AVIATION SECURITY INTERNATIONAL

www.asi-mag.com

THE GLOBAL JOURNAL OF AIRPORT & AIRLINE SECURITY

Screening Technologies: from A to Z

ALSO:
X-RAY TRAINING
CYBERTERRORISM
DISCRIMINATION
SECURITY THEATRE

FEBRUARY 2015 VOLUME 21 ISSUE 1

CHO HYUN-AH: MACADAMIA NUTS

SEE PAGE 12

ADELAIDE AIRPORT: FRONT OF HOUSE

SEE PAGE 18

Screening Technologies: an A to Z

When the airport security checkpoint was first introduced in the 1960s, we relied on X-ray (transmission, backscatter or fluorescence) and walk-through or hand-held magnetometers to detect the weapons used by aerial pirates to hijack flights. As terrorism has evolved and the modus operandi of our enemy has matured, so has the range of technologies expanded in order that we be able to detect miniscule quantities of an infinite number of explosive compounds which might be secreted in baggage, cargo and within the human body. ***Steve Wolff*** *has summarised the key technologies deployed and under research and development and brings ASI readers an A to Z (well almost!) of screening technologies, assessing their maturity, cost and speed.*

KEY

UNIT COST	SPEED OF SCREENING	MATURITY OF TECHNOLOGY
Over £500,000	<5 seconds	Widely Deployed
£100,001-£500,000	6-10 secs	Limited Deployment
£50,001-£100,000	11-20 secs	Undergoing Trial
£10,001-£50,000	21-60 secs	Under Development
Under £10,000	>1 min	Concept

Active Millimetre Wave

Application: Screening of travellers

Capability: To look underneath clothing for anomalous objects

Liability: Inability to see beneath visible surface

Scientific Principle: Clothes are generally transparent to millimetre-wave radiation (60 - 150 Ghz). An RF transmitter array sends millimetre wave radiation to the body and a receiver antennae array collects reflected radiation and constructs an image. Automatic software (Automatic Target Recognition or ATR) inspects the image and shows anomalies on a mannequin image, preserving privacy/modesty.

Backscatter X-ray

Application: Traveller, bag, container, vehicle screening

Capability: Distinguishes organic from inorganic materials near surface of a person/container

Liability: Inability to penetrate more than a few cm. No material identification/detection.

Scientific Principle: High atomic number elements absorb X-rays, whereas lower atomic number elements (in most explosives) backscatter X-rays. X-rays pass through a rotating collimator to create a narrow, sweeping X-ray pass beam while the X-ray tube/collimator assembly moves perpendicular to the sweeping beam. Uncollimated detectors located on the same side as the source collect backscattered X-rays from the target, creating a 2D image. The locations of the beam and the collimator are tracked allowing the image to be constructed.

Chemical Analysis Swabs

Application: Surface screening

Capability: Simple and cheap

Liability: Less sensitive to small quantities, requires manpower to conduct screening

Scientific Principle: Explosive residue detection occurs by observing a colour change in a chemical reagent, usually a test paper that is used as a swab. Different sprays are used sequentially for rapidly identifying different explosives. Variants include test kits based on chemicals and antibodies, highly specific proteins made by animals in response to foreign substances.

Chemiluminesence (CL)

Application: Trace detection technique applicable to bag, passenger, cargo, vehicle screening

Capability: No radioisotope needed; flexible vapour or particulate sampling; compact

Liability: Limited to nitro (NO-) based explosives only

Scientific Principle: The technique collects the sample either by collecting vapour near the object under suspicion or swiping its surface to collect particulate samples. Once the sample is inside the system, a chemical reaction between the explosive and a reagent produces infrared light with intensity that is proportional to the amount of NO present (equivalent to the amount of explosives in the sample). Like many other trace techniques, to identify the material, CL must be combined with a gas chromatograph (GC) to separate materials as they travel through a column. This allows the combined system to identify materials based on detection and time-of-flight through the GC.

