions. This would require the articulation of broader consensus of goals, objective and requirements and associated metrics.

Strategic Goals and Questions

A set of strategic goals were developed for this hypothetical enterprise. Then a set of strategic questions were developed that will help articulate metrics important for assessment of overall efficacy.

Strategic goals

The first strategic goal would be to establish a new worthwhile mission of detection and interdiction of radiological and nuclear threats at the hypothetical border crossing.

The second strategic goal would be to provide enduring support to this new mission at the border crossing station.

The third strategic goal would be to bring support to the international, national and regional missions and associated initiatives that affect or are affected by RadNuc screening operations related to the border crossing without doing any unacceptable harm to any of those missions.

Strategic questions

Related to strategic goal for a worthwhile mission, what is the process used by whom to judge the effectiveness of the mission and with what results?

Related to the strategic goal about enduring support, are adequate plans put into place for organizations to continue to support this mission and at what levels?

Related to the strategic goal for bringing support to other missions affected by this RadNuc mission, how will which organizations ensure that this mission is symbiotic with the other international, national, state and local missions that affect or are affected by operations related to the border crossing?

Development of Supporting Questions

The development of the next level of questions to expand our understanding of the efficacy of the addition of RadNuc screening to the border crossing station is accompanied by a discussion of some related metrics. For each strategic question, a set of supporting questions is developed.

Is the new mission worthwhile?

The exploration of the questions as to whether the new mission will be worthwhile leads to suggestions for more detailed questions that will provide insight into the process and the metrics used to answer this question. The first supporting set of questions is related to the ability of this new mission to provide deterrence of radiological and nuclear threats. As our literature survey shows, this set of instruments, protocols and trained officers will not, even in the best of circumstances, be expected to be able to detect and interdict every type of threat 100% of the time. However, the very presence of the mission capabilities at the border crossing station is expected to add another layer of difficulty for the adversary to consider when contemplating an attack. This will provide some degree of deterrence. A next set of questions would be concerned with what fraction of the RadNuc threat space does the RadNuc screening operations have to detect and interdict RadNuc threats. To detect the threats, a level of discrimination will have to be used sufficient to provide sensitivity to the presence of the threat. But we have seen from our dynamic simulation model results that as we increase the sensitivity to gamma and neutron radiation, there will be consequences in terms of traffic backup and in terms of number of Secondary screening personnel. The literature clearly shows that as traffic backs up and the amount of trade going through the border crossing decreases, there are serious concerns about associated costs. We also saw that in some cases, a Tertiary screening capability would be needed, with likely support from national level assets for reachback and for local bomb squad support. It is certainly probable

that as the level of detection increases, then the number of arrests might increase, with an attendant increase in case loads for investigation and prosecution.

From the diagrams showing the broad range of agencies that would be involved or affected, it seems clear that there would likely be a large group of stakeholders. When we consider that businesses and trade activities will be affected, and that their commodities shipped across the border will cause alarms, it becomes clear that they will in some way be stakeholders. Considering that people crossing the border in private cars will be affected by traffic slowdowns, occasionally get stopped because of radioactive materials in their bodies from medical test and procedures, and also have to deal with reminders of their vulnerability to radiological and nuclear threats, leads to the conclusion that the public affected by the border crossing also will be stakeholders. As the benefits and costs associated with this mission are considered, there will be a need to define a broad set of stakeholders for whom we want to assess the benefits and costs (and the willingness to pay the costs or accept other considerations).

As we consider the costs, we will want to ask how the costs will be controlled. The first requirement will be to examine the full range of costs to the stakeholders identified. An examination will also consider how costs could be lowered by leveraging assets already available in the region. Benchmarking of similar mission stand up and operations will help ensure that costs are reasonable. There will need to be a well detailed and reviewed procurement plan including provisions for requisite training and maintenance (including spare parts management).

Beyond the consideration of cost, stakeholders will ask whether the system will work to meet the expectations. Included in this line of reasoning will be questions about what fraction of the threat space is covered by the innate capacity of the equipment, whether the staff has the requisite training to use the equipment, whether there are adequate concepts of operations, and whether there is adequate supporting reachback and response staff to resolve the alarms and respond to incidents of illicit transport (or threats). Associated with whether the system will work are considerations around readiness of the equipment and the staff. With respect to readiness, there will be questions about the commitment of the requisite staff to actually operate and respond to the equipment.

From these considerations, supporting questions around deterrence and fraction of threat space addressed are:

1. Given the limitations of the RadNuc screening mission that may exist, is there a consensus on the level of deterrence provided versus that needed? We would look for metrics related to the level of deterrence the

presence of this mission activity at the border would provide. In the literature, we have not found a widely accepted set of metrics on this subject. In fact, there is a difficult question around who should make that evaluation. It could be made at a local level, but since this system might be part of one layer in a multi-layer RadNuc architecture, then the evaluation might need to include the perspectives of national (and perhaps international) partners. Furthermore, since discussions around this type of metric might be considered sensitive and not open for public discussion, there is a question about how to discuss deterrence at a high level in a way to gain broad support by the people and organizations likely to pay the costs of delays in transit at the border crossing. While getting multi-party agreement on the level of deterrence would be difficult, we would expect to see an acknowledgement that some aspect of worthiness of the enterprise should be discussed with respect to deterrence. The most valuable metric then is likely the most difficult to obtain. To support our approach, we still need to articulate the metrics most likely related to deterrence. Related metrics are:

   – A broad enduring consensus of the definition of deterrence
   – A broad enduring consensus on the definition of deterrence of the Radnuc threat
   – A broad enduring consensus on the level of deterrence of the RadNuc threat that is worthwhile
   – A consensus among the agencies associated with the border crossing of the level of deterrence achievable at an acceptable cost.

2. When we developed the diagrams showing the large list of agencies whose missions would include, support or affect our new RadNuc mission, we pointed out that many of these would be stakeholders for the mission. We also noted that the public and businesses affected by the border crossing operations would be stakeholders. The exact number and types of stakeholders will vary from location to location. The question here is whether the appropriate stakeholders have been identified. Related metrics will be

   – The presence and quality of a reviewed consensus document acknowledging the stakeholders and describing how they have been considered in the planning for, the execution of and the assessment of the prospects for the success of the mission. These stakeholders may come from international, national, regional and local considerations. The stakeholders will also include representatives of the regional public.
   – The presence and quality of a document that articulates the benefits and costs to all of the stakeholders that will:

        - Derive benefit from the mission
        - Be affected by the mission
        - Affect the mission as they execute their other missions
    - Documentation recording committee formation to discuss ways to increase benefits and decrease or compensate costs to all of the stakeholders.
    - Documentation showing agreements among the stakeholders on how costs and benefits are assessed. This is likely to be a difficult metric because of the wide range of interests and goals of the stakeholders.

3. Has there been sufficient activity to elevate awareness of the threat, of the approach to counter the threat and of the expected consequences of the approach? Increasing public awareness is a way to help stakeholders find a rationale to accept the cost of the system, the cost of the deployment operations and the cost to trade and to convenience would seem to be one way to establish a pathway for getting their buy-in of the mission. Related metrics would include:
    - The number of times the mission is discussed in the popular regional press
    - Frequency of popular media showing delay times at the border crossing before and those predicted after installation of the mission screening operations
    - Number of workshops held to brief community leaders on the nature of the threat, on non-threat sources of radiation, on detection methods, on operational considerations, and on expected costs to trade and convenience
    - Number and quality of advanced training courses and workshops in law enforcement and emergency response communities
    - Number and fraction of relevant district attorneys and judges have been briefed on the initiative
    - Documentation identifying necessary legal points of contact relevant to RadNuc mission actions
    - Quality of communication to support the medical community. This would include raising their awareness around the intensity of radiation emitted from patients receiving diagnostic tests or treatments that result in radioisotopes residing in the bodies of patients. This also would include supporting the medical community in explaining to the patients that they might cause alarms in the detection systems at our border crossing. An associated metric would be the fraction of these patients who would have access to documentation to carry with them in case documenting why they would have elevated radiation levels for a certain period of time.

4. What portion of the RadNuc threat space can be addressed by the equipment utilized? Under the proposed operational protocols, how much of that space will be covered? Related metrics include:
   – Types of equipment purchased for Primary, Secondary and Tertiary screening stations
   – Types of equipment purchased to support communications within the station and to regional or national information fusion centers
   – Test results giving the probability of detecting various threat types for the RPMs in the presence of the nuisance alarms expected
   – Test results giving the probability of resolving the threats in Secondary screening
   – Modeling results that estimate the effects of varying conditions, like traffic speed, weather conditions, temperature changes on the ability to detect threats and resolve alarms

5. How does the lead agency assure readiness of the equipment, the operations personnel and support services? Related metrics include:
   – Failure modes and effects of the various system components, like detectors, communication systems, displays, procedures
   – Calibration plans and reports
   – Data related to quality assurance of the measurements systems
   – Effectiveness of training
   – Trainee knowledge scores following initial and refresher training courses
   – Fraction of trainees demonstrably capable of executing RadNuc screening duties
   – Evaluation scores during drills and other exercises.

6. How well does this RadNuc mission deployment at the border crossing support the Country A's overarching missions related to radiological and nuclear materials? Country A will have broader missions related to radiological and nuclear materials. Some of these missions will include ensuring the transport of these materials along the federal highways is done in a controlled and safe manner, ensuring that all attempts to import or export these types of materials is authorized, participation in international agreements to control and interdict the unauthorized production, storage and trade of these types of materials. Related metrics are:
   – The presence of written and reviewed documents (or set of documents) articulating how this mission of screening at the border crossing supports these broader missions related to radiological and nuclear materials.
   – The presence of a reviewed plan to continue to upgrade the level of support as technology and methodology advances. Examples would include agreements to support the operational evaluation of these advancing technologies in detection, communication and

information fusion. Other examples would include evaluation of more integrated concepts of operation as the mission gets a broader footprint.

7. What is the likely rate of encounter with normally occurring radiological and nuclear material? We have seen in the literature that there are many types of NORM that can cause alarms. What effect will this rate of interaction have on operations at the border crossing station? Related metrics are:
   – Types and quantities of commodities expected to flow through the border crossing
   – Types of packaging and packing that might change the levels of the radiation reaching the RPMs from these commodities
   – Predictions of frequency of nuisance alarms in primary screening as a function of detection settings for gammas and for neutrons.
8. As was discussed in previous Chapters, the response to a NORM alarm might require a Tertiary screening which might require specialized capabilities (like bomb squads from regional and local police stations or fire stations). Related metrics are:
   – The predicted times for responses by these special capabilities
   – The expected minimum and maximum times for resolution
   – The variation inability to respond depending on frequency of request, and other factors like regional fires, weather conditions, and public events
   – Documentation (like Memoranda of Agreements or some other documentation) describing the commitments among these organizations to provide timely, certified support to the border crossing station.
9. Are there documented concept of operations and reachback protocols? Are they benchmarked against some other installation regarded as successful? Are they being implemented? Are they being tested with red team exercises and/or drills? If so, what are the results? Related metrics include:
   – The presence of a signed regional concept of operations (ConOps), detailing the roles, responsibilities and protocols for all the principal partners.
   – How frequently the basic concept of operations is tested. This would involve testing of actions taken by the primary screening station upon the presence of an alarm. Does the operator send the vehicle to secondary under physical control? Is the concept of operation for secondary followed?
   – How frequently the complete concept of operations is tested. This would include the operation of secondary and tertiary screening as well as reachback and bomb squad support. Since this type of operation generally involves cooperation between multiple organizations in more than one jurisdiction and since we expect the

occurrence of radiological and nuclear threats to be low in frequency, we might expect the concept of operations to be less familiar to the personnel whose daily attention is placed elsewhere.
   - The response time to adjudicate alarms during the more frequent detection of normally occurring small quantities of radiological and nuclear materials being transported throughout the region in the course of normal business activities.
10. What is the level of commitment to this RadNuc screening mission by the people at the border crossing station, and by the people who have to respond from off site? Metrics related to level of commitment may be difficult to develop and measure. Related metrics include:
   - The types and amount of additional equipment they have to operate
   - The types and amount of additional equipment they have to maintain
   - The degree of additional concept of operations responsibilities they have to train for and execute
   - The degree that these personnel feel that the changes brought about by the RadNuc mission enables them to perform their jobs more or less effectively
   - The degree to which they have confidence in the equipment to detect things they care about
   - The degree to which they are likely to turn off the equipment or ignore alarms.
11. What is the appropriate level of information sharing to support this new mission requirement? Radiological and nuclear threats can be transported throughout a region very quickly. To improve the likelihood of detecting the movement of these threats, a region can use data and information fusion centers. Relevant metrics include:
   - The presence and use of information fusion centers for collecting, analyzing and sharing information that might be relevant to all sorts of criminal activity, and relevant to situational awareness for natural disasters, like fires, floods, earthquakes, severe storms, etc.
   - Memoranda of agreements among the institutions (international, national, state, regional) which would have or want this data. We expect this to be a difficult metric because information that is aggregated up to sensitive or classified levels will have restrictions on distribution. This information is also likely to contain personal information that will need to be controlled, like driver's license information, passport data and arrest records,
   - The partners might have to decide how to share threat information, situational awareness reports, and readiness levels
   - Ability to get timely and sufficient information to the users throughout the region, as demonstrated in exercises.
12. What will be the cost of the equipment? This will include purchase price, installation cost, maintenance cost for an acceptable frequency of

maintenance, and cost of spare parts. We expect that some metrics in this area will be easy to capture. They would include publicly available budget projections and reports related to:

- Capital and annual support costs for each equipment type
- Routine calibration, maintenance and repair costs
- Average cost to equip and train each type of equipment operator.

