Automatic Threat Recognition Solutions for Security Imaging

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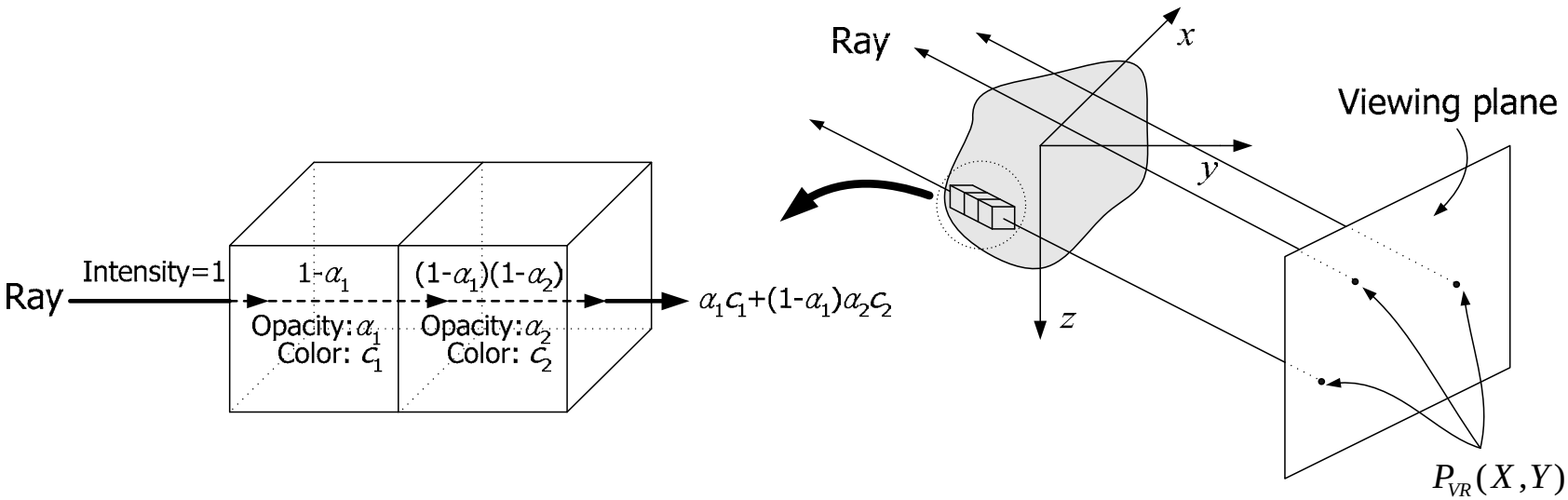
ATR=Automated Threat Detection

- Current airport screening methods are labor intensive
- Algorithms are under development to automate many aspects of threat detection
- ATR can be used to enhance operator performance
- In certain cases ATR can replace human operators

Airport (ATR) Applications

- Checked luggage: electronic unpacking
- Liquid classification in carry on bags
- Trucks and shipping containers at the borders
- Whole Body Imaging at the checkpoint
- The Common Workstation

Volume Rendering for Electronic Unpacking of Checked Luggage



$$I(s) = \int_{s_0}^{s} q(s')e^{-\int_{s_0}^{s'} \kappa(s'')ds''} ds'$$

Discretization: $$I = \sum_{k=0}^{n-1} q(s_0 + k\Delta s')e^{-\sum_{k'=0}^{k-1} \kappa(s_0 + k'\Delta s'')} = \sum_{k=0}^{n-1} q(s_0 + k\Delta s')\prod_{k'=0}^{k-1} e^{-\kappa(s_0 + k'\Delta s'')}$$

