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Port Security Technology for Closed Container Inspection at United States Seaports of Entry

CAPSTONE REPORT

Archibong J. Ituh
International Trade Specialist
Aurora Networks, Inc.

University of Oregon
Applied Information Management
Program

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Continuing Education
1277 University of Oregon
Eugene, OR 97403-1277
(800) 824-2714

Approved by

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Dr. Linda F. Ettinger

Running Head: PORT SECURITY TECHNOLOGY

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Archibong Ituh

Aurora Networks, Inc.

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Abstract

This study examines technologies currently deployed at United States seaport points of entry to enable U.S. Customs (CBP) agents to inspect all entering closed containers. Analyses of literature published between 2002 and 2009 focuses on use, effectiveness and development of selected technologies, including gamma-ray and X-ray imaging, and radiation detection, as well as research on current screening technologies. The outcome supports CBP inspectors to detect dangerous cargo and minimize disruptions to the international supply chain.

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Introduction

Problem Area

Following the terrorist acts and the attack on the World Trade Center in New York on September 11, 2001, the recognition of the threat that a nuclear or radiological device could be smuggled inside a cargo container lead some members of Congress to request that the United States Customs Service do closed inspections of all containers entering through the country's seaports (U.S. House of Representatives, P.L. 107-295, 107th Congress, 2002). In response, the Security and Accountability for Every Port (SAFE) Act (House of Representatives, H.R. 4954, 109th Congress, 2006) signed by President George W. Bush, authorized the development of high technology inspection equipment that would enable United States Customs agents to check cargo containers for dangerous materials without opening them.

Kennedy (2008) states that the ubiquitous use and high importance of information technology to handle the transportation of goods and materials through our seaports has added a new dimension to our homeland security and data security. These systems also provide the means for the Department of Homeland Security (DHS) to track and inspect cargoes to ensure that materials potentially hazardous to safety and well-being are not entering into the United States without their knowledge (Kennedy, 2008).

According to the Department of Homeland Security (DHS), (2006), there are various technologies currently being deployed at U.S. ports and at a few selected ports around the world. The deployment involves a combination of existing technology and proven nuclear detection devices to six foreign ports: Port Qasim in Pakistan; Puerto Cortes in Honduras; Southampton in the United Kingdom; Port Salalah in Oman; Port of Singapore; and the Gamman Terminal at Port Busan in Korea (DHS, 2006).

Purpose

To address and minimize the disruption to the international supply chain, (Peterson & Treat, 2008) state that "the events of 9/11 precipitated a change in cargo security measures at national borders" (p.3). The purpose of this study is guided by two concepts provided by the Government Accountability Office (GAO). These include (a) to document the technologies currently being used in support of closed container inspections (Stana, 2006), and (b) identify the companies and organizations leading research efforts on developing new technologies (Stana, 2006). A third concept provided by Bakshi, Flynn and Gans (2009) is also used to guide the purpose of the study, which is (c) to examine the impact of technology deployment in relation to a set of pre-selected criteria, including the detection of dangerous and illegal cargo in closed container inspections.

For example, in relation to documenting technologies in use, there are two primary types of technologies currently available on the market that can perform non-intrusive cargo inspection. The first uses a radiological source to generate gamma rays, which pass through/interact with the container to be inspected, providing a picture of the contents. The second type of technology uses a radiation machine (an x-ray generator or linear accelerator) to electrically generate and emit x-rays, which perform the same function as do the gamma rays (SAIC, 2005).

Significance

The issue of port security and how it affects the international supply chain flow is related to manufacturing and logistics operations (Sarathy, 2006). For example, the majority of Aurora Networks products are manufactured and supplied by vendors in the Asia Pacific (APAC) countries. The products are moved in cargo containers (Aurora imports two to three containers a month) and shipped into the port of Oakland, CA. The availability of faster screening technology at the ports mean cargos are cleared faster and delivered to the warehouse (Bottan, 2009).

Port screening technology plays an important role in the international supply chain, and adversely affects operations at many U.S. companies (Rice, 2003). Seaports are the backbone of the worldwide commercial traffic (Maritime Security, 2007). The rapid growth of maritime trade creates a continuing need to expand seaports and provide high-quality services (Maritime Security, 2007). At the same time, technological, regulatory, security, and economic trends are placing new demands on seaports and cargo screening technologies (Maritime Security, 2007).

According to Banamyong (2005), security measures are necessary to guarantee the protection of global supply chains against acts of terrorism or any possible unexpected threats. Since September 11, 2001, the United States has pursued a layered approach to port security intended to ensure the integrity of the supply chain from the point of container loading to the arrival in the United States without hindering the flow of commerce through ports (Langhoff & Pillai, 2007). Under the layered security system, the United States Customs and Border Protection (CBP) determines risk by carefully analyzing various data sources including ship and cargo manifest information on shippers and cargo points of origin, as well as classified intelligence. These capabilities provide CBP and other federal agencies the intelligence they need to make informed decisions regarding the level of cargo risk, determine which merit additional scanning and investigation, and help get information to the field personnel (Langhoff & Pillai, 2007).

Audience

The intended audiences for this literature review are professionals with an interest in movement of goods and potential disruptions to the international supply chain. These professionals are involved with exports and imports, as described below.

Exports. Traffic managers, shipping and receiving specialist, and freight forwarders are engaged in the business of exporting products out of the United States, and dealing with the maze of regulations associated with exporting goods out of the United States. The compliance and regulatory issues by the various U.S. government agencies affect and impact international trade between the United States and other nations. It is important for exporters to stay updated and informed on regulations by agencies such as the Department of Commerce (DOC) and other federal agencies that may affect their logistics supply chain.

Imports. Customs brokers, clearing agents, logistics planners, purchasing, and manufacturing managers all have an interest in movement of goods and potential disruptions to the international supply chain. The primary issue is that of time; the time it takes to get their products from their international suppliers to their factories and warehouses, and what role port security plays in the supply chain.

Outcome

The study is intended as a guide to professionals engaged in the arena of exports and imports, and international logistics. This guide covers security screening of inbound cargo containers at foreign ports and at United States points of entry, with focus on materials that could be used to make atomic weapons or other instruments of weapons of mass destruction, including biological and chemical weapons. Manufacturing managers, purchasing managers, trade specialist and planners need to understand that these inspections may cause delays, and affect the logistics flow of goods which may impact their businesses. Under these conditions, time reliability is very important. An industry under tight schedule operations (just in time (JIT) supply chains) cannot afford delays on delivery (Banomyong, 2005).

Delimitations

Focus. The study focuses specifically on technologies for screening inbound cargo containers destined for, and at United States seaports of entry for materials that could be used to make atomic weapons or other instruments of weapons of mass destruction, including biological and chemical weapons.

The study does not provide for or cover movement of cargo between nations, the costs to businesses due to disruptions associated with the screening process other than its effect on delays to the international supply chain. A significant limitation associated with the screening is the lack of direct control of outbound cargo destined for United States seaports. Specifically, this pertains to the cooperation of foreign governments, and the issue of national sovereignty hinders and limits the desire of the United States Customs Service to place its officers, inspectors and inspection equipment at these foreign ports. To address this, the Container Security Initiative (CSI) program was developed by the United States Customs Service to encourage enhanced security arrangements and agreements between the United States and specific trading partners.

Time Frame. Prior to September 11, 2001, security was viewed as raising costs, undermining efficiency, and undermining reliability. Since September 11, 2001 the goal is largely to retrofit some security into existing systems (Flynn, 2006). This study covers what is being done to ensure cargo container security post September 11, 2001, from 2002 to 2009.

Sources. The sources of material for the literature review are from searches done using EBSCO HOST Academic Search Premier, Google Scholar, FirstSearch ECO, LexisNexis Academic, Web of Science, and the Congressional Quarterly. Search results are focused towards obtaining specific information covering seaport scanning and screening technologies affiliated with port security technology. A wide variety of types of source material is used in this study, including books, journal articles, and government publications, articles in daily and weekly newspapers, magazine articles, and company web sites. Many of these sources are noted in the paper with the use of acronyms and abbreviations. An explanatory list is provided in Appendix A.

Audience. The intended audiences for this literature review are individuals engaged in inspecting inbound cargo containers, and those involved in the field of import, export, logistics, freight forwarding and customs brokerage. They include United States Customs and Border Protection agents and field inspectors who are responsible for screening inbound cargo containers, traffic managers, shipping and receiving specialist, and freight forwarders engaged in the business of exporting products out of the United States, and customs brokers and clearing agents concerned with importing into the United States.

Data Analysis Plan Preview

The study seeks to examine cargo screening technologies at United States seaports of entry. The approach taken to data analysis is described as conceptual analysis by Busch, De

Maret, Flynn, Kellum, Le, and Meyers (2005). This process provides a research tool which can be used to verify the presence of certain words or concepts within texts or sets of texts.

Search on selected literature targets keywords related to detection of dangerous nuclear and radioactive materials in cargo containers. Keywords address the three categories described in the purpose of the study: (1) technologies currently being used in support of closed container inspections (Stana, 2006), (2) companies and organizations leading research efforts on developing new technologies (Stana, 2006), and (3) impact of technology deployment in relation to the detection of dangerous and illegal cargo in closed container inspections (Bakshi, Flynn & Gans, 2009). The goal is to report how available technologies are applied most effectively to prevent illicit materials in cargo containers from passing through United States Customs Service inspections at the ports of entry.

