Additional Modalities and Screening Devices for DICOS v03

Abstract: This document introduces Additional Modalities and Screening Devices to be added to DICOS v03 standard. These screening devices will not require new modalities Information Object Definitions (IODs) be added to the standard but may use existing modalities IOD modules with enhancements to the tag attribute set. Each section will provide a brief introduction to the screening device with any additional required tag attributes or modality IODs being added. Each of the following headings presents one screening device with a table and brief attribute descriptions:

This document will examine the following screening technology or modality:

a) Shoe Scanner
b)
c) Bulk Resolution Tools (BRTs) (BRT 1-Modified BLS, BRT 2-Modified CAD, BRT 3-Legacy BLS Raman-based, and BRT 4-Legacy BLS Electro Magnetic-based) with:
    - Gravimetric Analyzer (GA) (built into BRT 1 and 4)
    - Cameras System/Barcode Reader (CS/BR) (built into BRTs 1-2)
d) Explosives Trace Detector (ETD)
e) Differential Phase Contrast (DPC) Imaging
f) Air Cargo
g) Material Identification of Unknown Substance (MIDUS)
h) X-Ray Diffraction (XRD)
i) Enhanced Walk-Through Anomaly Detector (EWTAD)
j) Orthogonal Air Cargo Technologies.

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1.1 ADDITIONAL/ENHANCED SCREENING TECHNOLOGIES FOR DICOS V03

Introduction

This document introduces Additional and Enhanced Screening Devices to be added to DICOS v03. Each section will provide a brief introduction to the screening device with any additional required tag attributes. Each of the following tabs represents one screening technology with a table and brief attribute descriptions. The following is brief description of each tab:

Shoe Scanner is designed to eliminate the need for travelers to remove their shoes at checkpoint. Instead, the traveler would stand on a designated spot on the analyzer and the shoes would be scanned by the shoe scanner system. **Bulk Resolution Tool 1 (BRT 1)** is a modified Bottled Liquid Scanner (BLS), a benchtop system with an enclosure, which can screen not only liquids but any items brought to checkpoints in passenger carry-ons, including solids, powders, aerosols, creams, gels, liquids, and pastes. BRT 1 uses Raman spectroscopy for passenger items' screening, supported by **Gravimetric Analysis (GA)** for screening of passenger items in metal, ceramic and other nontransparent containers, and **Cameras System/Barcode Reader (CS/BR).** CS/BR system consists of at least one camera mounted inside the enclosure and barcode reader mounted outside the enclosure. They photograph and read SKU#, respectively, from passenger items which have alarmed on primary checkpoints' X-rays and are undergoing AR screening at secondary checkpoints. **BRT 2** is based on a modified chemical analysis device (CAD), also uses Raman spectroscopy for AR screening, supported by CS/BR, but without GA. BRT 2 is modified by the addition of an enclosure to the originally handheld CAD system. **BRT 3** consists of a legacy Bottled Liquid Scanner (BLS), a desktop system that can distinguish liquid threats from benign liquids in unopened glass, plastic and other containers with walls transparent to Raman laser beams. **BRT 4** is another legacy BLS based on electromagnetic principles of operation.

Explosives Trace Detectors (ETDs) consist of explosive detection equipment able to detect traces of explosives.. The detection is accomplished by sampling non-visible "trace" amounts of particulates. **Differential Phase Contrast (DPC),** is a novel X-ray imaging method, the Talbot-Lau grating interferometry enabled X-ray phase contrast imaging method or spectral imaging, as being developed at Sandia National Laboratories (SNL), can simultaneously capture three unique object features from one set of acquired data. **Air Cargo** consists of Carbon dioxide (CO_2) and heartbeat monitors which are orthogonal technologies to detect intruders (stowaways and live animals) in air cargo. The primary motivation is to safely catch threatening terrorists who might wish to hide in air cargo and then emerge to hijack or threaten airplanes in which located. As we continue to discuss these technologies with OEMs the tabs will be updated to reflect these technologies. A variety of COTS **Material Identification of Unknown Substance (MIDUS)** provide advanced technologies for threat material (TM) identification. They provide the ideal solution for identifying a very wide range of explosives, biological and chemical weapons and everyday materials in trace or bulk amounts. **X-ray Diffraction (XRD)** is a highly versatile technique that provides chemical information for elemental analysis, as well as, for phase analysis. It increasingly might be employed as a secondary, confirmatory technology for CT-based primary detection systems. The **Enhanced Walk-Through Anomaly Detection (EWTAD**) detects anomaly on people passing through the detector, such as knives, weapons etc. All attempts have been made to gather relevant information from OEMs, however, there remains information that will need to be updated. This is a living document that will change as more information is gathered but in its current form represents a "best" encapsulation of all relevant information. **SHOE SCANNER**

Introduction

If a person's shoes require screening this normally requires that the shoes be removed and sent through an X-Ray Baggage scanner. This process is inconvenient for the traveler and slows down the screening time. The shoe scanner is designed to overcome this problem. The traveler stands on a designated spot on the analyzer and the shoes are screened.

The basic technology used for the shoe scanner can be: Millimeter Wave (MMW), Explosives Trace Detection (ETD), or another technology, e.g., Quadrupole Resonance (QR).

The type and manufacturer of shoe scanner will be identified in the General Equipment module and in the TDR module by the reconstruction method.

This section will be considered the following types of Shoe Scanners:

a. AIT/Microwave
b. Quadrupole Resonance (QR)
c. Explosives Trace Detection (EDT)

ADVANCED IMAGING TECHOLOGY (AIT)/MICROWAVE

For an AIT-2D based shoe scanner, the reporting of the image and meta data shall follow the *Advanced Imaging Technology (AIT) Image Information Object Definition (IOD)* shown in Section 9 of the DICOS standard. Section 9.2.2, 2D AIT IOD Module Table, Table 37, shall be used to report the image and meta data. The detection results will be reported as described in Section 11.4, Threat Detection Report (TDR) Module, Table 61.

For an AIT-3D based shoe scanner, the reporting of the image and meta data shall follow the *Advanced Imaging Technology (AIT) Image Information Object Definition (IOD)* shown in Section 9 of the DICOS standard. Section 9.3.2, 3D AIT IOD Module Table, Table 41, shall be used to report the image and meta data. The detection results will be reported as described in Section 11.4, Threat Detection Report (TDR) Module, Table 61.

QUADRUPOLE RESONANCE (QR)

For a QR based shoe scanner, the reporting of the image and meta data shall follow the *Quadrupole Resonance (QR) Image Information Object Definition (IOD)* shown in Section 10 of the DICOS standard. Section 10.2 QR Image IOD Modules, Table 54, shall be used to report the image and meta data. The detection results will be reported as described in Section 11.4, Threat Detection Report (TDR) Module, Table 61.

EXPLOSIVES TRACE DETECTION (ETD)

TBD

a.