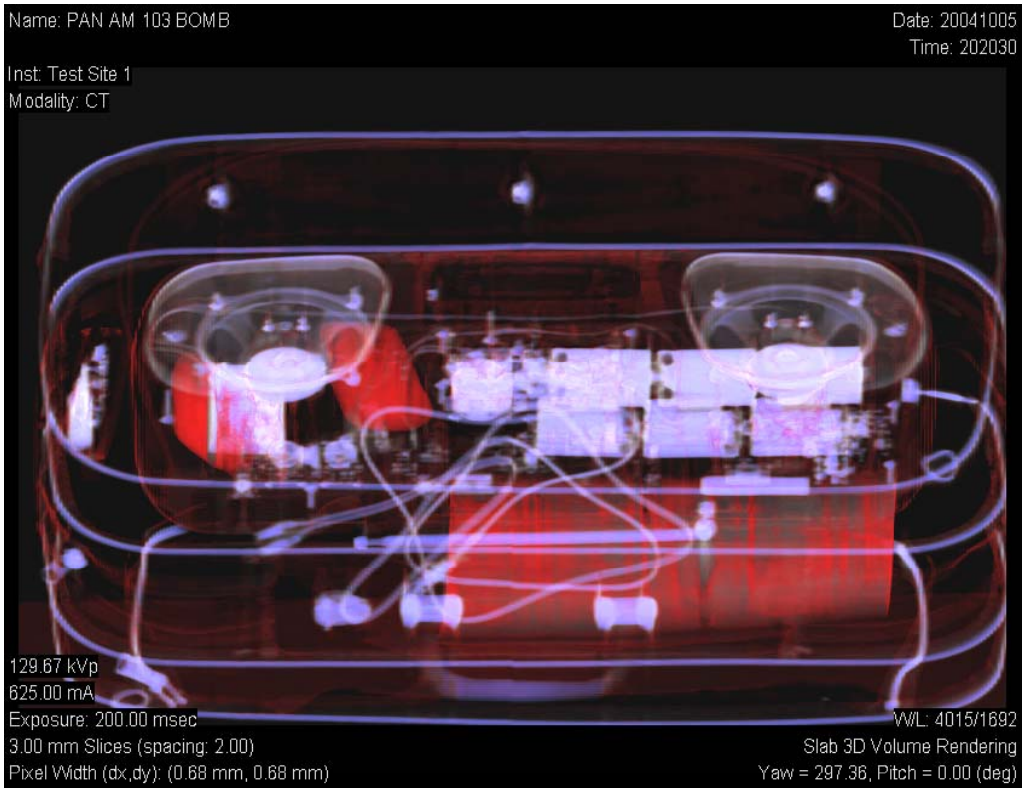
Unpacking of a Suitcase (1 of 4)

- **As the CT data is ready and received from the EDS …**
  - Photo-realistic rendering shows the bag providing a good reference

Images from a medical CT Scanner

Unpacking of a Suitcase (2 of 4)

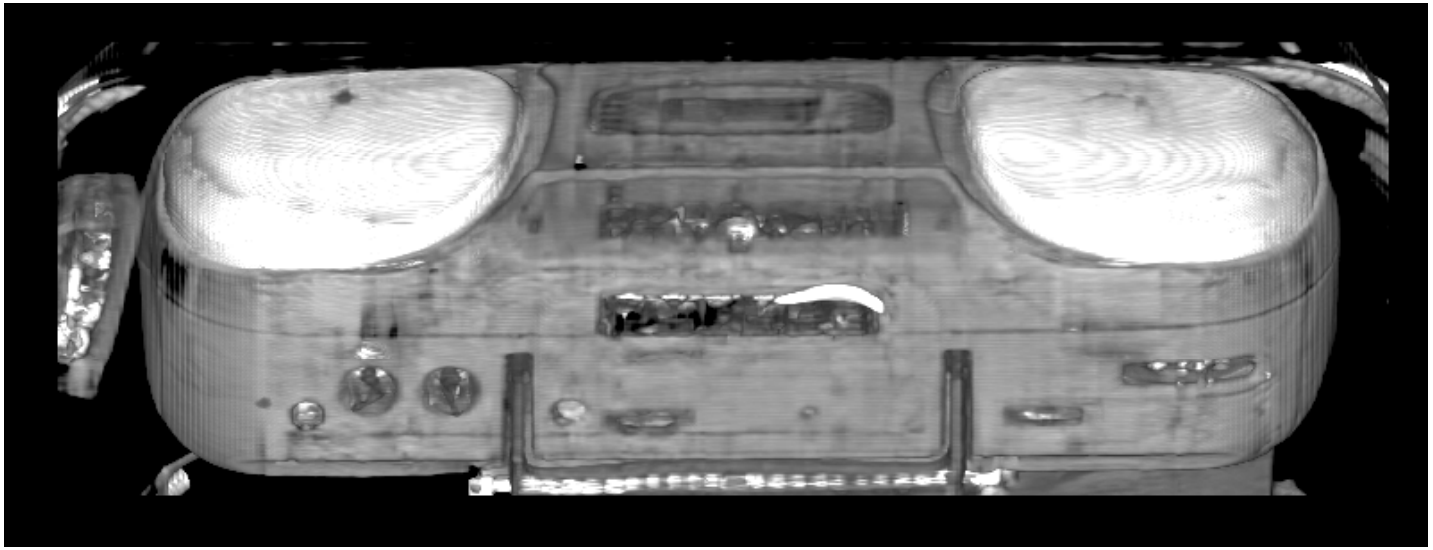
- **At the Click of a Button ...**
  - The volume rendering of the entire bag clearly reveals the cassette radio and other miscellaneous objects.



