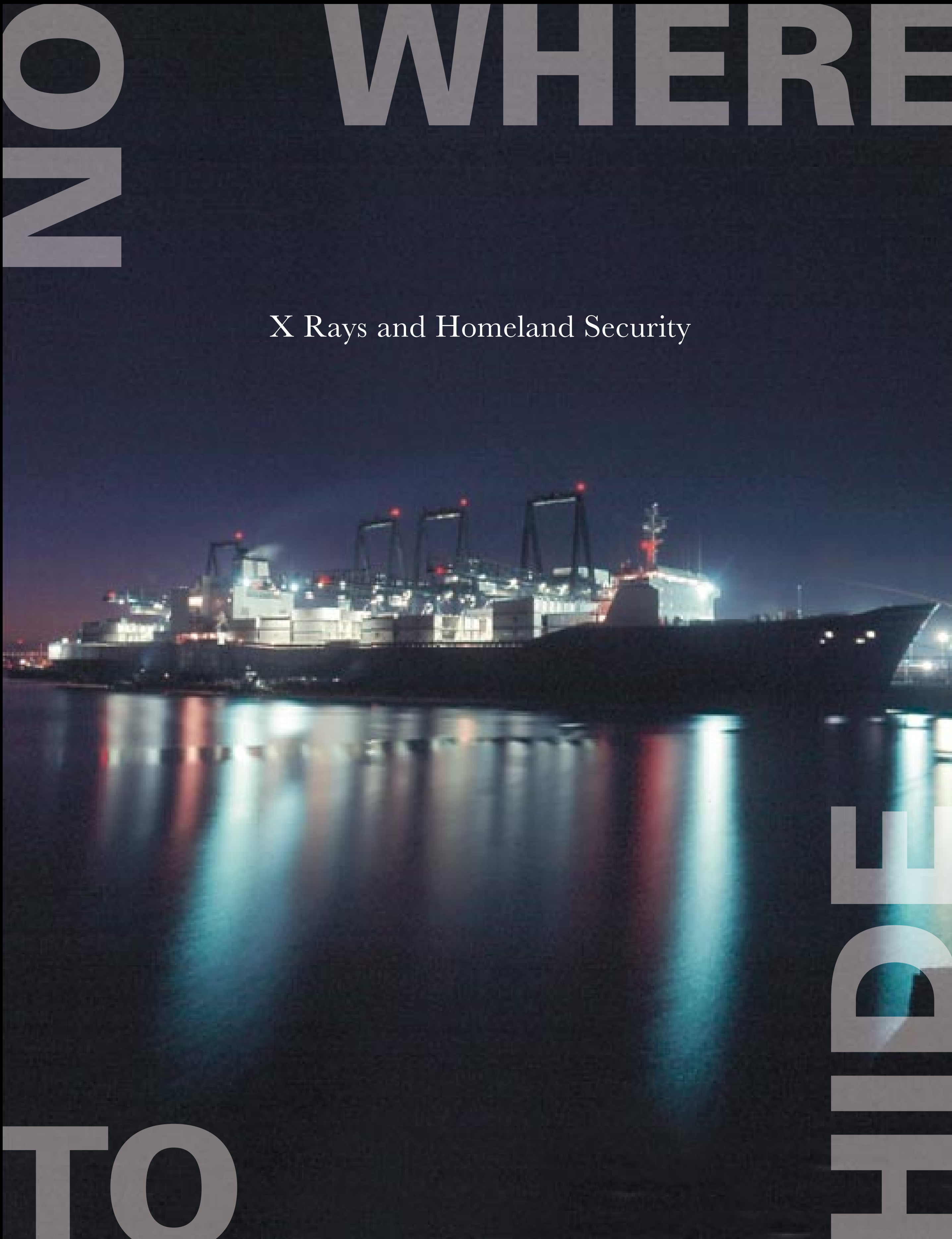
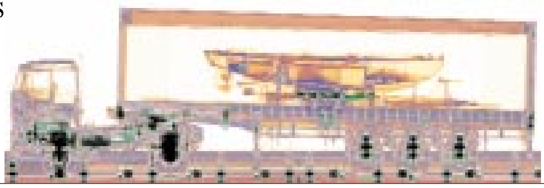
NO WHERE TO HIDE

X Rays and Homeland Security



PHOTOGRAPH BY TOM TRACY

Since the tragic events of September 11, 2001, anyone who has been to an airport is aware that security efforts in the U.S. have been greatly intensified. However, according to many experts, terrorist threats to homeland security are equally likely to come by way of the sea. The U.S. Customs Service reports that some 6 million cargo containers arrive through U.S. seaports every year. Ninety percent of the trade goods brought into the U.S. each year – some 2 billion metric tons worth – enter through the country's 361 seaports. Presently, less than 2 percent of these containers are ever opened and inspected by Customs Service officials.