BULK RESOLUTION TOOLS (BRTs)

Introduction

Alarms generated by passenger items on primary checkpoint AT-2 and CT X-ray systems are resolved in secondary checkpoints. **Bulk Resolution Tools (BRTs)** are involved in the resolution of bulk alarms on solids, powders, aerosols, creams, gels, liquids, and pastes, brought to checkpoints in passenger carry-ons. There are four types of BRTs. **BRT 1** is based on a modified Bottled Liquid Scanner with its original enclosure. It uses Raman spectroscopy to screen all passenger items, except for items in metal, ceramic, and other containers which are nontransparent to Raman laser beams. The nontransparent containers are screened by Gravimetric Analyzer (GA), which is a part of BRT 1. AR screening process begins when a container with passenger item is placed inside the enclosure of BRT 1. Then, BRT 1 directs a laser beam of an 830 nm wavelength at the container. The beam penetrates a majority of containers, while the nontransparent containers undergo Gravimetric Analysis. Once the BRT 1's beam penetrates a container, it interacts with its contents resulting in a scattered Raman radiation. Raman is the last name of an Indian physicist who discovered the effect. Raman spectroscopy identifies characteristic vibrational states of molecules through their inelastic scattering of light from the initial laser beam. The vibrational states of molecules become their signatures. The scattered light, carrying information identifying molecules in passenger items, is then collected and analyzed by the BRT 1's detector. The results are displayed to TSOs. BRT 1 screens for threats, HAZMAT, and the most common, benign passenger items. Results indicating a presence of threats or HAZMAT are displayed as alarms. When the BRT 1's laser beam cannot penetrate containers, BRT 1 begins its Gravimetric Analysis to assess a density of items inside such containers. GA assesses mass of containers by weighing them, volume is obtained from container labels, and eventually the density of passenger items inside nontransparent containers is calculated. Density cannot be assessed by GA if the value of items' volume cannot be obtained, and a *small bulk* or a *point & shoot* analysis is conducted, instead. In the cases where density of items can be calculated, BRT 1 still requires from TSOs to select on its display a type of passenger item being screened. If the calculated density is outside the range of densities expected for this particular type of passenger item, an alarm comes on, and the container has to be cleared by another method, like the above mentioned *small bulk* or *point & shoot* analyses, for example. The *small bulk* approach involves a transfer of a small amount of passenger item from its original nontransparent container into a transparent vial, and its Raman analysis. BRT 1, while utilizing its enclosure, can also use a higher laser power, like, e.g., 650 or even 1300 mW, while still remaining 100% safe for human eyes and skin. The higher laser power increases the chances of the laser beam penetration of containers (except for metal and ceramic ones, for example), generates stronger Raman response resulting in lower false alarm rate, and the shorter analysis time.

Additionally, BRT 1 is equipped with Cameras System and Barcode Reader (CS & BR). At least one camera will be installed in each BRT 1's enclosure. Passenger items still alarming at secondary checkpoints will be photographed and their barcode identified. Their pictures and barcode readings will aid future TSA's R&D needs and help in tracking items' origins online by using a Google Lens application, for example. Good quality pictures and barcode can provide important details of passenger items, like volume, mass, SKU number, and chemical composition. Such details can be very useful in the Gravimetric Analysis, as well as, in the interpretation of BRT 1's Raman spectra.

BRT 2 is based on a modified chemical analysis device (CAD). The modification involves an addition of enclosure to the handheld CAD system to eliminate safety issues of an unprotected laser beam. As in the case of BRT 1, such enclosure 'contains' the laser beam light, which cannot escape; therefore, such screening process becomes 100% safe to eyes and skin. BRT 2 uses the laser beam of a 1064 nm wavelength to initiate Raman scattering process and to minimize fluorescence effects. BRT 2 system uses Raman spectroscopy, Cameras System, and Barcode Reader for AR screening, but no Gravimetric Analysis. When Raman fails to resolve an alarm, the described above *small bulk* or *point & shoot* analysis is conducted. The Raman analysis, photography and barcode readouts are conducted in a similar fashion as in BRT 1. The enclosure of BRT 2 is also equipped internally with at least one camera, and externally with a barcode reader.

BRT 3 is a legacy Bottled Liquid Screener (BLS) using Raman effect initiated by a laser beam of a 785 nm wavelength. BRT 3 is similar in operation to BRTs 1-2, except that it is used for screening of liquids only. BRT 3 does not use camera(s) nor barcode reader.

BRT 4 is also a legacy BLS which uses electromagnetic principle for screening, including Wideband Radio Frequency (RF), Infrared (IR), Magnetic Induction, and Gravimetric Analysis.

PLEASE SEE THE SEPARATE SPREADSHEET WITH ATTRIBUTES TABLE IN SHEET1

Table 1. First draft of recommended tag attributes for Bulk Resolution Tool

Attribute Name	**Tag**	**Type**	**VR**	**VM**	**Attribute Description**
SAMPLING MODULE					
Sampling Method					. BRTs 'sample' the inelastically scattered Raman radiation and use GA, RF, IR or Magnetic Induction to screen passenger items. When BRTs fail to resolve X-rays alarms,the small bulk or a point & shoot approach is used by TSOs or TSS-Es.
Container Type					Plastic. Metal, Glass, Ceramic, Wood, Cardboard, Corrugated Cardboard, Paper
Is laser beam able to penetrate container wall?					If no, GA or small bulk or point & shoot approaches are used.

Sample State					The types of sample states: • liquidsolidpowder • aerosolgel • gel • cream • paste.
Attribute Name	Tag	Type	VR	VM	Attribute Description
GENERAL OPERATION MODULE					
Type of Bulk Resolution Tools					The types of Bulk Detectors are: 1st type BRT: Raman Spectroscopy + Gravimetric Analysis + Cameras System/Barcode Reader 2nd type BRT: Raman Spectroscopy + Cameras System/Barcode Reader. 3rd type BRT: legacy BLS' using Raman, GA or legacy BLS' using RF, IR, Magnetic Induction and GA.
Modes of Operation					1st type BRT: Raman, Gravimetric, and Cameras/Barcode Reader modes 2nd type BRT: Raman, and Cameras/Barcode Reader modes 3rd type BRT: Raman, GA or RF, IR, Magntic Induction and GA modes 1.
Detection Algorithms					Detection algorithms are identified by their version numbers, the same way as software versions are identified.

Alarm Response					For threats and HAZMAT items, codes will be displayed. Benign items will be cleared with a possible display of substance(s) detected.
Clear Response					Benign items will be cleared with a possible display of names of substance(s) detected.
Codes					Special codes will be displayed, probably the X-ray codes for threats. Non-threats' names will be displayed. Threats' names or CAS numbers and threats' codes cannot be displayed simultaneously.
Attribute Name	Tag	Type	VR	VM	Attribute Description
BULK RESOLUTION TOOL's RAMAN MODULE					
Laser Type					Near Infra-Red (NIR) 785, 830 or 1064 nm wavelength. Class 3b or 4 but reduced to Class 0 (100% safe to eyes & skin) in enclosure
Laser Power					Ranges of laser power: • <500, • 650, or • 1300 mW or • Continuously adjustable
Raman spectrum					Plot of intensity of Raman response vs. Raman shift [cm^{-1}]. 1st type BRTs-any format. 2nd type BRTs-JSON, text, SPC or other formats, if TSA has a preference.