Images from a medical CT Scanner

Unpacking of a Suitcase (3 of 4)

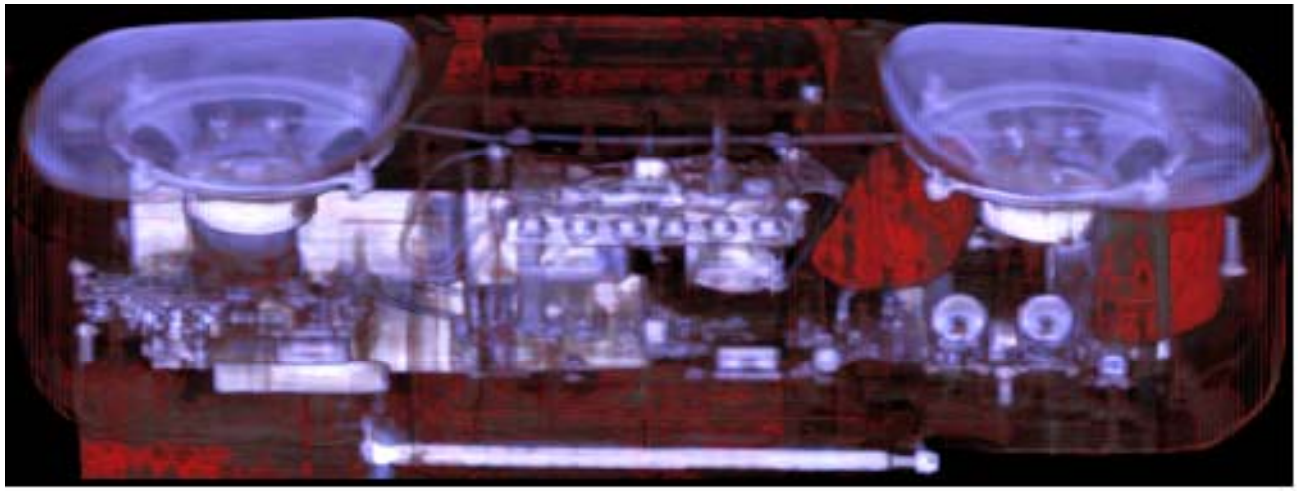
- **For further scrutiny …**
  - The cassette radio can be electronically unpacked and rendered as a surface image.