HEIMANN SYSTEMS X-RAY IMAGE

These trailer-sized, steel-walled cargo containers are typically sealed in foreign ports and not opened again until delivered by trucks to points all across the United States. It's not hard to imagine these containers being used for smuggling contraband – even a weapon of mass destruction. To physically open each container and extract and inspect the contents by hand would be too time-consuming and unrealistic. Clearly, what's needed is some means of searching the containers quickly and thoroughly without disrupting the flow of goods. An X-ray imaging system like Varian Medical Systems' Linatron® linear accelerator is an excellent candidate for the job. It can generate steel-piercing X rays that "see" through container walls and allow contraband nowhere to hide.

"The challenge is to provide customs officials with a solution that lets them look inside these containers quickly and efficiently. You need to generate enough energy to penetrate up to 440 mm (17 inches) of solid steel and produce high-quality images that show even small objects in fine detail," says Lester Boeh, vice president for Varian's Security and Inspection Group. "The Linatron meets those specifications. It has already been incorporated into cargo screening systems all over the world, but there are comparatively few in the U.S. The impact of September 11 could change all that for the U.S. and many nations engaged in international trade."

Varian's Linatron, which generates high-energy X-ray beams, has already been incorporated into cargo inspection systems in countries like Australia, Belgium, China, France, Germany, Ghana, Indonesia, Israel, Japan, Korea, Mexico, Saudi Arabia, Taiwan, Turkey, and the U.K. Japan operates multiple units at its six busiest ports; the U.K. at more than a dozen. Eurotunnel uses the technology to scan freight cars that pass between France and the U.K.

IMAGING THE CONTENTS OF A CARGO CONTAINER

The Linatron has been incorporated into fixed-site and mobile cargo scanning systems built by companies like ARACOR, Heimann Systems, L3, and RapiScan. These systems work like a giant airport baggage screening system. They use the high-energy X rays generated by the Linatron to send a beam of photons through a cargo container. The photons are absorbed and scattered in varying amounts by the materials in their path, depending on their densities. On the far side of the cargo container, a detector array collects and records the photons that make it through unabsorbed, generating an electronic signal that is translated into an image. The image, which shows the container's contents, can be viewed on a monitor. A Linatron-based cargo screening system can scan a full container in less than three minutes. Fixed-site systems are built into garage-like facilities, and trucks carrying cargo containers are moved through these facilities the way cars are moved through a carwash. The truck passes between the Linatron X-ray beam and the photon detector. Electronic images are captured and transmitted to a computer monitor at an operator's station.

For customers who need to move a cargo inspection system from site to site, mobile systems can be mounted on trucks.

Similarly, it is also necessary to scan air cargo. Each year, more than 30,000 tons of air freight are transported in cargo and commercial aircraft in the U.S. and virtually none of it is ever inspected. The Linatron M is an ideal solution to this problem and is already working in airports outside the U.S.

PENETRATION, CONTRAST, RESOLUTION

Three basic physics criteria are used to measure the effectiveness of any imaging system: penetration, contrast, and resolution. All three are related to the level of energy – and hence the number of photons – sent through whatever is being scanned. A Linatron-based screening system generates higher energy X rays than competing gamma-based systems.

Penetration is probably foremost of the three criteria for cargo screening. The inspection obviously fails if the imaging photons lack the energy to punch through a container's thick steel walls. The key to penetration is photon energy – the more energetic, the deeper the photons penetrate into a material. Steel is the bar by which the penetration capabilities of an imaging technique are measured. Varian's Linatron can generate X rays at energies of 9 million electron volts (MeV). That's enough power to pass through 440 millimeters (17 inches) of solid steel and still provide enough energy to produce a high-contrast image – a critical issue for scanning big trucks and containers.

Says Boeh, "Without full penetration of a cargo container and its contents, too much can be missed."

