

The X files: Part 2

In the second part of a three-part series, Paul J. Bjorkholm and James Johnson of Varian Medical Systems, Security & Inspection Products, discuss state-of-the-art, high-energy X-ray systems used for cargo security screening.

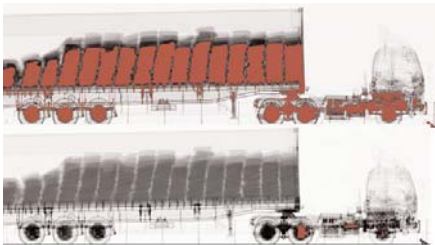


Figure 1

Part 1 of “The X Files” discussed the history and development of high energy X-ray screening. Part 2 of the series covers the state of the art of high-energy X-ray screening, and the final article will discuss possible future developments.

A perfect cargo screening system would detect any contraband 100% of the time and never cause a false alarm. Naturally no system is perfect and typically the false alarm rate increases as the detection rate increases. How a system is calibrated to balance these two elements—detection and false alarm rates—depends on the goals set for the system. If the goal is manifest verification or drug interdiction, then the consequences for less than 100% detection are few and the response to a false alarm, usually devanning, is expensive. In this instance, the risk benefit ratio tends to suggest a lower detection rate is acceptable. If the goal of the system is interdiction of conventional arms, then detection becomes more important and the cost of false alarms may be acceptable. However if the goal of the system is interdiction of weapons of mass destruction, then the risk benefit ratio requires 100% detection.

The characteristics that are important to good X-ray screening and detection are: penetration, contrast sensitivity, and resolution. Penetration defines the ability of the X-rays to pass through the cargo to be detected on the other side of the container. If the X-rays don't pass through (poor penetration), then there is nothing to see. It is like trying to take a picture without enough light; the film will be black. Contrast resolution defines the ability to differentiate portions of the cargo with small differences in density. In photographic terms a picture with poor contrast resolution is “washed out.” With the advent of digital cameras, most people now understand

the idea of resolution. It is critical for distinguishing what is in the image, identifying objects, and preventing false alarms. State-of-the-art, high-energy X-ray inspection systems provide excellent penetration, contrast sensitivity, and resolution.

In general penetration is related to the maximum energy of X-rays used. The minimum useful energy for reasonably loaded containers measuring 8 X 8 X 40 ft is 3.8 MeV. Six MeV is typically required for moderate to heavily loaded containers and 9 MeV will usually penetrate anything that can be loaded into a multi-modal container. Figure 1 (Courtesy of Rapiscan, Inc.) is a real X-ray image taken at 9 MeV but modified to show what areas would not be penetrated (red) if the energy were < 3 MeV.

Contrast resolution is more complex, as it requires the use of two characteristics of the X-rays: dose and X-ray spectrum. First the noise (or graininess) in an X-ray image is related to the number of X-ray photons (or dose level) used to make the image; more dose generally produces a better image. The dose that can be used is limited by government regulations regarding dose to cargo or the environment. But typically these restrictions do not limit the quality of the images.

The high energy X-ray spectrum used for cargo screening contains both low- and high-energy photons (called polychromaticity). This is important to image quality. The high-energy X-ray photons can penetrate the dense parts of the container, but are not that useful in imaging less dense parts where they yield very low contrast detail. The low energy photons, however, contribute good contrast sensitivity in the thin parts of the image. Therefore the combined polychromatic spectrum allows for excellent imaging over the full range of object thicknesses. Figure 2 (Courtesy of L3 Detection Systems)

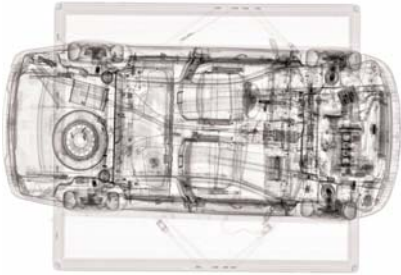


Figure 2

shows an image of a car taken with a 9 MeV polychromatic X-ray spectrum. Note that the dense parts of the car are fully penetrated, and the thin straps holding the car can also be seen. This superior dynamic range and contrast sensitivity at all thicknesses is directly related to the dose and polychromaticity of the beam.

Finally, even with good penetration and contrast sensitivity providing an image that allows you to see all the components in the cargo, good resolution is still needed to be able to fully identify the objects. Figure 3 (Courtesy of Rapiscan, Inc.) shows an X-ray image of a container both at full size and with two zoom boxes. At the full size one can recognize that the container is uniformly packed with something of moderate to low density, probably mechanical parts. The red zoom box shows that the cargo consists of bicycles. But the yellow zoom box offers even more detail. It shows the wheel spokes and even the details of the derailleur. Typically a detector size of 5 mm is sufficient to obtain excellent images such as these in a multi-modal container.

Modern X-ray scanners are capable of penetrating all the most heavily packed containers, with contrast resolution sufficient to show all of the contents, and with sufficient spatial resolution to identify the contents. How, then, do they fit into a port?

There have been basically three different configurations of X-ray scanners designed and built to date:

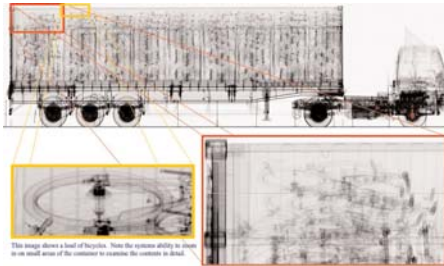


Figure 3

mobile, relocatable, and fixed. The mobile scanners are self-contained imaging systems built onto truck frames (as shown in Figure 4, courtesy of Smiths Heimann). These typically use a 3.8 MeV spectrum. The system has a boom that can extend over the object to be inspected and they image the object as the truck drives by. The boom can be stowed for travel from one inspection site to another over normal highways, usually at highway speeds. They are useful where there are many ports of entry that need inspection but few available systems. This type of mobile system can typically be set up at a new site in a few minutes. They are also effective when smugglers are using multiple entry points and change their point of entry whenever a single point has an inspection system.

The relocatable systems typically incorporate the same components as the fully mobile system, except they replace the truck chassis with rails on the ground and a drive mechanism. The relocatable system has the benefit of higher penetration using a 6 MeV X-ray spectrum. They can be moved



Figure 4

from site to site but require dismantling. It normally takes days or weeks to relocate one. One variant system is designed to resemble a straddle carrier typically seen in a port. It can move within the port but still needs special handling to move to another port.

The fixed-site systems require extensive permanent infrastructure and are never intended to be moved to another site. This is because they use the highest energy X-ray spectra and need extensive shielding to be safely used.

Fixed-site systems find application around the world. Japan has an ongoing project building fixed site systems at many of their ports. The UK has dramatically reduced the smuggling of untaxed cigarettes using mobile systems. China has collected duties on undeclared goods that exceed the costs of the installations by many times. These are just a few of the success stories.

In summary, modern high energy X-ray systems have the penetration, contrast sensitivity, and resolution to complete inspect fully loaded multi-modal containers for all applications such as manifest verification, drug and weapon interdiction, and detection of weapons of mass destruction. They have been successfully integrated into airport and sea port operations in many countries around the globe.

Part III will focus on how new developments in integrating the inspection process into normal cargo flow and how automatic detection routines will dramatically change this already successful technique.

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