					3rd type BRT's-to find out from Smiths Detection.
Attribute Name	Tag	Type	VR	VM	Attribute Description
1st and 3rd Type BULK RESOLUTION TOOL's GRAVIMETRIC ANYLYZER MODULE					
Unopened Container Mass					Gravimetric Analyzer has a scale on which masses of metal and ceramic containers are assessed.
Density of passenger items in unopened containers					Approximate density is calculated by dividing the mass of container by the volume of passenger item inside the container.
Passenger Item's category					TSO will be asked to press on the passenger item's image which best describes a type of the passenger item being screened by GA.
Ranges of expected densities for the screened passenger items					GA has a defined range of densities for a given type of passenger items.
Fail					If the calculated density falls outside the expected range of densities.
Pass					If the calculated density falls within the expected range of densities.
Attribute Name	Tag	Type	VR	VM	Attribute Description
BULK RESOLUTION TOOLS' CAMERAS SYSTEM /BARCODE READER MODULE					

Good Quality Photographs/SKU Numbers of Passenger Items					Applies to 1st & 2nd Type of BRTs. Majority of passenger items are available in stores. An extensive information about such items is available on their containers' labels, and online. E.g., their volume or mass, SKU number, and chemical composition can be identified from good quality pictures of their containers and barcode reader. If not all, then the remaining information can be found online.
SKU Numbers of Passenger Items					Good quality photographs/barcode reader will allow for the identification of items' SKU numbers.
Volume or Mass of Passenger Items					Good quality photographs will allow for the identification of items' volumes or masses.
Chemical Composition of Passenger Items					Good quality photographs will allow for the identification of the passenger items' chemical compositions which might be very useful in the interpretation of BRTs' Raman spectra, and GA's densities.
Name, Brand of Item					Can be identified from good quality pictures or through online search.
Manufacturer					Can be identified from good quality pictures or through online search.
Attribute Name	Tag	Type	VR	VM	Attribute Description

BULK RESOLUTION TOOLS' WIDEBAND RADIO FREQUENCY, INFRARED, MAGNETIC INDUCTION, and GRAVIMETRIC MODULES					Applies only to one type of 3rd Type BRTs-legacy BLS'. Check with Chris if they show a cumulative result of all of them or individual ones.
Pass					As indicated by the instrument
Fail					As indicated by the instrument

CAMERAS SYSTEM

EXPLOSIVES TRACE DETECTION (ETD)

Introduction

Explosives Trace Detectors (ETDs) consist of explosive detection equipment able to detect traces of explosives.. The detection is accomplished by sampling non-visible "trace" amounts of particulates. A trace sample is collected onto a swab/trap material which is inserted into a desorber on the system. The sample trap is heated in the desorber to release vapors from any explosive that was collected. The sample is then analyzed by Ion Mobility Spectrometry. The vapor is drawn into an ionization chamber, ionized, analyzed, and sample leftovers are exhausted from the system. If a compound of interest is found, the system processes an Alarm. Explosives' detection and identification is based on the measurements of molecular ion mobility within a drift tube. After ionization, ions start their journey to the collector, pulled or drawn by an electrical field along the drift tube, while colliding with millions of clean air molecules at atmospheric pressure. Small ions arrive earlier, the larger ions move slower and arrive at the collector later. A stereochemistry of ions also plays an important role in the mobility of ions. Ionizable molecules are identified by their arrival time at the collector, called "drift time". . There are a variety of emerging ETD technologies such as Mass Spectrometry, , , and Capillary Zone Electrophoresis. In addition, trap materials such as enhanced traps and chemically coated mesh are under development as well as sampling devices such as vapor and/or particle collection devices.

The first cut tag attributes are shown in Table 1.

Table 1. First draft of recommended tag attributes for ETD

Attribute Name	Tag	Type	VR	VM	Attribute Description
SAMPLING MODULE					
Sampling Method	(3300, 0312)	1	ST	1	Method by which sample is acquired: hand sampling/swabbing, wand, external device that collects the sample.
Sample Trap Media	(3300, 0314)	1	ST	1	Composition of sample trap: Nomex®, paper, Teflon™ coated fiberglass, metal mesh, chemically enhanced traps.
Sample State	(3300, 0316)	1	ST	1	Sample state of explosive(s) or chemical substance(s) being analyzed, particle or vapor.
Sampling Wand Pressure	(3300, 0318)	1	ST	1	Certain wands are built to measure pressure applied during sample collection with a sample trap.
GENERAL OPERATION MODULE					
aType of ETD	(3300, 0308)	1	LT	1	Identifies the technology type of ETD: • Ion-mobility spectrometry (IMS) • Raman Spectroscopy • Mass spectrometry (MS) - Fourier Transform - Time of Flight - Quadrupole - Ion trap - Low Temperature Plasma (LTP) - Triple Quadrupole • Mid-Wave Infrared Reflectance Spectroscopy • Infrared Backscatter

					• Capillary zone electrophoresis • High Performance IMS-MS ETD
Mode of Operation	(3300, 0310)	1	ST	1	The mode of operation of the unit. • Handheld • Benchtop
Detection Algorithms	(3300, 0320)	1	LO	1	Separate Algorithm for each explosive or chemical substance. An algorithm consists of the requirements that must be met for the system to give an alarm response for an explosive or chemical substance.
Alarm Response	(3300, 0322)	1	ST	1	Indication that the system detected explosive(s) or chemical substance(s). The requirements set out in the algorithm(s) were met.
Clear Response	(3300, 0324)	1	ST	1	Indication that no explosive(s) or chemical substance(s) were detected. The requirements in the algorithm(s) were not met.
E-Codes	(3300, 0326)	1	ST	1	E-Codes for the explosive(s) or chemical substance(s) that the system alarmed on.

