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Airport X-ray Screening Technology Becomes a Viable Explosives Detector

Science has breathed life into what was once thought an obsolete technology. Dual-energy beams, backscatter techniques, color displays and other scientific advances have made X-ray the near-term explosives finder.

by
Frank G. McGuire
Editor and Publisher
Security Intelligence Report

Security screening checkpoints are usually the last barrier before a terrorist bomb gets aboard a civilian airliner, and the screening system most likely to be found at the boarding gate is an X-ray unit. Although it is not an impenetrable barrier, X-ray is a better one than many believe. X-ray technology is the most effective defense for detection of terrorist bombs.

Many believe that because X-ray has been around for almost a century (discovered in 1895), it therefore must be obsolete. However, this is like saying the airplane is obsolete because it has been around for nearly a century.

It will be a long time before X-ray systems are superseded by newer technology as a primary means of finding weapons and explosives. Although there are more scientifically sophisticated techniques than X-ray that are presently in the planning stages, they will not be operational for some years. X-ray technology for screening airline baggage is economical compared to many other methods, and it is cost-effective in terms of how much security is obtained for the money.

Despite the merits of X-ray systems, however, scientists warn they are not foolproof, because airport security X-ray systems were originally designed to find guns, not explosives.

Taking a Look Back

In the early days of airport security in 1972, there were metal detectors and a few X-ray machines. These sufficed to handle the immediate threats at that time, which were handguns and small weapons. The X-ray machine was the single-beam transmission type, which sent radiation through the suitcase or container, then a human operator evaluated the silhouetted image on a screen.

Later, the threat escalated to automatic weapons such as those used in terrorist attacks at Rome and Vienna in December 1985, but these weapons bypassed the X-ray barrier because of their size and were limited to airport terminal ticketing area attacks which killed dozens of people. Another instance occurred in Karachi where an attack took place when terrorists in a van illegally entered the airport ramp through a service gate and attacked a widebody jet. Bombs had already come onstage, however, and they were becoming increasingly sophisticated.

After the bombing of Pan Am Flight 103 over Lockerbie, Scotland, in December 1988, an outcry for better explosives detection caused the U.S. government to press thermal neutron analysis (TNA) technology into service, although many scientists said it was not yet mature. With the highly controversial TNA program now slowed, the U.S. government has been seeking ways to provide better security than the 1970s-era equipment makes possible, without causing massive dislocation of airport operations or undue impact on airline finances.

The result is a generation of X-ray machines more capable than ever of finding explosives.

Three firms in this particular field include:

- EG&G Astrophysics Inc. (EG&G), Long Beach, Calif., U.S.

- American Science and Engineering Inc. (AS&E), Cambridge, Mass., U.S.

- Heimann Systems Co., a division of Germany's Siemens Components Inc., Iselin N.J., U.S.

Systems marketed by these three companies passed the U.S. Federal Aviation Administration's (FAA) tests at the FAA Technical Center in Atlantic City, N.J., in November 1990, and they use different methods to do the explosives screening job. There are other companies in various countries working in this field, but these three are representative of the technology which is typically entering airline and airport service.

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The discovery in the decade of the 1980s that backscatter detection techniques and dual beams of differing energy levels could be effective in finding certain classes of material under some circumstances led to the improved X-ray machines that are available. Development of these machines is proceeding at several companies into even more sophisticated realms of detection and analysis.

This article discusses the three units without comparing them, because it is not possible to go through the marketing brochures, make point-by-point comparisons and draw conclusions. Technological differences make that an unworkable approach, not to mention other variables in the total system. The FAA has said that it does not yet have a special protocol for testing X-ray units, and depends instead on a "step-wedge" (a staircase-shaped piece of metal to test radiation penetration through various thicknesses) adopted by the American Society for Testing Materials (ASTM) to measure X-ray performance.

How Does the Modern X-ray Detector Work?

EG&G and Heimann use dual-energy systems with color video displays. EG&G uses the marketing name "E-Scan" (explosives scanning) and Heimann has its Hi-MAT system, to scan high-density materials. These machines are generally less expensive than the backscatter type because they have very few moving parts. Prices of various technologies can range, like any other high-tech system with many models and options, from $25,000 to more than $100,000 per unit. The initial cost of dual-beam technology is lower, as are its ongoing maintenance costs, and it should theoretically have higher mean-time-between-failures (MTBF) than a machine with many moving parts. The user, of course, must balance the MTBF against overall performance and make a choice.