13. What will be the cost to the other agencies not directly related to this mission but affected because of it? Obtaining an answer to this question might be difficult because these organizations will be accustomed to accounting nomenclature and information clustering and cost tracking around the missions for which they have lead responsibility. Related metrics are:
    - The annual cost for each relevant organization to execute and support the new or increased mission
    - Cost of red team exercises and/or drills for each participating organization.
14. What space will be required for this RadNuc screening operation? Will a Tertiary screening station be required, and is there space to accommodate that need? Related metrics include:
    - The presence and quality of a space utilization plan showing how the space required for this mission fits into the overall space management strategy
    - The presence and quality of a plan to provide special needs for Tertiary screening, where the vehicle should be placed under stricter control, access by others should be controlled, special equipment will be used.
15. How are RadNuc equipment types/models for procurement selected? Related metrics are:
    - Presence of a committee responsible for selection of equipment for the RadNuc mission. The members of this committee should include representatives knowledgeable about current and planned the infrastructure at the border crossing station.
    - Committee members are familiar with testing of the RadNuc equipment in accordance with expected operating requirements (power quality, power cycles, temperature, vibration, moisture, wind, ground currents, thermal shock, dropping, snow, rain, temperatures, radiofrequency spectrum, time required to start up after operational upsets).
    - Reference to benchmarking performance with similar equipment used in other locations.
16. Does procurement of the equipment follow a procurement plan approved at the appropriate levels? Related metrics include:
    - Clarity of description of source of funding (federal, state, and/or local agencies)

- Clarity around which organization will be responsible for the first purchase of equipment, and then which organizations will continue to buy equipment as needed
- Degree of consideration of standardization of equipment throughout Country A, or at least in DHS-A
- The presence and quality of a plan reviewed by competent experts, supported by modeling and simulation that establishes the number and types of equipment needed
- The level of understanding by the authorizers of the procurement around the mission requirements and at some level the technical basis for the equipment selection
- The level of consideration of the long term requirements for maintenance and spare parts, and spare instruments
- The quality of adequate conditioned space for storage of the equipment, including spare parts
- The presence and quality of an analysis around whether the procurement plan helps or hurts the prospects of any of the other missions relevant to the border crossing
- Clarity of the acceptance requirements for procured equipment.

17. How well is the procurement plan being followed? We would expect to see:
    - Evidence that the acceptance tests were performed in accordance with the plan
    - Documented results of testing
    - Evidence of communication of the results to the appropriate people
    - Data showing how much of the equipment was found to be unacceptable and why.
18. Is there a maintenance plan for the long term maintenance of the equipment, reviewed by the appropriate authorities? Related metrics include:
    - The presence and quality of a written and reviewed maintenance plan that details how the equipment will be maintained: by individual agencies, by a regional capability, and/or by vendors
    - Inclusion of the costs of this maintenance plan in the estimated procurement and operating costs
    - Degree to which the maintenance planning addresses the equipment of all of the agencies which will support the mission.
19. Are the costs incorporated into an overall business model that also includes the costs of impact of the screening? Related metrics include:
    - Quality of a business model
    - Discussion of cost expectations related to impact on flow of commerce through the border crossing
    - Revenue generation from fines and tariffs
    - Costs of additional caseloads associated with arrests

- Presence of periodic updates to validate or improve business model.

20. Does this mission leverage existing capabilities in the region for detection and interdiction of RadNuc threats? These capabilities might include equipment (like handheld radioisotope identifiers, radiation pagers, and calibration sources), protocols (like protocols used by police or emergency management organizations dealing with hazardous materials), training (for dealing with suspicious cargo or vehicles) and legal constructs (right to stop, detain, arrest suspicious vehicles or persons)? To what degree does this mission application use these existing resources to control costs to lower or control costs? Related metrics will include:
    - Type and numbers of equipment
    - Documentation of training and certifications for hazardous materials characterization, handling, examination, especially radiological and nuclear
    - Number and quality of existing protocols and procedures for response to radiological situations (spills, orphaned sources)
    - Type and number of exercises and drills in the country, state and region applicable to the RadNuc mission operational envelope
    - Number and type of emergency responders within each agency in the region.
21. What approach was taken (e.g. seminars, workshops, meeting, etc.) to establish a common understanding of the RadNuc mission among partner agency representatives (e.g., the nature of the threat, detection methods, etc.)? Which agency leaders participated in these efforts? Related metrics include:
    - Types and numbers of their planned workshops, seminars for RadNuc reachback operations
    - Types and numbers of drills to reinforce learning and test skill levels and protocol efficacy
    - Types and numbers of agency leadership participation in drills.

How will the mission endure?

The literature showed that that there are many new security related initiatives being placed onto border crossing operations. In some cases funding is provided for initial startup and initial operations of security missions but there may be an expectation that the mission will be integrated into border crossing operations in a manner that continuing funding from the originating agency for the mission will stop or at least be reduced as time goes on. A further challenge is that the RadNuc screening mission can be viewed as looking for a threat that hopefully will never occur. That means that for an entire career, a border crossing official will be dealing with nuisance alarms and may never see an actual threat, all the while having to execute his other mission responsibilities. This is exacerbated by the fact that, as we saw in the literature, he may be evaluated by the amount of

goods he processes or the amount of violations of regulations he detects. His management may not have a mechanism to get any revenue from this RadNuc screening operation. As we saw from the literature, in some countries, a significant part of their budget comes from tariffs and fines at border crossings. In the case of RadNuc screening, there may have to be some sort of revenue generating paradigm.

Another challenge is that the public may get tired of paying the cost in terms of delays in vehicle crossings, in terms of increased costs of goods that have to be screened, and in terms of societal costs of being reminded about their vulnerability to radiological or nuclear terrorism.

Supporting questions related to whether the mission will endure are:

1. Is there a championing organization in the region for the mission and for the application of the mission to the border crossing? Related metrics include:
   - Level of advocacy publicly through the press
   - Level of advocacy at planning meetings among the stakeholders.
2. How will an enduring awareness of the need for the RadNuc mission be established? As metrics, we might expect to see:
   - Scores from public opinion polls around whether the cost (financial as well as societal) is reasonable for the threats
   - Number of threat awareness, detection, interdiction and response workshops held
   - Number of press/media releases
   - Presence of and participation in citizen engagement programs for radiological and nuclear security
   - Quality of a plan to establish and maintain a sound legal basis for detection and interdiction.
3. How is this mission regarded in Country B, in other countries, in other states and regions? Is the threat continuing to be viewed as credible?
4. How will political support in Country A be maintained? Related metrics include:
   - The number and fraction of appropriate officials briefed
   - Number and fraction of strong partnerships with international, national, regional, state and local organizations associated or affected by the mission.
5. What levels of legal support are required, and how will that support be sustained? Related metrics include:
   - The quality of a plan to establish and maintain a sound legal basis for detection and interdiction.
   - The number and fraction of appropriate district attorneys and judges briefed.

6. Has the lead agency implemented a transition plan and sustainment concept to provide the ability to maintain operational capabilities? Related metrics include:
   - The presence and quality of an approved plan for long term operations
   - The presence in the budgets of other agencies of the necessary funding to fully support the mission long term as necessary
   - A sustainable consensus between partners over the multiple years required to develop and solidify an effective regional capability
   - Presence and quality of a clear business model for the RadNuc mission in the region
   - Evidence that the agencies involved or affected have a clear understanding of the transition plan for the operations to go from startup to multi-year term continuous operation.
7. How will the lead agency engender an enduring commitment by the personnel to continue to use the appropriate detection equipment and do so in a manner aligned with the agreed upon concept of operations? When the mission is new and there may be some excitement about the new equipment and new relationships associated with the concept of operations, then the level of commitment might be high. However, if there are several nuisance alarms that take time away from other activities the personnel normally do, then that might lead to an erosion of commitment. In our case, we want to protect the metropolitan area MA1 From which we would expect many of the staff to come. But if the staff feels the threat is really to areas outside their circle of interest, they also might have an erosion of commitment. Related metrics include:
   - The presence and quality of a written and reviewed plan to maintain commitment.
   - Results of benchmarking for maintaining commitment in similar mission spaces
   - The presence and quality of a methodology to assess commitment, including a discussion of best practices in other similar low mission spaces
   - Documentation discussing quality of commitment during refresher training
   - Demonstrated capabilities of personnel in red teaming exercises.
8. Does a plan for sufficient continuing training beyond first operation include all of the agencies and personnel necessary to support the RadNuc mission? Is the planning being followed? Related metrics include:
   - Number and type of training courses for each agency
   - An assessment of the quality of the training around the concepts of operations training

- Availability of additional complementary specialized training (hazardous materials, responder operations, tactical operations, response, FBI-A training on handling suspected or actual threats of different types, and vendor training)
- Written and budget authorized plans for requalification of personnel involved in scanning, especially in Secondary, in Tertiary and in reachback operations
- Availability and use of refresher training and/or requalification
- Frequency of updates to the training plan
- Degree to which training costs are controlled, minimized and judged reasonable by the agencies and the individual participants.

9. How many additional personnel need to be trained for each agency as a result of this additional mission? We would expect to see analyses of the impact on other agencies affected by the new mission.
10. What drills and other exercises are planned/performed that include the border crossing station? Related metrics include:
    - How many personnel from each partner agency participated in each?
    - Is participant performance quantified as part of these exercises? If so, how, and with what results?
    - What is the number and quality of after action reports?
11. Is there evidence of taking stock about what seems to be working well and what does not work well regarding inter-agency coordination? We would expect to see:
    a. Committee meetings for the purpose of discussion around inter-agency coordination issues and approaches for optimization.
12. What are the strengths and weaknesses of the RadNuc screening mission program and the program structure? What could be done better? Related metrics are:
    - Transparency of structure
    - Transparency of decision-making processes
    - Clarity of long range view
    - Continuing assessment of costs of the mission application
    - Continuing assessment of the benefits, including the difference the mission is making relative to regional security (expected benefits would include improved technologies and integrated concepts of operations resulting in increased detection of other regulatory compliance transgressions)
    - Long term collection of data in accordance with a written plan on the subjects of alarms, calibration results, equipment issues, noncompliance with concepts of operations. This metric may be difficult because we would expect that agencies and personnel will be reluctant to share operational issues.

13. Are lessons learned from other benchmarking locations being communicated and utilized? We would expect to see metrics around benchmarking activity and how lessons learned are being considered in revisions to planning.
14. How important is standardization in this mission space for this application? To what degree is standardization being explored, planned, executed and evaluated? Standardization could apply to the equipment, the types of personnel, training, maintenance, and concepts of operations, standards of operations and accounting and assessment of the mission. Related metrics include:
    - Establishment and use of standardized equipment configurations and detection parameter settings. We expect that standardization in this area would simplify and make more effective activities including training, planning for and analysis of exercises, the adjudication of alarms and maintenance of equipment, and acquisition of spare parts.
15. How well is the concept of operations being followed and how effective is it? Does it contain steps that can be eliminated, streamlined, improved? Are there additional steps that would make the mission space more effective? To what degree is the concept of operations seen as reasonable and well integrated? Related metrics include:
    - The degree of standardization within the concept of operations
    - The degree to which the concept of operations is being followed
    - The degree to which the concept of operations is aligned with the region, the state and international best practices
    - The degree to which the concept of operations is aligned with training, equipment procurement, reporting, evidentiary data gathering
    - The number of times the concept of operations is not followed, the reasons why and any consequences
    - The quality of the concept of operations as viewed by the operating personnel, the reachback support, local law enforcement and the trainers
    - The quality of the concept of operations as seen by the remaining stakeholders
    - The presence of a committee or other group to review and assess the concept of operations, including the incorporation of lessons learned from drills and red team exercises and results of benchmarking with similar mission deployments at other locations.
16. How well are lessons learned from drills, red team exercises and normal operations being utilized? Related metrics are:
    - A documented formal process/plan to capture lessons learned from each workshop, drill, and exercise

- Lessons learned from drills and exercises are captured in after-action reports and briefings from the exercises.
- The presence of a formal process for reporting of learnings from normal operation and how much it is being used.

17. How effective is the sharing of lessons learned to the appropriate stakeholders? Related metrics will be:
    - Number and quality of reviewed reports documenting lessons learned
    - Presence and quality of reviewed periodic summaries of lessons learned
    - Number and quality of meetings to brief lessons learned to stakeholders
    - Presence and quality of web addressable resources for reviewing or adding lessons learned.
18. What legal/jurisdictional/inter-agency issues were identified as part of STC? Related metrics are:
    - To what extent were the Country A Attorney/District Attorney Offices were involved in developing the mission
    - To what level they remain committed to the mission
    - Comparison between what they expected to happen and what has happened
    - The quality of the experience with issues around the necessity for probable cause, reasonable suspicion, search and seizure, as well help in obtaining search warrants relative to the RadNuc mission.

Is the new RadNuc mission symbiotic with the other international, national, state and local missions?

We have made the point that this RadNuc screening mission will have to be integrated into an existing set of missions at the border crossing. We should also point out that the missions already being executed at the border crossing are part of a broader national (and probably international) set of mission responsibilities. Just as those missions extant at our border crossing should be integrated into a larger strategic security plan, so should this new RadNuc screening mission. Advantages are that there more likely will be support from the other mission resources, like sharing of information technology infrastructure, sharing of space, and willingness to integrate concepts of operations including interdiction and response. In terms of willingness to accept costs among the agencies, a symbiotic relationship would be expected to be a positive.

Supporting questions around this question of symbiosis are:

1. How are the international, national, regional and local partnerships created to support this RadNuc screening initiative and how have the partners embraced the mission as evidenced by developing tactics, techniques and

procedures that will help achieve the overall enterprise goals? Related metrics include:

- The presence and quality of multiagency committees that address the full scope of missions related to trade facilitation, regulatory compliance, security at all levels, regional and local governmental operations and public perception and impact and how this RadNuc mission is related
- Frequency of documented meetings of these committees
- Level of representation of the partner delegates at these meetings
- Written plan assessing effectiveness with respect to this mission
- of the partnerships and the likelihood of continuing them
- Written description of the RadNuc mission program metrics and the level of acceptance by these partners
- Level of agreement among the partners on how mission performance will be measured and what data will need to be collected to enable the measurement
- Amount and quality of data collected as planned
- Level of involvement with international stakeholders affected by this mission.