ION MOBILITY STECTROMETRY MODULE					
Ionization Source IMS	(3300, 0328)	1C	ST	1	The type of ionization source used to impart charge to molecules to be analyzed in IMS. • Ni63 (radioactive) • Photo-emission (nonradioactive) • Corona discharge (nonradioactive)
IMS spectrum	(4300, 0330)	1C	ST	1	An intensity vs. drift time plot representing an IMS analysis of an explosive or chemical substance. Hence, the IMS spectrum presents drift times, which are arrival times of sample ions at the collector/ detector..
Peak amplitude	(3300, 0332)	1C	SL	1	Amplitude of peak in the IMS spectrum.
Peak width	(3300, 0334)	1C	SL	1	Width of peak in the IMS spectrum
Peak Slope	(3300, 0336)	1C	SL	1	Peak Slope in the IMS spectrum
Peak position(0-25 milliseconds)	(3300, 0338)	1C	SL	1	Location of peak in the IMS spectrum
Peak threshold	(3300, 0340)	1C	SL	1	Peak Thresholds defined in the algorithm required for alarm response.
Mode (Polarity)	(3300, 0342)	1C	SH	1	Negative or Positive Mode. (Negative or positive ions detected.) For IMS systems.
Delta					It is called different names on different detectors. It is a difference between the center of the detection window and the actual position of the peak. Usually, a peak

					positioned at the center of the window would constitute the ideal hit. If it is a far away from the center, it might mean a false alarm. It can be given also as a percentage of the window width.
MASS SPECTROMETRY MODULE					
Ionization Source (MS)	(3300, 0344)	1C	ST	1	The type of ionization source used to impart charge to molecules to be analyzed in an MS • Low Temperature Plasma • Laser • Electrospray ionization • Chemical ionization • Electron ionization • Atmospheric pressure chemical ionization • Spark ionization • Glow discharge
Mass Spectrum (Plural Spectra) (MS)	(3300, 0346)	1C	SH	1 … n	An intensity vs. m/z (mass-to-charge ratio) plot representing an MS analysis of an explosive or chemical substance. Hence, the mass spectrum of a sample is a pattern representing the distribution of ions by mass (more correctly: mass-to-charge ratio) in a sample.
Mass to charge ratio	(3300, 0348)	1C	SH	1	Mass to charge ratio of selected peaks in an MS spectrum. Plotted as a function of intensity.
Peak intensity at a specific mass	(3300, 0350)	1C	SH	1	Peak intensity at a specific mass to charge ratio in an MS spectrum.

INFRARED SPECTROSCOPY MODULE					
Spectrum	(3300, 0352)	1C		1 … n	A transmittance vs. wavenumber (measured in cm^{-1}) plot representing an IR analysis of an explosive or chemical substance. Hence, the spectrum of a sample is a pattern representing the distribution of molecules by wavenumber in a sample.
Wavenumber (IR Spectroscopy)	(3300, 0354)	1C	SL	1	Measured in cm^{-1}. Location of peak(s) in the IR Spectrum. Function of transmittance.
RAMAN SPECTROSCOPY MODULE					
Laser Wavelength	(3300, 0356)	1C	SL	1	Wavelength of light used to interact with the sample. Used for Raman Spectroscopy.
Raman Spectrum	(3300, 0358)	1C		1 … n	An intensity vs. wavenumber (Raman shift) plot representing a Raman analysis of an explosive or chemical substance. Raman shift is the difference in frequency between the laser light and the scattered light from interaction with sample molecules.
Wavenumber (Raman Spectroscopy)	(3300, 0358)	1C	ST		Raman Shift cm-1. Location of peak(s) in the Raman Spectrum.
CAPILLARY ZONE ELECTROPHESIS MODULE					

Electropherogram	(3300, 0360)	1C	LT	1 … n	Data is displayed as an electropherogram, which reports detector response as a function of time.
Table 71 General Equipment Module					
Manufacturer	(0008, 0070)	1	LO	1	Manufacturer of the equipment that produced the composite instances.
Manufacturer's Model Name	(0008, 1090)	1	LO	1	Manufacturer's model name of the equipment that produced the composite instances.
Device Serial Number	(0018, 1000)	1	LO	1	Manufacturer’s serial number of the equipment that produced the composite instances. Note: This identifier corresponds to the device that actually created the images, such as a CT console, and may not be sufficient to identify all of the equipment in the imaging chain. Example: L123456.
Machine Location	(0008 0080)	1	LO	1	Airport code or other unique location identifier where the equipment that produced the composite instance is located.
Machine Address	(0008,0081)	1	ST	1	The location identifier or physical address where equipment that produced the composite instances is located.
Machine ID	(0008,1010)	1	SH	1..n	One or more user-defined names identifying the machine that produced the composite instances.
Machine Sub-Location	(0008,1040)	3	LO	1	User-defined sub-location where the equipment that produced the composite instances is located, e.g., airport terminal.

Software Versions	(0018,1020)	1	LO	1…n	Manufacturer's designation of software version of the equipment that produced the composite instances.
Date of Last Calibration	(0018,1200)	1	DA	1…n	Date when the image acquisition device calibration was last changed in any way. Multiple entries may be used for additional calibrations at other times. See Sec. 12.1.1.1.1 for further explanation.
Time of Last Calibration	(0018,1201)	1	TM	1…n	Time when the image acquisition device calibration was last changed in any way. Multiple entries may be used. See Sec. 12.1.1.1.1 for further explanation.
Table 61 TDR Module					
TDR Type	(4010,1027)	1	CS	1	Identifies the alarm decision type of the TDR.
					Defined Terms include:
					MACHINE
					OPERATOR
					UNDEFINED
					Note: MACHINE and OPERATOR are fully defined.
Alarm Decision	(4010,1031)	1	CS	1	Identifies the alarm decision for the OOI.
					Enumerated Values are:
					ALARM
					CLEAR
					UNKNOWN
					Note: The Value 'UNKNOWN' should be used to indicate 'NO DECISION' and other outcomes in operator TDR. The value 'ALARM' should be used

					to indicate ‘SUSPECT’ and other outcomes in operator TDR.
Threat Detection Algorithm and Version	(4010,1029)	1C	LO	1…n	The order of values shall be: Manufacturer, version number designation for Detection algorithm and accompanying control parameters (such as configuration). String. Vendor-defined. Required if TDR Type (4010,1027) = ATR.
Number of Total Objects	(4010,1033)	1	US	1	The non-negative number of PTOs in the OOI evaluated and reported by the detection system or operator.
Number of Alarm Objects	(4010,1034)	1C	US	1	The number of PTOs that alarmed. Shall be less than or equal to the Number of Total Objects (4010,1033) and contain a value of zero or greater. Required if Alarm Decision (4010,1031) equals ALARM.

The standard General Equipment module will be used to note the system characteristics.

DIFFERENTIAL PHASE CONTRAST (DPC) IMAGING

Background

There have been advances in X-ray technology that will eventually make their way into the Digital X-rays (DX) and Computed Tomography (CT) of security equipment implementation and DICOS. The three most promising are Coded Aperture Imaging (CAI), Phase Contrast Imaging (PCI), and Differential Phase Contrast (DPC) imaging. CAI and PCI are exceptional cases of DPC and will be treated as a subset of DPC in DICOS. This document provides a short description of each of the three X-ray technologies and figures showing how they relate to grating locations for DPC.

Differential Phase Contrast Imaging

A novel X-ray imaging method, Talbot-Lau grating interferometry enabled X-ray phase-contrast imaging, can simultaneously capture three types of unique object information from one set of acquired data: Absorption, Differential Phase Contrast (DPC), and Dark-Field (DF). A high-level implementation is shown in Figure 1.