Writing Plan Preview

The writing plan that directs the organization of information in the Review of the Literature section of this paper begins with an overview of the purpose of the study and then examines the results of the data analysis process. As noted in Leedy and Ormrod (2005), "begin your literature review from a comprehensive perspective, like an inverted pyramid – broad end first. Then as you proceed, you can deal with more specific ideas and studies and focus in more and more on your own particular problem" (p.79). In this case, a thematic approach is taken (UNC, 1998) as a way to frame the outcome of this study – a guide on the topic of port security technology. Initial themes used to frame the guide are aligned with the three areas of analysis, including (1) technologies currently being used in support of closed container inspections for materials that could be used to make atomic weapons or other instruments of weapons of mass destruction, including biological and chemical weapons, (2) companies and organizations leading research efforts on developing new technologies, and (3) the impact of technology deployment in relation to the detection of dangerous and illegal cargo in closed container inspections. Additional themes may emerge during the data analysis process.

Definitions

Lester and Lester (2007), state that “the definition must interpret the term as it used in relation to the researcher’s project” (p.56). The goal of this section and the terms defined provide an insight into the subject of this study on port security technologies. The terms are defined to align with the purpose of the study, and are also a guide in understanding materials presented in the study.

Container Inspection System: The container/vehicle inspection systems comprise 3 major series: the fixed, the mobile and the reloadable systems. They are designed for the customs service to inspect cargo containers without opening them (China National Aero Technology Company, 2009)

Container Scanning Technology: The term ‘‘scan’’ means utilizing nonintrusive imaging equipment, radiation detection equipment, or both, to capture data, including images of a container (Cirincione, R., Cosmas, A., Low, C., Pech, J., & Wilds, J., 2007).

Container Screening Technology: The container screening device (CSD) is the tool for checking for materials that can be used to build weapons of mass destruction, concealed contraband and illegal substances, and identifying fraudulently labeled containers (Department of Energy, 2009).

Container Security Device: The container security device snaps into the door jamb of a container and indicates when the container door has been opened. The device can easily accommodate the addition of light, chemical, and/or radiation sensors (Customs and Border Protection Today, 2003).

Container Security Initiative: The fundamental objective of the Container Security Initiative (CSI) is to engage both so-called 'mega-ports' (ports sending the highest volume of ocean going container traffic into the United States) and the national governments where these ports are located in a way that will facilitate the pre-screening of outbound containers destined to the United States (Banomyong, 2003).

Examination: CBP defines an “examination” as a physical inspection of a conveyance and/or the imaging of a conveyance, using large-scale non-intrusive inspection (NII) technology (Customs and Border Protection.gov).

Homeland Security: Homeland Security leverages resources within federal, state, and local governments, coordinating the transition of multiple agencies and programs into a single, integrated agency focused on protecting the American people and their homeland (Department of Homeland Security.gov).

International Supply Chain: The transport and logistics system (organizations, people, technology, activities, information and resources) for the world's cargo. The international supply chain encompasses manufacturing, procurement and distribution, and involves multiple enterprises, including suppliers, manufacturers and retailers who work together to meet a customer need for a product or service (Canadian Border Services Agency.gc.ca).

Non-Intrusive Inspection Technology: Active, non-intrusive interrogation technologies are inspection systems that take advantage of an externally applied “source” to perform traditional imaging of, or to stimulate characteristic emissions from, an inspected object (Jones, 2003).

Port Security: The safeguarding of vessels, harbors, ports, waterfront facilities, and cargo from internal threats such as destruction, loss, or injury from sabotage or other subversive acts, as well as accidents, thefts, or other causes of similar nature (DOD Dictionary of Military Terms, 2009).

Pulsed Fast Neutron Analysis: A system that uses a nanosecond pulsed beam of fast neutrons to interrogate the contents of small volume elements – voxels – of a cargo container or truck (Brown, Coates, Kuo, Loverman, Pentaleri & Rynes, 2004)

Scintillator: Material that emits light when particles traverse it (Lawrence Berkeley Labs, 2009).

Research Parameters

This section describes the methods used in conducting the study. It covers the research questions, the search strategy, search process documentation, and the search results. Also presented are the approaches to data collection, reference evaluation, and the detailed approaches to data analysis and data presentation.

This study is designed as a literature review. “A review of literature presents a set of summaries in essay form for two purposes; it helps you investigate the topic because it forces you to examine and then describe how each source addresses the problem, and it organizes and classifies the sources in some reasonable manner for the benefit of the reader” (Lester & Lester, 2007, p. 65).

Research Questions

Main Question. How effective are selected deployed technologies in the detection of illegal and dangerous cargo in unopened containers at US seaport entry points? (Department of Homeland Security.gov).

Sub-Questions.

• What are the key types of technology in use? (Department of Homeland Security and Port Security Council, 2009).

• How is the deployed technology being used (Customs and Border Protection.gov)?

• What is the impact of the use of this technology on cargo international supply chain logistics management (Banomyong, 2005).

• What is the impact of the use of this technology on illegal container detection? (Keefer, 2008).

• Which organizations are leading the research effort to develop additional technologies in support of closed container inspection, and how are they being funded (Department of Homeland Security and Port Security Council, 2009).

Search Strategy

Search terms. The following key search terms were derived from articles, books and journals while conducting a search of available literature for the proposed topic. Search results are reported in Appendix B and evaluated as to quality. Poor means inadequate useful sources, fair is a selected few useful article, good means a number of useful and related articles, and excellent means the articles found cover the search term. Search terms include:

Container Inspection System

Container Port Security

Container Scanning Technology

Container Screening Technology

Container Security Initiative

Homeland Security

Non-Intrusive Inspection Technology

Scanning Systems

Evaluation Criteria

The evaluation of available material for the study is focused on the resources available and its appropriateness for the research. Phillips (2008) offers suggestions for evaluating a range of resources, including books, articles and websites. It covers suitability – scope, audience and timeliness, and discusses scholarly journals versus popular magazines (Phillips, 2008).

A scholarly journal is generally one that is published by and for experts (Phillips, 2008). For this study, a number of peer reviewed journals are examined that focus on research work being done on technologies that can detect nuclear, chemical and biological materials that can be used to make illicit and weapons of mass destruction. These researchers at institutions and organizations such as the Lawrence Livermore National Laboratories, Science Applications International Corporation, the Idaho National laboratories and the University of California at Berkeley are widely acknowledged experts in their fields, and provide content and scope in these journals that relate to the topic covered in the review.

Popular magazines range from highly respected publications to general interest newsmagazines (Phillips, 2008). For this study, scientific publications accessed through searches, for example, in the Web of Science, provided valuable data on current technologies being used in scanning cargo containers.

All of the relevant literature reviewed covered research work and publication done after 2001. The quality of the articles selected had to be relevant to the topic, well-organized, and provide information on data that is clear and descriptive.

Data Analysis Plan

The data analysis focuses on addressing the three categories described in the purpose of the study. Content is reviewed in terms of the presence of specific terms and narratives. There are two goals: to look for patterns among the data, and to look for patterns that give meaning to the study (Busch, De Maret, Flynn, Kellum, Meyers, Saunders, White, & Palmquist, 2005).

Step 1: Level of analysis. Search on selected literature targets keywords and a set of keywords related to detection of dangerous nuclear and radioactive materials in cargo containers, such as “non-intrusive inspection”.

Step 2: Number of concepts. Keywords address the three categories described in the purpose of the study: (1) technologies currently being used in support of closed container inspections (Stana, 2006), (2) companies and organizations leading research efforts on developing new technologies (Stana, 2006), and (3) impact of technology deployment in relation to the detection of dangerous and illegal cargo in closed container inspections (Bakshi, Flynn & Gans, 2009). Words or set of words associated with the categories outlined above will be coded.

Step 3: Coding approach. The goal is to report how available technologies are applied most effectively to prevent illicit materials in cargo containers from passing through United States Customs Service inspections at the ports of entry. Coding will be done for the existence of keywords, such as “non-intrusive inspection” regardless of how many times it many appear in the collected literature.

Step 4: Level of generalization. Concepts that are coded and appear to be the same or similar will be regarded as the same. As an example, “container scanning technology” and “container screening technology”; “container security initiative” and “homeland security”; “non-intrusive inspection” and “container inspection system” will be recorded as the same. Words that are similar but have different implicit meaning will be coded separately.

Step 5: Translation rules. Translation rules ensure consistency and coherence by streamlining and organizing the coding process. As an example, “scanning system” is coded under "container scanning technology" and "container screening technology" and having this rule allows for consistency throughout the study.

Step 6: Irrelevant information. Irrelevant information will be ignored for the purpose of this study.

Step 7: Code the texts. Coding will be done manually by posting words on markers, reading the text, posting the markers to sections that contain key concepts that are relevant to the study, and then transferring the information onto a worksheet. The worksheet will be organized to reflect each concept, terms, article and author's names.

Step 8: Analyze results. Upon completing of the coding, data is examined and an attempt is made to reach possible conclusions based on themes presented in the study.

Writing Plan

The writing plan that directs the organization of information in the Review of the Literature section of this paper begins with an overview of the purpose of the study and then examines the results of the data analysis process. In this case, a thematic approach is taken (UNC, 1998), as a way to frame the outcome of this study – a guide on the topic of port security technology. Initial themes used to frame the guide are aligned with the three areas of analysis, including (1) technologies currently being used in support of closed container inspections for materials that could be used to make atomic weapons or other instruments of weapons of mass destruction, including biological and chemical weapons, (2) companies and organizations leading research efforts on developing new technologies, and (3) the impact of technology deployment in relation to the detection of dangerous and illegal cargo in closed container inspections. Additional themes may emerge during the data analysis process.

Theme 1: Technologies in current use to support closed container inspections. The analysis of these technologies is based upon research of available information and provides an introduction to each of these technologies, their capabilities, efficacy, associated standards and benefits and the trends and policies driving their use. A number of technology vendors are researched as part of the technologies currently being used in support of closed container inspections for materials that could be used to make atomic weapons or other instruments of weapons of mass destruction, including biological and chemical weapons. Non-intrusive inspection (NII), radiation detection, and RFID container intrusion detection have been the technologies at the center of currently deployed technologies and its utilization in a port environment are examined.