Images from a medical CT Scanner

Unpacking of a Suitcase (4 of 4)

- **At the click of a button …**
  - Localized volume rendering clearly reveals all components within the cassette radio, e.g., speakers, battery back, and two explosive simulants



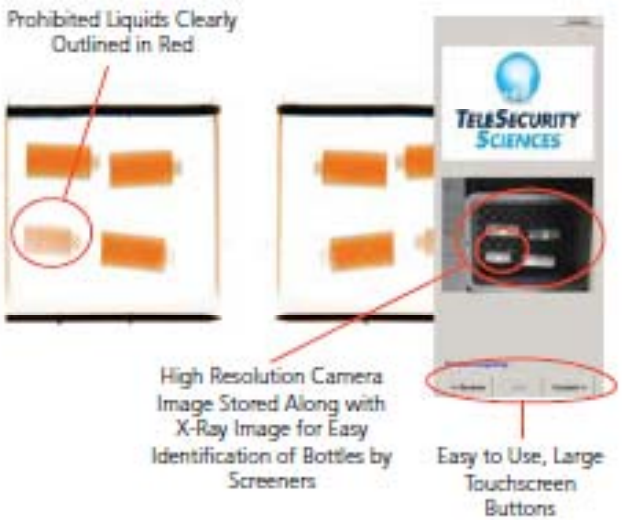
Images from a medical CT Scanner

Checkpoint Screening

- Public opposition to carry-on liquid restrictions
- Maximum size restricted to 3 oz; all bottles must fit in a single 1-quart plastic bag placed in a single bin
- With sophisticated image-processing algorithms, it is possible to automatically segment and classify liquids in bottles of all sizes

Liquid Screening with checkpoint scanners

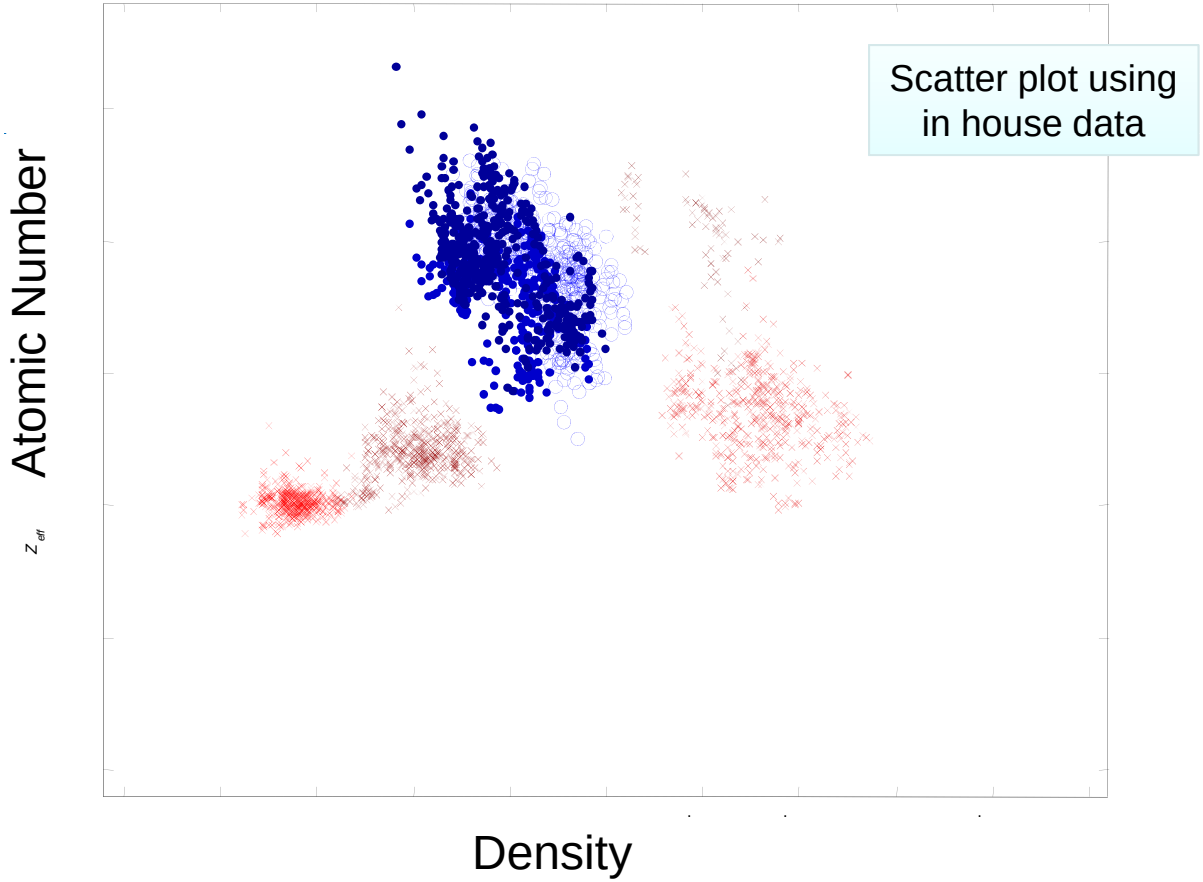
- Classification of liquids in bin mode
- Precision measurements of density and Z
- Use for dual-energy single and multi-view line scanners