Coherent Scatter X-ray

3 (CABIN BAG)
4 (HOLD BAG)

Application: Bag screening

Capability: Highly material-specific; identifies the specific threat

Liability: Expensive; power consuming; better for solids than liquids; slow. Older systems: large

Scientific Principle: X-rays from a coherent, monochromatic X-ray generator interact with materials and scatter at different angles and energies. Molecules have unique diffraction patterns and energy distributions. An energy-resolving detector array (e.g. CdTe or CZT) is offset from the transmission X-ray beam which is collimated so that only scattered X-rays from a small volume of the container are captured. By also collimating the detector array on the same volume, the energy spectrum is collected at each angle, compared with a threat library and any threat identified. Various (proprietary) methods are used to adjust the X-ray beam and collimation to cover the entire bag or, alternatively, target a location within the bag based on object location from a CT or multi-view X-ray.

Computed Tomography (CT)

Application: Bag screening

Capability: Automatic and operator-assisted baggage inspection

Liability: Expensive; currently limited to baggage inspection; damages film

Scientific Principle: CT systems contain an X-ray source and a focused single or dual energy detector array to collect transmission X-ray views from different angles around a bag as it passes through the scanner by either mechanically rotating the array around the bag (3rd generation) or via micro-X-ray generators activated in sequence to produce the X-ray fan beams at different angles without rotation (4th generation CT). Software reconstructs cross sectional CT slices, and stacks them to form 3D images. Each bag item is independently analysed for material density and, if dual- or multi- energy detectors are used, atomic number to detect threats.

Dielectric Bottle Scanner

Application: Screening of bottles for explosives

Capability: Allows detection of anomalies relative to bar code

Liability: Currently no ability to identify specific materials at low energies

Scientific Principle: A low-intensity RF field can be used to measure dielectric constant and loss properties of materials, which vary with a material's physical, chemical, and structural properties. Systems estimate dielectric constant from the phase and magnitude of the EM field lines and then compare the measurement to known values.

Lead/Facing image: Smiths Detection HI-SCAN aTiX system automatically detects explosives (Credit: Smiths Detection)

Electron Capture Detection

Application: Trace detection technique applicable to bag, passenger, cargo, vehicle screening

Capability: Fast; high sensitivity (~1 ppb); low cost; lighter; highly portable

Liability: Limited to nitro (NO-), halogen based explosives only with high electron affinities; uses radioisotope (beta emitter). Requires ultrapure carrier gas (cylinder)

Scientific Principle: The technique collects the sample either by collecting vapour near the object under suspicion or swiping its surface to collect particulate samples. Once the sample is inside the system, a carrier gas (nitrogen, typically) is stripped of electrons by a radionuclide or pulsed plasma. The electrons accelerate towards an anode providing a baseline current. Any electronegative molecules that absorb electrons reduce the current, allowing their detection. Like chemiluminescence, it is generally combined with a gas chromatograph (GC) to separate and identify specific materials.

Fast Neutron Analysis (Pulsed)

Application: Cargo, unmanned vehicle screening

Capability: High penetration of most containers; ability to separate threat from non-threat

Liability: Large; costly; high maintenance; some items can have residual radioactivity; not suitable for high hydrogen content containers

Scientific Principle: Pulsed 14MeV neutrons from a generator are sent through the container to a detector array that combines low-energy resolution sodium iodide with high-resolution detectors (e.g. high purity germanium) located on the other side. This assembly moves vertically to scan the container. Non-elastic collisions between neutrons and atoms yield energetic nuclei, which (usually) rapidly decay to ground states, emitting characteristic gamma rays for C, N, O. A 2D view is created from the vertical location of the array and the movement of the container through the scanner, with depth (3D) determined by the neutrons' known energy/speed. Software compares the elemental ratios (C/N, C/O, N/O) within each voxel to explosives resulting in an automatic threat decision and a crude 3D localisation with 10 – 15 cm resolution. As the neutrons slow (moderate), the technique can also collect gamma data from thermal neutron capture (TNA).