Theme 2: Companies and organizations leading research efforts. Companies and organizations leading research efforts on developing new technologies address issues such as enhancing the technological differences between the available systems currently in use, and working on technologies not only designed to detect or identify the radiation, but also to determine the nature and type of device detected in the scanned cargo container.

Theme 3: The impact of technology deployment. The impact of technology deployment in relation to the detection of dangerous and illegal cargo in closed container inspections focuses on how effective the deployed technology has assisted the United States Customs and Border inspectors in detecting illicit cargo, and its impact on the international supply chain. Deployed technology is reviewed for operational and optimization standards and comparison are made on detection methods for efficiency. With the deployments, there are associated port security infrastructure changes and these changes impacts the ability of ports and their terminals to securely and efficiently operate.

Annotated Bibliography

This annotated bibliography is a list of citations to books, articles, and documents that serve as key references to the development of the study. The purpose of the annotation is to inform the reader of the relevance, accuracy, and quality of the sources cited (Cornell University Library, 2009). Lester and Lester (2007) states that an annotated bibliography does two important things: (1) it gives a bibliographic list of a selection of sources, and (2) it summarizes the contents of each book or article (p.117).

The selection of key references used to develop this study is organized according to three categories aligned with the key goals of the study; current closed container inspection technologies in use to detect materials that could be used to make atomic weapons or other instruments of weapons of mass destruction, including biological and chemical weapons, research efforts and potential technologies, and areas of impact of the deployed technology. Each entry includes the bibliographic citation and an annotation, in the form of an abstract, pulled from the original reference. A brief description of how the reference is used to inform this study is also included, as well as how the credibility of the study is determined.

Current Closed Container Inspection Technologies

Brown, D., Coates, A., Kuo, S., Loveman, R., Penttaleri, E., & Rynes, J. (1997) *Cargo inspection system based on pulsed fast neutron analysis,* Proceedings Of SPIE, *The International Society of Optical Engineers, 2936* (76) 1997. Retrieved from http://cat.inist.fr/?aModele=afficheN&cpsidt=17419023

Abstract: The pulsed fast neutron analysis (PFNA) cargo inspection system (CIS) uses a nanosecond pulsed beam of fast neutrons to interrogate the contents of small volume elements -- voxels -- of a cargo container or truck. A color display shows the three-dimensional location of suspected contraband, such as drugs or explosives. The neutrons interact with the elemental contents of each vowel, and gamma rays characteristic of the elements are collected in an array of detectors. The elemental signals and their ratios give unique signatures for drugs and other contraband. From the time of arrival of the gamma rays, the position of the vowel within the truck is determined. The PFNA CIS is designed to scan five or more trucks per hour. The operator interface has been designed to assist in the rapid identification of drugs, explosives or other contraband.

Comments: What is unique about the PFNA is that the technology offers real time detection and the location of contraband or explosives hidden inside the cargo container. The PNFA highlights technology currently being used to scan cargo containers, and its ability to scan five or more containers per hour will enhance the supply chain and aid in speeding inspections at the ports. The article, published in a peer reviewed journal, is relevant to the study as support for the development of the Significance of this study.

Jones, J., (2003). Active, non-intrusive inspection technologies for homeland defense. Idaho *National Engineering and Environmental Laboratory,* Retrieved from http://www.inl.gov/technicalpublications/Documents/2585364.pdf

Abstract: Active, non-intrusive inspection or interrogation technologies have been used for over 100 years with the primary focus being radiographic imaging. During the last 50 years, various active interrogation systems have been investigated and most have revealed many unique and interesting capabilities and advantages that have already benefited the general public. Unfortunately, except for medical and specific industrial applications, these unique capabilities have not been widely adopted, largely due to the complexity of the technology, the overconfident reliance on passive detection systems to handle most challenges, and the unrealistic public concerns regarding radiation safety issues for a given active inspection deployment. The unique homeland security challenges facing the United States today are inviting more “out-of-the-box” solutions and are demanding the effective technological solutions that only active interrogation systems can provide. While revolutionary new solutions are always desired, these technology advancements are rare, and when found, usually take a long time to fully understand and implement for a given application. What’s becoming more evident is that focusing on under developed, but well understood, active inspection technologies can provide many of the needed “out-of-the-box” solutions. This paper presents a brief historical overview of active interrogation. It identifies some of the major homeland defense challenges being confronted and the commercial and research technologies presently available and being pursued.

Comments: Radiation sources and emissions are discussed in this paper and detection methods are fully covered. Various inspection methods and technologies are discussed, along with the companies that manufacture imaging, explosion detection and nuclear material detection equipment. The Idaho National laboratory is a leading and recognized research organization that is funded by the U.S. government. Technologies discussed such as the explosive and nuclear material detection discussed are part of the current technologies being deployed for cargo screening and inspections. The reference is part of the data set for coding, and provides information presented in the Review of the

Literature section of the paper. It is also relevant to the study as it covers key terms in detail, such as non-intrusive technology.

Orphan, V., Muenchau, E., Gormley, J. & Richardson, R. (2005). Advanced y ray technology for scanning cargo containers. *Applied Radiation and Isotopes, 63* (5/6), 723-732. Retrieved from http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6TJ0-4GHBP6P-5&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&_docanchor=&view=c&_searchStrId=1139005403&_rerunOrigin=google&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=1909986267ea9f48154d13c9ed1b4ca1\

Abstract: The shipping industry is striving to increase security for cargo containers without significantly impeding traffic. Three Science Applications International Corporation (SAIC) development programs are supporting this effort. SAIC"s ICIS system combines SAIC"s VACIS ***γ*** ray imaging, radiation scanning*, OCR,* elemental analysis and other technologies to scan containers for nuclear materials and other hazards in normal terminal traffic. SAIC"s enhanced γ ray detector improves VACIS image resolution by a factor of three. And SAIC"s EmptyView software analyzes VACIS images to automatically verify empty containers.

Comments: SAIC’s scanning technology is currently being deployed at various ports across the United States, including the ports of Los Angeles, San Diego, Oakland and Seattle. What is unique about this technology is that it produces radiographic images of cargo containers and vehicles in less than a minute. Science Application International Corporation is one of the leading manufacturers of cargo screening and scanning technology in the United States. As mentioned above, SAIC systems are currently being deployed at seaports across the country. This article is published in a peer reviewed journal. It is part of the data set for coding, and provides information about current technologies being deployed, as reported in the Review of the Literature section of the paper. These three researchers at SAIC are widely recognized as experts in the field of scanning technology.

Redus, R., Alioto, M., Sperry, D. & Pantazis, T. (2007). VeriTainer radiation detector for intermodal shipping containers. *Nuclear Instruments and Methods in Physics Research A, 579* (1), 384–387. Retrieved from http://www.amptek.com/pdf/gradpaper.pdf

Abstract: The VeriSpreaderTM radiation detection system uses neutron and spectroscopic g-ray detectors into a container crane spreader bar, the part of the crane that directly engages the intermodal shipping containers while moving from ship to shore and vice versa. The use of a spectroscopic g-detector reduces the rate of nuisance alarms due to naturally occurring radioactive material (NORM). The combination of g and neutron detection reduces the effectiveness of shielding and countermeasures.

Comments: VeriTainer's container crane mounted radiation detection and identification system employs advanced passive scanning technology and sophisticated identification algorithms to detect and identify gamma and neutron sources in shipping containers as they are loaded or discharged from a container ship. The VeriTainer radiation detection system is currently being used at the Port of Oakland, California. The article, written by Veritainer researchers, is published in the peer reviewed journal. It is part of the data set for coding, and highlights another cargo scanning device being deployed at United States seaports, as reported in the Review of the Literature section of the paper.

Research Efforts and Potential Technologies

Gozani, T. (2007). Principles and applications of neutron-based inspection techniques. *Nuclear Instruments & Methods in Physics Research, 261* (1-2), 311-315. Retrieved from http://www-pub.iaea.org/MTCD/publications/PDF/P1433_CD/datasets/papers/ap_int-04.pdf

Abstract. Neutron based explosive inspection systems can detect a wide variety of substances of importance, for a variety of purposes from national security threats (e.g., nuclear materials, explosives, narcotics) to customs duties, shipment control and validation, and for protection of the environment. The inspection is generally founded on the nuclear interactions of the neutrons with the various nuclides present and the detection of resultant characteristic emissions. These can be discrete gamma lines resulting from the thermal (n,γ) neutron capture process or inelastic neutron scattering (n,n´γ) occurring with fast neutrons.

The two types of reactions are generally complementary. The capture process provides energetic and highly penetrating gamma rays in most inorganic substances and in hydrogen, while fast neutron inelastic scattering provides relatively strong gamma-ray signatures in light elements such as carbon and oxygen. In some specific important cases, though, unique signatures are provided by the neutron capture process in light elements

such as nitrogen, where unusually high energy gamma rays are produced. This forms the basis for key explosive detection techniques.

The detection of nuclear materials, both fissionable (e.g., 238U) and fissile (e.g., 235U), are generally based on the fissions induced by the probing neutrons and detecting one or more of the unique signatures of the fission process. These include prompt and delayed neutrons and prompt and delayed gamma rays. These signatures are not discrete in energy (typically they are continua) but temporally and energetically significantly different from the background, thus making them readily distinguishable.

Comments: This is a journal review covering recent advances in neutron based explosive inspection systems. The review covers just one of the technologies being deployed. It is part of the data set for coding. It is relevant to the study because it highlights research work being done to enhance current technologies, and the neutron based systems can detect a variety of illicit cargo, as reported in the Review of the Literature section of the paper.