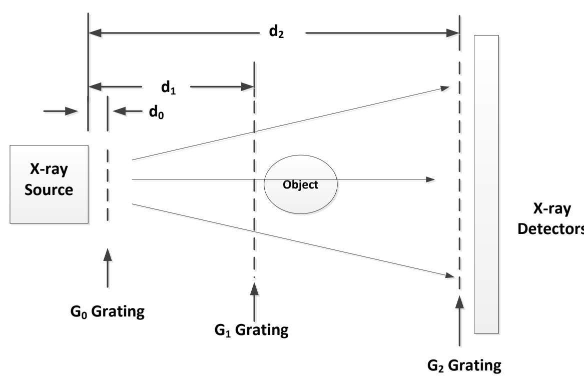


Figure 1. High-level schematic of a DPC Imaging System. This G_0 is the Coherent grating next to the X-ray source, G_1 is the Object or Phase Grating, and G_2 is the Analyzer Grating in front of the X-ray detectors. The distance from G_0 to the X-ray source is d_0, G_1 to the X-ray source is d_1, and the distance from G_2 to the X-ray source is d_2.

Studies have found that the DPC signal could provide superior contrast performance for certain low-density, low *Z* materials compared to the conventional absorption contrast. Besides, the DF signal is susceptible to specific delicate structures such as element composition. Due to these potential advantages, numerous research interests have been attracted with the hope of translating such novel X-ray imaging methods into security applications.

Despite these likely advancements, however, the low radiation dose efficiency of the Talbot-Lau interferometer strongly impedes its wide applications. This is mainly due to the photon absorption on the analyzer grating. The pitch or frequency of the gratings will be a function of the effective energy of the X-ray beam. Usually, the analyzer grating blocks more than half of the photons that have already penetrated through the object. The three different images are generated from the same set of X-Ray detectors. There are various methods of reconstructing the three additional images from the captured X-ray detector data. The most popular implementation is based on the Fourier Transform, but other reconstruction methods can be found in present research publications.

If DPC or its variants are present on the screening device, the DPC macro shown in Table 2 would be added to the General Equipment Module with the necessary gratings and related information completed.

Table 2. Added the General Equipment module as a macro when present in the X-Ray Modality.

Attribute Name	Tag	Type	VR	VM	Attribute Description
Effective Energy	(4300, 0902)	1	ST	1	This is the energy for which the gratings were designed for.
Type of G_O	(4300, 0904)	1C	CS	1C	Defined Terms: • X-RAY ANODE • GRATING • MASK
Mask Characteristics	(4300, 0906)	1C	ST	1C	Describe how the CAI mask was designed. For example: random binary matrix, sinusoid in *x* (horizontal, and a quadratic in *y* (vertical), or Hadamard matrix.
Distance G_O from X-ray Source	(4300, 0908)	1C	IS	1C	Distance from the output of the X-ray source to the G_0 grating. Distance in centimeters
Type of G_1	(4300, 0910)	1C	ST	1C	Defined Terms: • GRATING • OTHER
Distance of G_1 from X-Ray Source	(4300, 0912)	1C	IS	1C	Distance from the output of the X-ray source to the G_1 grating. Distance in centimeters
Type of G_2	(4300, 0914)	1C	ST	1C	Defined Terms: • GRATING • OTHER
Distance of G_2 from X-Ray Source	(4300, 0916)	1C	IS	1C	Distance from the output of the X-ray source to the G_2 grating. Distance in centimeters
G_0 Absorption Period	(4300, 0918)	1C	IS	1C	The pitch or period of the G_0 grating
G_1 Phase Period	(4300, 0920)	1C	IS	1C	The period of the G_1 grating
G_2 Analyzer Period	(4300, 0922)	1C	IS	1C	The period of the G_2 grating
Visibility	(4300, 0924)	1C	IS	1C	The resulting visibility of the phase and dark image

Absorption X-ray Detector Size	(4300, 0926)	1C	DS	3	The resulting size of the X-ray detectors which are combined to provide the absorption pixel size (x, y)
Absorption Reconstruction Voxel Size	(4300, 0928)	1C	DS	3	The resulting size of the X-ray detectors which are combined to provide the absorption pixel size (x, y)
Phase X-ray Detector Size	(4300, 0930)	1C	DS	3	The resulting size of the X-ray detectors which are combined to provide the absorption pixel size (x, y)
Phase Reconstruction Voxel Size	(4300, 0932)	1C	DS	3	The resulting size of the X-ray detectors which are combined to provide the phase pixel size, (x, y)
Dark Image X-ray Detector Size	(4300, 0934)	1C	DS	3	The resulting size of the X-ray detectors which are combined to provide the absorption pixel size (x, y)
Dark Image Reconstruction Voxel Size	(4300, 0936)	1C	DS	3	The resulting size of the X-ray detectors which are combined to provide the dark image pixel size, (x, y)
Reconstruction Algorithm for Phase Image	(4300, 0938)	1C	CS	1C	The type of algorithm used for reconstruction of the phase or dark image. • FFT • MODIFIED FFT • OTHER
Reconstruction Algorithm for Dark Image	(4300, 0940)	1C	CS	1C	The type of algorithm used for reconstruction of the phase or dark image. • FFT • MODIFIED FFT • OTHER
Table 71 General Equipment Module					
Attribute Name	Tag	Type	VR	VM	Attribute Description
Manufacturer	(0008, 0070)	1	LO	1	Manufacturer of the equipment that produced the composite instances.
Manufacturer's Model Name	(0008, 1090)	1	LO	1	Manufacturer's model name of the equipment that produced the composite instances.

Device Serial Number	(0018, 1000)	1	LO	1	Manufacturer's serial number of the equipment that produced the composite instances. Note: This identifier corresponds to the device that actually created the images, such as a CT console, and may not be sufficient to identify all of the equipment in the imaging chain. Example: L123456.
Machine Location	(0008 0080)	1	LO	1	Airport code or other unique location identifier where the equipment that produced the composite instance is located.
Machine Address	(0008,0081)	1	ST	1	The location identifier or physical address where equipment that produced the composite instances is located.
Machine ID	(0008,1010)	1	SH	1.. n	One or more user-defined names identifying the machine that produced the composite instances.
Machine Sub-Location	(0008,1040)	3	LO	1	User-defined sub-location where the equipment that produced the composite instances is located, e.g., airport terminal.
Software Versions	(0018,1020)	1	LO	1…n	Manufacturer's designation of software version of the equipment that produced the composite instances.
Date of Last Calibration	(0018,1200)	1	DA	1…n	Date when the image acquisition device calibration was last changed in any way. Multiple entries may be used for additional calibrations at other times. See Sec. 12.1.1.1.1 for further explanation.
Time of Last Calibration	(0018,1201)	1	TM	1…n	Time when the image acquisition device calibration was last changed in any way. Multiple entries may be used. See Sec. 12.1.1.1.1 for further explanation.