Fluorescence Detection

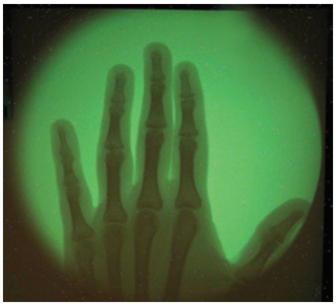
Application: Trace detection technique applicable to bag, passenger, cargo, vehicle screening

Capability: Fast; high sensitivity (~1 ppb); low cost; highly portable

Liability: Need to formulate for explosives

Scientific Principle: Fluorescence detection measures a change in fluorescence (light) emanating from molecules (chromophores) that are targeted to absorb a specific explosive. The change in fluorescence is detected, indicating the presence of the particular material. One variant uses a polymer formulation that causes an amplifying effect when a single explosive vapour molecule quenches many linked fluorescent molecules, resulting in much greater sensitivity.

Fluoroscopic X-ray



Application: Mail, small parcel, baggage screening

Capability: Simple geometry; compact; high speed inspection

Liability: Generally suited to slow speed applications; smaller targets due to panel costs

Scientific Principle: A non-collimated X-ray tube produces a cone beam of X-rays, which are transmitted through the item to a fluoroscopic (or digital radiography) plate on the other side of the passenger. X-rays are attenuated resulting in a shadow projection image. The image can be collected without moving the bag or the bag can sit on a table and be rotated allowing inspection in real-time.

Gamma Ray Attenuation

Application: Cargo, unmanned vehicle screening

Capability: Medium penetration of most containers; low cost; fixed or mobile

Liability: Imaging system only. Low cost; limited resolution. Lower penetration of dense containers. Radioisotope licensing needed

Scientific Principle: Gamma transmission systems use the same approach as X-ray: namely attenuation of gamma rays by objects of different density to produce a shadow projection image. Gamma-based systems use a radioisotope (Cobalt 60, Cesium 137) instead of a generator to produce photons. This increases reliability, but produces lower energy photons; which results in lower penetration capability. A vertical detector array is placed on the opposite side of the container from the source.

Hand-held Magnetometer

Application: Passenger screening

Capability: Simple geometry; compact; low cost

Liability: Limited only to metallic objects, may interfere with certain medical devices

Scientific Principle: An alternating current passes through a coil producing an alternating magnetic field to induce eddy currents in any electrically conductive metals close by. These currents produce their own magnetic field. Another coil measures the change in the magnetic field and, if detected, sounds an alarm.

Credit: Garrett

Ion Mobility Spectrometry (IMS)

Application: Trace detection technique applicable to bag, passenger, cargo, vehicle screening

Capability: Fast; high sensitivity (~1 ppb); highly portable

Liability: Uses consumables; after contamination might need significant drawdown time

Scientific Principle: An IMS system consists of a collector, a GC and the IMS detector. With IMS and its variants, typically (but not always) a radioisotope ionizes the sample from the GC. Ions then enter an electrical potential gradient inside a drift tube. The time the ions take to traverse the length of the tube (drift time) depends on the ions' mass, charge and size. Drift time is used to identify a material as a potential explosive. The ions are collected producing a short-term electrical current. Discrimination is largely based on the drift time.

Laser Vaporisation / Breakdown / Fluorescence

UNKNOWN

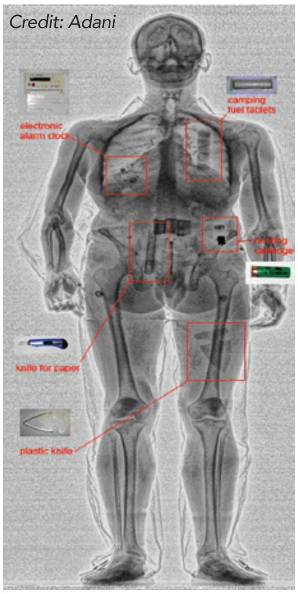
Application: Stand-off trace detection technique applicable to bag, passenger, cargo, vehicle screening

Capability: High sensitivity rapid inspection using eye-safe laser at multiple 10s of metres

Liability: Currently only detects NO based explosives

Scientific Principle: A single nanosecond pulse of a tunable laser is used to vaporise and photo-dissociate a trace sample, which induces fluorescence either into diatomic molecules or atoms, depending on the specific technique variant. A photomultiplier tube and narrow band filter then detects the NO fragments as they decay from a higher vibrational energy state emitting shorter wavelength (blue shift) than the laser. A filter allows the signal to pass while blocking the scattered light from the laser.