American Science and Engineering Inc., has patented a technique called backscatter detection, using a low-energy narrow-width X-ray beam to scan a target, which it calls the "Flying Spot." The backscatter technology was developed in the mid-1980s and went through the normal sequence of prototypes, early production models that experienced problems, then refinements based on customer feedback and now is apparently a developed technology. The FAA said it trains its enforcement personnel on the backscatter equipment, along with other types of detection.

Materials vary in their atomic density, and this has a great deal to do with bomb detection. Materials with a low atomic density are called low-Z and those with a high atomic density are called high-Z. Atomic density should not be confused with chemical bonds. X-rays penetrating a material can: (1) pass through it without being affected; (2) be absorbed by an atom of high-Z material; or (3) it can be deflected (or "scattered") in another direction. Possibility (2) is called the photo-electric effect and possibility (3) is called the Compton effect.

Typical high-Z materials are inorganic metals, glass, bone, ceramics and others. Typical low-Z materials are organic plastics, wood paper, most drugs, oil and others. Explosives and narcotics are mostly organic low-Z materials, but wiring, timers and other parts of a bomb are usually inorganic high-Z materials.

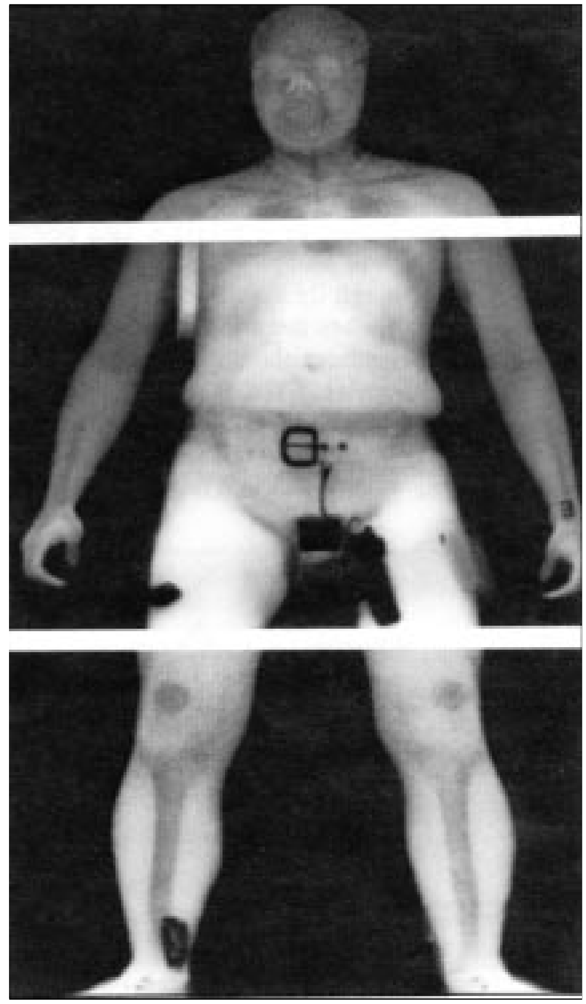
X-ray equipment works best at detecting high-Z materials, so special operating techniques must be applied to "fool" it into finding low-Z materials. Therefore, the critical task in X-ray security screening is to find the low-Z materials and to display that information so it may be interpreted correctly. Because of their high-Z signature and characteristic shapes, firearms and knives are detected with relative ease by most X-ray units.

There is a body of thought which holds that too much emphasis is being placed on finding explosives. What security services should look for, say some, is a device, in other words, all the wires and pieces that constitute a bomb, such as timer, detonator, batteries and so on. "A person could fly all over the world with four pounds of plastic explosives in his suitcase, but it wouldn't matter until he wired it with a detonator, timer and all that," said a Heimann marketing specialist. It is the wires and other parts of a device that are mostly easily seen by dual-beam X-ray systems, and this approach favors those technologies.

Unfortunately, a great deal of what is in a suitcase is the organic materials that are detected by the Low-Z-seeking aspects of an X-ray unit. A pair of plastic ski boots, or any similar bulk of plastic, will perhaps trigger an alarm. This becomes even more complicated when suitcases jammed with wool sweaters, plastic personal accessories, souvenirs, and other material overlap many times and totally confuse the image. Thus, some prefer to seek the wiring, detonators or batteries of a device, even though these may give the appearance of pocket calculators, cassette recorders or other innocent-looking items.