Coded Aperture Imaging

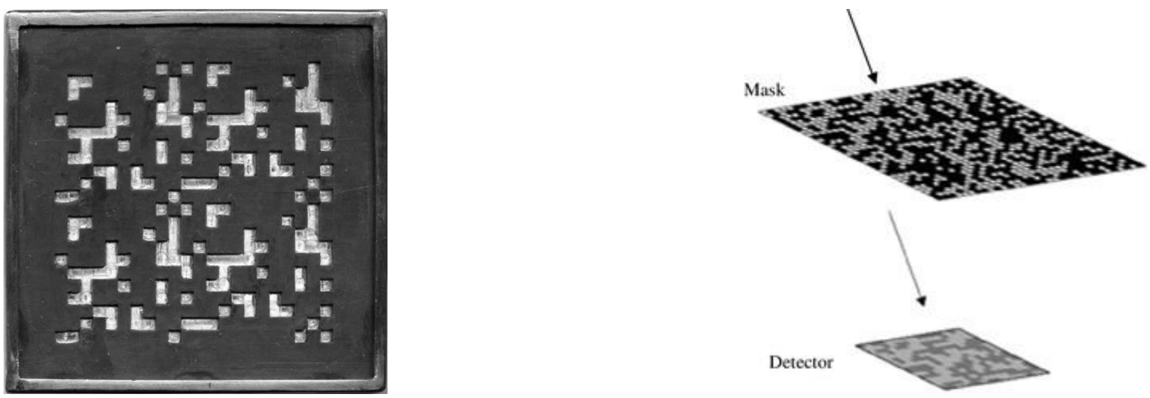
The energy of hard X-rays is too high to be reflected or refracted and cannot be focused by lenses or mirrors as for visible light. Instead, image modulation by apertures is therefore often used.

Coded apertures or coded-aperture masks are grids, gratings, or other patterns of materials opaque to various wavelengths of electromagnetic radiation. The wavelengths are usually high-energy radiation such as X-rays and gamma rays. A coded "shadow" is cast upon a plane by blocking radiation in a general pattern. The properties of the original radiation sources can then be mathematically reconstructed from this shadow.

In a coded aperture implementation, images from multiple apertures will overlap at the detector array. It is thus necessary to use a computational algorithm, which depends on the precise configuration of the aperture arrays, to reconstruct the original image. By using this algorithm, a higher quality image can be achieved without a lens. Furthermore, the image is formed and tolerant to faults in individual sensors.

One arrangement using a mask is shown in Figure 2a. The wavelengths are usually high-energy radiation such as X-rays and gamma rays. By blocking radiation in a known design, common patterns are shown in Table 2; a coded "shadow," as shown in Figure 2b, is cast upon a plane. A high-level schematic of a layout of a CAI system is shown in Figure 3.

The information of CAI would be completed if present in the screening device as shown in Table 3. This would be related to the G_0 grating and related information.



(a) Mask Layout

(b) Imaging on the X-ray detectors

Figure 2. (a) A typical mask placed right after the X-ray tube (b) the shadowing of the mask on the X-ray detector array.

Table 3. Listing of some standard CAI masks taken from [1]

Description Based on	Implementation
Identity Matrix	Coordinate or polar
Hadamard Matrix	Coordinate or polar
Random Binary Matrix	Coordinate or polar
Sinusoid in *x* (horizontal) and a quadratic residual in *y* (vertical)	Coordinate or polar

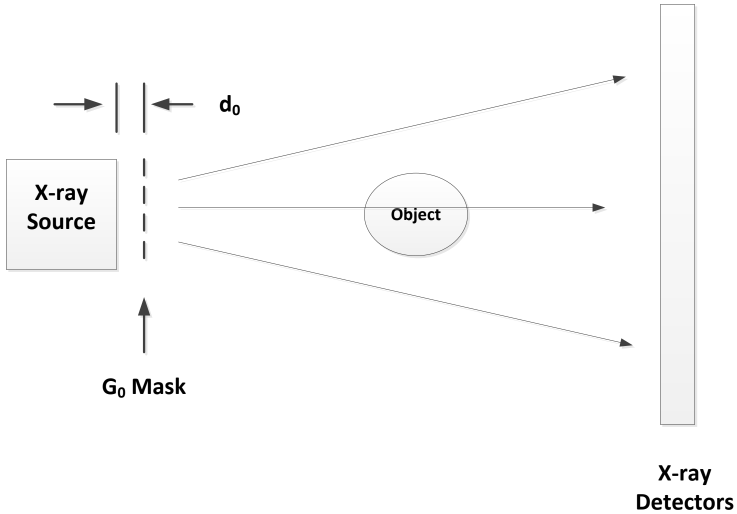


Figure 3. High-level schematic of a CAI system. G_0 is the mask or grating next to the X-ray source. The d_0 gives the distance from the mask to the X-ray source.

Phase Contrast Imaging

PCI, also known as phase-sensitive X-ray imaging, is a general term for different technical methods that use information about changes in the phase of an X-ray beam that passes through an object to create its images. Standard X-ray imaging techniques like DX or CT rely on increasing the X-ray beam's attenuation when traversing the object of interest. This attenuation can be measured directly with X-ray detectors. In PCI, however, the beam's phase shift caused by the object of interest is not measured directly. Still, it is transformed into variations in intensity, which the detector can then register. A high-level diagram is shown in Figure 4.

In addition to producing projection images, PCI, like a conventional transmission, can be combined with tomographic techniques to obtain the 3D distribution of the fundamental part of the refractive index of the object of interest. When applied to samples of atoms with low atomic number *Z*, PCI is more sensitive to density variations in the example than conventional transmission-based X-ray imaging.

Various PCI techniques have been developed, all of which are based on observing interference patterns between diffracted and undiffracted waves. The most common procedures are crystal interferometry, propagation-based imaging, analyzer-based imaging, edge-illumination, and grating-based imaging.

The information of PCI would be completed if present in the screening device as shown in Table 1. This would be related to the G_1 and G_2 grating and related information.

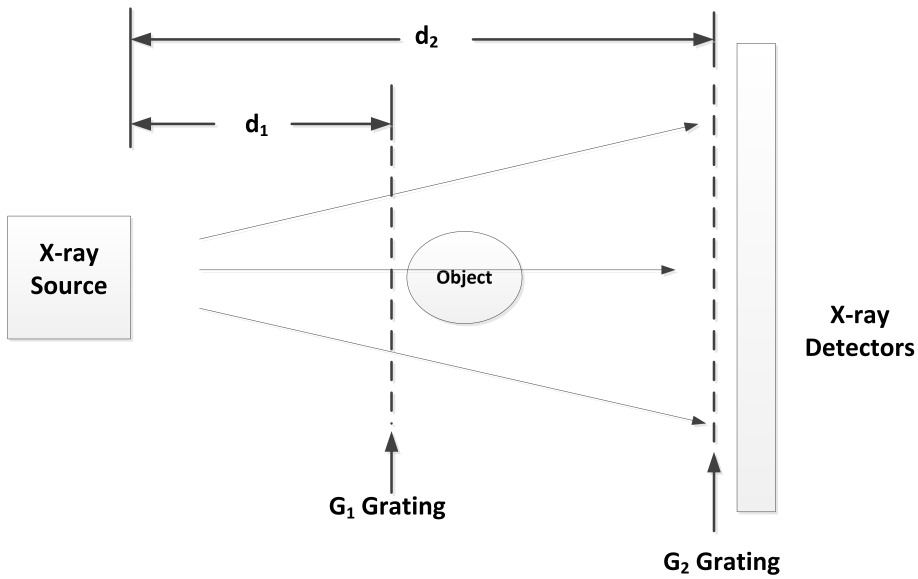


Figure 4. High-level schematic of a PCI System. In this case, the Object or Phase Grating is G_1, and the Analyzer Grating in front of the X-ray detectors is G_2. The distance from G_1 to the X-ray source is d_1, and the distance from G_2 to the X-ray source is d_2.