Line Scan Transmission X-ray



Credit: Adani

Application: Bag, passenger screening

Capability: Automatic + operator inspection for baggage; operator-only for passenger screening

Liability: High false alarm rate when used automatically; success depends on operators. Unable to penetrate high density/high Z objects (e.g. lead crystal)

Scientific Principle: A collimated X-ray tube produces a fan beam of X-rays, which pass through the target to a linear array of detectors on the opposite side. Fewer X-rays pass through denser, high atomic number objects resulting in a shadow projection image that is built up line-by-line as the target moves through the system. Variants include single view; multi-view, single energy, dual energy and multi-energy (photon counting) detector arrays. In multi-view systems, several single views are placed to intersect the bag at different angles, to minimise the ability to hide threat objects. Typically 2 – 5 view systems are used. Dual energy systems estimate density and atomic number and are primarily used for security applications.

Magnetic Resonance

Application: Bottle scanning

Capability: Good ability to distinguish explosives from innocuous liquids.

Liability: Unable to see inside metallic containers

Scientific Principle. Materials that contain nuclei with odd numbers of protons or neutrons have a magnetic moment and angular momentum are aligned using a constant magnetic field. This alignment is then perturbed using an alternating magnetic field, which changes the spin state (precession) of the nuclei. Once the alternating field is removed, the nuclei relax back to their normal spin state, emitting a small RF field, which is detected using a coil. Magnetic resonance (MR) frequencies are directly proportional to the applied magnetic field strength and are unique to the material if the field strength is constant.

Mass Spectrometry (MS)

Application: Trace detection technique applicable to bag, passenger, cargo, vehicle screening

Capability: High sensitivity (~1 ppb) and specificity; no radioactive source.

Liability: Expensive; some need an external gas or vacuum system. Relatively slow warm-up time and analysis time.

Scientific Principle: Most MS systems use a sampler and front-end GC, even though this technique filters molecules based on their mass by ionizing them and passing them through a filter (e.g., magnetic, ion trap, time-of-flight filter). This allows ions to be identified based on their charge-to-mass ratio making it a highly specific tool for chemical analysis. It uses no radioisotope and is considered the 'holy grail' of trace techniques.

Multi-Energy / Many View X-ray

Application: Baggage scanning

Capability: Good ability to distinguish explosives from innocuous materials. Some geometries scale-up to cargo.

Liability: Large; suitable for hold baggage only; lower resolution than CT.

Scientific Principle: A hybrid between multi-view X-ray and CT, using a number (9 – 30) of collimated X-ray tubes arranged around several planes of unfocussed detector arrays. Each tube transmits collimated fan beams of X-rays at different angles through the bag to the detector arrays. This provides many more views than is possible with traditional multi-view X-ray, though usually fewer than CT. There is no mechanical rotation and sophisticated software is used to create 3D images from sparse data and unfocussed detector arrays. Fewer views lead to lower image quality; so photon-counting detectors (e.g. cadmium zinc telluride - CZT) can be used to give better atomic number measurements than dual energy detector arrays, which is designed to offset the lower spatial resolution while achieving detection standards.

Muon Inspection

Application: Cargo screening for fissile materials

Capability: Likely capable of high Z material detection/discrimination. Passive, so no radiation safety issues.

Liability: Large fixed infrastructure; unable to detect explosives without other techniques

Scientific Principle: A muon is an unstable charged particle ~200 times an electron's mass. The earth's surface receives an approximately uniform flux of ~10,000 muons/square metre/minute at 4 GeV average energy, higher energy than can be easily produced artificially. When they pass close to a nucleus they are deflected slightly. The extent of this deflection is determined by detecting the muon's x, y entrance and exit trajectories from two sets of orthogonal detector arrays on either side of the container. The three-dimensional particle track is reconstructed and the scattering angles determined. As denser higher Z materials cause more deflection, any highly deflected trajectories are detected and analysed by software.

