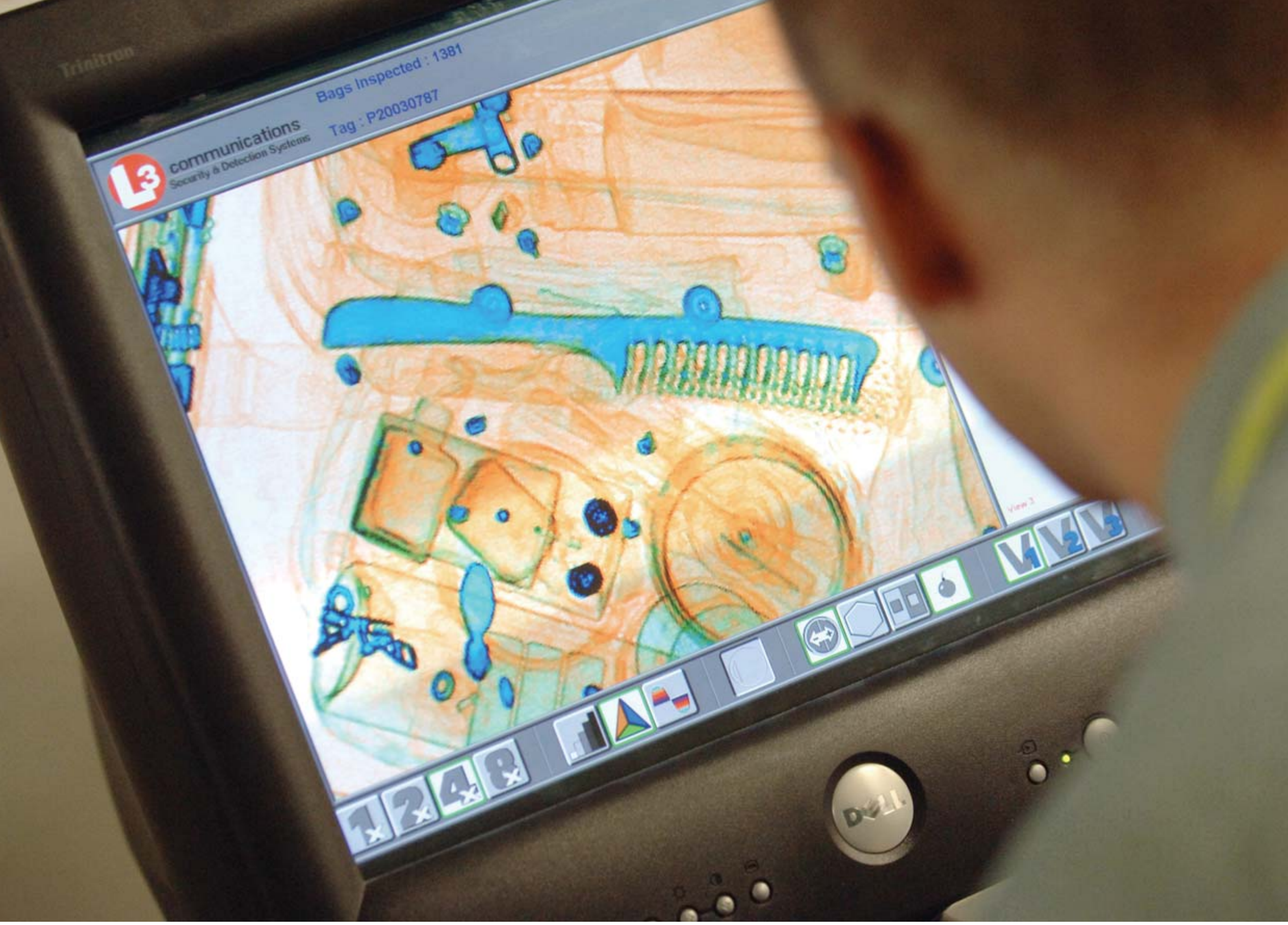


X-ray:

still a role to play in baggage screening?

X-ray technology for baggage inspection has been around since the 1970s and it will remain a cornerstone for screening hold baggage, cabin baggage and certain types of cargo for the foreseeable future, unless the laws of physics change. Compared to any of the alternative screening technologies, X-ray is hard to beat when it comes to good penetration, low cost, compact size, ease of use and range of imaging capabilities. So far, other approaches that have been developed and tested have included trace, neutron- and radio frequency-based techniques, all of which have, so far, fallen short relative to those attributes key to integration with baggage handling systems and checkpoint operations. ***Steve Wolff*** *focuses on the various aspects of X-ray screening of baggage, some of the challenges that remain unresolved and where the technology is headed.*

X-ray scanners have, alongside the changing terrorist threat, evolved dramatically over the past 35 years, from the early green-screen fluoroscope systems that used single energy X-rays to the automated, multi-view and CT systems on the market today.

