IPNDV Working Group 3: Technical Challenges and Solutions
High Explosives (1)—Technology Data Sheet

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High Explosives (HE) Technology Name: X-ray Computed Tomography (CT)
Physical Principle/Methodology of Technology: Computed Tomography (CT) is an X-ray imaging technique that can produce a three-dimensional (3D) image of the internal structure of an object from a large number of two dimensional X-ray scans taken around a single axis of rotation. The technology works by rotating an X-ray generator and detector, which are on opposing sides of an object and acquiring multiple transmission measurements that are then reconstructed into a 2D slice (cross-section) of an object. Multiple slices of an object can then be combined to create a 3D representation of the object.[1] Traditional single energy CT enables the estimation of the density of the scanned objects. The subsequent development of dual energy CT has provided the effective atomic number from measurements of scanned objects in addition to density information.[2] The effective atomic number and the density information allow for a better determination of the material type. For example, water and the explosive ANFO can have similar densities; however, they differ significantly in their effective atomic numbers.[3] CT technology is very mature and has been widely studied and deployed for X-ray screening applications. CT requires full access to the object being scanned and is therefore not suitable for standoff detection applications. The two main applications of CT scanners are medical imaging and baggage screening for border protection activities. The principles of the technology are the same for the various applications. To reduce the surrounding dose exposure, medical devices are designed to be used inside a concrete bunker, while the baggage scanners have an integrated shielded tunnel through which bags pass.
Potential Monitoring Use Cases (pre-dismantlement, dismantlement, post-dismantlement, storage stage): *Pre-dismantlement*: COTS version of this technique could have limited use in this stage as the device would need travel through the scanner or rotate on a stage. The presence of dense material can cause artifacts in the image and heavy shielding can prevent the transmission of X-rays trough the object of interest. *Dismantlement*: This technique would be able to identify the presence, shape, and quantity of HE once it had been separated assuming that it could be packaged small enough to travel through the tunnel of the device. *Post-dismantlement*: See above. *Storage*: See above. **For detection technologies, what does the method determine/measure?** The technology provides the following information: 3D volumetric information, shape, location, effective atomic number, density, mass, material type.
Physical Description of Technology (e.g., approximate size, weight): Physical footprint of CT scanners is approximately 2 m × 5 m, although this can vary between models and application of CT scanner.

CT scanners have a limit on the size of the object that can be scanned due to device having to surround the object. The maximum size of the tunnel/bore is as follows:

- Medical CT scanners: bore maximum of 90 cm wide
- Aviation baggage scanners: tunnel maximum of approximately 1 m × 0.7 m

Time Constraints (e.g., measurement times including distance from object, time to install the equipment):

Equipment needs to be installed by trained technicians and installation can take hours/days.

Measurement times can range from seconds to tens of minutes.

Will this method work in the presence of shielding? If so, what is the maximum amount of shielding that will still allow the method to work?

This technology will be affected by shielding because it requires an X-ray beam to pass through the item and be detected on the other side. The X-ray energy of medical and border protection CT systems is typically within the 80–160 kV range. The Half Value Layer (HVL) for lead in this energy range is approximately 0.06 mm to 0.52 mm and for concrete is approximately 4.32 mm to 25 mm. The HVL is the length of material required for the intensity of the photon beam to halve.

Technology Complexity (e.g., hardware, software, and ease of use by personnel):

The technology requires an X-ray generator, X-ray detector, and a gantry for rotating the object of interest or to rotate the X-ray system components around the object. However, Rapiscan has recently introduced a motionless gantry system design.[4] The hardware/software is complex, but this complexity is hidden from the end user.

Infrastructure Requirements (e.g., electrical, liquid nitrogen, etc.):

This equipment requires a dedicated circuit board and cannot be run from general main power.

Technology Limitations (e.g., detection limits for HE, operational temperature range, differences in technology detector materials):

The size of the tunnel or bore will limit the size of the object that can be scanned. Typical sizes are a maximum of 1 m × 0.7 m.

The 160 kV X-ray photon energies will not penetrate through materials with a high density thickness.

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[1] S. Singh and M. Singh, *Explosives Detection Systems (EDS) for Aviation Security: A Review, Signal Processing* (Exeter, England: University of Exeter, 2003), available at http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.19.4827&rep=rep1&type=pdf.
[2] Z. Ying, R. Naidu, and C.R. Crawford, "Dual Energy Computed Tomography For Explosive Detection," *Journal of X-ray Science and Technology* 14 (2006): 235–56.
[3] Ibid.
[4] Rapiscan Systems, available at http://www.rapiscansystems.com/en/products/hbs/rapiscan_rtt.

Information Collected by the Technology (used to help determine if an information barrier is required for use):

The technology provides the following information: 3D volumetric information, shape, location, effective atomic number, density, mass, material type. The technology can identify objects that are surrounded (hidden) by other objects.

The technology has the ability to determine the absence/presence of HE as well as identify of type of HE. Embedded system algorithms determine both the presence and identification of HE within an object.

The technology has the capability to collect very sensitive information and an information barrier would be essential for its use.

Safety, Security, Deployment Concerns:

CT scanners use an X-ray generator that needs to be shielded in order to prevent a radiation hazard. Industrial systems used to scan baggage use a shielded tunnel so that there is minimal external radiation dose but medical systems are designed to the used within a concrete bunker and do pose a radiation hazard if used outside of these conditions.

This technology requires a dedicated electrical feed to run and if not appropriately rated there is a risk of damage to equipment.

Technology Development Stage (Technology Readiness Level, TRL):

This technology is at TRL 9 for the applications mentioned previously. Further developments would be required in order to meet issues with the disclosure of sensitive information, but it would be possible to modify existing systems to meet verification requirements. This would likely be in the form of modifications to the software interface.

Where/How the Technology Is Currently Used (e.g., international safeguards, border protection):

Medical imaging applications.

Border protections applications for the screening of explosives, weapons, and other contraband items.

Examples of Equipment:

Baggage scanning systems:

- Rapiscan RTT 100
- L3 examiner XLB
- Smiths Detection HI-SCAN 10080 XCT
- Nuctech XT2100HS

Medical imaging systems:

- GE Optima CT580 W
- Phillips CT Big Bore CT simulator