Near Infrared Spectroscopy

UNKNOWN

Application: Stand-off detection

Capability: Detection of higher vapour pressure explosives in vapour phase, on surfaces.

Liability: Unknown – still under development; likely will be fairly costly. Vapour detection will not allow pinpointing of the source of the signal, so may be of limited use in high background environment.

Scientific Principle: A near infrared (Quantum Cascade) laser source is used to illuminate a target. The light passes through the clothing and signals were reflected by materials of interest back through the clothing to the detector, where it is analysed by a spectrometer. Comparing the intensities of light at each wavelength using complex multivariate statistical analysis techniques is being explored to detect threat materials in vapour phase and underneath clothing.

Neutron Radiography

Application: Cargo/container screening

Capability: High penetration for dense materials.

Liabilities: Low penetration for highly hydrogenous (water/organic) materials. Requires high output neutron generator (life/reliability). Potential secondary radiation from neutron activation of certain elements (e.g. Al, Au)

Scientific Principle: A collimated neutron generator focuses the emitted neutrons from a generator into a largely mono-directional beam, which is then slowed down to the desired energies and is then directed through the target container. Detectors containing elements with high neutron absorption cross sections (such as Li, B, Gd) in the energy range of interest are used to capture the image, which is a shadowgraph related to the number of neutrons that penetrate each object, resembling in many ways an X-ray image. Neutrons are attenuated by different materials (low Z) than X-rays (high Z), so this technique can complement X-ray to ensure penetration of cargo containers in addition to being used on its own.

Neutron Resonance Fluoroscopy (NRF)

Application: Cargo screening

Capability: Excellent ability to distinguish explosives from innocuous materials.

Liability: Large; costly; low throughput; requires other technologies to identify volumes for scanning. Under development.

Scientific Principle: This secondary search technology identifies the contents of cargo, resolving any alarms that are flagged by a primary scan. When an object is irradiated with a beam of 9 MeV X-rays, non-hydrogen nuclei absorb and then re-emit characteristic energy gammas for each element. These signatures are captured with a highly collimated array of high-purity germanium (HPGE) detectors. NRF can hence predict the molecular composition and compare it to a library of materials. A 3D density and Zeff imager automatically directs the NRF detectors to the specific area of interest.

Olfaction

5 (DOGS) 4 (MICE)
2 (INSECTS)

Application: Cargo, passenger, bag screening

Capability: Highly mobile (dogs), good for search ability to follow a scent to its source. High sensitivity

Liability: Limited duty/availability; long training times; high operating costs; requires routine training; unable to ID materials; narrow range of materials detectable. Can be subject to unknown, unpredictable handler-canine psychological effects

Scientific Principle: Intricate nasal anatomy and the highly developed olfactory lobe of canine, goat, pig, mice and insect brains can be trained to be highly sensitive to explosives. A well-trained dog can recognise more than 15 different types of materials. Dogs are trained to identify explosive ingredients rather than specific products, but are typically trained to detect 9-14 different explosives. Other animals such as mice and bees have been explored for explosives detection applications, with the advantage of smaller size and not requiring a handler, though at the expense of mobility and intelligence.

Credit: BioExplorer, Tamar Group

Passive Millimetre Wave

Application: Screening of travellers

Capability: To look underneath clothing for anomalous objects

Liability: Inability to see beneath body surface; low resolution so suitable for larger masses only

Scientific Principle: Passive imaging systems rely on an apparent temperature or emissivity difference between a human body and concealed items on it. It works like a photographic camera, but in the millimetre-wavelength range. All objects generate electromagnetic radiation at all wavelengths and also reflect incident radiation from the environment. For each material the sum of the emissivity and the

FULL BODY SECURITY
SCREENING SYSTEM

THE MOST EFFECTIVE THREAT IMAGING SOLUTION FOR OBJECTS LOCATED ON OR IN THE HUMAN BODY

CONPASS

EFFICIENT

- A single scan can identify all hidden items

FAST

- Only 7 seconds for whole-body scanning

SAFE

- Ultra low-dose scanning compliant to ANSI 43.17-2009

FLEXIBLE

- Easy to integrate with most Access Control Systems

Swallowed drugs

Ceramic knife in rectum

Prosthesis

Breast implants

DETECTION CAPABILITY:

Objects hidden internally and externally on the body; within prosthetic devices, artificial limbs, shoes etc.