2. Are the costs of this new mission characterized by each stakeholder and acceptable to those agencies that are affected at the local, national and international levels? Related metrics include:
   - Presence and quality of written and reviewed analyses of financial and other costs to each organization
   - Documentation of meetings discussing these costs, ways to control them, ways to reduce them in the future, and ways to compensate for them.
3. Are the benefits to each stakeholder characterized and accepted by relevant representatives of the stakeholder? Related metrics include:
   - Presence and quality of written and reviewed analyses of benefits to each organization
   - Documentation of meetings discussing these benefits, ways to continue or increase them
   - Evidence of success in maintain or improving benefits to stakeholders in a way that does not cause uncompensated loss to others.
4. To what degree is the equipment to be used for RadNuc screening compatible with the equipment being used in related activities like law enforcement, customs compliance checks, safety checks, reachback and emergency management? Related metrics include:
   - Evidence of committees continuing to work toward better integration of equipment used at the border crossing station.

5. How compatible are the concepts of operations for RadNuc screening with the concepts of operation for the other missions at the border crossing? Related metrics include:
   – Evidence of committees continuing to work toward better integration of the operations used at the border crossing station.
6. Does the RadNuc mission positively or negatively impact the ability to execute other law enforcement missions? Related metrics include:
   – Written analysis of increase or decrease in arrests, fines, tariffs at the border crossing not related to the RadNuc mission
   – Written analysis of an increase or decrease in personnel required at the border crossing and in the region caused by the RadNuc mission.
7. What is the quality of commitment by the partners to support this increased mission space in the region (especially at the border crossing)? We would look for evidence a significant dialogue around the increase in mission space and how it was bringing various levels of cost and benefits to the partners. Related metrics include:
   – The presence of relevant high level strategic goals in the strategic plans of all of the partners,
   – Inclusions of the new mission space into the existing mission statements of all of the partners,
   – Budget and appropriations processes for each of the partners to support the new mission
   – Evidence of a strong consensus needed between the lead agency and the relevant partners on programmatic goals and objectives, timelines and metrics.
8. Have the partners established and committed to a governance structure that includes this new mission? If a threat is detected but not interdicted in one part of the region, will the authorities in another part of the region interdict it? Will the legal framework support this type of interdiction throughout the region? Metrics that might be applicable include
   – Establishment of necessary regional committees and subcommittees
   – Number and fraction of relevant state and local government agencies/representatives involved
   – Number and fraction of relevant federal agencies/officials involved
   – Number and fraction of needed cooperative agreements signed
   – Requisite number and frequency of committee, subcommittee meetings
   – Presence of a signed regional ConOps
   – Degree of participation in region-wide red team exercises around the new mission space.
9. Are there partnerships with other international, federal, and state and local organizations that are mutually beneficial? For example, federal and state

and local emergency management organizations might want to share equipment requirements development processes. They also might want to provide mutual procurement activities. Furthermore, planning for response to and recovery from the detonation of a radiological or nuclear threat should include many of the resources that will be used in the detection and interdiction phases. Related metrics include:

- Agreements around what types of information could be shared with which organizations in the event of a detonation
- Signed memoranda of understanding about information sharing
- Presence of signed protocols to support these memoranda
- Presence in the information sharing software architecture to support the protocols
- Presence of effective integrated planning teams to continually assess and advocate improvements in architectural elements of the combined mission space.

From these considerations, then, an interesting set of metrics related to planning and management of the RadNuc mission can be developed for our hypothetical border crossing station.

A summary of the metrics derived in the report is shown here. The list will be followed by a series of tables describing how the values of some of these metrics can be found. Other metrics will prove difficult to measure or obtain. Unfortunately they are the ones most valuable in determining the efficacy of our enterprise.

1. Deterrence metrics
   - Consensus definition of deterrence
   - Consensus definition of deterrence of the Radnuc threat
   - Consensus on the level of deterrence of the RadNuc threat that is worthwhile
   - Consensus on level of deterrence achievable at an acceptable cost
   - Actual deterrence effect on adversaries
2. Stakeholder planning commitment metrics
   - Presence of a championing organization in the region
   - Level of advocacy for the mission
   - Degree of involvement by stakeholders in planning
   - Consensus on benefits and costs to all deriving benefit
   - Consensus on benefits and costs to all affected by the mission
   - Committee to discuss ways to increase benefits and decrease or compensate costs to all of the stakeholders.
   - Consensus on how costs and benefits are assessed
   - Number of jurisdictions involved
   - Results of benchmarking commitment plans in other similar mission spaces

3. RadNuc awareness metrics
   - Frequency of press coverage
   - Fraction of informed press coverage
   - Frequency of popular media comparing effects of RadNuc mission compared to predictions (delay times, costs, arrests)
   - Number of workshops held to brief community leaders
   - Number and quality of advanced training courses and workshops in law enforcement and emergency response communities
   - Fraction of relevant district attorneys and judges have briefed
   - Availability of relevant legal points of contact
   - Quality of communication to support the medical community.
   - Fraction of these patients with documentation about radioisotopes from medical procedures
   - Presence of and participation by citizen engagement programs
   - Number and fraction of authorized source holders briefed/provided
   - Scores from public opinion polls around whether the cost (financial as well as societal) is reasonable for the threats
   - Presence of and participation in citizen engagement programs for radiological and nuclear security
   - Quality of a plan to establish and maintain a sound legal basis for detection and interdiction
4. Coverage of threat space metrics
   - Types of equipment purchased for screening stations
   - Types of equipment purchased to support communications
   - Test results giving the probability of detecting threats in Primary
   - Test results giving the probability of resolving the threats in Secondary
   - Test results giving the probability of resolving the threats in Tertiary
   - Modeling results that show systems capability under varying conditions
   - Modeling results showing probability of encountering threat quantity materials
5. Readiness metrics
   - Consideration of system component failure modes and effects
   - Quality of calibration plans
   - Data related to quality assurance of the measurements systems
   - Effectiveness of training
   - Trainee knowledge scores following initial and refresher training courses
   - Fraction of trainees capable of executing RadNuc duties
   - Evaluation scores during drills and other exercises
   - Number of emergency responders initially trained for each course
   - Refresher training frequency
   - Percentage of emergency responders trained for each partner agency
   - Number/frequency of discussion-based exercises (seminars, workshops, tabletops)

- Number/frequency of operations-based exercises (functional, drills, full scale)
- Level of partner agency participation in each exercise
- Training and exercise participant feedback metrics
- Number and type of training courses for each agency
- An assessment of the quality of the training around the concepts of operations training
- Availability of additional complementary specialized training (
- Written and budget authorized plans for requalification of personnel involved in scanning
- Availability and use of refresher training and/or requalification
- Frequency of updates to the training plan
- Degree to which training costs are controlled, minimized and judged reasonable

6. Support to Country A's overarching missions metrics
   - Consensus on how screening at the border crossing supports broader radiological and nuclear missions.
   - Agreements to support the operational evaluation of advancing technologies in detection, communication and information fusion at border crossing
   - Agreements on evaluation of more integrated concepts of operation at the border crossing as the mission gets a broader footprint.
7. Rate of threat material encounter metrics
   - Types and quantities of commodities expected g
   - Types of packaging and packing that might alter radiation levels
   - Predictions of frequency of nuisance alarms from NORM
8. Commitment for Tertiary screening support
   - The predicted times for responses by requisite special capabilities
   - The expected minimum and maximum times for resolution of alerts
   - The variation in ability to respond depending on frequency of request, and other factors like regional fires, weather conditions, and public events
   - Documentation of commitments to provide timely, certified support
9. Concept of operations and reachback metrics
   - Benchmarked against some other installation regarded as successful
   - Degree of implementation
   - Presence of a signed regional concept of operations (ConOps)
   - Frequent validation of integrated concept of operations
   - Frequent validation of reachback and bomb squad support. operations
   - Response time to adjudicate alarms in Secondary and Tertiary
   - The degree of standardization within the concept of operations
   - The degree to which the concept of operations is being followed
   - The degree to which the concept of operations is aligned with the region, the state and international best practices

- The degree to which the concept of operations is aligned with training, equipment procurement, reporting, evidentiary data gathering
- The number of times the concept of operations is not followed, the reasons why and any consequences
- The quality of the concept of operations as viewed by the operating personnel, the reachback support, local law enforcement and the trainers
- The quality of the concept of operations as seen by the remaining stakeholders
- Continuing assessment of concept of operations

10. Operations impact at border crossing metrics
    - The types and amount of additional equipment to operate
    - The types and amount of additional equipment to maintain
    - The degree of additional concept of operations responsibilities
    - The degree that personnel feel that the changes enable them to perform their jobs more or less effectively
    - The degree to which they have confidence in the equipment
    - The degree to which they are likely to turn off the equipment or ignore alarms
    - Delays in passenger vehicles caused by RadNuc screening mission
    - Delays in commercial vehicles caused by RadNuc screening mission
    - Impact of delays on just-in-time trade
    - Number of safety events at border crossing caused by RadNuc screening operations
    - Quality of the experience as public go through screening
11. Information sharing metrics
    - The presence and use of information fusion centers
    - Agreements among relevant institutions (international, national, state, regional) to provide and share data.
    - Agreement on how to share threat information and situational awareness reports
    - Ability to get timely and sufficient information to the users throughout the region, as demonstrated in exercises
12. Cost of the equipment metrics
    - Capital and annual support costs for each equipment type
    - Routine calibration, maintenance and repair costs
    - Average cost to equip and train each type of equipment operator.
13. Cost to other agencies metrics
    - Annual cost for each relevant organization to support the mission
    - Cost of red team exercises and/or drills for each organization
14. Space requirements metrics
    - Space utilization plan showing how mission fits
    - Plan to provide special needs for Tertiary screening
15. Procurement metrics

- Qualified procurement committee responsible for selection of equipment
- Reference to benchmarking performance with similar equipment
- Clarity of description of source of funding (federal, state, and/or local agencies)
- Clarity around which organization will be responsible each phase of procurement
- Modeling and simulation that establishes the number and types of equipment needed
- Level of understanding by the authorizers of the procurement around the mission requirements
- Level of understanding of technical basis for the equipment selection
- Quality of long term planning for for maintenance and spare parts, and spare instruments
- Quality of adequate conditioned space for storage of the equipment, including spare parts
- Analysis around whether the procurement plan helps or hurts the prospects of any of the other missions relevant to the border crossing
- Clarity of the acceptance requirements for procured equipment
- Evidence that the acceptance tests were performed per plan
- Documented results of testing communicated to appropriate people
- Data showing how much of the equipment failed acceptance tests

16. Maintenance planning metrics
    - The presence and quality of a written and reviewed maintenance plan that details how the equipment will be maintained: by individual agencies, by a regional capability, and/or by vendors
    - Inclusion of the costs of this maintenance plan in the estimated procurement and operating costs
    - Degree to which the maintenance planning addresses the equipment of all of the agencies which will support the mission
17. Leverage of existing capabilities metrics
    - Type and numbers of existing equipment
    - Existing training and certifications for hazardous materials characterization, handling, examination, especially radiological and nuclear
    - Number and quality of existing protocols and procedures for response to radiological situations (spills, orphaned sources)
    - Type and number of exercises and drills in the country, state and region applicable to the RadNuc mission operational envelope
    - Number and type of emergency responders within each agency
18. Partnership-related metrics

- Number and fraction of relevant State A and local government agencies/representatives involved
- Number and fraction of relevant Country A agencies/officials involved
- Number and fraction of needed cooperative agreements/MOUs/MOAs signed
- Frequency of committee, subcommittee and other related meetings
- Time/effort required to develop and finalize ConOps; revision frequency
- Number and fraction of needed agency-specific standard operating procedures in place; revision frequency
- Types and numbers of drills to reinforce learning and test skill levels and protocol efficacy
- Types and numbers of agency leadership participation in drills

19. External viewpoint metrics
    - Value of the mission as viewed by relevant international organizations
    - Alignment with international security missions
    - Alignment with Country A security missions
20. Quality of Operations metrics
    - Number of jurisdictions involved in screening, interdiction, response
    - Number of people involved
    - Consistency of operations
    - Operational characteristics of portal monitors and other fixed detectors
    - Frequency of alarms
    - Causes of alarms
    - Number and fraction of alerts referred to secondary screening, tertiary screening
    - Response times for primary detection, secondary screening, tertiary screening, technical reachback
    - Operational difficulties in escorting and controlling alarming vehicles to secondary and then to tertiary screening (when necessary)
    - Results of analysis of alarm adjudication/resolution results (categories, outcomes, etc.)
    - Results of analysis of number/frequency of missed alarms (red teaming, exercises, known calibration sources)

Further Categorization of Metrics

In this section the following general questions are addressed as they pertain to the proposed metrics for regional nuclear security upgrades. These questions ask:

(1) From what sources are particular data for metrics obtained?, and

(2) What methodologies are most applicable to obtaining the data?

Understanding how to categorize the metrics and their data helps us determine the best means for gathering the necessary data. No one organization collects or stores all the data for a particular metric, partly because the scale of the data must be taken into account and understanding the scope of the data is necessary. There exist different organizations that store data at the federal, state, and local levels; thus, it would be incorrect to focus on any one specific organization from which to obtain a particular subset of metric data.

Three broad principal metric types may be categorized in this study: financial metrics, operational metrics, and performance metrics. Generally, financial metrics help determine the cost-benefits of the program, operational metrics describe how an organization or agency conducts itself within the context of a larger system, and performance metrics aid us in understanding the effectiveness of the program implementation.

Alternatively, some metrics do not lend themselves well to categorization under these three types because their data are more specific. They fit best within categories tailored to their role within the mission space. Some of these metrics will be available within the public sphere of knowledge through organizations such as the Country A Transportation Security Administration (TSA-A), Department of Transportation (DOT-A), and Department of Homeland Security (DHS-A), while others will be more difficult to obtain due to their sensitivity. These metrics are categorized into groups that are defined based on the needs of the proposed mission space.

Both static and dynamic data will exist. Generally, static data includes infrastructure data such as border crossing layout and facilities, roadways and waterways into and out of a region or cost data for equipment and facilities. Dynamic data is that which changes with time such as traffic flow, commodity profile data for a region or response times to threat alerts. Time-in-motion data is a form of dynamic data that may be used for operational assessments. This particular data type is useful, for example, for determining the best changes to the existing organizational structure in order to increase the efficacy and effectiveness of the RadNuc mission. For much of the metrics, however, the designation is provided or assumed that the data collected will consist of an “initial” assessment.

