The X Files: Part 1

In the first of a three-part series, Paul J. Bjorkholm and James Johnson of Varian Medical Systems Security & Inspection Products offer a brief history of high-energy cargo screening

In November 1895, William Conrad Roentgen discovered x-rays and in less than two months demonstrated that they could be used to reveal the internal structure of objects. Soon thereafter, x-rays were used for a variety of applications including medical imaging and treatment, entertainment and for the verification of container contents.

There have been two similar reasons for x-ray inspection of cargo. First, x-ray inspection can be used to determine the validity of customs declarations and detect undeclared, under-declared, and misrepresented goods in cargo for enforcement of revenue collection. In this case, the local customs agency is usually the driving force. The second major use is for contraband interdiction. In this case, one is looking for undeclared goods that usually are drugs or weapons. Customs and/or security agencies are responsible for these applications.

Early applications

These two themes have been recurring throughout the history of cargo inspection. The first use of x-rays in cargo inspection known to the authors was to inspect bales of cotton to detect stones added to increase the weight and therefore the value of the bales. This is a typical manifest verification operation. However, these early applications were rare and there was little serious discussion of cargo screening until the early 1980s.

In 1981, a British patent was issued to Akery and Bourne, describing a cargo inspection system based on fluoroscopic imaging. The overall system consisted of a tunnel for containment of the x-rays, an x-ray source, and a fluoroscopic screen to image a container. The screen was viewed by TV cameras looking at the reflection in a mirror. This technology had been successfully used to inspect running airplane engines and was implemented in Qatar in two systems in early 1986. The systems faced major limitations. X-rays at high energy are not simply absorbed as they are at lower medical energies. They scatter as well. The scattered x-rays form a general haze that obscures the absorbed x-rays used to produce the image, i.e. they create 'noise' in the information and interfere with the contrast resolution. Since for a loaded container the vast majority of x-rays exiting the container have been scattered, it was difficult to get excellent images through any significant amount of material. Although the Qatar systems demonstrated that it was possible to x-ray trucks, they had limited penetration and were eventually removed

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Manifest destiny

The next major cargo inspection effort was for manifest verification. The United States and the USSR signed a treaty limiting the number of certain types of missiles. The USSR manufactured two types of missiles that were nearly identical except for their diameter. The Strategic Arms Reduction Treaty (START) limited the manufacture of the larger diameter missiles but not the smaller. In order to verify compliance, a high-energy x-ray imaging system was built and installed in 1989 at the exit of the missile manufacturing plant in Vodkinsk, USSR. Every container leaving the factory was x-rayed and the diameter of the missile was determined. Unfortunately, this system design was limited by treaty both in spatial resolution and in the region to be imaged (only the outer edges of the missile). It therefore was not useful as a prototype for modern imaging systems. This system performed its desired function through the early 1990s.

Inspection of cargo using high energy x-rays has become a common and important tool for the security of international trade and it will increase in criticality as terrorism continues to focus on the world economy. This is the first article in a three-part series which will examine the history, the current and future status of high-energy x-ray cargo screening. This article will look at the major technical developments and the motivation that led to today's modern x-ray cargo scanning equipment.

Air cargo scanning began with a system built at Roissy Charles de Gaulle (CDG) airport in France. It was intended to detect explosives and prevent them from being introduced onto aircraft but quickly was seen to have a use in drug interdiction as well. In this system, the x-rays are emitted in a narrow fan and the detectors are designed to intercept only this fan. The scatter from the cargo is largely rejected and therefore this type of system does not suffer from loss of contrast because of the scatter. There were 2,048 detectors in the fan and this is typical for modern resolution. However, the detectors were gas-filled and therefore not very efficient. The x-ray source was a constant-intensity, 2.5 MeV accelerator. The combination of low x-ray energy and the inefficient detectors meant that the system was not able to penetrate thick material. Therefore, while it was a major step in the development of modern cargo imaging, it was far from being capable of optimal performance.

In the late 1980s and the early 1990s, the **Eurotunnel** project was coming to fruition. The tunnel clearly represented a high-value asset that could be extremely vulnerable to a terrorist threat. Therefore, it was decided to use high-energy x-ray inspection to examine trucks prior to entry into the tunnel. This became operational in December, 1993 and was the first site dedicated to security (see *Cargo Security International*, December, page 28).

In 1991, China decided to place two inspection systems on the border between Hong Kong and the mainland. They chose to place orders for these systems with two different companies. The designs were very similar. Both utilize a Linatron for the x-ray source and a solid state linear array for detection. This design has become the gold standard in the industry for cargo inspection. They are fixed, 9 MeV systems and consist of a tunnel for radiation protection, a fan beam imaging system, and a conveyance to move the trucks through the fan beam. The only major difference between the sites was the conveyance. One site used a 'drag through' system where the front axle of the truck was captured and the truck was pulled through the beam. The other site used a platen system where the trucks were stationary on a platen that was then moved through the beam. There were multiple platens used within a closed loop. One platen would be available to load the next truck, one platen would be in use scanning a truck, and a third platen would be being returned to the start. In this way a truck would always be ready for scanning whenever the scan tunnel became available. Both of the conveyance systems are used in modern inspection systems.

China had two reasons for wanting these inspection systems: manifest verification; and contraband interdiction. But after early use it became clear these systems were extremely valuable for the collection of duties as significant underreporting, misreporting, and failures to report were found in the manifest data. Since the load and the rig were confiscated until the duties and significant fines were paid, these inspection systems paid for themselves very quickly.

As of early 1997, over 43,000 trucks had been scanned, resulting in over 450 seizures valued at over $10,000,000. Even though these systems were complex, they achieved availability rates of about 96% and really proved the economic utility of high energy x-ray screening. These were the first implementations of high energy x-ray screening. The technology has developed further and several different types of imaging modalities have been developed. These include fully mobile systems, relocatable systems, and site-specific systems. These will be described in detail in the next article in this series.

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