ITEMS DETECTED:

Explosives, metals, ceramics, drugs, jewellery, electronics etc.

info@adanisystems.com www.adanisystems.com

reflectivity is 1 and each varies with wavelength. Metal objects have lower emissivity than human skin whereas plastics and ceramics have higher emissivity than metals but lower than human skin, so both objects can be distinguished from skin. Some passive systems use ambient conditions, others use an incoherent millimetre wave source to 'illuminate' the body to improve the contrast by making reflective objects appear warmer than the body.

Piezoresistive Polymer Cantilever

Application: Vapour detection technique applicable to area monitoring, cargo, vehicle screening

Capability: High sensitivity, and specificity, small, low cost, low power.

Liability: Unknown as still under development. May be limited to nitro-aromatic compounds

Scientific Principle: A mesh filter is used to remove dust before air enters an array of low-cost piezoresistive polymer cantilevers, which adsorb explosives. Monitoring the resonance is one highly sensitive way of measuring small explosive masses (picogram); the resonant frequencies differ for different materials (explosives) adsorbed on to their surfaces. In another variant, the adsorption generates stress, deflecting the cantilever and changing its resistance. In both cases the cantilever surface rapidly regenerates after detection for subsequent measurements. These devices are small, low power and ideal for area and remote vapour phase detection of explosives when integrated with wireless capability.

Protein Coated Carbon Nanotubes

Application: Receptor based trace detection technique applicable to bag, passenger, cargo, vehicle screening

Capability: High sensitivity (potentially single molecule) and specificity; no radioactive source

Liability: Unknown as still under development. May be limited to nitro-aromatic compounds

Scientific Principle: Carbon nanotubes are coated with protein fragments called peptides (bomboltins) from bee venom. When explosive molecules are adsorbed on the bomboltins, the nanotubes' fluorescence changes, either in brightness or by shifting wavelength (the latter resulting in a higher signal to noise measurement). Different nanotube-peptide combinations are needed to detect different explosives compounds in a single detector and concentrator.

Quadrupole Resonance

Application: Screening of travellers, bags

Capability: To look for explosives concealed on, and inside, targets; low intrinsic false alarms. Highly specific. The only non-ionizing technique that can detect explosives concealed inside a body

Liability: Metallic objects can shield the signal or distort the RF field. Technique is limited to solid materials and some N-based explosives. Potential for interference from AM radio stations, especially at night.

Scientific Principle: Non-spherical nuclei (e.g. 14-N) in explosives typically have 1 ground and 2 excited rotational states/orientations, with corresponding resonance frequencies that vary with their molecular environment. The excited states can be achieved by applying RF in the 0.3 ~ 6 MHz range using an antenna coil. At these frequencies, RF momentarily excites N-based molecules in the target explosives. When the RF is stopped or shifted to a different frequency, the nuclei relax from the energised states emitting a weak RF signal with a set of frequencies unique to each explosive, which is picked up by the same antenna allowing detection and identification of the explosive. Technique variants include single sided or tunnel antenna/coil configurations and can use pulse-sequenced, multi-pulsed tuned frequencies or most recently, continuous wave chirped multi-power techniques that oscillate the target nuclei between 2 energised states, offering different approaches for improving signal to noise and hence sensitivity.

Radar Detection

Application: Standoff screening of passengers

Capability: To look underneath clothing for anomalous objects. Easy to use.

Liability: Anomaly detection only. Non-imaging so alternative methods needed to resolve rejects. Inability to see beneath body surface. Low resolution so suitable for larger masses only.

Scientific Principle: Two visible/IR video cameras automatically detect and track individuals up to several hundred metres. Low-level radar beams aimed at them. A computer analyses the radar return signal and compares it to an extensive library containing both normal responses for people of varying shapes and sizes and anomalous responses. The system displays red/green for threat/no threat and can sound an alarm.