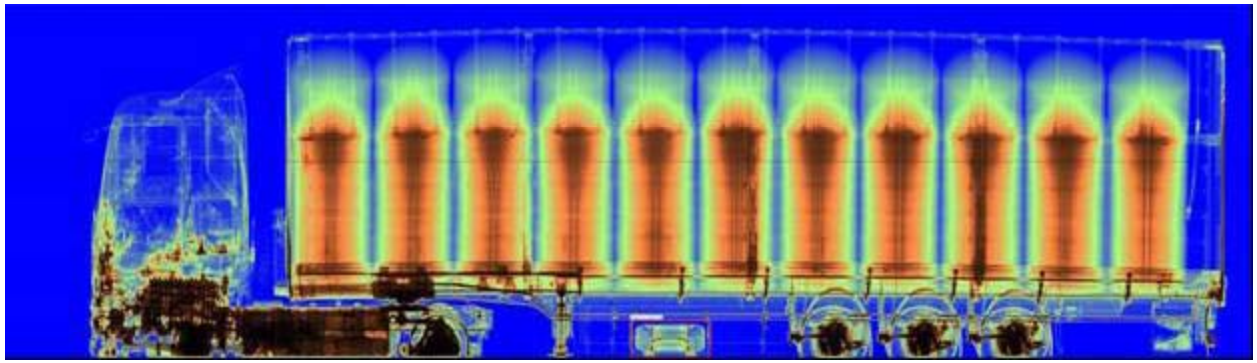
A common workstation module for checkpoint scanners

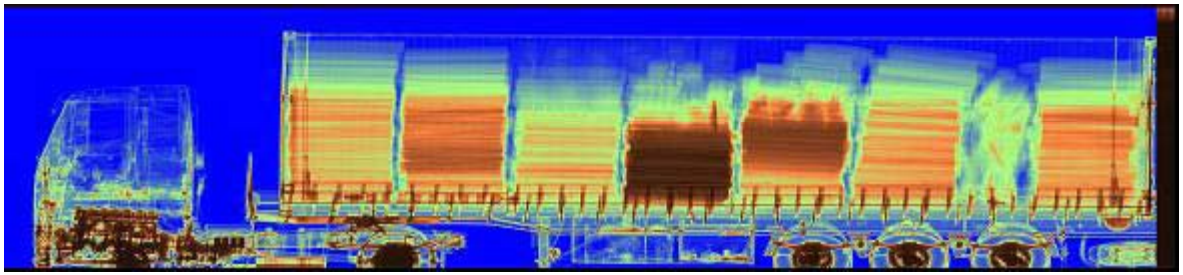
Liquid Classification Results

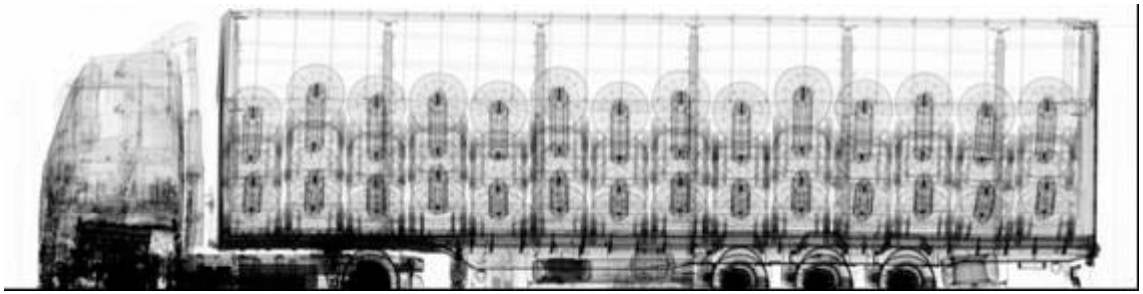
Blue points are water and common beverages, the other points are for prohibited liquids