References

[1] Brady, David J.; Marks, Daniel L.; MacCabe, Kenneth P.; and O'Sullivan, Joseph A., ,"Coded apertures for x-ray scatter imaging." Applied Optics.52,32. 7745-7754. (2013).

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AIR CARGO

Introduction

Air Freight, also known as air cargo, is the mode of transport used to transport cargo swiftly by air. Airfreight is the preferred form of transport when shipping or transporting goods in the fastest time around the globe. Air cargo is shipped through the same gateway as the passenger or commercial airlines.

General and Special are the two types of Air Cargo:

General Cargo - This type of cargo consists of high-value cargo like pharmaceuticals, jewelry, and electronics and currency. Even though air shipping is more expensive than sea transport, it is still the best mode for transporting high-value fragile goods.

Special Cargo - Preferred type for transporting under special conditions such as temperature control, air conditions, and special casing, usually in cases of hazardous goods or livestock

Since in most cases air cargo is shipped in the aircraft cargo bay, which in most cases also carries passengers' luggage, it must be checked for the presences of explosives. Presently the air cargo detection standard is slightly different from the Checkpoint CT and Checked Baggage, but soon will be the same. The same standards used for checked baggage and check-point are applied.

In most applications, the process before energizing any X-ray sources, the air cargo container needs to be checked for the presence of any life forms. This would be done using the appropriate Orthogonal Air Cargo Technologies which provides a simple binary result. For Air Cargo, there needs to be a check for the presence of carbon dioxide and a heartbeat before proceeding with further investigation. The results of these two safety checks need to be reported to the scanning device control system before performing any radiation screening. The two Orthogonal Air Cargo Technologies used for air cargo are defined below.

Carbon Dioxide (CO_2) and heartbeat monitors are orthogonal technologies to detect intruders (stowaways and live animals) in air cargo. The primary motivation is to catch threatening terrorists who might wish to hide in air cargo and then emerge to hijack or threaten airplanes in which located.

The second motivation is to identify any animals being smuggled in through air cargo. Among the observations from early testing of heartbeat monitors were that results/reliability were sensitive to the amount of background vibration in the airport complex. This process might obscure the 4 Hz signal from a heartbeat. Air shipment is currently being inspected using trained dogs with heartbeat monitors and CO_2 sensors as confirmatory technologies.

The process defines that the Orthogonal Air Cargo Technologies results be reported to the control station and must be negative before energizing any of the scanning sources. The IOD is shown in Table 4 that would need to be completed for the CO_2 and Heartbeat detector to accompany the imaging Air Cargo IOD (DX, CT, or ETD.)

The type of air cargo system will be identified by General Equipment Module and the reconstruction method/identification in the TDR module.

This section will be considered the following types of Air Cargos:

a. Digital X-Ray (DX)
b. Computed Tomography (CT)
c. Explosives Trace Detection (EDT) – modified version

DIGITAL X-RAY (DX)

For a DX based Air Cargo, the reporting of the image and meta data shall follow the *Digital X-Ray (DX) Image Information Object Definition (IOD)* shown in Section 8 of the DICOS standard. Section 8.2.1, DX IOD Module, Table 30, shall be used to report the image and meta data. The detection results will be reported as described in Section 11.4, Threat Detection Report (TDR) Module, Table 61.

Also included would be the CO_2 and Heartbeat Detector identified in Section Orthogonal Air Cargo Technologies.

COMPUTED TOMOGRAPHY (CT)

For a CT based Air Cargo, the reporting of the image and meta data shall follow the *Computed Tomography (CT) Image Information Object Definition (IOD)* shown in Section 7 of the DICOS standard. Section 7.3, CT Image IOD Module, Table 14, shall be used to report the image and meta data. The detection results will be reported as described in Section 11.4, Threat Detection Report (TDR) Module, Table 61.

Also included would be the CO_2 and Heartbeat Detector identified in Section Orthogonal Air Cargo Technologies.

EXPLOSIVES TRACE DETECTION (ETD)

TBD

Also included would be the CO_2 and Heartbeat Detector identified in Section Orthogonal Air Cargo Technologies.

MATERIAL IDENTIFICATION OF UNKNOWN SUBSTANCE (MIDUS)

Introduction

A variety of COTS Material Identification of Unknown Substance (MIDUS) systems were introduced around 2010 for the purpose of providing advanced technologies for threat material (TM) identification.   They provide the ideal solution for identifying a very wide range of explosives, biological and chemical weapons and everyday materials. This technology also detects substances through a range of containers such as plastic bags and glass bottles. MIDUS technologies are frequently organized under the category of "bulk" material identification to distinguish them from ETD technologies.

The type of air cargo system will be identified by General Equipment Module and the reconstruction method/identification in the TDR module.

This section will be considered the following types of MIDUS:

d. Digital X-Ray (DX)
e. Computed Tomography (CT)
f. Quadrupole Resonance (QR)
g. Explosives Trace Detection (EDT) – modified version

DIGITAL X-RAY (DX)

For a DX based MIDUS, the reporting of the image and meta data shall follow the *Digital X-Ray (DX) Image Information Object Definition (IOD)* shown in Section 8 of the DICOS standard. Section 8.2.1, DX IOD Module, Table 30, shall be used to report the image and meta data. The detection results will be reported as described in Section 11.4, Threat Detection Report (TDR) Module, Table 61.

COMPUTED TOMOGRAPHY (CT)

For a CT based MIDUS, the reporting of the image and meta data shall follow the *Computed Tomography (CT) Image Information Object Definition (IOD)* shown in Section 7 of the DICOS standard. Section 7.3, CT Image IOD Module, Table 14, shall be used to report the image and meta data. The detection results will be reported as described in Section 11.4, Threat Detection Report (TDR) Module, Table 61.

ADVANCED IMAGING TECHOLOGY (AIT)

For an AIT-2D based MIDUS, the reporting of the image and meta data shall follow the *Advanced Imaging Technology (AIT) Image Information Object Definition (IOD)* shown in Section 9 of the DICOS standard. Section 9.2.2, 2D AIT IOD Module Table, Table 37, shall be used to report the image and meta data. The detection results will be reported as described in Section 11.4, Threat Detection Report (TDR) Module, Table 61.