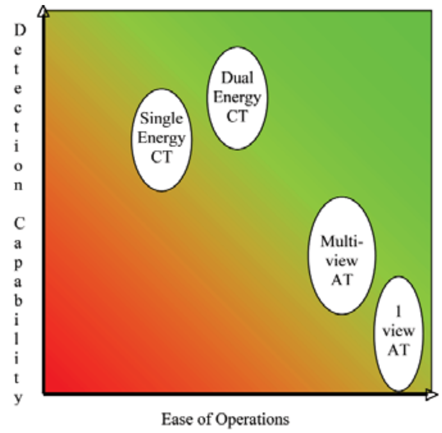
History

The single-energy X-ray systems that started the process of baggage inspection in the 1970s were aimed at combating hijackings. The high contrast between guns, knives and grenades relative to other items in baggage successfully countered this early threat. However, as we know, the threat changed in the 1980's as terrorists switched from guns and hijacking to improvised explosive devices (IEDs) and acts of aerial sabotage. In the 1990s, following the destruction of Pan Am 103, it was clear that terrorists had all but abandoned hijackings in favour of concealing bombs in hold baggage. Mostly organic in nature, explosives look a lot like plastics and food, making them less distinguishable from innocuous items in baggage. Regardless, X-ray technology evolved in an attempt to counter the new threat. Dual energy measurements, which enabled systems to discern organic from inorganic materials were combined with digital imaging and sophisticated software, made possible by the rapid increase in computational power that occurred in the 1980s and 1990s to further help discriminate suspected explosives from other organic materials.

Checkpoint X-ray systems were scaled up to address hold baggage and even cargo screening. These methods were only partially successful. Many types and configurations of explosives remained difficult or impossible to see using conventional, single-view X-rays, even with the addition of sophisticated software algorithms. Hold baggage scanners pioneered by Vivid Technologies (now part of L3), improved detection of many types of explosives but limitations remained for sheet and homemade explosives. While used extensively outside the U.S. for hold baggage, these so called "AT X-ray systems" never met the strict U.S. Certification requirements for hold baggage. Also, when these advanced techniques were reapplied to cabin baggage, FAA side-by-side tests showed that overall detection (machine plus operator) was actually lower with auto-assisted X-ray than with conventional X-rays, likely due to a combination of false alarms distracting operators from true threats and missed detections arising from a belief that the "machine was always right". The balance between operator and machine performance needed to be better understood and optimised.

It was clear by the early 1990s that conventional X-ray would not meet the FAA's requirements for hold baggage screening. However, another X-ray technique, Computed Tomography (CT), also took advantage of the revolution in computational power. While common in medical applications, early tests in the late 1980s showed CT's promise for explosives

Optosecurity's touch-screen user interface identifying threat liquids detection. Where conventional X-ray systems had one, sometimes two views, CT rotates the X-ray tube and detector continuously around the bag, generating over 500 views from all angles for each location in the bag. High-speed computers reconstruct cross-sectional images (or "slices") of the bag, clearly separating out each object, which is then analysed to determine whether it has the characteristics (initially density) of explosives. InVision Technologies (now part of GE) developed the early single energy systems, the first being certified by FAA in 1994; later L3 Communications working with Analogic, Inc developed a variant.



How good are the new systems?

In the late 90s, hold baggage scanners became even more sophisticated: multi-view X-rays tried to find a balance between the complexity of CT and the simplicity and speed of X-ray. While several companies had prototypes both for hold baggage and cabin baggage prior to 9/11, afterwards, manufacturers expanded their product lines and system capabilities for both hold- and cabin baggage screening. Multi-view X-rays systems that had been developed for HBS were either resuscitated and improved or new systems developed and scaled down to cabin bag size. For example, Smiths' ATiX, basically a scaled down version of the EDtS for hold baggage, and Rapiscan's 620 DV are examples of the new generation of multi-view X-ray systems. They typically use between 2 and 4 views. These systems, while significantly better than the single view systems of 10 years ago in terms of detection, still do not meet TSA's Certification standards and still have a difficult time with sheet, and with many of the homemade explosives that are the modern day terrorist's weapons of choice.

With CT, similar developments occurred. Instead of the "one size fits all" approach of the mid 1990s, new systems are tailored to different types of operations. Some (such as the CTX-9000 series) have higher speeds and larger tunnels for improved baggage handling system integration, while smaller, slower systems (such as the Reveal CT-80) are optimised for small airports and stand-alone operations. New CT scanners are now almost exclusively dual energy, providing additional advantages over the single energy systems of the 1990s. Today's hold baggage systems have good detection at specifications that are even tighter than the original FAA Certification standards. Even so, false alarm rates are substantially lower (close to a factor of 2) than the earlier CT systems, thanks to dual energy and improved inspection algorithms.