Financial Metrics

The implementation and increase in mission space can be a financial burden on a government or agency or businesses, and financial metrics are used to calculate direct and indirect costs. Measuring the costs against the estimated

overall benefit of the new mission space allows an agency to determine the effectiveness of the program. Ultimately, this information will help an agency decide the degree of implementation available for the new program.

Financial metrics generally include metrics dealing with cash flow, including spending and earnings. In an assessment, we would analyze financial metrics such as equipment repair costs, costs of training exercises, and cost/benefit data regarding impacts to commerce in a region. Any piece of data which provides insight into how money is managed within an organization is applicable under this category. These metrics are important to the stakeholders of the mission, especially those who make decisions of whether or not to fund particular projects under the sustained mission.

Mostly, the data for financial metrics already exist in some form. Some of this data like equipment costs and warranties may come from the manufacturer or an insurance agency. Other data such as costs for training each type of RadNuc operator may come from those conducting the training, the agencies being trained, or both. Furthermore, data necessary for determining the total cost for each agency to execute and sustain the missions will come from a variety of public and agency specific sources and may even need to be synthesized from multiple metrics and data.

Operational Metrics

Operational metrics mostly concern the utilization of resources within each agency. They track the dynamics of each organization and how they are linked to other organizations. Metrics which address the operational level may include the “number of something” on the agency level, such as number and type of equipment owned and maintained and number of emergency responders who undergo RadNuc training. They may also include regional level metrics such as number of roadways/waterways near the border crossing or into or out of a region and the number of vehicles using these roadways. Some of this data such as number of roadways into and out of a region may be obtained simply by analyzing a current map of the region. Others, such as number and type of traffic across these roadways, will need to be acquired from Department of Transportation (DOT-A) databases and state and local transportation agency sources.

To help measure how agencies are linked within the existing architecture, metrics dealing with information sharing may fall under this category as well. These include the number of interconnected regional fusion centers, number of shared “lessons learned” incident reports, and community-of-interest feedback and inquired. The metrics involving information sharing help determine the level of interconnectedness between agencies and also the appropriate behaviors a

particular agency should undertake in a variety of situations. For instance, when a threat is detected, what level of information may one agency share with another or, when a known threat crosses into another agency's jurisdiction, what process is required for an agency to either continue pursuing the threat or pass along the pursuit. The data for these metrics are likely to be sensitive in nature since they include specific details on how each agency and how the integrated mission operates and thus may not be available in the public domain. Because of this, close cooperation with agencies will need to be established in order to obtain the necessary data for these metrics.

Performance Metrics

Some metrics assess how well an organization performs against a set of criteria. These performance metrics may focus on how well an organization performs against itself. For instance, during an in-house upgrade, a before and after performance snapshot may be taken to determine the effectiveness of the upgrade. Under this category fall metrics such as knowledge scores from before and after training courses and probability of detection of various types of threats before and after equipment upgrades. Other performance metrics may focus on how well an organization performs against a critical success factor, in our case defeating a radiological or nuclear threat. "Red cell" results and data from threat alerts would be used to assess the performance of an organization versus multiple threat types and a variety of threat pathways. Benchmarking also provides a source of data. These metrics could then be used to modify the mission to improve the effectiveness of the organization at combating these threats.

Data for these metrics may be obtained from a full spectrum of sources, some public and others agency specific. Even still, due to the nature of performance metrics, some data would need to be obtained through more sensitive channels. This is because these data may be used to outline capabilities and weaknesses and could be used by an enemy to negatively impact the agency or mission.

Data Sources for Metrics

Surveys

One approach to data collection consists of surveys. These surveys may be questionnaires or polls, which serve to determine key data on any scale whether it is at a regional or local level. They must focus on the metrics they collect data for due to the difficulty in follow-up questions to clarify responses. Questionnaires may be automated, freeing up time for later analysis. One must keep in mind, however, that while questionnaire type surveys are relatively

simply to generate and collect, they may receive a small response from the population of interest. Further time would need to be spent to determine if this level of response is sufficient for the purposes of our study. Data for metrics that involve the public stakeholder (public, press, decision and policy makers, etc.) support and acceptance for the increase in mission space may be collected using questionnaires and polls. Furthermore, individual agency data and statistics may be obtained through the use of questionnaires.

Interviews/Expert panels

Other types of surveys include interviews and expert panels. These surveys are not as scalable as questionnaires and are more time intensive. They may require large amounts of resources and represent narrow viewpoints. However, when facing a complex issue, direct input from those involved on a day-to-day basis helps collect valuable information. While raw quantitative data may not be obtained from an interview or expert panel, other useful information may be recorded.

Government/Agency maintained databases

Empirical data may be obtained from databases maintained by the government and local supporting agencies. The data found here are generally highly credible. Some databases may contain information sensitive in nature and thus data collection from them may be difficult. These databases may contain data that are both static and dynamic, which would affect data collection methods.

Suggested Data Sources for Various Metrics

Country A Transportation Security Administration (TSA-A)

The TSA-A collects and assesses transportation security data for the entire Country A. Much of this data includes infrastructure data and usage data for the many threat pathways relevant to by our RadNuc mission. Some of the information is sensitive such as training information and threat procedures for security personnel in the transportation field. Also collected may be technology data that relates to security. Crucial to an assessment of regional security, this may include efficiency data and detection rates for portal monitors and other radiation detectors.

Metrics for which data may be collected from TSA-A databases include test results giving probability of detecting various threat types for each detector type, response data to alerts including alarm adjudication/resolution results, causes of alerts, and frequency of alerts. Much of the data relating to national security may

be sensitive in nature, and estimation may be required to determine data for certain metrics.

Country A Department of Homeland Security (DHS-A)

The DHS-A collects and provides data and statistics from multiple response layers of the nuclear detection architecture. These response layers address emergency planning and recovery, infrastructure protection, and threat mapping for regional police, fire, and emergency teams. While possibly sensitive, this data would be essential in determine numerous metrics such as number and frequency of missed and incorrectly handled alerts, "red cell" results, and operating characteristics of portal monitors and other fixed detectors.

Critical Infrastructure and Key Resource (CIKR) data may be laid over the foundational maps. These may include data associated with law enforcement facilities, commercial facilities, emergency services, healthcare and public health centers, and regional and local government facilities. Metrics for which data may be collected using DHS-A databases and these tools include mapping regional jurisdictions of emergency and medical response agencies and estimating response times for interdiction of detected threats. Included would be metrics dealing with roadways along with traffic data for these pathways.

Country A Federal Emergency Management Agency (FEMA-A)

The Federal Emergency Management Agency (FEMA-A) is part of the DHS-A. In developing an integrated regional RadNuc security plan, data from FEMA-A would aid in determining the level of interoperability among the existing emergency organizations. Furthermore, data for metrics such as the degree of collaboration on the existing emergency response infrastructure, number and types of benefits to state, local, and federal emergency responders, and number and fraction of current standard operating procedures (SOP) for emergency threats are available from FEMA-A. This information would help determine the overall quality of information sharing and mutual benefit among organizations, along with the overall preparedness of individual organizations and agencies to combat a threat. Because FEMA-A develops response data to natural disasters as well as terrorist threats, they are an ideal source for developing an integrated model.

Country A Department of Transportation (DOT-A) and Bureau of Transportation Statistics (BTS-A)

The Department of Transportation (DOT-A) and its organizations provide transportation data and statistics on federal and state levels. An example of a state level organization under the DOT is the State A Department of Transportation (DOT-A1). These organizations maintain and provide dynamic

volume data such as population by area or cargo through specific pathways. For instance, volumes of commodities of different types expected to pass through our border crossing will be included in data the DOT-A maintains. This data would aid in developing metrics such as random encounter probability of a threat along pathways, number/frequency/durations of vehicles and vessels patrolling region and of surge deployments, and integration of partnerships among regions.

Equipment vendors

Individual vendors of detection equipment would need to be contacted to collect data on specific equipment metrics. These metrics would focus on statistical data on equipment operation characteristics and instrumentation quality control data.

Local/Regional agencies

Local and regional agencies are expected to be a vital resource when investigating metrics dealing with these agencies specifically. Each agency operates differently, and because of this, specific attention will need to be committed to each to appropriately address particular metrics. These metrics for equipment and training purposes may include fraction of time equipment is applied to the mission, fraction of time equipment is found to be improperly calibrated, number and frequency of seminars, workshops, and tabletops. Other metrics, which deal with the quality of regional partnerships, support for the increase in mission space, and mutual benefits among agencies, include number and fraction of agency-specific SOPs in place, number and fraction of authorized source holders briefed/provided with “best practice” reports, and number of signed MOAs about information sharing.

Data from these agencies may be provided by each within their own databases or even maintained by a higher-level agency. For instance, local agencies may provide data to district or state organizations. If not, methods such as interviews and surveys may need to be employed in order to determine key data for specific agencies.

Tabulated Metrics

The following three tables are simply examples of how the metrics may be tabulated to chart the types of data they are associated with, whether the data may change over time, and from where the data may be obtained. Under the “source(s)” column, “agency” is listed for any metrics from which the organization that provides the data may differ from region to region in the case of local agencies; “agency” may also refer to multiple agencies from which the data may be obtained.

Table 8. Metrics associated with threat coverage and operations

Equipment costs and associated maintenance	***Type***	***Static/Dynamic***	***Source(s)***
Number of each type of equipment purchased	Operational	Static	CBP-A
Number of each type of equipment maintained	Operational	Static	GSA
Costs of procurement and maintenance	Financial	Static	CBP-A, Vendor, GSA
Fraction of time equipment is available for use (fully functional and operational)	Operational	Dynamic	CBP-A
Fraction of time equipment is applied to mission	Operational	Dynamic	CBP-A
Mean time to repair	Operational	Dynamic	Vendor
Rates of equipment loss/upgrade/replacement	Operational	Dynamic	CBP-A
Causes of failure and failure modes	Operational	Dynamic	Vendor
Calibration frequency for each type of equipment	Operational	Static	CBP-A
Fraction of time equipment is found to be improperly calibrated	Operational	Dynamic	CBP-A
Instrumentation quality control data	Operational	Dynamic	CBP-A
Capital, recurring (equipment warranty), and routine costs (calibration, maintenance, and repair) for each equipment type	Financial	Dynamic	CBP-A, Vendor, GSA

Table 9. Metrics associated with financial considerations

Personnel training, perceived benefits of training, and costs	***Type***	***Static/Dynamic***	***Source(s)***
Number of emergency responders who undergo initial training	Operational	Static	CBP-A, Training Provider
Number of refresher courses for trained emergency responders	Operational	Static	Agency, Training Provider
Number and Fraction of emergency responders trained within each agency	Operational	Static	Agency, Training Provider
Number and frequency of seminars, workshops, and tabletops	Operational	Static	Agency, Exercise Provider(s)
Number and frequency of functional exercises, full scale exercises, and drills	Operational	Dynamic	Agency, Exercise Provider(s)
Feedback from training and exercise participants	Performance	Dynamic	Agency, Training Provider, Questionnaire
Evaluation scores during drills and other exercises	Performance	Dynamic	Training Provider
Trainee knowledge scores following initial and refresher training courses	Performance	Dynamic	Training Provider
Fraction of trainees demonstrably capable of executing PRND duties	Operational	Dynamic	Training Provider
Costs of training (exercises, refresher courses, workshops, seminars, tabletops, and drills)	Financial	Static	Agency, Training Provider
Average cost to equip and train each type of PRND operator (PRD, RIID, backpack, mobile detector, portal monitor, fixed detectors)	Financial	Static	Agency, Vendor

Table 10. Metrics associated with threat types and pathways

Coverage of threat types and pathways	***Type***	***Static/Dynamic***	***Source(s)***
Size and fraction of the physical area actually covered by screening operations	Operational	Static	GSA-A,DOT-A
Number of lanes used at border crossing equipped with RPMs	Operational	Static	CBP-A
Number of vehicles using roadways (interior/perimeter)	Operational	Static	DOT-A, BTS
Fraction of trainees demonstrably capable of executing RadNuc duties	Performance	Dynamic	Training Provider
Number/frequency/duration of vehicles patrolling region and available	Operational	Static	State A Highway Patrol, MA1 Police Department, County Sheriff
Operating characteristics of portal monitors and other fixed detectors	Operational	Static	Vendor
Number and fraction of emergency responders carrying detection equipment on shifts daily	Operational	Dynamic	Agency
Causes of alerts	Operational	Dynamic	Agency
Frequency of alerts	Operational	Dynamic	Agency
Number and fraction of alerts referred to secondary screening or tertiary screening	Operational	Static	CBP-A
Alarm adjudication results (categories, outcomes, etc.)	Performance	Static	CBP-A
Number and frequency of missed alerts	Performance	Dynamic	CBP-A
Number and frequency of incorrectly handled alerts	Performance	Dynamic	CBP-A
Response times for primary detection, secondary screening, and technical reachback	Performance	Dynamic	CBP-A
"Red teaming" results	Performance	Dynamic	Training Provider

Table 10. Continued

Coverage of threat types and pathways	*Type*	*Static/Dynamic*	*Source(s)*
Test results giving probability of detecting various threat types for each detector type	Performance	Static	Vendor
Modeling results which estimate the probability of detecting threats under varying conditions	Operational	Static	Vendor, Assessment Team

Metrics requiring broader consideration, discussion and consensus

The metrics in the previous three tables can be achieved with surveys and/or just a few meetings with single organizations. There are many important metrics, however, that will require multi-organization discussions, probably over a substantial length of time. In fact, in the introduction of a new mission to an already complex environment, a phased approach is recommended. The first phase would involve building relationships with a broad community of stakeholders. In this phase, high level broad goals would be developed for not only this new mission but goals that are broader that would include this new mission. The next phase could include considerations of how the existing architecture would have to be modified to support this broader mission – and to support the new mission. Benchmarking of similar enterprises could be leveraged. This phase could also include plans to transition the enterprise from startup to sustained operation. The next steps could include phased installation of the equipment, development of integrated concepts of operations, and synthesis of lessons learned.