Contrast sensitivity, the second important criterion for cargo screening, is extremely important for distinguishing between items inside a container. Imaging experts say that the higher the contrast sensitivity, the greater the chances for detecting contraband. Linatron-based systems have proven to be ten times more contrast sensitive than other systems.

"The objective of nonintrusive screening is to image the contents of a cargo container with enough clarity to make a decision about the contents," says Jim Johnson, general manager for Varian Industrial Products.

The third criterion, resolution, is a measurement of the ability to see spatial details in an image. If you are looking for hundreds of pounds of drugs, just knowing there's something large and unexpected inside the container is enough. However, if you're looking for nuclear weapons components, which can be surprisingly small, you want the best resolution you can get. While resolution depends to a large degree on the quality of the detector that is collecting the imaging photons, the more photons that penetrate the cargo's interior, the better your chances are of obtaining high resolution. Again, the advantage falls squarely to linac-generated X rays.

In addition to the three main criteria, several other factors involved in imaging give linac-generated high-energy X rays a distinct technological advantage for use in cargo screening. Varian's Linatrons can also provide dual views by sending in two perpendicular beams to help overcome the problem of a lighter material being shadowed behind a denser material. And thanks to the high energy and photon output of the Linatron, images can be obtained very quickly – an important consideration for a busy port.

"Before September 11, the U.S. Customs Service was mostly interested in screening cargo containers to find illegal drugs. Now their primary concern is finding weapons of mass destruction," Boeh explains. "For this task, there does not seem to be any competitive technology on the horizon better than high-energy X rays."

Numerous customs services, both in Europe and Asia, have installed cargo-screening systems that use Varian Linatrons to generate X rays. They are successfully finding illegal drugs, weapons, and other contraband. According to Boeh, many of these governments have found that the ability to verify manifests, find deliberate falsifications, and levy taxes on the undeclared contents generates enough revenue to pay for the inspection systems.

NON-DESTRUCTIVE TESTING

Varian's Linatron technology is also useful in other forms of non-destructive testing. Highway engineers use a portable version called the Linatron MP to test the structural integrity of large steel and concrete structures like bridges and overpasses. A major manufacturer of jet engines is using the Linatron M with a Varian flat-panel image detector to inspect turbine blades.

"They bought the Linatron to replace a kilovoltage (kV) imaging system," says Boeh. "They needed a system that could penetrate the larger cross-section of the new blades. Using the previous kV system was taking them 30 minutes to scan a turbine blade for structural flaws. With the Linatron, they have reduced this to about 30 seconds. In addition, we were able to design a compact shielding package so that the system fit into their existing facility."

Varian's Linatron has also been used to inspect large castings, rocket motors, and pressure vessels – large metal containers that carry pressurized contents. The technology enables engineers to find tiny cracks and flaws. "These are not things that you want to see fail," says Johnson.

STERILIZATION

The Linatron technology has additional applications in sterilization. It is being used in medical settings to irradiate and sterilize medical products. A system in Hawaii is used to treat papayas, which are subject to a federal fruit-fly quarantine and cannot be distributed on the U.S. mainland without treatment. Unlike other solutions that Hawaiian growers had tried, including the use of chemicals and heat, the Linatron solution does not adversely impact the appearance or nutritional value of the fruit, or damage the environment, according to the grower, Hawaii Pride LLC. Food irradiation can be used to instantly eliminate the threat of harmful food-borne pathogens such as E. coli, listeria, and salmonella in meat and poultry, as well as fruits and vegetables, without changing their texture or taste.

"The Linatron enables us to harness and focus energy, and put it to work in a number of different ways," says Boeh. "High energy X rays are very useful for inspection and for sterilization. There are a lot of as-yet-untapped potential applications for this technology." ■

New Looks for Airport Security

INVISION TECHNOLOGIES X-RAY IMAGE

The need for improved security extends beyond cargo screening to a whole new set of security needs at airports. For years, carry-on bags have been screened, but checked luggage has been loaded onto airplanes without screening.
As of the end of 2002, however, the U.S. Federalization Security Act is requiring that all checked bags be screened by devices that can detect explosives.

Screening luggage for explosives poses unique challenges. Current screening systems for carry-on bags are not sensitive enough to do the job. These systems use stationary low energy X-ray tubes and line-by-line scanning to show two-dimensional shapes. They detect a knife within a pile of clothes, for example.