Hazi, A. (2005). Screening *cargo containers to remove a terrorist threat.* Lawrence Livermore National Laboratories, United States Department Of Energy. Retrieved from http://uolibraries.worldcat.org/oclc/316318762&referer=brief_results

Abstract: Improving security at U.S. ports is thus one of the nation's most difficult technical and practical challenges because the systems developed for screening cargo must operate in concert with ongoing seaport activities. Working at this intersection of commerce and national security, Lawrence Livermore researchers are applying their expertise in radiation science and detection to develop improved technologies for

detecting hidden radioactive materials. One new technology being designed and tested at the Laboratory is a neutron interrogation system for cargo containers. This system will quickly screen incoming shipments to ensure that nuclear materials such as plutonium and highly enriched uranium (HEU) are not smuggled into the United States.

Comments: This research work at the Lawrence Livermore laboratories is relevant to this study because it provides detailed analysis on work being done to detect plutonium and highly enriched uranium in cargo containers. With a focus on detecting the gamma-ray signature and on projects such as the liquid scintillator, this research addresses the sub questions of key technologies in use and organizations leading the research effort. It is part of the data set for coding, and provides information reported in the Review of the Literature section of the paper.

Im, H. & Song, K. (2006). *Applications of prompt gamma ray neutron activation analysis: Detection of illicit materials. Applied Spectroscopy Reviews 44* (4), 317-334. Retrieved from http://www.ingentaconnect.com/content/tandf/laps/2009/00000044/00000004/art00002

Abstract: Prompt gamma ray neutron activation analysis (PGNAA) is an efficient nondestructive multi-elemental detection technique for samples such as metals, coal (mineral), cement, and radioactive materials as well as for explosives, chemical warfare agents, various narcotics, land mines, etc. The technique can be used in the laboratory or for on-site analysis for various samples. In addition, the PGNAA technique in elemental analysis can provide more accurate detection results with low false alarm in variety of application fields when combined with image scanning and chemometric treatment of the

obtained data. The development of small-sized neutron generators enabled and widened these applications because a stationary nuclear reactor is no longer an indispensible element in PGNAA.

Comments: The bulk of the research on prompt gamma-ray neutron activation analysis is on the elimination of much of the background spectrum and pulse pileup. This leads to an increase in the signal-to-noise (S/N) ratio, and enables measurement of emission rates of characteristic prompt gamma rays produced by neutron capture. This research, published in a peer reviewed journal, is relevant to the study as it covers a key component of the primary technology mentioned in the purpose of the study. It is part of the data set for coding, and provides information reported in the Review of the Literature section of the paper.

Johnson, A., Volberding, W. & Reiter, R. (2004). ARPA nonintrusive cargo inspection technology testbed. *Analytical Systems Engineering Corp*. Retrieved from http://spiedl.aip.org/getabs/servlet/GetabsServlet?prog=normal&id=PSISDG002276000001000192000001&idtype=cvips&gifs=yes&ref=no

Abstract: The Advanced Research Projects Agency (ARPA) Nonintrusive [Cargo] Inspection Technology Testbed, located in the port of Tacoma, Washington, began operation on 21 May 1993. The testbed is a part of the Department of Defense Counterdrug Research and Development Program. It is used to evaluate the ability of existing inspection technologies, as well as new technologies and prototype systems, to detect contraband, primarily drugs, hidden in large intermodal cargo containers and vehicles without the need to open them or manually remove the cargo. Currently, a dual-

image, high-energy radiographic imaging system and an advanced information processing and display system are being evaluated at the testbed. Work is under way to install and begin testing of a pulsed fast neutron analysis cargo inspection system in early 1995. The testbed can also accommodate other sensors such as particle/vapor detection systems. The testbed was designed, constructed, and is now operated for ARPA by Analytical Systems Engineering Corporation. This paper provides a brief overview of the testbed, the high-energy radiographic imaging system, the information processing and display system, and the test program.

Comments: Research and test conducted at the port of Tacoma, Washington as part of ARPA's development program adds another dimension to container screening technology. The involvement of the Department of Defense (DOD) in this project highlights the cooperation between the DOD and private enterprises in advancing work on non-intrusive cargo inspections systems. This non-scholarly article is part of the data set for coding, and provides information on available resources for testing of research work being done on cargo screening technology, reported in the Review of the Literature section of the paper.

Jones, J., Norman, D., Haskell, K., Sterbentz, J., Yoon, W., Watson, S., Johnson, J., Zabriskie, J., Bennett, B., Watson, R., Moss, C. & Frank, H. (2006) Detection of shielded nuclear material in a cargo container. *Nuclear Instruments & Methods in Physics Research Section A, 562*(2), 1085-1088. Retrieved from http://cat.inist.fr/?aModele=afficheN&cpsidt=17855751

Abstract: The Idaho National Laboratory, along with Los Alamos National Laboratory and the Idaho State University's Idaho Accelerator Center, are developing electron accelerator-based, photonuclear *inspection* technologies for the detection of shielded nuclear material within air-, rail-, and especially, maritime-cargo transportation containers. This paper describes a developing prototypical cargo container inspection system utilizing the Pulsed Photonuclear Assessment (PPA) technology, incorporates interchangeable, well-defined, contraband shielding structures (i.e., "calibration" pallets) providing realistic detection data for induced radiation signatures from smuggled nuclear material, and provides various shielded nuclear material detection results. Using a 4.8-kg quantity of depleted uranium, neutron and gamma-ray detection responses are presented for well-defined shielded and unshielded configurations evaluated in a selected cargo container inspection configuration.

Comments: The article in this peer-reviewed journal highlights work by researchers at the Idaho National laboratories on advances in gamma-ray detection system in order to utilize photon signatures to detect nuclear material inside a shielded container. It covers detection characterization, normalization factors, and numerical simulations and experiments are documented. It is part of the data set for coding, and provides information on the Idaho laboratory, which is one of the organizations leading research efforts in advancing cargo screening technologies, reported in the Review of the Literature section of the paper.

Leahy-Hoppa, M. & Fitch, M. & Osiander, R. (2009). Terahertz spectroscopy techniques for explosive detection. *Analytical and Bioanalytical Chemistry, 395*(2), 247-257.

Retrieved from http://www.springerlink.com/content/212344k64558633r/

Abstract: Spectroscopy in the terahertz frequency range has demonstrated unique identification of both pure and military-grade explosives. There is significant potential for wide applications of the technology for nondestructive and nonintrusive detection of explosives and related devices. Terahertz radiation can penetrate most dielectrics, such as clothing materials, plastics, and cardboard. This allows both screening of personnel and through-container screening. The capabilities of the technology to detect and identify explosives highlight some of the critical works in this area.

Comments: Timely research work that addresses an area that needs more attention; the detection and identification of explosives in cargo containers. Its application will be useful beyond the seaport, and will serve the dual purpose of air cargo and airline passenger screening. This research work, published in a peer reviewed journal, is relevant to the study because it highlights the importance of detecting chemical explosives. The recent incident of an attempted bombing of an inbound American airliner on December 25, 2009 with explosives is an example for the need and relevance of research work in this area. It is part of the data set for coding, and provides information reported in the Review of the Literature section of the paper.

Staples, E., (2006). *Chemical profiling cargo with an ultra-high speed gas chromatograph, ol-factory images, and virtual chemical sensors*, Electronic Sensor Technology, LP, Retrieved from http://www.techmondial.co.uk/assets/documents/Cargo_Container_Odors.pdf

Abstract: Ultra-high speed gas chromatography is a powerful analytical method for analysis of odors, fragrances, and chemical vapors produced by explosives, chemical and biological weapons, contraband, and hazardous industrial materials. A portable chemical profiling system incorporating an ultra-high speed chromatography column, a solid-state sensor, a programmable gate array microprocessor, and an integrated vapor preconcentrator is described.

Using ultra-high speed chromatography, chemical vapors within containers can be speciated and their concentration measured in less than 10 seconds with picogram sensitivity using a SAW sensor with electronically variable sensitivity. Odor concentration and intensity are measured directly with an integrating GC sensor. The solid-state sensor produces high resolution 2-dimensional olfactory images unique to many complex odors. Examples involving odors from explosives, contraband drugs of abuse, hazardous chemicals, and even biological life forms are presented.

Comments: The use of chemical profiling with high speed gas chromatography adds a new dimension and tool to cargo inspection technologies. By being able to chemically detect sample vapors and odor intensity from explosives, contraband drugs, hazardous chemicals, biological life and money, these sensors provide a reliable, fast and cost effective screening tool for CBP inspectors. This article is relevant to the study as it addresses and highlights research work in an area that is of concern to the United States Customs inspectors, and that is chemical and biological weapons detection. It is part of the data set for coding, and provides information reported in the Review of the Literature section of the paper.

Impact of Technology Deployment

Bennett, A. & Chin, Y. (2008). 100% container scanning: security policy implications for global supply chains. *Massachusetts Institute of Technology.* Retrieved from http://dspace.mit.edu/handle/1721.1/45248

Abstract: On August 3, 2007, President George Bush signed into law HR1 the "Implementing Recommendations of the 9/11 Commission Act of 2007." The 9/11 Act requires 100% scanning of US-bound containers at foreign seaports by 2012 through the use of non-intrusive (NII) and radiation detection equipment. Maritime stakeholders and the government community have actively debated the feasibility of this plan, citing economic impacts, barriers to global trade and insufficient technology and physical space. This thesis focuses on importer concerns relating to potential shipment delays, financial burdens, sourcing issues and contingency planning concerns in global supply chain operations. Using port statistics, field study data as well as industry insights, frameworks are developed to identify major stakeholder issues and quantify the financial costs and delay risks bourn across the entire supply chain. Cost and delay analyses are based on 2 prototypical ports - a small/low-volume export port and a large/high-volume export port. Cost analysis is performed for a consolidated (port authority) level installation and a segmented (terminal operator) level installation to calculate a per-box scanning fee. Queuing models and Monte-Carlo simulations are also developed to quantify truck congestion due to primary scanning and the risk of containers missing vessels due to secondary inspections. Results of the cost analysis indicate that scanning configurations, particularly related to NII, greatly affect the-per box scanning cost. It is not economically feasible to scan only US-bound containers at half of the 600 ports with direct connections to the US. Analysis of truck congestion suggests that the ramp metering effect of the entry gate can help to abate congestion at the scanning area.