Finding low-Z materials and displaying the information can be done in several ways, and the airport/airline security decision maker's task is to decide which technology is best for the application. EG&G and Heimann use two X-ray beams of different energy levels to scan the target material.

EG&G described the functioning of its dual-beam machine thus: "Because the absorption and scatter cross sections behave differently as a function of energy, one can infer, using exact mathematical formulae, the relative amount of low-Z and high-Z material in the object being measured." The mathematical formulae are applied by the machine, which displays pre-assigned colors to various classes of materials.



Backscatter X-ray image of a dressed subject using the AS&E Bodysearch™ personnel inspection unit. The upper of the three image frames shows no threats. The middle frame indicates the presence of a plastic explosive under the right armpit, a Smith & Wesson 9mm caliber automatic pistol in the crotch area, a bundle of keys on the right thigh and a wallet on the left thigh. The lower frame reveals a folded Swiss army knife on the right ankle.

AS&E seeks low-Z materials by using a single "Flying Spot" pencil-beam X-ray to scan the object using "two completely independent sets of detectors and two video display screens to present the operator separately with high-resolution images of metal objects … and organic objects. AS&E installs 'backscatter' detectors to detect photons in the X-ray beam that are scattered … by organic materials in the object being inspected. These photons are not detected in any other system. Information from these detectors is then used to create an image on the second video screen, showing all organic material in bright white. The operator can then compare the two screens and determine if there is any unexplained or anomalous organic material or metal."

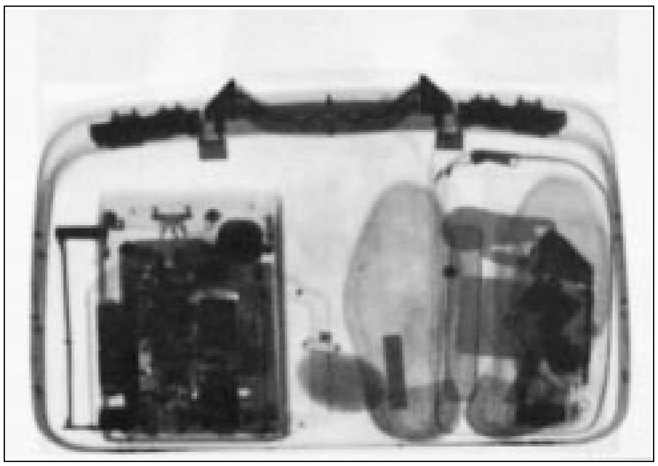
Consequently, AS&E displays two images: a straight X-ray transmission image of the object on one screen which shows the familiar silhouette display, as well as the fuzzier (but more revealing) backscatter information on the second screen. It is this double-screening of the scanned target, says the company, which accounts for the higher cost of the AS&E backscatter equipment, which the company claims pays off in better detection.

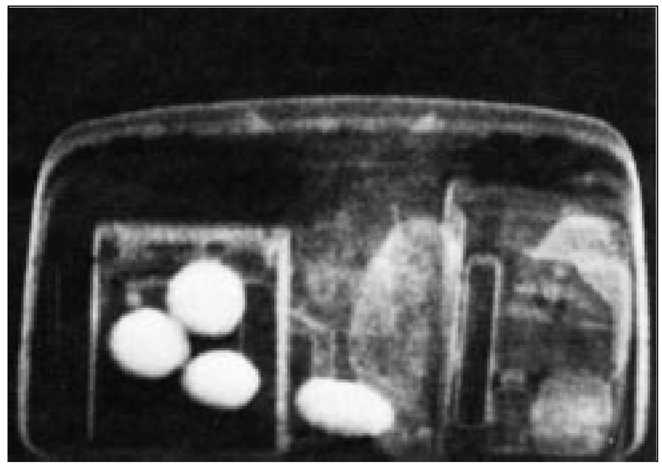
[AS&E backscatter model designations end with either a Z or ZZ. The backscatter detectors in a single-Z system are placed in such a way as to measure data primarily from the nearest side of a bag. AS&E points out that a bag must be run through its system twice (after turning the bag around) *only* when there is confused image to be resolved, while competitors claim *every* bag must be run through the system twice. The AS&E ZZ system has detectors on both sides, so there is no need for running bags through the system twice. The initial cost of the ZZ unit is appreciably more than the Z model.]