A list of some of the metrics associated with this broader planning and support building, architecture modifications and lessons learned is shown in Table 11.

Table 11. Broader more meaningful and difficult metrics

Broader planning and consensus building	*Type*	*Static/Dynamic*	*Source(s)*
Deterrence provide by RadNuc at border crossing	Benefit	Static	DHS-A, DOD-A, FBI-A, CIA-A, International
Optimal multi-party cost/benefit	Value	Static	Country A Agencies, regional business, International business, Regional political, Regional and state public representatives
Symbiosis with other missions in region	Value	Dynamic	Country A agencies, Country B agencies
Acceptable cost to trade	Cost	Static	Country A trade representatives, regional trade representatives, DHS-A, Regional politicians
Public support for mission	Value	Dynamic	Federal, state and local press, Country B press, regional citizen action groups
Inclusion in strategic planning (transition plans)	Value	Dynamic	Country A agencies, State A agencies, regional trade
Mission advocacy	Value	Dynamic	Regional champion, DHS-A
Quality of information sharing	Operational	Static	DHS-A, DOD-A, DOJ-A, DOT-A, DEA-A, regional politicians, regional police, regional justice
Quality of regional concepts of operation	Operational	Dynamic	DHS-A, DOJ-A, DOT-A, DEA-A, regional law enforcement, public representatives

Table 11. Continued

Broader planning and consensus building	***Type***	***Static/Dynamic***	***Source(s)***
Benchmarking	Operational	Static	DHS-A, international experts, Department of Commerce-A, DOJ-A, DOT-A
Integrated architecture	Operational	Dynamic	Country A Agencies, regional business, International business

Summary Discussion Regarding Metrics

In a large metropolitan area, there are many organizations involved in detection and interdiction (and prosecution) of criminal activities. There are also several organizations involved in the planning and execution of response and recovery from natural disasters and terrorist activities. These organizations generally have federal, state and local connections. Frequently, there are also international connections. Each of these organizations has an architectural construct (whether identified or not) to support its needs (like policy development, budget management, operations, legal, etc.) The introduction (or expansion) of the mission of detection and interdiction of radiological and nuclear threats will add requirements to many of these organizations. This additional burden will be continuous. If the program designed to introduce this added functionality/burden to the organizations with the region is compartmentalized to consider only its near-term and limited perspective, then the metrics used to assess the quality of the program also will be limited, and may not be representative of the attributes necessary for sustained mission success.

If one broadens his perspective to consider how this new mission can interleave with the missions space already existing in the region, then other metrics might be developed. These metrics are more about the quality of partnerships, commitment by the partners to continue to support the new missions, perception of mutual benefit to other federal and state and local programs, and public acceptance of the cost and societal impact of the new mission. These other metrics are more difficult to articulate and to measure. However, the act of constructing the consensus around the definitions of these metrics and consensus around how to assess them is viewed by the author as very valuable.

Of course, if the application of RadNuc screening at our border crossing can deter the adversary from trying to attack anywhere within Country A, that result would be very beneficial. If this can be done with acceptable cost, then the solution is nearing ideal. But the level of deterrence can only be approximated since the mind of the adversary is not known. Nonetheless, the discussion around how much deterrence might be provided by this border crossing application, in concert with a layered architecture of other deterrence strategies, would be an excellent way to improve the prospects. This is one of the objectives espoused by the U.S. Department of Homeland Security, who proposes a Global Nuclear Detection Architecture, or GNDA.(Government Accountability Office, 2012)

The chart in Figure 65 below depicts the relationship between the difficulty in obtaining metrics and their value to assessing overall efficacy of the new RadNuc mission. The metric concerning direct measure of deterrence is considered as

most difficult but most significant. At the lower left part of the chart are shown those metrics most often discussed in the literature and in the experience of this author. These metrics are easiest to measure. Because of the emphasis in cost benefit ratio, they are popular since they feed easily into CBA analyses. However, the most important costs are likely those that are not so easily measured, like the costs to the other agencies, the costs to business and the cost to the public. Similarly, the benefits are broadly difficult to measure, beyond those most often mentioned in the literature – like goals associated with how much tariff is generated, or how many arrests are made. More important benefits would be taking the opportunity to develop a broad informed consensus on trade facilitation with simultaneous security improvements at the border crossing.

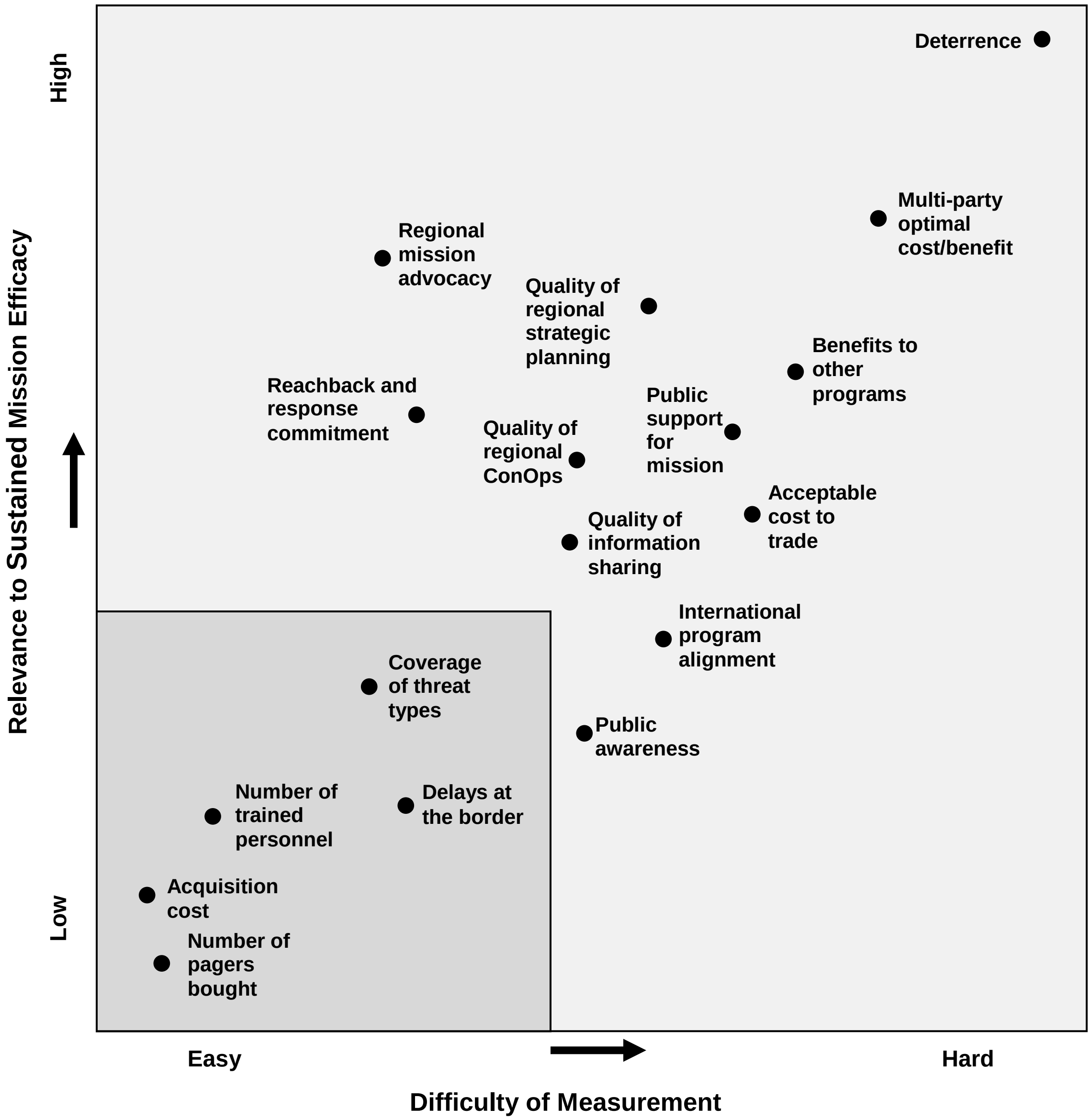

Figure 65. Metrics for success of RadNuc mission added to existing border control mission space

CHAPTER VI
CONCLUSIONS AND RECOMMENDATIONS

The author has shown a framework for assessment of the long term efficacy of RadNuc detection systems at international land border crossings. This framework is composed of five elements. The first element is a three dimensional model of the border crossing to help develop strategic questions. This three dimensional model should include perspectives showing primary, secondary and tertiary screening locations. The second element is a two dimensional dynamic model of the traffic flow across the border, including the degree to which different types of vehicles might be delayed. This two dimensional dynamic model also should include primary, secondary and tertiary screening simulation. The third element is a model of the organizational structure which will be necessary to implement the RadNuc mission, including its relationship with the organizational structure already extant in the region to support all the other missions associated with the border crossing. The fourth element is a strategic view of how the RadNuc screening mission at the border crossing fits into the overall global, national and regional picture. The fifth element is an approach to develop the metrics by which one can judge the efficacy of the overall enterprise in executing this RadNuc mission addition.

From the literature search, we have seen how several types of approaches have been undertaken to get at the issue of assessing efficacy of border crossing operation – even before the introduction of the additional RadNuc screening mission. We have seen that the general conclusion is that some combination of objective and subjective techniques might provide different perspectives that would but supportive in the development of a holistic view of the situation.

What has been surprising to the author is that the literature discusses the importance of getting the views of a broad collection of relevant stakeholders but when the analysis is actually done, the collection of stakeholders becomes relatively narrow compared to the community of stakeholders affected by the notional policy change or mission additions. In fact, the author has concluded that one characteristic that hampers the quality of the analysis is that the mission statement is imprecise in spite of obvious effort to make the statement precise. The imprecision comes from a lack of full understanding of the potential impacts on the full range of important stakeholders. An example is the statement that we want to examine the efficacy of the RadNuc screening mission at an international border crossing. A better statement would be that we want to examine how the addition of a RadNuc screening mission impacts the efficacy of the complete set of missions and operations of the entire enterprise in contact with the border crossing. Of course, one will want to limit the scope of any analysis. But the author believes that a deliberative process should be developed (and reviewed) for selection of which stakeholders might be impacted in the long run. Another

conclusion is that the analysis should include a steady state operation (which is what most of the literature seems to represent) but also should include unusual conditions to determine if there is an unexpected set of stakeholders or missions to consider. An example might be how a hurricane or a flood or a fire at the border crossing station or an armed insurrection might affect the ability to execute the RadNuc mission or how the RadNuc mission might affect the ability of the enterprise to execute the planned response to these upset conditions.

The use of a static isometric view of the border crossing location and of a dynamic simulation model helps bring to mind what if questions that will elicit perspectives not obvious previously.

The model of the organizational structure helps one ask questions about the quality of relationships that would be important to ensuring the long term efficacy of the enterprise when the RadNuc mission is added to it. It makes obvious questions about metrics like whether joint working groups have been developed, and are still operational and effective. It raises obvious questions about who has responsibility for what part of the mission space under differing conditions.

One of the most important conclusions, from the point of view of the author, is that the most important metrics will be some of the most difficult to articulate to everyone’s satisfaction, and the hardest to measure. But the dialogue around articulating the metrics is likely to be very important in shaping a holistic view of the enterprise in which our new mission will reside. Everyone may view the picture through a different perspective. But everyone’s perspective likely will be better informed because of the discussion.

LIST OF REFERENCES

Cambridge Systematics, I. (2011). El Paso Regional Ports of Entry Operation Plan.
Conway, B. (2010). Land Port of Entry. *Whole Building Design Guide*. www.wbdg.org/design/land_port.php
Duggan, R. (2009). Metrics for Border Management Systems.
Dumitrescu, A. a. M., P. (2006). Southeast Europe: Improving the Climate for Trade and Transport.   Retrieved june 19, 2013, 2013, from www.mfdr.org/sourcebook/6-8SoutheastEurope.pdf
French, S., Bedford, T., & Atherton, E. (2005). Supporting ALARP decision making by cost benefit analysis and multiattribute utility theory. *Journal of Risk Research, 8*(3), 207-223. doi: 10.1080/1366987042000192408
Government Accountability Office. (2006). *Combating Nuclear Smuggling: DHS's Cost-Benefit Analysis to Support the Purchase of New Radiatin Detection portal Monitors Was not Based on Available PErformance Data and Did Not fully Evaluate All the Monitor's Costs and Benefits*. (GAO-07-133R).
Government Accountability Office. (2012). *Combating Nuclear Smuggling: DHS has Developed Plans for its Global Nuclear Detection Architecture, but Challenges Remain in Deploying Equipment, Statement of David C. Maurer, Director, Homeland Security and Justice, and Gene Aloise, Director, Natural Resources and Environment, Testimony Before the Subcommittee on Cybersecurity, Infrastructure Protection, and Security Technologies, Committee on Homeland Security, House of Representatives*. (GAO-12-941T). Washington, D.C.: Retrieved from https://www.hsdl.org/?view&did=718297.
International Atomic Energy Agency. (2013). Nuclear Security Systems and Measures for the Detection of Nuclear and Other Radioactive Material out of Regulatory Control: Implementing Guide.
Kouzes, R. T. (2005). Detecting illicit nuclear materials (vol 93, pg 424, 2005). *American Scientist, 93*(6), 486-486.
Kouzes, R. T. (2009, 7-10 June 2009). *Challenges for interdiction of nuclear threats at borders.* Paper presented at the Advancements in Nuclear Instrumentation Measurement Methods and their Applications (ANIMMA), 2009 First International Conference on.
Kouzes, R. T., Ely, J. H., Geelhood, B. D., Hansen, R. R., Lepel, E. A., Schweppe, J. E., . . . Warner, R. A. (2003, 19-25 Oct. 2003). *Naturally occurring radioactive materials and medical isotopes at border crossings.* Paper presented at the Nuclear Science Symposium Conference Record, 2003 IEEE.
Kouzes, R. T., Siciliano, E. R., Ely, J. H., Keller, P. E., & McConn, R. J. (2008). Passive neutron detection for interdiction of nuclear material at borders. *Nuclear Instruments & Methods in Physics Research Section a-Accelerators Spectrometers Detectors and Associated Equipment, 584*(2-3), 383-400. doi: 10.1016/j.nima.2007.10.026

Ludlum Model 3500-1000 Radiation Detector System. (2010). Ludlum Measurements. Sweetwater, Texas. Retrieved from https://ludlums.com/multisites/medphys/...manuals/M3500-1000.pdf

McGill, W. L., & Ayyub, B. M. (2009). Regional Capabilities Performance Assessment for Homeland Security. *Ieee Systems Journal, 3*(2), 192-198. doi: 10.1109/jsyst.2009.2017398

Organization for Security and Co-operation in Europe. (2012). Handbook of Best Practices at Border Crossings – A Trade and Transport Facilitation Perspective (pp. 268p).