Comments: The thesis is on the impact of screening inbound cargo containers on the global supply chain. The thesis addresses concerns relating to potential shipment delays, financial burdens, sourcing issues and contingency planning concerns. It is relevant to the study because it highlights the impact of deployed technology at the seaports as it relates to the description of the Audience of the study. The study is a master's degree thesis, produced at MIT, and is thus deemed credible.

HT Media. (2009). Sens. Lieberman, Collins reacts to limited progress on 100 percent percent cargo scanning at foreign ports. Retrieved from http://www6.lexisnexis.com/publisher/EndUser?Action=UserDisplayFullDocument&orgId=574&topicId=25151&docId=l:1090001615&isRss=true

Abstract: The Government Accountability Office (GAO) found that although Customs and Border Protection (CBP) has been able to scan a majority of the cargo passing through low-volume ports, it has been able to scan no more than 5 percent of freight coming into large ports, necessitating an extension of the 2012 deadline for 100 percent scanning at major ports.

Reacting to this news, United States Senator Susan Collins noted that "Under the SAFE Port Act, all cargo designated as high-risk at foreign ports is now scanned for radiation and X-rayed. In addition, all arriving cargo at every major U.S. seaport is scanned for radiation. These security measures currently in place are part of a layered, risked-based method to help ensure that cargo entering the U.S. is safe, and, by extension, that the U.S. is kept safe.

"This GAO report highlights the substantial challenges with attempting to scan all U.S.-bound cargo containers at foreign ports with X-ray technology. Until this technology is proven effective at detecting radiological material and not disruptive of trade, requiring the scanning all U.S.-bound cargo, regardless of risk, at every foreign port is misguided and provides a false sense of security."

Comments: The impact of this report by the GAO and the reaction from Senators Collins and Lieberman means continued funding by Congress for inspection technologies for use by the CBP at seaports of entry. The article and statements by the United States senators provide information on Congressional activities related to port security screening. As such, it supports development of the Purpose section of this paper.

Kumar, S. & Verruso, J., (2008) Risk assessment for the security of inbound containers at U.S. ports: a failure, mode, effects, and criticality analysis approach, *Transportation Journal*, Retrieved from http://www.entrepreneur.com/tradejournals/article/189552854.html

Abstract: This study proposes a design of a decision support framework for a reliable cargo container shipment and handling system based on failure mode effect and criticality analysis for inbound containers at U.S. ports. The proposed prototype of a simple risk assessment system is offered that safeguards against potential security risks in cargo container shipments entering U.S. ports. An application of the proposed framework is presented--in a situation involving an inbound shipment from China designated for a U.S.

destination--that shows how effectively it helps reduce the risk of failure. Additionally, the industry research looks at how the initiatives being deployed affect supply chain managers as they contend with the changes and the associated costs faced by their businesses.

Comments: This study proposes a risk assessment model for inbound cargo containers. It is conducted in line with the recommendations in the CSI and more in line with the supply chain than the impact of technology deployment. This article, published in a peer reviewed journal, provides background information for the Problem Area.

Philips, B., Novikova, E., Wulf, E. & Kurfess, J. (2006). Comparison of shielded uranium passive gamma-ray detection methods, *Naval Research Lab.* Retrieved from http://spie.org/x648.html?product_id=666342

Abstract: The detection of shielded special nuclear materials is of great concern to the homeland security community. It is a challenging task that typically requires large detectors arrays to achieve the required sensitivity to detect shielded enriched uranium. We simulated the performance of three different configurations of scintillation detectors in a realistic gamma ray background. The simulations were performed using the GEANT4 simulation package fine tuned for low energy photon transport. The background spectrum was obtained by modeling high-resolution background spectra obtained by various groups in various locations. The performance of a non-imaging scintillating array was compared to the performance of two imaging arrays: a coded aperture imager and a Compton imager. The sensitivity was modeled at three energies for the emission from a 1 kg sphere of uranium enriched to 95% U-235: the 185 keV emission from U-235, the 1001 keV emission from U-238, and the 2614 keV emission from U-232. The instruments

were modeled with and without passive shielding. The most detectable signal is the 2.614 MeV emission from U-232 contamination if present at a level greater than tens of parts per trillion. While the non-imaging array has the highest efficiency, it also has the highest background rate and is therefore not the most sensitive instrument.

Comments: The comparison of the detection methods in this work funded by the United States Naval Research Laboratories provides another relevant example of the impact of deployed technology at the seaports of entry. The simulations conducted on three gamma ray detectors and the results obtained are useful information in determining inspection technologies with the highest efficiency. Its relevance on the study is that by comparing the technologies highlighted in the purpose of the study, efficient technology that can effectively detect illicit cargo will be deployed. It is part of the data set for coding, and provides information reported in the Review of the Literature section of the paper.

Zhu, Y., Li, M., Young, C., Xie, M., & Elsayed, E., (2005). *Impact of measurement error on container inspection policies at port-of-entry.* Department of Industrial and Systems Engineering, Rutgers University. Retrieved from http://dimacs.rutgers.edu/TechnicalReports/TechReports/2009/2009-11.pdf

Abstract: Containers and cargos arriving at port-of-entry are inspected using sensors and devices to detect drugs, weapons, nuclear materials and other illegal items. Measurement errors associated with the inspection process may result in higher percentage of misclassification of containers. In this paper, we propose and formulate three inspection policies for containers at port-of-entry assuming the presence of sensor measurement errors. The optimization of the policies is carried out and the performance of each in

terms of misclassification probabilities is compared. In each of the policies, the optimum settings are determined by minimizing the probability of false rejection while limiting the probability of false acceptance at a very low tolerance level. The results show that the policy of repeat inspections improves the performance in terms of correct container classification.

Comments: This collaborative research project by a team of scientist from various universities and research laboratories examines the collection and analysis of information from different types of detectors utilized for inspecting inbound cargo containers at seaports of entry. The accuracy of inspections in terms of accepting or rejecting those containers affects the supply chain. The mathematical model they develop allows for evaluation and improvement of the process by comparing their performance to minimize misclassification and disruption to the inspection flow. Although the data provided cannot be corroborated, the article is part of the data set for coding, and the mathematical model is included in the list of potential technologies reported in the Review of the Literature section of the paper.

Review of the Literature

The terrorist attacks in New York City and the events of September 11, 2001 heightened awareness about the vulnerability to terrorist attack of all modes of transportation (Fritelli, 2005). Fritelli (2005) further explains that the vulnerability of the maritime container supply chain to potential acts of terrorism has led to increased utilization of several container security technologies. The integrity of a container during its transport from point A to point B in the logistics chain cannot be assured. Given sufficient time, opportunity and a remote location, people will be able to open a container and tamper with its contents (van de Voort, O'Brien, Rahman & Valeri, 2003).

The term "port security" serves as shorthand for the broad effort to secure the entire maritime supply chain, from the factory gate in a foreign country to the final destination in the United States (Haverman & Shatz, 2006). Container security is not primarily about port security; it is about everyplace security. Indispensable and ubiquitous, a container is an excellent vector, or carrier, for weapons of mass destructions (WMDs) such as nukes or "dirty bombs' (Cohen, 2005). There is no way to completely inspect all the millions of containers entering the United States. Given the difficulties of complete inspections, defense needs to be layered, with checks at multiple stages on a container's journey. One of the layers is technology; technology – the use and development of new inspection and tracking technologies (Cohen, 2005).

The purpose of this study is to document the technologies currently being used in support of closed container inspections, and identify the companies and organizations that are leading research efforts on developing new technologies. This Review of the Literature section is organized around three major themes. The first theme examines technologies currently being used in support of closed container inspections for materials that could be used to make atomic weapons or other instruments of weapons of mass destruction, including biological and chemical weapons. The second theme is focused on companies and organizations leading research efforts on developing new technologies. The third theme looks at the impact of technology deployment in relation to the detection of dangerous and illegal cargo in closed container inspections.

Theme 1: Current Technologies for Closed Container Inspections

Three specific categories of security technology have been the focus of increased research, testing and deployment in recent years; non-intrusive inspection (gamma and x-ray imaging), radiation detection, and RFID container intrusion detection (Unisys Corp, 2007). For the purposes of this study, two of these widely used technologies at the seaports of entry are examined – non-intrusive inspection and radiation detection.

Gamma-ray and X-ray Imaging. Non-intrusive inspection (NII) technology provides the capability to image the contents of containers without having to perform the time-consuming process of devanning a container and physically inspecting its contents (Unisys Corp, 2007).

Active inspection systems have two requirements: (a) an interrogating source of radiation (a photon source) and (b) a means of detecting the characteristic object emissions. Numerous photon sources are available and include both gamma-ray (from atomic nucleus) and x-ray (from atomic structure) sources (Jones, 2003). Jones (2003) states that this dual requirement drives the need for higher photon beam energies with performance matched imaging detectors. Two of these higher energy systems are the SAIC VACISTM system and the Rapidscan (formerly ARACOR) EagleTM system.

As container-inspection technology advances, security authorities need to manage increasing amounts of information from non-intrusive inspection (NII) systems, radiation-detection systems, and other sources — all without impeding the flow of traffic (SAIC, 2010). The SAIC VACIS® integrated container inspection system (ICIS) (see Figure 1) is designed to integrate and manage images and data. When these features are combined with high-speed scanning capabilities, the company claims that a single ICIS lane can handle more than 300 containers per hour (SAIC, 2010).