The following is from an AS&E marketing paper: "In simple cases, where the X-ray beam passes only through thin metal, and through relatively thick (but not too thick), organic material, 'dual energy' systems do accurately identify materials. However, 'dual energy' systems cannot provide any information concerning the composition of the material if it is too thick. A metal plate and a thick layer of drugs will look the same to a 'dual energy' system."

One infers from this that the aluminum cookie tray would make the suitcase appear to be full of narcotics or explosives.

The EG&G system has no moving parts whatever except the conveyor belt. In contrast, the AS&E "Flying Spot"





The suitcase on the left contains four balls of C4 plastic explosive. A normal X-ray inspection image of the suitcase barely reveals the shape of only one piece of the explosive; the other three are shielded inside the case of a radio and are not visible. The backscatter X-ray image at the right clearly reveals the four balls of explosive.

EG&G and Heimann systems use multi-colored screens, which they say is easier for the operator to interpret. A major tug-of-war is being waged between marketers of the diverse technologies over whether a security operator can more efficiently interpret the colors on one screen or interpret a comparison glance at two black-and-white screens.

As with any other kind of technology, there are weaknesses in every system. The following is from an EG&G marketing paper: "E-scan techniques will fail when the object is radiographically very thick; backscatter techniques will fail when the low-Z material is shielded by high-Z materials, or when the low-Z contraband material is shielded by low-Z innocuous material. Specific examples are: low-Z material behind a thin sheet of metal."

One may infer from this that a terrorist could put an aluminum cookie tray in a suitcase and effectively shield a bomb without adding much weight.

system, does have moving parts in addition to the conveyor. There is no doubt that the number of moving parts is statistically significant in a maintenance and reliability sense, but as noted earlier, a balance must be struck between the MTBF level and performance.

One major sales point often made by X-ray firms is to emphasize the amount of solid steel their unit's beam can penetrate. One may wonder how many steel plates are found in a typical airline passenger's suitcase. Even if several metal objects in a suitcase should overlap to create a greater-than-average metal thickness, it seems quite unlikely that they would total 17 mm (about .66 inch) thickness of solid steel, which is the penetration rating of the E-scan unit. If so, detection of that amount of steel alone would warrant second-level screening. Cargo containers are another matter because penetration is more critical.

Color displays are another major marketing point. The reality seems to be that they are of limited use in finding explosives. The author interviewed a member of the International Association of Bomb Technicians and Investigators (IABTI) because this group does not sell, buy or own the machines and therefore is an objective pool of expertise on which unit does the job best. The strong consensus was that the color displays are of dubious help. Typical was this comment from a U.S. Federal Bureau of Investigation (FBI) expert: "The enhancement that companies push is that the color will be able to distinguish certain types of explosives, etc. Usually, we question whether the organic content of the explosive would really show up. When we interview operators, they say the color picture is not clear by virtue of its being color, which inherently has less sharpness and clarity than black-and-white displays.

"A lot of the operators of X-ray machines turn off the color. They just hit the switch and turn it off. So that airlines and others are paying thousands more for the color, yet the operator who is making six dollars an hour is turning it off because he does not feel it is any clearer at all. There's reason to think he may be right. My gut feeling on it was always 'they were never asked.' Airlines seem to feel there's no reason to ask people who are doing it for eight hours a day."

The author of this article was shown four X-ray images of a color display, one of which included a scan of an object with a hidden explosive. He finally gave up and had to ask where the explosive was because he could not differentiate it in the maze of lines, shadows, colors and image densities. There was unlimited time for this demonstration, but a security screener has only seconds. It demonstrates the importance of training.

An IABTI veteran said, however, "I think you ran into exactly the way it is in the real world. The companies pump up this stuff, but if they think the machine is going to throw out an answer to an uneducated, untrained individual, it doesn't happen. X-ray units came into the airline industry to find guns, and they do a limited job finding explosives. They are not geared to find an explosive device."

Explosives detection systems have many facets. Not all the good facets are in the same package. There is the explosives detection aspect itself from a technical proficiency standpoint, but there is also system reliability, initial cost, operating and service costs and availability, radiation protection, physical dimensions and all the considerations that would go into buying any other piece of equipment. If the equipment under consideration was a crash/fire/rescue truck, it could have the highest capacity water pump on the market, but if the engine couldn't propel it out of the station, there is no point in buying it.