Shattan, M. (2008). *Adaptive road border crossing system management.* (Master of Science in Nuclear Engineering), Adaptive road border crossing system management. Retrieved from http://hdl.handle.net/1721.1/44773

Shea, D. (2009). *Global Nuclear Detection Architecture: Issues for Congress*. (CRS-2009-RSI-0299). Retrieved from HTTP://congressional.proquest.com.proxy.lib.utk.edu:90/congressional/docview/t21.d22.crs-2009-rsi-0299?accountid=14766.

Shea, D. (2010). *The Advanced Spectroscopic Portal Program: Background and Issues for Congress*. (RL34750). Congressional Research Service Retrieved from www.crs.gov.

SITPRO. (2008). A UK Review of Security Initiatives in International Trade. http://webarchive.nationalarchives.gov.uk/20100918113753/http://www.sitpro.org.uk//policy/security/initiatives0108.pdf

Stern, P. C. F., Harvey V. (1996). Understanding Risk: Informing Decisions in a Democratic Society (1996 ed.). Washington, D.C.: National Academy Press.

DNDO Director Warren Stern, Before the House Committee on Homeland Security, Subcommittee on Cybersecurity, Infrastructure Protection, and Security Technologies, 'The Last Line of Defense: Federal, State, and Local Efforts to Prevent Nuclear and Radiological Terrorism within the United States' (2011).

U.S. Department of Transportation. (2010). Freight Transportation: Global Highlights, 2010 (B. o. T. S. Research and Innovative Technology Administration, Trans.). Washington, D.C.

U.S. Environmental Protection Agency. (2000). *Guidelines for Preparing Economic Analyses*. Washington, D.C.: EPA Office of the Administrator.

U.S. General Services Administration. (2013, 2013, June 09). AGENCIES TYPICALLY LOCATED AT LPOE. from http://www.gsa.lpoe

U.S. General Services Adminstration. (2013). San Ysidro Land Port of Entry Project Overview. Retrieved June 21, 2013, from www.gsa.gov/sanysidrolpoe

UK KM Revenue and Customs, D. f. B., Innovation and Skills. (2009). Simplifying Trade Across UK Borders.

United States Department of Transportation. (2008). Border Crossing Guide for Commercial Truck Drivers. Available from Homeland Security Digital Library (HSDL) Homeland Security Digital Library (HSDL) Retrieved 2008,

from United States. Dept. of Transportation. Federal Motor Carrier Safety Administration https://www.hsdl.org/?view&did=703381
White, J., Waters, A and Hall,H. (2011). Securing the Cities Initiative: An External Strategic Assessment: Oak Ridge National Laboratory.