Figure 1. SAIC Integrated Container Inspection System

Figure 2. The Rapidscan Eagle

The Rapidscan Eagle, shown in Figure 2, is a mobile, cargo inspection unit providing real-time, radiographic imaging of large inspected items, including a cargo container at a port. The cargo image is acquired and displayed as the unit "drives over" the cargo container or other inspected item (Jones, 2003).

The Rapidscan Eagle®, designed to meet the high x-ray imaging requirements for cargo inspection, employs a 9 mega volt linear accelerator x-ray generator and delivers 425 millimeters of steel penetration. As a result, these systems can inspect a wide range of cargo, including densely-loaded trucks and containers, thereby eliminating the need for costly and time-consuming manual inspections. Trucks are automatically moved through a stationary x-ray beam on a cargo motion system. According to the company, an entire 20-foot container on a truck can be inspected in less than 30 seconds (Rapidscan, 2009).

Radiation Detection. VeriTainer container crane mounted radiation detection and identification system, called the VeriSpreaderTM, employs passive scanning technology and identification algorithms to detect and identify gamma and neutron sources in a shipping container as they are loaded or discharged from a container ship (see Figure 3) (VeriTainer, 2009). The product is designed to integrate sensitive neutron and spectroscopic gamma ray detectors into a container crane spreader, which is the piece of the container crane that directly engages an intermodal shipping container as it is moved onto and off of a container ship at a container terminal (Redus, Alioto, Perry & Pantazis, 2007).

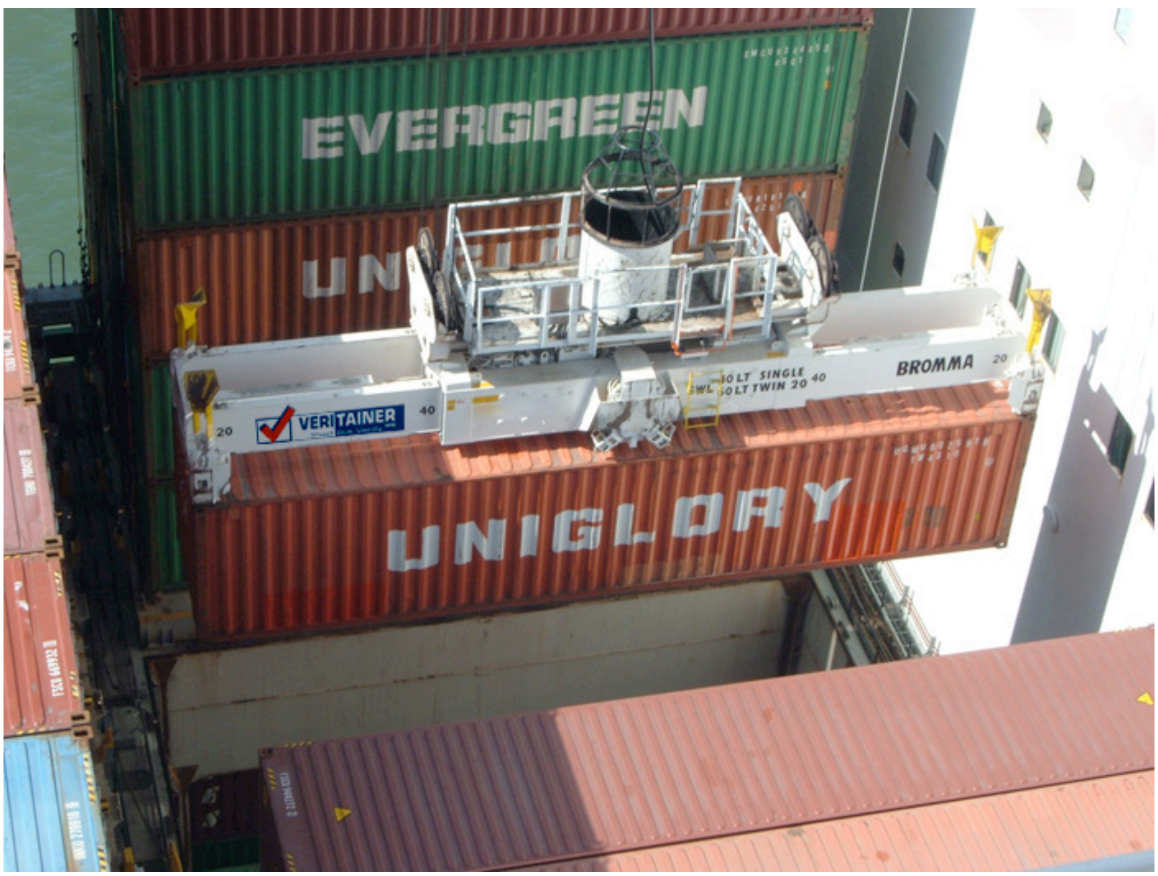

Figure 3. Photograph of VeriSpreaderTM in use at the Port of Oakland, California

Theme 2: Research Efforts on Developing New Technologies

The research work being done on advancing current screening technologies is focused on improving detection of neutron based explosives, and activation analysis. The advances range from the synchronous inspection of two sides of vehicles, increasing throughput and sensitivity and reducing imparted dose to the inspected object and its occupants (if any), to taking advantage of the neutron kinetic behavior of cargo as a way to remove systematic errors, thus reducing background effects and improving fast neutron signals (Gozani & Strellis, 2007). Stowsky (2005) states that the research emphasis in screening technology is in the area of so-called "smart screening" systems. The idea is to arm the screening machines with software that can detect anomalies and then automatically alert human operators to the need for further inspection and, perhaps, the need to instigate countermeasures.

Lawrence Livermore National Labs (LLNL). The Lawrence Livermore National Laboratory is a national security laboratory, whose mission is to advance and apply science and technology to: ensure the safety, security, and reliability of the U.S. nuclear deterrent, reduce or counter threats to national and global security, enhance the energy and environmental security of the nation, and strengthen the nation's economic competitiveness (Lawrence Livermore National Laboratory, 2008). Working at this intersection of commerce and national security, Lawrence Livermore researchers are applying their expertise in radiation science and detection to develop improved technologies for detecting hidden radioactive materials.

One new technology being designed and tested at the laboratory is a neutron interrogation system for cargo containers. According to Sprouse (2004), this system will quickly screen incoming shipments to ensure that nuclear materials such as plutonium and highly enriched uranium (HEU) are not smuggled into the United States. Sprouse (2004) further explains that the design for the detector system calls for a belowground neutron generator that would bathe containerized cargo with neutrons (see Figure 4). Interaction of the neutrons with fissile material inside the container would produce fission, followed by delayed gamma rays detected by an array of liquid scintillators as the container moves through the system. A scintillator is a material that emits light when particles traverse it, and a scintillator instrument detects and measures gamma radiation by counting the light flashes (scintillations) induced by the radiation.

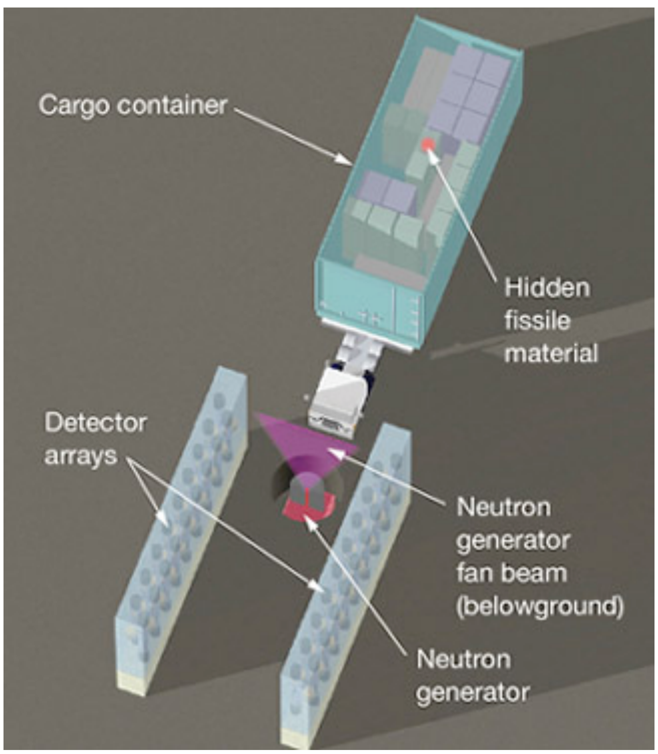

Figure 4. Belowground neutron generator

Simultaneously, efforts are moving forward to develop a large array of liquid scintillators that are sensitive to both neutron and gamma rays. Liquid scintillator is a good candidate material for the cargo interrogation problem. It has a fast response time, and it can be inexpensively instrumented to scan a large volume of material, which helps to ensure that a large fraction of the particle flux emitted by the neutron-irradiated nuclear material will be detected (Sprouse, 2004). Livermore physicist Adam Bernstein, who leads the detector design team, says, "Neutrons and gamma rays create a 20-nanosecond pulse of blue light when they scatter in the medium, and this fluorescent pulse can be detected in photomultiplier tubes" (Sprouse, 2004). Such detectors can be used in various cargo detection and interrogation scenarios. For example, even with the neutron source off, the detector array may still be sensitive enough to scan cargo for some types of radioactive materials of concern.