There is abundant evidence that the weakest link in the entire security chain is the human operator … .

Each system has its strong proponents, and the choice of a system comes down to overall performance, price, serviceability and other factors subsidiary to the explosives detection argument. Considering the litigious times we are in, however, it is certain that buyers of a machine that was "good enough" could be swamped by legal actions for not having bought "better" if a bombing incident occurs. Presumably the manufacturers, the FAA and the airlines know this, and they are in a situation where they have no choice but to claim that all X-rays are similar, if not superior, to each other. The meager record of terrorist bombings of airliners in the United States makes it difficult to argue that the threat is severe on a system-wide basis, although that does not provide much comfort to the families of terrorist victims. Nevertheless, budgeting realities and absence of precedent do not provide insulation from liability at least under U.S. law.

X-ray Detection Continues to Improve

The FAA is trying to upgrade the security level from "security screening systems" to "explosives detection systems" (EDS). One major difference is in the automation of the machine, with EDS automatically sounding an alarm when a suspicious image is found. There is abundant evidence that the weakest link in the entire security chain is the human operator who, having screening hundreds of pieces of baggage and packages, can become bored, inattentive or distracted after hours on the job.

AS&E is working on an automatic EDS requiring no video or human monitor. It will use the backscatter system and artificial intelligence for image interpretation. If the alarm sounds, the bag will be automatically removed from the conveyor and sent to a second-level screening machine such as a computer-assisted tomography (CAT) scan or other image analysis system. Toshiba has already acquired a license for the backscatter display to deal with competitive pressure from other firms who use color displays.

EG&G is developing a partially automated version of the E-Scan using multiple X-ray generators and considerable computer involvement to greatly enhance operator capability. The firm is also working on a fully automated system using TNA-type technology coupled with E-Scan.

Training Is the Bottom Line

It appears the dual-energy, color-display and variants are the frequent choice of airlines and other large organizations that require many machines or where initial cost and the cost of operations and maintenance are major factors in the selection of technology. In these cases, the threat is sometimes more statistical than actual. Also, many do not feel the need to know what is inside the black box, so long as it meets the FAA standards. Dual-beam systems currently meet the standards.

On the other hand, it appears that the backscatter technology is often chosen where cost is not a factor or the threat is more than statistical. It is clear that, on the specific point of finding organic materials, the backscatter technology is superior. This technology has now been adopted as the sole screening technology for the White House, Air Force One, U.S. Supreme Court, U.S. Customs and many other high-profile users where cost is not the highest consideration. It has also been selected by the international consortium of foreign airlines operating from Las Angeles International Airport, as well as Trans World Airlines, El Al Israel Airlines and Japan Airlines.

From the standpoint of aviation security and the level of ability to find explosives, the appropriate question is not "what is a safe level?"; it is, "how great is the risk?" The record of airline bombings in the United States is not extensive, but the anticipation of bombings is high.

Some would argue that a simulated X-ray machine may be as effective in deterring terrorism as the very best operating unit. Perhaps, but any machine is useless if it is not used properly. For that reason, training is as important as technology selection. ♦

[The full text of a five-page comptroller general decision on a U.S. Customs Service assessment of EG&G Astrophysics and AS&E equipment may be obtained at no charge by calling the U.S. General Accounting Office (GAO) at (202) 275-6241 in Washington, D.C. Ask for Decision File Number B-241171, dated 28 December 1990. The GAO does not conduct technical assessments, but the U.S. Customs Contraband Laboratory does, and that is the source of the technical data cited. It is the most objective and comprehensive report available to the public. — Ed.]

About The Author

Francis ("Frank") G. McGuire has been a journalist writing and editing almost exclusively about aviation, law enforcement and security for more than 30 years. He is founding editor & publisher of Counter-Terrorism and Security Intelligence, *a biweekly newsletter focused on ideological and political violence around the world.*

A past president of the Aviation/Space Writers Association (AWA), he has been an accredited correspondent to the U.S. Congress for more than a dozen years.

In 1985, he won a national award for investigative reporting after a series on aircraft safety.

A revised edition of his reference work, Who's Who in Terrorism: A Security Intelligence Sourcebook, *was published in 1989 and included profiles of terrorist groups and leaders, areas of operation, tactics, links with other groups, statistics on terrorism and other data.*

McGuire's 100-page report, Aviation Security — Strategies for the 1990s, *was published in 1989 by McGraw-Hill Information Systems Division.*

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