

Implementing X-ray cargo screening

Dr. William A. Reed, Marketing Strategy & Communications Manager, Varian Medical Systems, Security and Inspection Products Group, Palo Alto, Las Vegas, NV, USA

X-ray inspection systems for cargo containers have now become a standard feature in many ports. This rapid adoption has been accelerated by the needs of port security, but made practical by the systems' unique ability to non-destructively penetrate entire containers and generate images of the contents in just a few seconds. Even at this large scale, the resulting images are comparable to those obtained through traditional baggage scanning at airports and capable of identifying objects smaller than a baseball (see Figures 1 and 2). Consequently, these systems are commonly employed for manifest verification and contraband interdiction in a variety of environments.

In a prior article (see Port Technology 35), I reviewed the component technologies that contribute most to X-ray image quality in cargo screening systems. Those included a stable source of high-energy X-rays (usually a linear accelerator) and a number of design parameters associated with the detection process such as detector modularity, dynamic range, sensitivity, pixel size, etc.

This article extends the prior review by looking at the broader system considerations in selecting and implementing a cargo screening system. Beginning with differences due to inspection objectives, the discussion covers several variations in available X-ray inspection systems, each with certain advantages. From that point, actual system performance is driven by the effectiveness of the 'imaging chain,' which is described in terms of the interaction of its core components, with special attention toward the multi-faceted nature of imaging software.

Inspection objectives

Inspection objectives are important considerations for the design and implementation of a cargo screening system and will impact the type and utilisation of screening equipment and the process of interpreting the resulting images. X-ray cargo inspection is typically performed for three different (but not mutually exclusive) objectives; manifest verification, homeland security, and

contraband interdiction. Screening equipment is often specified or operated differently, depending on the screening objectives.

Manifest verification is often performed for tariff enforcement with the objective to confirm the contents of a container, both in type and quality. Here, operators may choose to examine the container for overall compliance with their requirements, with less focus on small anomalies. Containers with homogeneous contents can be cleared quickly, especially when prior images of similar shipments are available for comparison and verification.

Image inspection for detecting contraband involves a more detailed analysis assuming that the contraband is likely to represent a small percentage of the overall container volume. In addition, perpetrators are expected to intentionally disguise or hide the materials of interest. In these cases, inspectors must examine both the cargo itself and the common vehicle hiding areas such as the frames or tanks. Because some contraband can be disassembled into component parts and distributed among permissible cargo, a combination of operator training and advanced software features provides a robust capability to help identify such violations.

The newest and perhaps most urgent need for screening cargo containers comes from the threat of smuggled special nuclear materials. The rarely expected occurrence of this event is offset by its potential impact should such material be used for terrorist purposes. Fortunately, the densities of special nuclear materials make them clearly visible on X-ray images in contrast to virtually all permissible products. Additionally, the advent of dual-energy screening systems adds a second level of material discrimination, allowing software to clearly identify the unusual nature of this threat.

System type

At the equipment selection stage, authorities consider whether mobile, relocatable, or fixed installations will offer the best implementation for their needs. Fixed installations are



Figure 1. SUV Scan.



Figure 2. Close-up of Figure 1 (Weapon shown hidden in rear door panel).

permanent sites that are built for a specific screening system. Typically these are shielded concrete buildings where containers enter at one end and leave through an opposite exit. This allows their throughput to be limited only by the amount of time it takes to move a container through the installation.

Mobile (truck based) systems offer the advantage of being quickly deployable to different ports or locations but generally operate with a lower total throughput than fixed sites. A screening truck must first extend its detector boom, and then drive past one or more aligned subject containers. However, pre-staging the containers can improve the overall scanning rate.

Finally, the emergence of relocatable scanning systems has provided a third choice. Relocatable systems take advantage of a fixed infrastructure (control room, x-ray bay, etc.) yet, are designed to be readily moved to alternate sites based on user needs. Once installed, a relocatable system operates very much like a fixed site.

The image quality for each type of system can be virtually identical, assuming that the proper design considerations are met for each system. As discussed in the previous article, photon scatter is often a limiting factor, causing the equivalent of fogging in traditional film exposures. Thus, each system type incorporates scatter control, but in somewhat different ways. For mobile systems, the physical location and orientation is often chosen such that the background immediately behind and adjacent to the detector array is free of obstructions. For enclosed sites, the geometry of the beam path and the orientation of the detector array are primary considerations in the design of special collimators that are positioned in the exposure area to significantly reduce stray photons from interfering with the detectors.

Imaging chain

The imaging chain consists of three primary components, the X-ray source, the detectors, and the software that produces images from the resulting signals. The first two components provide the essential information for processing and the software converts this information to a viewable form. Once the system is designed and the physical surroundings are determined, it is the imaging chain that is most responsible for image quality. This begins with the X-ray source, which is almost always a linear accelerator due to the required output power. X-rays originate as a point source and are collimated (filtered) through a thin vertical slot to produce a fan beam suitable for penetrating a tall container. The accelerators used for cargo screening are pulsed types, creating short bursts of x-rays at a rate of a few hundred bursts per second. New systems that advertise interlaced 'dual-energy' capability offer enhanced material discrimination by measuring each vertical slice at one energy output and then repeating the measurement with a different energy. Carefully designed detector arrays are capable of receiving both signals in very quick succession, and maintain good signal to noise ratios until the signals are digitised for further processing.

Software

The nature of cargo inspection requires authorities to assess the contents of a large container in a matter of seconds or, at most, a few minutes. Today's software makes this possible by implementing intuitive user interfaces, expedient pan and zoom features, and automated tools such as edge detection or density colorisation. While the imaging software is responsible for constructing the overall image from the thousands of individual data slices, it also performs many other important tasks. For example, in most systems, the software is utilised in a periodic calibration or alignment process that ensures the best image resolution possible. It may also provide data logging for both calibration data and actual inspection scans along with a database history of previous images. Such records often remain available for training, image comparison, and legal documentation. Finally, software data interfaces provide the ability to integrate other systems such as those holding manifest data and access to remote data centres.

Summary

While today's cargo inspection systems offer a great deal of flexibility in their use, specific inspection objectives should influence the type of system selected. This will allow users to benefit from a variety of newly available features such as improved throughput, higher image quality, increased sensitivity to material density variations, and enhanced software algorithms. Once a system type and inspection site is selected, careful system design including special attention to the 'imaging chain' can greatly contribute to the overall system performance and image quality.

ABOUT THE AUTHOR



Dr. William A. Reed is the Marketing Strategy & Communications Manager for Varian Medical Systems' Security and Inspection Products Group. He has held engineering and management positions for security equipment design firms for over 25 years and holds both US and International patents for security products.

ABOUT THE COMPANY

Varian Medical Systems, Inc., Security & Inspection Products, is the market leader for industrial CT systems, high energy X-ray linear accelerators, and matching detector arrays. With over 35 years of experience in manufacturing industrial products, Varian has produced over 500 linear accelerators for the security and inspection market and maintains sales and support offices worldwide.

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William A. Reed, Ph.D.
Tel: +1 (702) 938 4863
Email: bill.reed@varian.com
Website: www.varian.com/sip