APPENDIX

Program Code for NetLogo Model

```
g loba l s [ sample−car
rn ; ; Random number .
num−cars−secondary−incoming ; ; The t o t a l number of incoming v ehi c l e s in the secondary screening por t ion of the model .
num−cars−secondary−outgoing ; ; The t o t a l number of outgoing vehi c l e s in the secondary screening por t ion of the model .
tot−secondary ; ; Total number of v ehi c l e s in secondary s c reening .
num−cars−incoming ; ; The t o t a l number of v ehi c l e s wai t ing in l i n e to c ros s the border on the incoming s ide .
num−cars−outgoing ; ; Tht t o t a l number of v ehi c l e s waiting in l i n e to c ros s the border on the outgoing s ide .
tot−wait ; ; Total number of v ehi c l e s wai t ing in l i n e to cros s the border .
s−l imi t ; ; The speed limi t f o r a l l vehi c l e s .
s2−l imi t ; ; The lowset s tar t ing speed given to a veh i c l e .
s2−upper−l imi t ; ; The upper l imi t f o r the random f l o a t given to the speed of v ehi c l e s .
tot−num−cars−incoming ; ; Used in determining the number of veh i c l e s that have crossed the border .
tot−num−cars−outgoing ; ; Used in determining the number of veh i c l e s that have crossed the border .
tot−num−cars ; ; Total cars c ros s ing border .
incoming−t r a f f i c −data ; ; Used f o r l oading incoming t r a f f i c data.
outgoing−t r a f f i c −data ; ;
flowtime−data ; ;
f lowtime ; ; The time assoc iated with the t r a f f i c f l ow . txt data . Used to t e l l NetLogo when to generate veh i c l e s .
t r a f f i c −flow−incoming ; ; Number of v ehi c l e s incoming according to Traf f icFlow . txt (this i s cur rent ly not being used .)
t r a f f i c −flow−outgoing ; ; Number of vehi c l e s outgoing according to Traf f icFlow . txt ( th i s i s cur rent ly not being used . )
bob ; ; Used to t e s t the random number generator
d i s t r i b u t i on ; ; .
prob ; ;
z ;;
]

t u r t l e s −own [ speed speed−l imi t speed−min t o t a l x wait−time wait−time−i wait−time−o ]


to setup
```

```
c lear−a l l
ask patches [ setup−world ]
ask patches [ setup−road ]
ask patches [ setup−secondary ]
ask patches [ setup−boundary ]
ask patches [ setup−lane1 ]
setup−cars
setup−trucks
do−p l o t s
load−t r a f f i c −data
s e t t r a f f i c −flow−incoming 1
s e t z 0
; watch sample−car
reset−t i c k s
end

to load−t r a f f i c −data
; ; This procedure loads in patch data from a f i l e . The format of the f i l e i s : pxcor
; ; pycor pcolor . You can view the f i l e by opening the f i l e Fi le IO Patch Data . txt
; ; using a simple text editor . Note that i t automatical ly loads the f i l e ” Fil e IO
; ; Patch Data . txt ”. To have the user choose their own file , see load−own −patch−data .

; ; We check to make sure the f i l e exi s t s f i r s t
i f e l s e ( f i l e −e x i s t s ? ”Flowtime . txt ” )
[
; ; We are saving the data into a l i s t , so i t only needs to be loaded once .
s e t incoming−t r a f f i c −data [ ]

; ; This opens the f i l e , so we can use i t .
f i l e −open ”Flowtime . txt ”

; ; Read in a l l the data in the f i l e
whi le [ not file−at−end? ]
[
; ; f i l e −read give s you va r i abl e s . In th i s case numbers .
; ; We store them in a double l i s t ( ex [ [ 1 1 9.9999] [1 2 9.9999] . . .
; ; Each i t e rat ion we append the next three−tuple to the current l i s t
s e t incoming−t r a f f i c −data sentence incoming−t r a f f i c −data ( l i s t f i l e −read ) ; f i l e −read f i l e −read ) )
]

; user−message ” F i l e l oading complete ! ”
```

```
; ; Done reading in patch information . Close the f i l e .
f i l e −c los e
]
[ user−message ”There i s no Tra f f icFlow . txt f i l e in current d i r ec t ory ! ” ]


prin t incoming−t r a f f i c −data
end


to setup−world
; color 63 is a dark green
i f ( pcolor = black ) [ set pcolor 63]
end

to do−p l o t s
c lear−plot
s e t di s t r ibut ion [1 997 2375 3170 3363 3302 3106 2827 2524 2162 1904 1644 1352 1163 976 842 595 534 423 376 255 257 202 141 125 91 53 72 50 37 34 28 17 11 16 12 10 5 7 3 3 3 1 1 0 2 1 0 0 2 0]
s e t prob [0 0.02 0.04 0.06 0.08 0.1 0.12 0.14 0.16 0.18 0.2 0.22 0.24 0.26 0.28 0.3 0.32 0.34 0.36 0.38 0.4 0.42 0.44 0.46 0.48 0.5 0.52 0.54 0.56 0.58 0.6 0.62 0.64 0.66 0.68 0.7 0.72 0.74 0.76 0.78 0.8 0.82 0.84 0.86 0.88 0.9 0.92 0.94 0.96 0.98 1]
l e t m 0
; set−current−plot−pen ” Dist ”
whi le [m < l ength di s t r ibut i on ]
[ plotxy item m prob item m distribution
s e t m m + 1]
end

to setup−road ; ; patch procedure
; ; This i s f o r the incoming ( bottom) lane s
i f ( pycor < −12) and ( pycor > −19) [ s e t pcolor white ]
i f ( pxcor < 2) and ( pxcor > 0) and ( pycor < −12) and ( pycor > −19) [ s e t pcolor red ]
i f ( pxcor < 37) and ( pxcor > 35) and ( pycor < −12) and ( pycor > −19) [ s e t pcolor blue ]
; ; This i s f o r the outgoing ( top ) lane s
i f ( pycor < 18) and ( pycor > 11) [ s e t pcolor white ]
i f ( pxcor < 2) and ( pxcor > 0) and ( pycor < 18) and ( pycor > 11) [ s e t pcol o r red ]
i f ( pxcor < −34) and ( pxcor > −36) and ( pycor < 18) and ( pycor > 11) [ s e t pcolor 86]
; ; This i s f o r changing the color of the incoming lane s be for e the por t a l s
i f ( pxcor < 1 ) and (pxcor > −57) and ( pycor < −12) and ( pycor > −19)
```

```
[ set pcolor 9.8]
; ; This i s f o r changing the color of the outgoing lane s be for e the por t a l s
i f ( pxcor < 57) and ( pxcor > 1) and ( pycor < 18) and ( pycor > 11) [ s e t pcol o r 9 . 7 ]
end

to setup−secondary ; ; patch procedure
i f ( pycor < 10) and ( pycor > −11) and ( pxcor < 40) and ( pxcor > −40) [ s e t pcolor 9 ]
i f ( pycor < 8) and ( pycor > 6) and ( pxcor < 4) and ( pxcor > −1) [ s e t pcol o r green ]
i f ( pycor < 8) and ( pycor > 6) and ( pxcor < 40) and ( pxcor > 38) [ s e t pcol o r orange ]
i f ( pycor < 8) and ( pycor > 6) and ( pxcor < −37) and ( pxcor > −39) [ s e t pcolor 85 ]
i f ( pycor < −8) and ( pycor > −10) and ( pxcor < −37) and ( pxcor > −39) [ set pcolor 84 ]
i f ( pycor < −8) and ( pycor > −10) and ( pxcor < 37) and ( pxcor > 35) [ s e t pcolor 83 ]
; ; Patch used f o r outgoing−secondary s c r e ening v ehi c l e s ( bottom l e f t patch of secondary )
i f ( pycor < −9) and ( pycor > −11) and ( pxcor < −38) and ( pxcor > −40) [ set pcolor 87 ]
i f ( pycor < −9) and ( pycor > −11) and ( pxcor < 40) and ( pxcor > 38) [ s e t pcolor 88 ]
i f ( pycor < 8) and ( pycor > 6) and ( pxcor < −34) and ( pxcor > −36) [ s e t pcolor 64 ]
end

to setup−boundary ; ; patch procedure
i f ( pycor < −12) and ( pycor > −19) and ( pxcor > 55) and ( pxcor < 57) [ set pcolor yellow ]
i f ( pycor < 18) and ( pycor > 11) and ( pxcor > −57) and ( pxcor < −55) [ set pcolor yellow ]
end

to setup−lane1 ; ; patch procedure
; ; lane f o r incoming ( bottom) lane s
i f ( pycor < −10) and ( pycor > −13) and ( pxcor < 40) and ( pxcor > 35) [s e t pcolor white ]
; ; lane f o r outoging ( top ) lanes
i f ( pycor < 12) and ( pycor > 9) and ( pxcor < −34) and ( pxcor > −40) [ s e t pcolor white ]
end

to setup−trucks
i f number−of−incoming−trucks > world−width
[
```

```
user−message (word ”There are too many trucks f o r the amount of road. Please decrease the NUMBER−OF−TRUCKS s l i d e r to below ”
( world−width + 1)
” and pres s the SETUP button again . The setup has stopped . ” )
stop
]
s e t s−l imi t 0.4
s e t s2−l imi t 0.0000001
s e t s2−upper−l imi t 0.3000009
; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ;
; ; ; This section i s used to construct 6 lanes of t r a f f i c on the INCOMING (BOTTOM) s i d e
set−default−shape t u r t l e s ” truck ”
c r t number−of−incoming−trucks [
s e t color red
s e t xcor random−xcor
s e t ycor −13
s e t heading 90
; ; ; set i n i t i a l speed to be in range 0.1 to 1.0
s e t speed s2−l imi t + random−f l o a t s2−upper−l imi t
s e t speed−l imi t s−l imi t
s e t speed−min 0
s e t total 0
s e t x 2
s e t wait−time 0
s e t wait−time−i 0
separate−trucks
]

c r t number−of−incoming−trucks [
s e t color red
s e t xcor random−xcor
s e t ycor −14
s e t heading 90
; ; ; set i n i t i a l speed to be in range 0.1 to 1.0
s e t speed s2−l imi t + random−f l o a t s2−upper−l imi t
s e t speed−l imi t s−l imi t
s e t speed−min 0
s e t total 0
s e t x 2
s e t wait−time 0
s e t wait−time−i 0
separate−trucks
]

c r t number−of−incoming−trucks [
s e t color red
s e t xcor random−xcor
s e t ycor −15
```

```
s e t heading 90
; ; ; set i n i t i a l speed to be in range 0.1 to 1.0
s e t speed s2−l imi t + random−f l o a t s2−upper−l imi t
s e t speed−l imi t s−l imi t
s e t speed−min 0
s e t total 0
s e t x 2
s e t wait−time 0
s e t wait−time−i 0
separate−trucks
]

c r t number−of−incoming−trucks [
s e t color red
s e t xcor random−xcor
s e t ycor −16
s e t heading 90
; ; ; set i n i t i a l speed to be in range 0.1 to 1.0
s e t speed s2−l imi t + random−f l o a t s2−upper−l imi t
s e t speed−l imi t s−l imi t
s e t speed−min 0
s e t total 0
s e t x 2
s e t wait−time 0
s e t wait−time−i 0
separate−trucks
]

c r t number−of−incoming−trucks [
s e t color red
s e t xcor random−xcor
s e t ycor −17
s e t heading 90
; ; ; set i n i t i a l speed to be in range 0.1 to 1.0
s e t speed s2−l imi t + random−f l o a t s2−upper−l imi t
s e t speed−l imi t s−l imi t
s e t speed−min 0
s e t total 0
s e t x 2
s e t wait−time 0
s e t wait−time−i 0
separate−trucks
]

c r t number−of−incoming−trucks [
s e t color red
s e t xcor random−xcor
s e t ycor −18
s e t heading 90
```

```
; ; ; set i n i t i a l speed to be in range 0.1 to 1.0
s e t speed s2−l imi t + random−f l o a t s2−upper−l imi t
s e t speed−l imi t s−l imi t
s e t speed−min 0
s e t total 0
s e t x 2
s e t wait−time 0
s e t wait−time−i 0
separate−trucks
]

; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ;
; ; ; This section i s used to construct 6 lanes of t r a f f i c on the OUTGOING (TOP) s i d e
c r t number−of−outgoing−trucks [
s e t color blue
s e t xcor random−xcor
s e t ycor 12
s e t heading −90
; ; ; set i n i t i a l speed to be in range 0.1 to 1.0
s e t speed s2−l imi t + random−f l o a t s2−upper−l imi t
s e t speed−l imi t s−l imi t
s e t speed−min 0
s e t total 0
s e t x 2
s e t wait−time 0
s e t wait−time−o 0
separate−trucks
]

c r t number−of−outgoing−trucks [
s e t color blue
s e t xcor random−xcor
s e t ycor 13
s e t heading −90
; ; ; set i n i t i a l speed to be in range 0.1 to 1.0
s e t speed s2−l imi t + random−f l o a t s2−upper−l imi t
s e t speed−l imi t s−l imi t
s e t speed−min 0
s e t total 0
s e t x 2
s e t wait−time 0
s e t wait−time−o 0
separate−trucks
]

c r t number−of−outgoing−trucks [
s e t color blue
s e t xcor random−xcor
```

```
s e t ycor 14
s e t heading −90
; ; ; set i n i t i a l speed to be in range 0.1 to 1.0
s e t speed s2−l imi t + random−f l o a t s2−upper−l imi t
s e t speed−l imi t s−l imi t
s e t speed−min 0
s e t total 0
s e t x 2
s e t wait−time 0
s e t wait−time−o 0
separate−trucks
]

c r t number−of−outgoing−trucks [
s e t color blue
s e t xcor random−xcor
s e t ycor 15
s e t heading −90
; ; ; set i n i t i a l speed to be in range 0.1 to 1.0
s e t speed s2−l imi t + random−f l o a t s2−upper−l imi t
s e t speed−l imi t s−l imi t
s e t speed−min 0
s e t total 0
s e t x 2
s e t wait−time 0
s e t wait−time−o 0
separate−trucks
]

c r t number−of−outgoing−trucks [
s e t color blue
s e t xcor random−xcor
s e t ycor 16
s e t heading −90
; ; ; set i n i t i a l speed to be in range 0.1 to 1.0
s e t speed s2−l imi t + random−f l o a t s2−upper−l imi t
s e t speed−l imi t s−l imi t
s e t speed−min 0
s e t total 0
s e t x 2
s e t wait−time 0
s e t wait−time−o 0
separate−trucks
]

c r t number−of−outgoing−trucks [
s e t color blue
s e t xcor random−xcor
s e t ycor 17
```

```
s e t heading −90
; ; ; set i n i t i a l speed to be in range 0.1 to 1.0
s e t speed s2−l imi t + random−f l o a t s2−upper−l imi t
s e t speed−l imi t s−l imi t
s e t speed−min 0
s e t total 0
s e t x 2
s e t wait−time 0
s e t wait−time−o 0
separate−trucks
]
end

to setup−cars
i f number−of−incoming−cars > world−width
[
user−message (word ”There are too many cars f o r the amount of road . Please decrease the NUMBER−OF−CARS s l ide r to below ”
( world−width + 1)
” and press the SETUP button again . The setup has stopped . ” )
stop
]
s e t s−limi t 0.4
s e t s2−limi t 0.000001
s e t s2−upper−limi t 0.3000009
; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ;
; ; ; This section i s used to construct 6 lanes of t r a f f i c on the INCOMING (BOTTOM) side
set−default−shape t u r t l e s ” car ”
c r t number−of−incoming−cars [
set color red
set xcor random−xcor
set ycor −13
set heading 90
; ; ; set initial speed to be in range 0.1 to 1.0
set speed s2−l imi t + random−f l o a t s2−upper−l imi t
set speed−l imi t s−l imi t
set speed−min 0
set total 0
set x 2
set wait−time 0
set wait−time−i 0
separate−cars
]

c r t number−of−incoming−cars [
s e t color red
s e t xcor random−xcor
s e t ycor −14
```

```
s e t heading 90
; ; ; set i n i t i a l speed to be in range 0.1 to 1.0
s e t speed s2−l imi t + random−f l o a t s2−upper−l imi t
s e t speed−l imi t s−l imi t
s e t speed−min 0
s e t total 0
s e t x 2
s e t wait−time 0
s e t wait−time−i 0
separate−cars
]

c r t number−of−incoming−cars [
s e t color red
s e t xcor random−xcor
s e t ycor −15
s e t heading 90
; ; ; set i n i t i a l speed to be in range 0.1 to 1.0
s e t speed s2−l imi t + random−f l o a t s2−upper−l imi t
s e t speed−l imi t s−l imi t
s e t speed−min 0
s e t total 0
s e t x 2
s e t wait−time 0
s e t wait−time−i 0
separate−cars
]

c r t number−of−incoming−cars [
s e t color red
s e t xcor random−xcor
s e t ycor −16
s e t heading 90
; ; ; set i n i t i a l speed to be in range 0.1 to 1.0
s e t speed s2−l imi t + random−f l o a t s2−upper−l imi t
s e t speed−l imi t s−l imi t
s e t speed−min 0
s e t total 0
s e t x 2
s e t wait−time 0
s e t wait−time−i 0
separate−cars
]

c r t number−of−incoming−cars [
s e t color red
s e t xcor random−xcor
s e t ycor −17
s e t heading 90
```

```
; ; ; set i n i t i a l speed to be in range 0.1 to 1.0
s e t speed s2−l imi t + random−f l o a t s2−upper−l imi t
s e t speed−l imi t s−l imi t
s e t speed−min 0
s e t total 0
s e t x 2
s e t wait−time 0
s e t wait−time−i 0
separate−cars
]

c r t number−of−incoming−cars [
s e t color red
s e t xcor random−xcor
s e t ycor −18
s e t heading 90
; ; ; set i n i t i a l speed to be in range 0.1 to 1.0
s e t speed s2−l imi t + random−f l o a t s2−upper−l imi t
s e t speed−l imi t s−l imi t
s e t speed−min 0
s e t total 0
s e t x 2
s e t wait−time 0
s e t wait−time−i 0
separate−cars
]
; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ;
; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ;
; ; ; This section i s used to construct 6 lanes of t r a f f i c on the OUTGOING
(TOP) s i d e
set−default−shape t u r t l e s " car "
c r t number−of−outgoing−cars [
s e t color blue
s e t xcor random−xcor
s e t ycor 12
s e t heading −90
; ; ; set i n i t i a l speed to be in range 0.1 to 1.0
s e t speed s2−l imi t + random−f l o a t s2−upper−l imi t
s e t speed−l imi t s−l imi t
s e t speed−min 0
s e t total 0
s e t x 2
s e t wait−time 0
s e t wait−time−o 0
separate−cars
]

c r t number−of−outgoing−cars [
s e t color blue
```

```
s e t xcor random−xcor
s e t ycor 13
s e t heading −90
; ; ; set i n i t i a l speed to be in range 0.1 to 1.0
s e t speed s2−l imi t + random−f l o a t s2−upper−l imi t
s e t speed−l imi t s−l imi t
s e t speed−min 0
s e t total 0
s e t x 2
s e t wait−time 0
s e t wait−time−o 0
separate−cars
]

c r t number−of−outgoing−cars [
s e t color blue
s e t xcor random−xcor
s e t ycor 14
s e t heading −90
; ; ; set i n i t i a l speed to be in range 0.1 to 1.0
s e t speed s2−l imi t + random−f l o a t s2−upper−l imi t
s e t speed−l imi t s−l imi t
s e t speed−min 0
s e t total 0
s e t x 2
s e t wait−time 0
s e t wait−time−o 0
separate−cars
]

c r t number−of−outgoing−cars [
s e t color blue
s e t xcor random−xcor
s e t ycor 15
s e t heading −90
; ; ; set i n i t i a l speed to be in range 0.1 to 1.0
s e t speed s2−l imi t + random−f l o a t s2−upper−l imi t
s e t speed−l imi t s−l imi t
s e t speed−min 0
s e t total 0
s e t x 2
s e t wait−time 0
s e t wait−time−o 0
separate−cars
]

c r t number−of−outgoing−cars [
s e t color blue
s e t xcor random−xcor
```

```
s e t ycor 16
s e t heading −90
; ; ; set i n i t i a l speed to be in range 0.1 to 1.0
s e t speed s2−l imi t + random−f l o a t s2−upper−l imi t
s e t speed−l imi t s−l imi t
s e t speed−min 0
s e t total 0
s e t x 2
s e t wait−time 0
s e t wait−time−o 0
separate−cars
]

c r t number−of−outgoing−cars [
s e t color blue
s e t xcor random−xcor
s e t ycor 17
s e t heading −90
; ; ; set i n i t i a l speed to be in range 0.1 to 1.0
s e t speed s2−l imi t + random−f l o a t s2−upper−l imi t
s e t speed−l imi t s−l imi t
s e t speed−min 0
s e t total 0
s e t x 2
s e t wait−time 0
s e t wait−time−o 0
separate−cars
]
; set sample−car one−of tur t l e s
; ask sample−car [ s e t color red ]
end

; th i s procedure i s needed so when we c l i c k ”Setup” we
; don’ t end up with any two car s on the same patch
to separate−trucks ; ; t u r t l e procedure
i f any? other t u r t l e s −here
[ fd 1
separate−trucks ]
end
to separate−cars ; ; t u r t l e procedure
i f any? other t u r t l e s −here
[ fd 1
separate−cars ]
end


to go
s e t bob random−gamma 2 13
```

```
; s e t t r a f f i c −flow−incoming 1
; i f z = incoming−t r a f f i c −data [
; c r t t r a f f i c −flow−incoming [
; s e t c o lor red
; s e t xcor −56
; s e t ycor −13
; s e t heading 90
; ; ; ; s e t i n i t i a l speed to be in range 0 .1 to 1.0
; s e t speed s2−l imi t + random−f l o a t s2−upper−l imi t
; s e t speed−l imi t s−l imi t
; s e t speed−min 0
; s e t t o t a l 0
; s e t x 2
; separate−trucks
;
; ] ]
; s e t z z + 1
; p r int z
; whi l e [m < l ength d i s t r i b u t i on ]
; [ plotxy item m prob item m d i s t r i b u t i on
; s e t m m + 1 ]


; ; makes the t u r t l e s ' Pause ' at each t o l l booth .
ask t u r t l e s [ i f ( pcolor = red ) and ( t o t a l = 0) [ s e t speed 0.04 s e t t o t a l t o t a l + 1 ] ]
; ; i f the v e h i c l e s have a t o tal = 1 you do not want to add 1 to the t o t a l again . Hence the next l i n e .
ask t u r t l e s [ i f ( pcolor = red ) and ( t o t a l = 1) [ s e t speed 0 . 0 4 ] ]

; ; Determine i f t u r t l e s go to secondary based on probabi l i ty
; ; The d i s c riminator alarm l e v e l can be changed on the i n t e r f a c e screen .
; ; Incoming
ask t u r t l e s [ i f ( pcolor = blue ) and ( t o tal = 0 or t o tal = 1) and ( bob > Discriminator−l e v e l −incoming ) [ move−to patch 39 −12 s e t heading 0 ] ]
; ; Outgoing
ask t u r t l e s [ i f ( pcolor = 86) and ( t o t a l = 0 or t o t a l = 1) and ( bob > Discriminator−l e v e l −outgoing ) [ move−to patch −39 11 s e t heading 180 ] ]

; ; Used f o r determining the t o tal number of cars that have passed through the c r o s s i n g .
; ; Incoming Side
ask t u r t l e s [ i f c o lor = red and ( pcol o r = yel low ) and ( x = 2) [ s e t tot−num−cars−incoming tot−num−cars−incoming + 1 s e t x x + 1 ] ]
ask t u r t l e s [ i f c o lor = red and ( pcol o r = red ) [ s e t x 2 ] ]
; ; Outgoing Side
ask t u r t l e s [ i f c o lor = blue and ( pco lor = yellow ) and ( x = 2) [ s e t tot−num−cars−outgoing tot−num−cars−outgoing + 1 s e t x x + 1 ] ]
ask t u r t l e s [ i f c o lor = blue and ( pco lor = red ) [ s e t x 2 ] ]
```

```
s e t tot−num−cars tot−num−cars−incoming + tot−num−cars−outgoing

; ; used to makes veh i c l e s in secondary turn l e f t
ask t u r t l e s [ i f ( pcolor = orange ) [ s e t heading −90]]

; ; Make veh i c l e s stop in secondary f o r screening
ask t u r t l e s [ i f ( pcolor = green ) [ s e t speed 0 ] ]

; ; making vehi c l e s turn once they reach the cyan patch
ask t u r t l e s [ i f ( pcolor = 85) [ s e t heading −180]]

; ; making vehi c l e s turn once they reach the second cyan patch ( c o lor 84)
ask t u r t l e s [ i f ( pcolor = 84) [ s e t heading 9 0 ] ]

; ; making vehi c l e s turn once they reach patch of col or 87
ask t u r t l e s [ i f ( pcolor = 87) [ s e t heading 9 0 ] ]

ask t u r t l e s [ i f c o lor = blue and ( pco lor = 88) [ s e t heading 0 ] ]

s e t num−cars−secondary−incoming 0

s e t num−cars−incoming 0
s e t num−cars−outgoing 0

; ; Determining how many incoming vehi c l e s are in the secondary s c reening por t ion
ask t u r t l e s [ i f c o lor = red and ( ( pcol o r = 9) or ( pcol o r = green ) or ( pcol o r = orange )
or ( pco lor = 85) or ( pcol o r = 84) or ( pcol o r = 83) or ( pco lor = 88) or ( pco lor = 64) ) [ s e t num−cars−secondary−incoming num−cars−secondary−incoming + 1 ] ]

s e t num−cars−secondary−outgoing 0
; ; Determining how many outgoing vehi c l e s are in the secondary s c reening por t ion
ask t u r t l e s [ i f c o lor = blue and ( ( pcol o r = 9) or ( pcol o r = green ) or ( pco lor = orange )
or ( pco lor = 83) or ( pcol o r = 87) or ( pcol o r = 88) or ( pco lor = 64) ) [ s e t num−cars−secondary−outgoing num−cars−secondary−outgoing + 1 ] ]

; ; Determining the number of veh i c l e s in secondary screening .
s e t tot−secondary num−cars−secondary−incoming + num−cars−secondary−outgoing

; i f tot−secondary > Threshold [ stop ]
i f t i c k s > 30000 [ stop ]