Detecting explosives, however, is harder; it requires the ability to distinguish materials of different densities as well as their shapes. And since an immense number of bags pass through the nation's airports in a single day, they must work quickly.

To tackle the job, the security industry has turned to CT scanning, which uses higher energy metal/ceramic X-ray tubes that spin around the luggage at two revolutions per second. They can detect and differentiate between the densities of scanned materials. They operate within explosive detection systems (EDS) that generate three-dimensional color-coded images highlighting suspicious items. EDS tubes represent some of the latest advances in X-ray tube technology.

X rays are a form of high energy light with very short wavelengths that make it possible for them to pass through solid objects. They are created by accelerating electrons to a very high speed and driving them into a metal target. The resulting subatomic collisions release energy in the form of X rays (1%) and heat (99%).

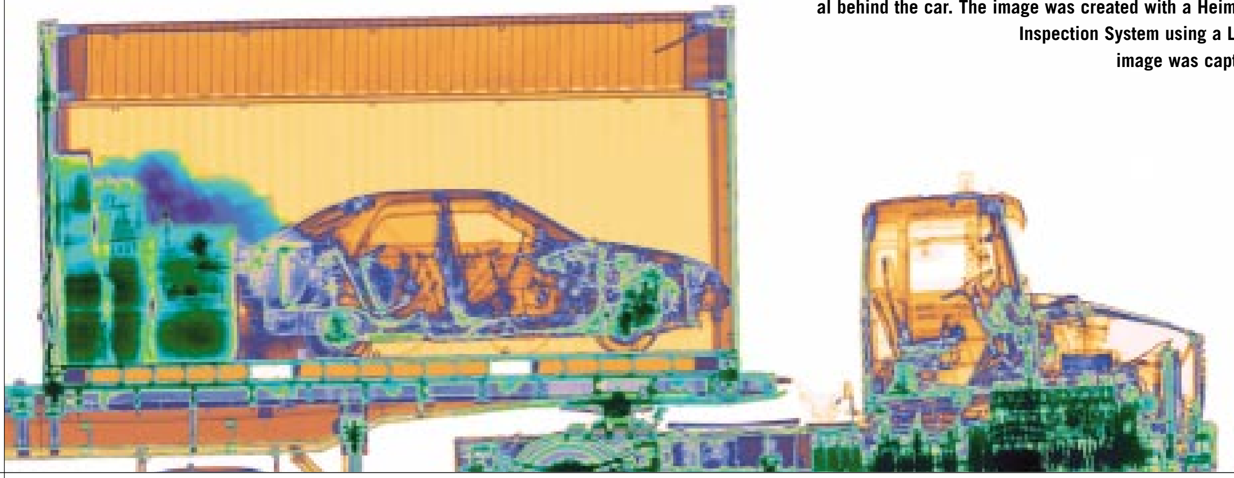
In an X-ray tube, electrical energy is applied to a filament, heating it up to white-hot temperatures so that it 'boils off' electrons. To accelerate these electrons, the tube is equipped with a cathode (a negative electrode) and an anode (a positive electrode). The application of a high voltage across the positive and negative electrodes creates a differential that causes the electrons to speed towards the anode at a very high velocity. This assembly is housed within a vacuum, which eliminates resistance so that the electrons can attain higher speeds by accelerating more rapidly.

The cathode incorporates a focusing cup to concentrate the electron stream and its kinetic energy onto a small focal spot, or target, within the anode. This target is usually made of tungsten or some other metal that can withstand very high temperatures.

The collision of electrons with the tungsten unleashes X rays that are channeled out of the tube through a small window or aperture. The velocity achieved by the electrons before they strike the anode is directly proportional to the amount and penetration power of the resulting X rays.

EDS series tubes operate at very high electrical voltages — between two and four times the voltage used in systems for screening carry-on luggage. This results in the higher contrast resolution needed for differentiating between materials and detecting explosives.

Varian's new line of EDS X-ray tubes are engineered to meet the specifications for CT based explosive detection systems that are now being installed at more than 400 U.S. airports. ■



An X-ray image reveals the presence of a stolen car hidden inside a truck behind a pile of other items. The stolen car contains some stolen television sets in the back seat and trunk. There are also bottles of alcohol hidden in a stack of material behind the car. The image was created with a Heimann Cargo Vision X-ray Inspection System using a Linatron®. This customs image was captured at an undisclosed port in Africa.