Idaho National Laboratory (INL). The Idaho National Laboratory, operated for the United States Department of Energy by Battelle Energy Alliance (BEA), has a mission to ensure the nation's energy security with safe, competitive, and sustainable energy systems and unique national and homeland security capabilities (Idaho National Laboratory, 2009). The Pulsed Photoneutron Assessment (PPA) technology is being developed at the Idaho National Engineering and Environmental Laboratory (INEEL) to address nuclear material detection within cargo containers. This technology uses the high penetration capability of energetic photons (up to 12 million electric volts) from a pulsed, linear electron accelerator to induce fissions in nuclear materials. The resulting delayed neutron emissions are measured between each accelerator pulse to detect the nuclear material contents, and variations in the electron beam energy can allow nuclear material identification (Jones, 2003). Jones (2003) further states that current research is directed toward the detection of nuclear smuggling, especially very difficult-to-detect Highly Enriched Uranium (HEU), and explosives within trucks and cargo containers.

The prototype neutron and gamma-ray detection system consists of a transportable stand consisting of an array of nine detector pairs at various elevations. Each collocated pair consists of a neutron and gamma-ray detector. Figure 5 shows a detector assembly positioned alongside a maritime-cargo container in a testing device at the Idaho Accelerator Center that provides container motion.

Figure 5. Deployed PPA detector assembly

The Lab reports that evolving research and development will incorporate other WMD interests, which will enable enhanced applications with higher beam energy operations. The goal is to provide a more comprehensive and in-depth understanding and evaluation for greater standoff distance interrogation applications. Technology is being designed that will investigate smaller quantities of nuclear material detection, and will support adversarial analyses for various threat scenarios.

Electronic Sensor Technology. Electronic Sensor Technology, Inc. has developed and patented a chemical vapor analysis process. This process applies gas chromatography calculations and technology toward a wide variety of industries, including Homeland Security, Life Sciences, Chemical and Petrochemical, Food and Beverage and Environmental. The process works through application of rapid analysis of chemical odors and vapors, and helps to provide real-time analysis (Electronic Sensor Technology, 2009).

Ultra-high speed gas chromatography is an analytical method that can be applied to analysis of odors, fragrances, and chemical vapors produced by explosives, chemical and biological weapons, contraband, and hazardous industrial materials (Staples, 2006). Using a solid-state surface-acoustic-wave (SAW) sensor with electronically variable sensitivity, it identifies the chemical species in the vapors inside cargo containers and determines their concentrations in 10 seconds with picogram sensitivity (see Figure 6).

Vapors within the container are sampled by inserting a sampling tube attached to the inlet of the instrument through a small opening in the container door, or through the ventilation ducts of the container.

According to Staples (2006), although the system is useful for sampling any accessible container, it currently holds immediate significance for America's ports. An important requirement for a chemical-profiling system is that it recognizes odors and fragrances on the basis of their full chemical signature, the combination of all the chemicals in an odor, which is unique to each substance producing the odor. Unlike a trace detector, it must see everything and miss nothing (Staples, 2006).

Figure 6. Direct sampling and chemical analysis of odors within a cargo container

Theme 3: Impact of Technology Deployment

In assessing the impact of deployed technology at the nation's seaports, the focus is on two areas; (a) impact on the logistics and international supply chain, and (b) the effectiveness of the deployed technologies.

Logistics and the international supply chain. As mentioned in the Audience section of this study, customs brokers, clearing agents, logistics planners, purchasing, and manufacturing managers all have an interest in movement of goods and potential disruptions to the international supply chain. The events of September 11, 2001 led to the implementation by the United States Customs and Border Protection of a strategic program known as the Container Security Initiative (CSI). The purpose of the CSI is to secure what is believed to be the most vulnerable but indispensable link in the global supply chain: the ocean going container (Banomyong, 2005).

CSI consists of four core elements: (a) Identify high-risk containers. CBP uses automated targeting tools to identify containers that pose a potential risk for terrorism, based on advance information and strategic intelligence; (b) Prescreen and evaluate containers before they are shipped. Containers are screened as early in the supply chain as possible, generally at the port of departure; (c) Use detection technology to prescreen high-risk containers to ensure that screening can be done rapidly without slowing down the movement of trade. This technology includes large-scale X-ray and gamma ray machines and radiation detection devices; and (d) Use smarter, more secure containers, which will allow CBP officers at United States ports of arrival to identify containers that have been tampered with during transit (U.S. Department of State, 2009).

With the CSI in place, much of the concern from importers relates to potential delays to the supply chain due to the use of detection technology at the ports of entry. Bennett and Chin (2008) state that there are also concerns about innocent alarms. Gerald Epstein, a homeland security expert for the Center for Strategic and International Studies, commented, "There are an awful lot of things that are radioactive out there… if all you're doing is looking at the total amount of radiation, you are going to be opening up a lot of boxes and finding kitty litter" (p.31). In interviews conducted by Bennett and Chin (2008) with several of the top 10 importers in the United States to get a better understanding of their opinions on current security programs, the majority of the importers state that delays are not currently an issue in the maritime transportation mode even with these additional new initiatives. Sporadic delays have occurred due to increased scanning and inspection, but are not yet of great concern (p.43).

Effectiveness of deployed technologies Containers arriving at a port-of-entry are inspected to prevent entry of undesired cargo such as illegal weapons, drugs, and dangerous material. Each container has several attributes and the presence of one or more of the attributes may lead to additional inspection that may require examining the contents of the container manually. The attributes may include radioactive material, biological and chemical agents, drugs and illegal weapons (Zhu, Li, Young, Xe & Elsayed, 2005). Zhu et al. (2005) advocate three policies that could mitigate misclassification errors in the deployed technologies. One policy capable of improving performance is to use more precise sensors in repeat measurements, which reduce the impact of measurement errors. This policy assumes that the measurement errors can be controlled and decreased in subsequent inspections.

Philips, Novikova, Wulf and Kurfess (2006) simulated the performance of three different configurations of scintillation detectors in a realistic gamma ray background. The performance of a non-imaging scintillating array was compared to the performance of two imaging arrays: a coded aperture imager and a Compton imager. It was found that while the non-imaging array had the highest efficiency; it also had the highest background rate and was therefore not the most sensitive instrument.

Gamma-rays can typically penetrate six inches of steel. The resolution of the gamma-ray images is sufficient to confirm empty containers, show the general shape of cargo, and identify anomalies in lightly-loaded containers. In comparison, x-rays are capable of penetrating roughly twelve inches of steel. The resolution of x-rays is much greater than that of gamma-rays and is able to give a much more detailed picture of a container, particularly when the container is heavily-loaded (Cirincione, Cosmas, Low, Pech & Wilds, 2007).

Bjorkholm (2006) notes that the most common imaging characteristics that are quoted for these systems are penetration, contrast detail and resolution. Ultimate penetration is a common measure of a system's ability to image a given thick object, but it must be considered in conjunction with the contrast sensitivity and the spatial resolution, which determine detection. In general, the contrast detail is worst for the gamma systems and improves for X-ray systems as the end point of the spectrum increases.

The effectiveness of the detection technologies has received mixed reviews. O'Harrow (2008) reported in the Washington Post that the current machines are effective at detecting the presence of radiation but often cannot distinguish benign sources, such as cat litter, from materials that can be used in weapons. Biesecker (2009) cites a GAO report that says the Advanced Spectroscopic Portals (ASP), which is the new technology being developed to passively scan containers for the presence of radioactive materials, "were frequently able to detect certain nuclear materials when shielding was below threat guidance, and both systems had difficulty detecting such materials when shielding was somewhat greater than threat guidance" (p.1).

Conclusion

The purpose of this study is to present the evolving efforts and the uses of various technologies in support of closed container inspections of goods and materials that pass through US seaports, as a way to address and minimize the disruption to the international supply chain. The study seeks to (a) document the technologies currently being used in support of closed container inspections (Stana, 2006) and (b) identify the companies and organizations leading research efforts on developing new technologies (Stana, 2006).

Technology is merely one part of the total overarching strategy for homeland security (Makarski & Marrero, 2002). For seaports of entry, other factors are also necessary for process efficiency, such as United States Congressional policy, and the cooperation between the United States Customs and Border Protection (CBP) and industry on programs such as the Customs-Trade Partnership Against Terrorism that encourages shippers and carriers to implement security plans and measures to promote greater security at all points along the supply chain in exchange for expediting of customs procedures.

The United States faces three key challenges to implementing efforts to improve the security of ports and containers: (a) creating and enforcing a set of security standards, (b) ensuring the cooperation of diverse groups with competing interests when it comes to the specifics of how things are to be done, and (c) paying the increased security bill (Hecker, 2002). The challenges faced in implementing the goal of 100% screening of all inbound containers using these technologies seem almost endless, but they can be summarized generally into the following themes, that form a basis of this study.

Technologies in Current Use to Support Closed Container Inspections

The potential threat of terrorists using containers as a way to smuggle a nuclear or radiological device inside a cargo container poses a large risk to our economies and to our societies (van de Voort, O'Brien, Rahman, & Valeri, 2003). The current technologies being used at the seaports of entry to detect dangerous cargo are not perfect or foolproof, but they are steadily improving in accuracy and reliability. Non-intrusive (gamma and x-ray) technology provide the capability to image the contents of containers without opening them. This technology is widely used and has benefited customs inspectors, but requires significant human operator involvement (Unisys Corp, 2007). Radiation detection technology is also a key tool, but is hampered by nuisance alarm rates that reduce its effectiveness. None-the-less, there are documented benefits of radiation scanning to government entities, including port authorities and customs inspectors, which include: (a) prevention of an act of terrorism, (b) meeting mandates and requirements established by domestic government entities for the radiation scanning of containers, and (c) providing assurances to the local community and port workers as to the security of cargo containers (Unisys Corp, 2007).