```

```
; ; Determining the number of veh i c l e s in l i n e to c r o s s the border on the incoming s i de
ask t u r t l e s [ i f ( pcol o r = 9 . 8 ) [ s e t num−cars−incoming num−cars−incoming + 1 ] ]
; ; Determining the wait time of veh i c l e s c r o s s i n g the border .
; ; Incoming
ask t u r t l e s [ i f ( pcol o r = 9 . 8 ) or ( pcol o r = red ) [ s e t wait−time wait−time + 1 ] ]
ask t u r t l e s [ i f ( pcol o r = 9 . 8 ) or ( pcol o r = red ) [ s e t wait−time−i wait−time−i + 1 ] ]
; ; Outgoing
ask t u r t l e s [ i f ( pcol o r = 9 . 7 ) or ( pcol o r = red ) [ s e t wait−time wait−time + 1 ] ]
ask t u r t l e s [ i f ( pcol o r = 9 . 7 ) or ( pcol o r = red ) [ s e t wait−time−o wait−time−o + 1 ] ]
; ; Resetting the wait time so i t i s not a continual sum
ask t u r t l e s [ i f ( pcol o r = yel low ) [ s e t wait−time 0 ] ]
ask t u r t l e s [ i f ( pcol o r = yel low ) [ s e t wait−time−i 0 ] ]
ask t u r t l e s [ i f ( pcol o r = yel low ) [ s e t wait−time−o 0 ] ]
; ; Determining the number of veh i c l e s in l i n e to c r o s s the border on the outgoing s ide
ask t u r t l e s [ i f ( pcol o r = 9 . 7 ) [ s e t num−cars−outgoing num−cars−outgoing + 1 ] ]
; ; Determining the t o t a l number of vehi c l e s waiting to c r o s s the border .
s e t tot−wait num−cars−incoming + num−cars−outgoing
s e t rn random 100
; ; Making t u r t l e s from OUTGOING s ide leave secondary a f t e r screening
; ; t u r t l e s are randomly d i s t r ibuted to the 6 OUTGOING l anes .
ask t u r t l e s [ i f c o lor = blue and ( pco lor = 64) and ( rn < 16) [ move−to patch −40 1 2 ] ]
ask t u r t l e s [ i f c o lor = blue and ( pco lor = 64) and ( rn >= 16) and ( rn < 33) [ move−to patch −40 1 3 ] ]
ask t u r t l e s [ i f c o lor = blue and ( pco lor = 64) and ( rn >= 33) and ( rn < 50) [ move−to patch −40 1 4 ] ]
ask t u r t l e s [ i f c o lor = blue and ( pco lor = 64) and ( rn >= 50) and ( rn < 66) [ move−to patch −40 1 5 ] ]
ask t u r t l e s [ i f c o lor = blue and ( pco lor = 64) and ( rn >= 66) and ( rn < 83) [ move−to patch −40 1 6 ] ]
ask t u r t l e s [ i f c o lor = blue and ( pco lor = 64) and ( rn >= 83) [ move−to patch −40 1 7 ] ]
; ; making vehi c l e s go to s t a r t t r i p over again .
ask t u r t l e s [ i f ( pcolor = 83) and ( rn < 16) [ move−to patch 40 −13] ]
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ask t u r t l e s [ i f ( pcolor = 83) and ( rn >= 16) and ( rn < 33) [ move−to patch 40 −14]]
ask t u r t l e s [ i f ( pcolor = 83) and ( rn >= 33) and ( rn < 50) [ move−to patch 40 −15]]
ask t u r t l e s [ i f ( pcolor = 83) and ( rn >= 50) and ( rn < 66. ) [ move−to patch 40 −16]]
ask t u r t l e s [ i f ( pcolor = 83) and ( rn >= 66. ) and ( rn < 83. ) [ move−to patch 40 −17] ]
ask t u r t l e s [ i f ( pcolor = 83) and ( rn >= 83. ) [ move−to patch 40 −18]]
; ; i f the v e h i c l e s reach the boundary then they die
ask t u r t l e s [ i f ( pcolor = yel low ) and ( t o t a l = 1) [ s e t t o t a l 0 ] ]
; ask t u r t l e s [ i f ( pcol o r = yel low ) [ die ] ]


; ; Making the outgoing t u r t l e s go to a random lane when they wrap around the world .
ask t u r t l e s [ i f c o lor = blue and ( pco lor = yellow ) and ( rn < 16) [ move −to patch 56 1 2 ] ]
ask t u r t l e s [ i f c o lor = blue and ( pco lor = yellow ) and ( rn >= 16) and ( rn < 33) [ move−to patch 56 1 3 ] ]
ask t u r t l e s [ i f c o lor = blue and ( pco lor = yellow ) and ( rn >= 33) and ( rn < 50) [ move−to patch 56 1 4 ] ]
ask t u r t l e s [ i f c o lor = blue and ( pco lor = yellow ) and ( rn >= 50) and ( rn < 66) [ move−to patch 56 1 5 ] ]
ask t u r t l e s [ i f c o lor = blue and ( pco lor = yellow ) and ( rn >= 66) and ( rn < 83) [ move−to patch 56 1 6 ] ]
ask t u r t l e s [ i f c o lor = blue and ( pco lor = yellow ) and ( rn >= 83) [ move−to patch 56 1 7 ] ]

; ; Making the incoming t u r t l e s go to a random lane when thy wrap around the world .
ask t u r t l e s [ i f c o lor = red and ( pcol o r = yel low ) and ( rn < 16) [ move −to patch −56 −13]]
ask t u r t l e s [ i f c o lor = red and ( pcol o r = yel low ) and ( rn >= 16) and ( rn < 33) [ move−to patch −56 −14]]
ask t u r t l e s [ i f c o lor = red and ( pcol o r = yel low ) and ( rn >= 33) and ( rn < 50) [ move−to patch −56 −15]]
ask t u r t l e s [ i f c o lor = red and ( pcol o r = yel low ) and ( rn >= 50) and ( rn < 66. ) [ move−to patch −56 −16] ]
ask t u r t l e s [ i f c o lor = red and ( pcol o r = yel low ) and ( rn >= 66. ) and ( rn < 83. ) [ move−to patch −56 −17]]
ask t u r t l e s [ i f c o lor = red and ( pcol o r = yel low ) and ( rn >= 83. ) [ move−to patch −56 −18] ]


; ; Determining how many times a car i s asked something whi le in the portal
; ask sample−car [ i f ( pcol o r = red ) and ( t o tal = 0) [ s e t t o t a l t o t a l + 1 ] ]
; ask sample−car [ i f ( pcol o r = yellow ) [ s e t t o t a l 0 ] ]

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; ; i f there i s a car r ight ahead of you , match i t s speed then slow down
ask t u r t l e s [
l e t car−ahead one−of t u r t l e s −on patch−ahead 1
i f e l s e car−ahead != nobody
[ s e t speed [ speed ] of car−ahead
slow−down−car ]
; ; otherwise , speed up
[ speed−up−car ]
; ; ; don ’t slow down below speed minimum or speed up beyond speed limi t
i f speed < speed−min [ s e t speed speed−min ]
i f speed > speed−l imi t [ set speed speed−l imi t ]
fd speed ]
t i ck
end

to slow−down−car ; ; tur t l e procedure
s e t speed speed − d e c e l e r a t i on
end

to speed−up−car ; ; tur t l e procedure
s e t speed speed + ac c e l e rat ion
end

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VITA

James Dale White became Vice President for Middle East Lab Operations, reporting to Dr. Ron Townsend, Executive Vice President, Battelle Memorial Institute on July 1, 2011.

Mr. White previously worked at Oak Ridge National Laboratory (ORNL) for 44 years in a wide variety of research and development activities related to nuclear power and nuclear security. During this time frame, his responsibilities have evolved from principal investigator to project manager to line management and then broad oversight of R&D program portfolios. His research and program management experiences have included nondestructive testing, heat transfer for reactor safety, instrumentation and control systems, man-machine interface for nuclear power, probabilistic risk assessment for nuclear safety, software engineering, radiation detection systems development and assessment, and nonproliferation R&D technologies. Mr. White frequently has developed and led multi-organizational R&D programs for federal and private sponsors. Recently, Mr. White led the Battelle funded Air Cargo Screening Cooperative Research and Development Cooperative Research and Development Agreement (CRADA), a collaboration of several national laboratories and Battelle. Mr. White has served in various leading roles for national and international technology assessments, and he has served as a U.S. representative to several international meetings and workshops. Mr. White has B.S. and M.S. degrees in nuclear engineering from the University of Tennessee at Knoxville (UTK). He currently is a doctoral student at UTK.

Specific positions Mr. White has held previously at ORNL are described here. From 1967 to 1987, he held various research and development positions, including program manager positions. From 1987 to 1991, Mr. White held the position of Program Manager, Department of Energy Advanced Controls Program. In this position, he was responsible for the overall DOE program for research and development in the application of modern control theory, human factors and advanced instrumentation to advanced reactor concepts being funded by the DOE.

From 1991 to 1994, Mr. White held the title of Manager, ORNL Light Water Reactor Program. In this position, Mr. White was responsible for all of the research and development at ORNL funded by the DOE related to light water reactors.

From 1994 to 1998, Mr. White moved into line management, holding the position of Head, Controls and Systems Integration Section, within the ORNL Instrumentation Division at ORNL. In this position, Mr. White was responsible for management of an organization whose mission was research and development in controls and systems integration applied to nuclear energy, the steel industry, and the glass products industry, among others.

From 1998 to 2001, Mr. White held the position of Head, Measurement Sciences Section, within the Instrumentation & Controls Division at ORNL. In this position, Mr. White was responsible for managing research and development at ORNL in the new and advanced measurement techniques, instrumentation and methodologies.

From 2001 to 2004, Mr. White held the position of Group Leader for Nuclear Material Detection and Characterization, Nuclear Science and Technology Division at ORNL. In this position, Mr. White was responsible for managing research and development in instrumentation and methodologies for systems that are used in detection and characterization of materials that might be used in radiological or nuclear threats.

From 2004 to 2006, Mr. White held the position of Director, ORNL Nonproliferation R&D Programs. In this position, Mr. White was responsible for management of the research and development of measurement systems and methodologies to detect nuclear proliferation.

From 2006 to 2007, Mr. White was assigned to the Department of Homeland Security to provide program management support for projects related to detection and interdiction of radiological and nuclear threats. In this position, Mr. White mentored the DHS Program Manager in management of research and development of systems for countering the nuclear threat in a metropolitan area. He helped coordinate research and development performed by several DOE national laboratories.

From 2007 to 2009, Mr. White held the position of Director, ORNL Advanced R&D Programs to Counter the Nuclear Threat. He was the program director for the work done throughout ORNL in research and development of systems to support U.S. government programs for detection and characterization of the nuclear threat.

From 2009 to 2011, Mr. White held the position of Director, ORNL Homeland Security and Advanced Programs. In this position, Mr. White was responsible for management of program at ORNL funded by the Department of Homeland Security. He also was responsible for the development of new program concepts related to the nuclear threat.

Mr. White also had several outside activities during his 44 years at ORNL. In 1990, he was a consultant to Loyola College (World Technology Evaluation Center). As a consultant, he served as a member of a panel which traveled to Japan to evaluate nuclear power technology and nuclear R&D in Japan relative to the same topics in the United States. In 1991, Loyola College retained Mr. White to co-lead a larger panel to examine how nuclear power instrumentation and controls systems in the United States compared to those in Russia, in the United Kingdom, in France, in Germany and other countries. Mr. White and his panel traveled to these countries and met with leaders in the application of modern instrumentation, control and human factors technologies and methodologies to nuclear power.

In 1993, Mr. White served as a member of the National Research Council for Safety Implications of Application of Digital Instrumentation and Controls to Nuclear Power Plants. In this position, Mr. White provided reviews of plans for U.S. nuclear power plants to use digital based controls and human factor support system in nuclear power plants.

In 2003, Mr. White was retained as a consultant to the U.S. Nuclear Regulatory Commission for Reactor Safeguards. In this position, Mr. White supported the NRC in evaluation of the use of modern instrumentation, control and human factors technologies in U.S. nuclear reactors.

Mr. White graduated from the University of Tennessee with B.S. and M.S. degrees in nuclear engineering in 1967 and 1968, respectively.