Raman Spectroscopy

Application: Bottle scanning, potential for stand-off explosives detection

Capability: Excellent ability to ID and distinguish explosives from innocuous liquids. Extremely low false alarm rates.

Liability: Unable to see inside metallic or fully opaque containers

Scientific Principle: A sample is illuminated with a monochromatic laser beam in the visible, near infrared, or near ultraviolet range. Materials will scatter this light (inelastic- or Raman scattering), shifting the light's wavelength up or down by an amount related to the specific material being scanned. A lens collects the reflected light and a filter removes any wavelengths close to the laser line (from Rayleigh scattering). The remaining light (much lower intensity) is dispersed onto a detector using holographic diffraction gratings and multiple dispersion stages to maximise signal to noise. High-speed Charge Coupled Device detectors make the technique fast enough for practical use. Several technique variants exist, including Raman and Spatially Offset Raman spectroscopy, the latter being able to inspect many opaque/semi-opaque objects.

Surface Acoustic Wave (SAW)

Application: Trace detection technique applicable to bag, passenger, cargo, vehicle screening

Capability: No radioisotope needed; works well when looking for specific compounds; flexible vapour or particulate sampling; compact

Liability: Will not detect compounds outside of the parameters of the crystal. Less specific; presence of other chemicals makes detection of explosives unreliable

Scientific Principle: This technique relies on materials being deposited on multiple piezo-electric crystals. The crystals vibrate in response to an electronic excitation signal with a frequency depending on the characteristics of the crystal, the polymeric film coating and the target material concentration. In operation, each new response pattern is compared to the stored response pattern for the target vapour. Improved discrimination can be obtained using a Gas Chromatograph in front of the sensor.

Tagged Neutron Inspection

(Associated Alpha Particle Fast Neutron Activation)

Application: Cargo, unmanned vehicle screening

Capability: High penetration of most containers; ability to separate threat from non-threat

Liability: Large; costly; high maintenance; some items can have residual radioactivity

Scientific Principle: Associated Particle Neutron Inspection (also known as Tagged Neutron Inspection - TNIS) uses the concurrent production (and measured direction) of the alpha particle that is produced along with each neutron and travels in the opposite direction to the neutron, allowing the neutron's path to be determined. Unlike PFNA, TNIS uses a lower dose, portable sealed-tube neutron generator to produce 14 MeV neutron beams that are tagged by a matrix of α-particle detectors. Knowing the direction of the neutron path and the time of flight allows the ability to pinpoint the interaction with materials in three dimensions. As with PFNA, the 14 MeV neutrons from the generator enter the item being inspected where non-elastic collisions with target nuclei causes the energetic nucleus to (usually) rapidly decay to its ground state, emitting gamma rays characteristic of the specific element. The gammas are detected using sodium iodide detectors and neutron moderation is also measured to calibrate the gamma signal.

Terahertz

Application: Screening of travellers, small packages.

Capability: To look underneath clothing for anomalous objects. Potential to discriminate materials.

Liability: Inability to see beneath skin; low resolution so suitable for larger masses only; cannot penetrate certain common materials (or wet materials)

Scientific Principle: Terahertz is located above millimetre waves from 100GHz (wavelength 3mm) up to roughly 30THz (wavelength 10 microns), just below far infrared on the EM spectrum. As wavelengths are shorter than millimetre waves, systems can be smaller and images are higher resolution (though lower than X-ray). Initial systems will measure reflected radiation (a transmission version can be used for small packages/mail), potentially with illumination from terahertz sources (quantum cascade lasers). In addition to imaging, using multiple frequencies or a broad spectrum can excite molecular vibrations, rotations, and phonon-band resonances in solid materials, so the unique signatures of different molecules can potentially be used to identify threats. There are 2 basic approaches: continuous wave and pulsed.

Thermal Neutron Analysis (TNA)

Application: Bags, cargo, unmanned vehicle screening

Capability: High penetration of most containers; orthogonal technique to X-ray inspection

Liability: Large; costly; limited to N- (and Cl-) based explosives only.