For an AIT-3D based MIDUS, the reporting of the image and meta data shall follow the *Advanced Imaging Technology (AIT) Image Information Object Definition (IOD)* shown in Section 9 of the DICOS standard. Section 9.3.2, 3D AIT IOD Module Table, Table 41, shall be used to report the image and meta data. The detection results will be reported as described in Section 11.4, Threat Detection Report (TDR) Module, Table 61.

QUADRUPOLE RESONANCE (QR)

For a QR based MIDUS, the reporting of the image and meta data shall follow the *Quadrupole Resonance (QR) Image Information Object Definition (IOD)* shown in Section 10 of the DICOS standard. Section 10.2 QR Image IOD Modules, Table 54, shall be used to report the image and meta data. The detection results will be reported as described in Section 11.4, Threat Detection Report (TDR) Module, Table 61.

EXPLSOIVES TRACE DETECTION (ETD)

TBD

X-RAY DIFFRACTION (XRD)

Introduction

X-ray Diffraction (XRD) is a highly versatile technique that provides chemical information for elemental analysis as well as for phase analysis. The technique identifies explosives from benign materials using the characteristic Bragg features seen in coherently scattered X-rays.

The XRD profiles arise from the molecular interference when X-rays are coherently scattered by a substance. The accurate identification of the target material depends on the ability to detect and resolve the peaks present in the coherent scatter profiles.

The type of XRD system will be identified by General Equipment Module and the reconstruction method/identification in the TDR module.

This section will address the CT XRD.

COMPUTED TOMOGRAPHY (CT)

> The reporting of the image and meta data shall follow the *Computed Tomography (CT) Image Information Object Definition (IOD)* shown in Section 7 of the DICOS standard. Section 7.3, CT Image IOD Module, Table 14, shall be used to report the image and meta data. The detection results will be reported as described in Section 11.4, Threat Detection Report (TDR) Module, Table 61.

ENHANCED WALK-THROUGH ANOMALY DETECTOR (EWTAD)

Introduction

The Enhanced Walk-Through Anomaly Detector (EWTAD) will detect metallic objects on people passing through the detector, such as knives, weapons etc. The EWTAD level of detection sensitivity can be adjusted to meet varying threats.

These systems have been specifically designed for rapid deployment, with stop and search operations for the detection of knives and weapons. They will detect both large and small concealed metallic items containing ferrous metals.

These are available with different numbers of detection zones, i.e., 1, 2, 6, 12, 18 and 33 zones, the greater the number of detection zones, the more accurate the location of a metallic object on the person can be determined, saving operator time.

The type of Enhanced Walk-Through Detector system will be identified by General Equipment Module and the reconstruction method/identification in the TDR module.

The present EWTAD presents a binary output (yes/no) for the TSO to determine the location of the threat on the passenger. There is no image or any other data that is presented, just a very basic Threat Detection Report (TDR) stating the results of the modality analysis. The required modules for the different Orthogonal Air Cargo Technologies will use the general form as seen in Table 4. The detection results will be reported as described in Section 11.4, Threat Detection Report (TDR) Module, Table 61.

Table 4. EWTAD IOD Modules

IE	Module	Reference	Usage
Owner	Owner	Sec. 3.1	U
OOI	OOI	Section 4	M
	Itinerary	Sec.4.2	U
Scan	General Scan	Section 5	M
Series	General Series	Section 6	M
Equipment	General Equipment	Sec. 12.1.1	M
	SOP Common	Sec. 12.4**Error! Reference source not found.**	M
	Common Instance Reference	Sec. 12.5	M
Note: M is Mandatory; C is Conditional; and U is User-Defined.			

There is only one type of EWTAD that will be considered and that is the magnetometer sensing screening system. A magnetometer is a device that measures magnetic field or magnetic dipole moment. Different types of magnetometers measure the direction, strength, or relative change of a magnetic field at a particular location. Other magnetometers measure the magnetic dipole moment of a magnetic material such as a ferromagnet, for example by recording the effect of this magnetic dipole on the induced current in a coil.

ORTHOGONAL AIR CARGO TECHNOLOGIES

Introduction

Orthogonal Air Cargo Technologies are the principal mechanisms of more effective screening capabilities into the air cargo chain. The main goal is to reduce the potential vulnerability in the air cargo system, while reducing costs so the improved capabilities are commercially viable for the Air Cargo screening stakeholders. This technology can go a long way in helping to prevent human trafficking, illegal immigration, animal trafficking and also, the radiation of living beings by cargo scanners.

Orthogonal Air Cargo Technologies provides aviation security and directly supports the DHS Transportation Security mission by providing support to the TSA Air Cargo Aviation Security mission.

Presently concerned with two types of modalities: the Carbon Dioxide (CO_2) and the heartbeat monitor.

Carbon dioxide (CO_2) and heartbeat monitors are orthogonal technologies to detect intruders (stowaways and live animals) in air cargo. The primary motivation is to catch threatening terrorists who might wish to hide in air cargo and then emerge to hijack or threaten airplanes in which located.

The second motivation is to identify any animals being smuggled in through air cargo. Among the observations from early testing of heartbeat monitors were that results/reliability were sensitive to the amount of background vibration in the airport complex. This process might obscure the 4 Hz signal from a heartbeat. Air shipment is currently being inspected using trained dogs with heartbeat monitors and CO_2 sensors as confirmatory technologies.

CO_2 Detector:

> A handheld or portable devices that collects air samples and evaluates the concentration of carbon dioxide to detect the presence of a concealed human or live animal in a tendered cargo item.

Heartbeat Detector:

> A device that detects heartbeats in stowaways, with magnetic-seismic sensors, which are attached to a vehicle or cargo hold.

The Orthogonal Air Cargo Technologies used present a binary output (yes/no). There is no image or any other data that is presented, just a very basic Threat Detection Report (TDR) stating the results of the modality analysis. The required modules for the different Orthogonal Air Cargo Technologies will use the general form as seen in Table 4.

Table 4. Orthogonal Air Cargo Technology IOD Modules

IE	Module	Reference	Usage
Owner	Owner	Sec. 3.1	U
OOI	OOI	Section 4	M
	Itinerary	Sec.4.2	U
Scan	General Scan	Section 5	M
Series	General Series	Section 6	M
Equipment	General Equipment	Sec. 12.1.1	M
	SOP Common	Sec. 12.4**Error! Reference source not found.**	M
	Common Instance Reference	Sec. 12.5	M
Note: M is Mandatory; C is Conditional; and U is User-Defined.			

This section will be considered the following types of Orthogonal Air Cargo Technology Modalities:

a. Carbon Dioxide (CO_2) detector
b. Heartbeat detector

CARBON DIOXIDE (CO_2) DETECTOR

For a CO_2 detector, used for Air Cargo, the reporting of the modality shall follow Table 4. The detection results will be reported as described in Section 11.4, Threat Detection Report (TDR) Module, Table 61.

HEARTBEAT DETECTOR

For a Heartbeat detector, used for Air Cargo, the reporting of the modality shall follow Table 4. The detection results will be reported as described in Section 11.4, Threat Detection Report (TDR) Module, Table 61.