Two companies, Analogic and Reveal have, at TSA's request, scaled down CT systems for screening cabin baggage. In the short-term, however, TSA appears willing to forego the potential for improved detection that CT has to offer cabin bag screening and is instead deploying multi-view X-rays at U.S. airports to replace the aging X-ray systems deployed after 9/11.

1. Moving Forward.

1.1 Hold Baggage Screening

New systems being developed that close the gap between X-ray and CT. GE and Analogic are speeding up rotating CT systems to better match operational needs. SureScan Corporation is developing a "many-view" X-ray system with 3D imaging capability, which is in early stages of testing with the TSA. Rapiscan is working on a non-rotating, ultra-high speed CT system that could be scalable for cabin- and hold baggage screening. If successful, these latter systems could lead to dramatic improvements in performance of hold and possibly cabin baggage screening, but these systems are likely 2+ years away from market readiness.

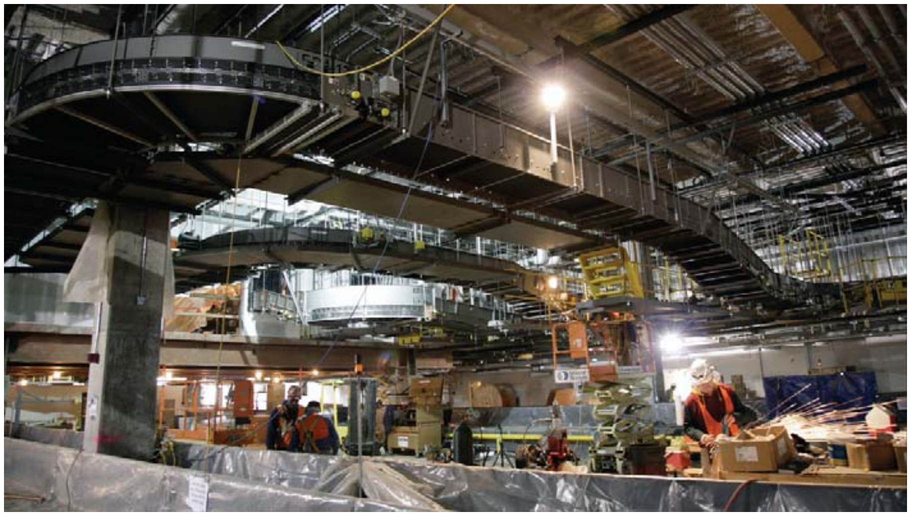
European regulators have taken steps to clarify to the industry how they see the increasingly complex technology being adopted, at least for hold baggage. The table shows the ECAC standards and how various systems can be deployed for upgrades, new airport construction and a longer-term upgrade path.

Standard 1	Single view AT X-ray with operator review or Certified EDS (large airports) of rejects	Can be used if in place Not an option for new operations
	Small airports can use conventional X-ray + 10% random hand search	No longer valid for any operations
Standard 2	Multi-view AT X-ray with rejects searched by Certified EDS	Current new facility/ upgrade minimum screening requirements
Standard 3	Certified EDS with operator resolution of rejects	100% screening required by 2013

In light of the changing threat, TSA is working with U.S. government labs to adapt sophisticated simulations used in designing nuclear weapons to model the relative destructive power of conventional explosives on various airframes. The results of these models will help TSA update the Certification standards for hold- and cabin baggage systems.

1.2 Cabin Baggage Screening

Unlike hold baggage screening, where Europe and the U.S. adopted different screening standards and hence deployed different technologies, with cabin baggage screening there is a concerted effort underway to be consistent. The TSA's test-bed checkpoint at Baltimore Airport is very similar to that being trialled in the UK by ECAC. This approach favours the widespread adoption of multi-view automated X-ray at checkpoints rather than CT, primarily for cost, reliability, readiness and space reasons. This focus on pragmatism rather than setting and enforcing detection standards represents at least a temporary philosophical



The baggage sortation system at Raleigh-Durham International Airport's Terminal 2 An in-line baggage screening system allows the airport to integrate Explosive Detection System machines, normally seen in airport terminal lobbies, with an airport's behind-the-scenes baggage handling conveyor system. The in-line baggage screening is fully integrated into the airport's baggage handling system.

departure for the TSA relative to HBS. It is likely that CT will play some role at the checkpoint (possibly combining hold- and cabin baggage screening at smaller airports) in future, but there are no current plans to do so. Of course, if there's an incident, then all bets are off.