Scientific Principle: TNA identifies the nitrogen content inside containers and uses this to assess the presence of explosives relative to other innocuous items, which have either lower nitrogen content or are much lower density. Nitrogen has the highest prompt gamma energy (10.83 MeV) of any element, so even though a low absorption cross-section gives a small signal; there is minimal background beneath the nitrogen peak so signal to noise ratio is low. Neutrons from a Californium 252 isotopic source or a D, D neutron generator are moderated (slowed down) and reflected into the bag. Different elements absorb neutrons and decay back to their ground state, emitting unique gamma ray energies. A sodium iodide (NaI) detector array detects and localises any items with high nitrogen density. TNA gives a red/green indication of threat based on high nitrogen concentration and provides a 3D location to within a few cms. TNA has no operator-viewable image.

Thermo-Redox

Application: Trace/vapour detection technique applicable to bag, passenger, cargo, vehicle screening

Capability: No radioisotope needed; flexible vapour or particulate sampling; compact; low cost

Liability: Limited to nitro (NO-) based explosives only; cannot distinguish materials

Scientific Principle: Thermo-redox technology is an electrochemical technique based on the thermal decomposition of explosive molecules and the subsequent reduction of NO2 groups. Air containing the explosive sample is drawn into a system through a concentrator tube that selectively adsorbs explosive vapour using a coating on the tube's coils. The sample is then heated rapidly to liberate NO2 molecules, which are detected using proprietary technology. Since only the presence of NO2 groups is detected, Thermo-redox cannot detect explosives that do not contain NO2 groups, nor can it distinguish between different explosives and innocuous substances that contain NO2 groups.

Ultraviolet Spectroscopy

Application: Standoff trace detection technique applicable to bag, passenger, cargo, vehicle screening

Capability: No radioisotope needed; standoff detection capability without eye harming visible lasers.

Liability: Limited breadth of materials currently. Under development.

Scientific Principle: Similar in principle to X-ray fluorescence, when exposed to UV light, electrons absorb the UV energy and jump to a higher orbital state. When the light is removed, the electrons relax to their ground state, emitting photons unique to the material, which are collected in a gated detector. In Ultraviolet Resonance Raman Spectroscopy, spectroscopic LIDAR using Nd:YAG lasers can be used to remotely induce and detect the Raman signatures in explosives traces on surfaces even in the presence of fluorescence.

The setup allows for time resolved measurements with high temporal resolution and laser power in the tens of mWs range have detected and identified explosives at distances up to 20 m.

Walk-through Metal Detection (WTMD)

Application: Screening of travellers

Capability: To look for metallic objects

Liability: Unable to discriminate threat from innocuous metals; low ability to pinpoint location. Unable to detect explosives. May not detect low surface area metals/orientations

Credit: CEIA

Scientific Principle: Most WTMDs use an array of transmitter coils to emit low-level, low frequency electromagnetic (EM) fields, which interact with metal objects that pass through them inducing surface eddy (electrical) currents, which produce their own magnetic flux. The receiver coils measure the response. Transmitter elements and receiver sensors are installed in both side panels. Eddy currents are surface effects, so larger surface areas mean greater eddy currents and a larger EM field. Other factors that affect the signal strength are object size, metal type, shape, orientation and speed moving through the metal detector. Both pulsed and continuous wave designs are used and zone-based units have some ability to localise the item on the body.

X-ray Fluorescence Analysis

Application: Screening of surfaces

Capability: Ability to detect explosives, compact, low cost

Liability: Surface technique only; high detection limits (10-100 ppm)

Scientific Principle: Illuminating a surface with X-rays or gamma rays causes materials to undergo X-ray fluorescence (XRF): the emission of characteristic 'secondary' (or fluorescent) X-rays. Each element present in a sample emits its own characteristic fluorescent X-ray energy spectrum allowing the elements (generally high Z used in primary explosives) present in the sample and their relative amounts to be identified. Like X-ray diffraction, it is capable of elemental analysis but unlike XRD, high detection limits has not led to its use for aviation security.

Steve Wolff is President of Wolff Consulting Services. He has 30 years experience developing and marketing advanced aviation security detection systems and was co-founder of InVision Technologies. He is co-inventor of several checkpoint integration patents and is consulting with companies and international organisations to promote new technologies and processes at the checkpoint.