Organizations Leading Research Efforts

The various companies and research institutions developing these technologies are focused on the development of an integrated technology that is efficient, is able to detect or deter terrorist or criminal threats, and satisfies the needs of the United States Customs and Border Protection agents and field inspectors who are responsible for screening inbound cargo containers. The technologies currently being developed include: (a) electronic sensors for the analysis of odors, fragrances, and chemical vapors produced by explosives, chemical and biological weapons, contraband, and hazardous industrial materials (Staples, 2006); (b) pulsed, linear electron accelerator to induce fissions in nuclear materials resulting in delayed neutron emissions that are measured between each accelerator pulse to detect the nuclear material contents (Jones, 2003), and (c) the neutron interrogation system for cargo containers which will quickly screen incoming shipments to ensure that nuclear materials such as plutonium and highly enriched uranium (HEU) are not smuggled into the United States (Sprouse, 2004), when deployed, will enhance detection of illicit cargo entering the United States.

The Impact of Technology Deployment

Prior to the terrorist attacks of September 11, 2001, the primary focus of port security was to prevent theft and to ensure that illegal or undeclared goods were not brought into the United States. The United States and international responses to the terrorist threat have expanded the focus of port security. Scanning equipment has enhanced security by enabling the detection of weapons at ports of entry, thereby preventing their transport onto the mainland by truck or train (Haverman & Shatz, 2006).

Martonosi, Ortiz and Willis (2006) explain that complete scanning and subsequent inspection of containers at ports would most likely deter terrorists and smugglers under particular circumstances (see Table 1: Cargo scan location consequence matrix). A sufficiently high detection rate would render irrational an attempt to employ a container in an attack on an interior target, since it would have little chance of reaching the desired location (p.22). Haveman and Shatz (2006) further explain:

> “the burden thus falls on technology - on the intelligent deployment of existing technologies and the rapid development of new and better technologies. Used in

conjunction with one another, rather than as replacements for one another, they could provide an excellent, although regrettably still imperfect, security shield (p.121)."

The transformation of ships into floating warehouses, a consequence of just-in-time manufacturing strategies, combined with the digital transformation of supply chain management, has also rendered economies more vulnerable to terrorist disruption (Stowsky, 2005). Due to the impact of technology deployment on logistics and the international supply chain, the expectation is that better screening technologies will also reduce commercial losses from fraud by enabling the quicker detection of illegal or dangerous goods and their removal from the supply chain (Haveman & Shatz, 2006).

Location of Scan	Consequence of Attack	Risk of Tamper	Trustworthiness of Scan	Technology Cost to U.S.
Prior to arriving at foreign port (exporter supply chain)	Low	High	Low	$
At Foreign Port	Low	Medium	Low to High	$
At U.S. Port	High	Low	High	$$
Beyond U.S. port (within importer supply chain)	High	Medium	Medium	$$

Table 1. Cargo scan location consequence matrix

However, more research must be done in the area of seaport cargo transportation security. A key area for further development is the transport chain for containers, which is currently quite fragmented and involves many different organizations (Haverman & Shatz, 2006). It is not sufficiently transparent, that is, the flow of information accompanying the flow of containers is not good.

But, early provisions of more complete information and greater access control have been put in place by the U.S. Customs and Border Protection service (Haverman & Shatz, 2006). As an example, ocean carriers are now required to send the U.S. CBP the manifest for each container, electronically, in a standard, machine-readable format, 24 hours before loading at a foreign port (Haverman & Shatz, 2006). Continued improvement in the ability to detect terrorist nuclear weapons in the maritime transportation system, designed to make a terrorist attack on a port less likely to succeed, may in fact make such attacks less probable.

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Appendix A

List of Product Websites

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Appendix B

List of Abbreviations and Acronyms

9-11: 11 September 2001 (Date of worst terrorist attack in U.S. history)

ACS: Automated Commercial Systems
The Automated Commercial System (ACS) is the comprehensive system used by the U.S. Customs Service to track, control, and process all commercial goods imported into the United States.

ARPA Advanced Research Projects Agency
(Agency of the United States Department of Defense)

ATS: Automated Targeting System
ATS is an intranet-based enforcement and decision support tool that is the cornerstone for all CBP targeting efforts.

ACI: Ancore Cargo Inspector

CBP: United States Customs and Border Protection
The U.S. federal agency in charge of customs and border management and protection for the United States.

CBRN: Chemical, Biological, Radiological, and Nuclear

CBSA Canadian Border Services Agency
(Canadian Customs Services)

CIS: Container Inspection System

CSD: Container Screening Device

CST: Container Scanning Technology

CSI: Container Security Initiative
A U.S. Customs and Border Protection program with four core elements: using intelligence and automated information to identify and screen high-risk containers; inspecting containers identified as high-risk, at the point of departure; using detection technology to quickly inspect high-risk containers; and using smarter, tamper-evident containers. It is best known for screening and inspecting containers at foreign ports.

C-TPAT: Customs- Trade Partnership Against Terrorism

A joint government business initiative that encourages shippers and carriers to implement security plans and measures to promote greater security at all points along the supply chain in exchange for expediting of customs procedures.

DHS: Department of Homeland Security
The U.S. federal department in charge of the national network of organizations responsible for U.S. homeland security.

DNDO: Domestic Nuclear Detection Office
An office within the DHS whose mission is to detect and report unauthorized attempts to import, possess, store, develop, or transport nuclear or radiological material for use against the United States.

DOE: Department of Energy
The U.S. federal department whose mission is to advance the national, economic, and energy security of the United States; to promote scientific and technological innovation in support of that mission; and to ensure the environmental cleanup of the national nuclear weapons complex.

DOT: Department of Transportation
The U.S. federal department in charge of the transportation system.

EDS: Explosion Detection System

FRR: False Rejection Rate

GAO: Government Accountability Office
The non-partisan agency in charge of studying the programs and expenditures of the U.S. federal government. Formerly known as the General Accounting Office.

HR: House Resolution

ICE: Immigration and Customs Enforcement
(Agency of the United States government)

IPSP: International Port Security Program

ISC: International Supply Chain
The transport and logistics system (organizations, people, technology, activities, information and resources) for the world's cargo.

IT: Information Technology
The use of computers and software (or any technology) to process, convert, store, retrieve, transmit or communicate information.

LFMI: Low Frequency Magnetic Imaging

NII: Non-Intrusive Inspection

POE: Port of Entry

PFNA: Pulsed Fast Neutron Analysis

R&D: Research and Development

RDE: Radiation Detection Equipment

RIID: Radiation Isotope Identification Device

RPM: Radiation Portal Monitor
A broad category of radiation detection equipment, some types of which are being implemented at U.S. seaports.

RST: Radiation Screening Technology

SAFE Port Act: Security and Accountability for Every Port Act of 2006

SAIC Science Applications International Corporation
(Organization)

SPIE The International Society for Optical Engineering

TNA: Thermal Neutron Analysis

TSA: Transportation Security Administration
A U.S. Department of Homeland Security agency responsible for protecting the nation's transportation systems.

USCS: United States Customs Service
(Agency of the United States government)

USCG: United States Coast Guard
One of the five U.S. military branches; responsible for maritime and coastal security as well as various humanitarian and law enforcement duties. It is a part of the Department of Homeland Security.

WMD: Weapons of Mass Destruction
Nuclear, biological, radiological, or chemical weapons.

Appendix C

Search Results

Search Engine	Search Terms	Results	Quality of Results
Worldcat	Container Scanning Technology	143	Fair
	Container Port Security	57	Poor
	Container Screening Technology	80	Poor
	Non-Intrusive Inspection Technology	1023	Good
	Container Inspection System	260	Fair
	Scanning Systems	5520	Poor
	Container Security Initiative	56	Good
	Homeland Security	13,265	Poor
EBSCO HOST Academic Search Premier	Container Scanning Technology	39	Good
	Container Port Security	128	Good
	Container Screening Technology	14	Poor
	Non-Intrusive Inspection Technology	10	Excellent
	Container Inspection System	74	Fair
	Scanning Systems	5432	Poor
	Container Security Initiative	164	Good

	Homeland Security	9262	Poor
Google Scholar	Container Scanning Technology	16	Good
	Container Port Security	45,000	Poor
	Container Screening Technology	62,000	Poor
	Non-Intrusive Inspection Technology	19,900	Good
	Container Inspection System	146,000	Good
	Scanning Systems	2,700,000	Poor
	Container Security Initiative	28,300	Poor
	Homeland Security	424,000	Poor
FirstSearchECO	Container Scanning Technology	2	Poor
	Container Port Security	7	Excellent
	Container Screening Technology	1	Good
	Non-Intrusive Inspection Technology	1	Good
	Container Inspection System	10	Fair
	Scanning Systems	2112	Poor
	Container Security Initiative	5	Good
	Homeland Security	556	Poor
	Container Scanning	1000	Poor

	Technology		
LexisNexis Academic	Container Port Security	1000	Poor
	Container Screening Technology	200	Fair
	Non-Intrusive Inspection Technology	97	Good
	Container Inspection System	454	Good
	Scanning Systems	998	Poor
	Container Security Initiative	1000	Fair
	Homeland Security	1000	Poor
	Container Scanning Technology	4	Good
Web of Science	Container Port Security	10	Excellent
	Container Screening Technology	3	Poor
	Non-Intrusive Inspection Technology	6	Excellent
	Container Inspection System	54	Fair
	Scanning Systems	18,758	Poor
	Container Security Initiative	3	Excellent
	Homeland Security	876	Poor
UO Libraries Catalog	Container Scanning Technology	0	Poor
	Container Port Security	5	Good
	Container Screening	0	Poor

	Technology		
	Non-Intrusive Inspection Technology	2	Poor
	Container Inspection System	1	Excellent
	Scanning Systems	42	Poor
	Container Security Initiative	3	Excellent
	Homeland Security	2267	Poor
CQ Researcher	Container Scanning Technology	3	Excellent
	Container Port Security	14	Fair
	Container Screening Technology	7	Good
	Non-Intrusive Inspection Technology	1	Poor
	Container Inspection System	15	Poor
	Scanning Systems	41	Poor
	Container Security Initiative	18	Fair
	Homeland Security	208	Fair