In the meantime, regulators are encouraging X-ray manufacturers to focus their algorithms on what they do best and drive the false alarm rate lower, replacing the earlier strategy of detecting everything, which leads to high operational false alarm rates. If successful, rather than having the operator resolve automatic rejects, both the operator and the automatic X-ray will have parallel primary detection roles. A Canadian company, Optosecurity, is developing an add-on to existing X-ray systems that will focus exclusively on finding liquid explosives and handgun threats. Other algorithms are being developed specifically for laptop inspection. If successful, these and other approaches will reduce the complexity of the operators' job by allowing them to rely on the machine for certain inspection tasks. This use of the relative strengths of both operators and automation is likely to be a major ongoing focus; in the future it may allow airports to upgrade certain older systems with new add-on technologies, rather than replacing them with the latest shiny new X-ray. The ability for new companies to offer such upgrades could change the marketing approach for security systems, especially in poorer countries and pose a challenge for regulators aiming to maintain detection standards and protocols across various combinations of hardware and software from different vendors.

2. Adding other technologies

Over the past eight years, several manufacturers integrated complementary technologies with X-ray and CT. One example is Rapsican's QXR1000, a combined X-ray - Quadrupole Resonance (QR) system (QR is a radio frequency technique that detects plastic explosives of any shape and thickness) with two complementary technologies. However, the combined system is currently too long and cumbersome for aviation applications and would likely require significant changes in the items passengers remove from bags. To date, it has not been deployed at airports, though it is in use for non-aviation applications.

Another example is the integration of explosive trace detection with X-ray. Regulators are rightfully wary of trace systems' ability to detect concealed explosives inside baggage – trace has been shown to work best when there is access to the interior of the bag as the primary challenge is getting a good sample of "sticky" explosives molecules into the trace analyser. Automatic sampling systems have been developed (by Traceguard, for example), but no systems have yet been approved for use.

In Russia, Thermal Neutron Activation (TNA) has been used to resolve operator rejects from X-ray. While TNA may work in this regard for some explosives, it only detects the presence of nitrogen and chlorine. These elements are missing in many homemade explosives (such as TATP). Fast neutron inspection can overcome this limitation, but at the expense of increased size, cost, more safety concerns and slower inspection that will relegate any such application to secondary search only. No attempt has yet been made to integrate TNA and X-ray.

Another technique that likely will become part of the screening solution for hold baggage is X-ray diffraction. Several attempts at X-ray diffraction systems have been tried in the past (such as Yxlon's 3500 – now owned by GE), usually yielding bulky, expensive systems that have seen only limited deployment, but such devices have excellent detection and specificity for many materials. Scaling these down to cabin bag size would be a challenge.

Operational impact

Having passengers remove items from bags for separate screening has substantially reduced checkpoint throughput – and raised passenger frustration. From a pre-9/11 average of 275 passengers per hour per lane; today's lanes more typically process 225–235 passengers per hour, being a 15 to 20% reduction. This has led many airports to undertake building modifications to add additional lanes to meet capacity. Some common-sense steps have now been widely adopted, such as replacing every other metal detector with an X-ray system, which helps compensate for the longer divesting times currently required to remove laptops, camcorders and liquids.

With the liquids detection trials currently underway in the UK, ECAC is aiming to allow larger quantities of liquids to once again be carried onboard. Some systems may even allow bottles to be placed inside bags, though at what cost remains to be seen. TSA recently relaxed (slightly) its rule on removing laptops from certain types of briefcases, but until this is broadened to include most briefcase types, it is unlikely to increase the processing rate at the checkpoint and may merely increase confusion and delays in the short term.

The Future

Hold baggage screening likely will evolve towards high-speed CT for primary search, with other techniques (X-ray diffraction, possibly in combination with a neutron-based technique) automatically resolving most of the nuisance and impenetrable object (shield) alarms. For cabin baggage screening, the detection problem is much more complex. A high-speed, cost-reduced CT system would likely provide the best detection capability, but it remains to be seen whether the hurdles of cost, reliability and size can be overcome for this application. If not, I'd expect to see X-ray systems with even more views start to approach the detection capability of CT. A suite of secondary technologies, such as QR, trace, possibly TNA likely will have a role in resolving primary search rejects.

To plan for the future, regulators worldwide (possibly via ICAO) should lay out a clear, realistic migratory path and timeline for new system deployments and performance requirements for both hold- and cabin-baggage screening in a manner similar to Europe's current hold baggage screening plan. This path should also have incentives for airports to adopt new technologies ahead of schedule (such as improved operations, relaxing of other security measures to improve customer service). Manufacturers can then raise capital and obtain government R&D funds to develop systems that meet the timeline and airports can plan the revenue needs, infrastructure and equipment purchases necessary to meet these requirements.

In summary, there's little of the electromagnetic spectrum that we haven't explored for baggage screening. Radio frequency, X-rays and even neutrons have been looked at from the standpoint of baggage screening. Given that 9/11 occurred 7 years ago and we're only just rolling out advanced X-ray screening at the checkpoints, in 10 years time it's almost certain that X-ray-based systems with their balance of low cost, safety, excellent imaging capabilities and good penetration of bags, will still a cornerstone of baggage security.

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