Truck and Cargo Inspection



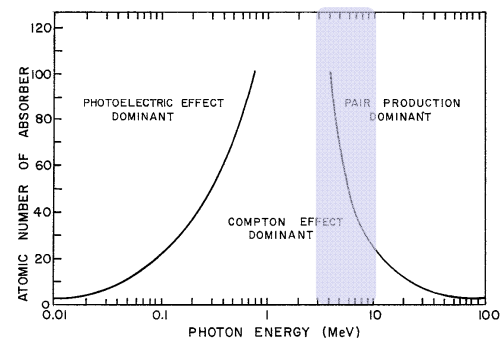




Projection mages are formed using high-energy X-rays produced by single or dual-energy linacs in the MeV range

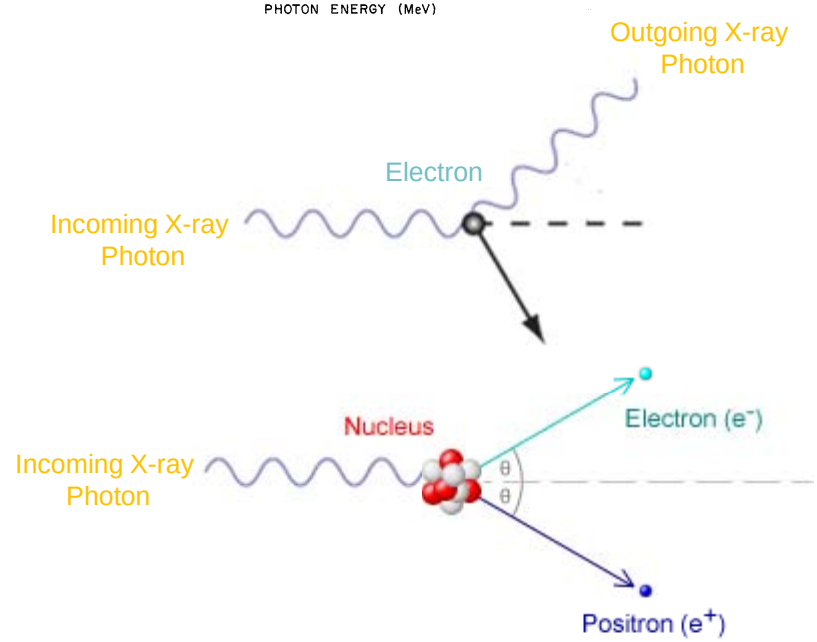
Physics of Scattering At High Energies

- X-rays are transmitted or attenuated by Compton Scattering or attenuated by Pair Production at energies of interest (5-10MeV)
- Scattered x-rays reduce visual contrast and distort quantitative attenuation data needed for dual energy calculation



- **Compton Scattering:** Interaction between X-ray and electron of an atom produces lower energy X-ray at different angle
- Ejected electron can interact with nearby atoms to produce other secondary X-rays (Bremsstrahlung)
- Probability given by Compton Scattering Cross Section:

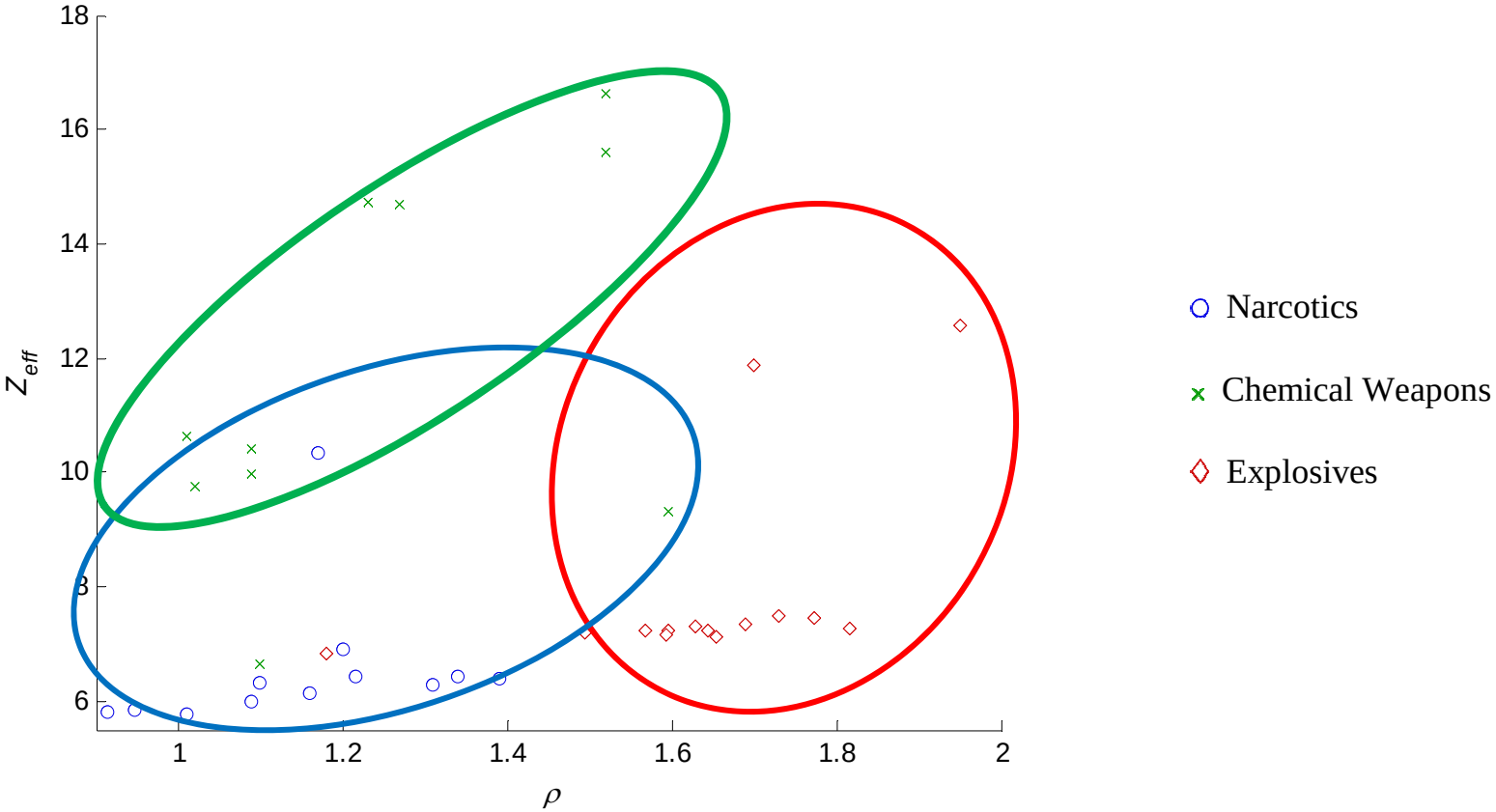
$$X_C = 2\pi r_0^2 \left(\frac{1}{\gamma}\right)\left(\frac{2(1+\gamma)^2}{\gamma(1+2\gamma)} - \frac{1+3\gamma}{(1+2\gamma)^2} + \left[\frac{1}{2} - \frac{1+\gamma}{\gamma^2}\right]\ell n(1+2\gamma)\right)$$



- **Pair Production Scattering:** Interaction of X-ray and nucleus of atom produces electron and positron.
- Positrons will annihilate and produce X-rays
- Electrons and positrons may interact with other atoms to produce Bremsstrahlung X-rays.
- Probability given by Pair Production Scattering Cross Section:

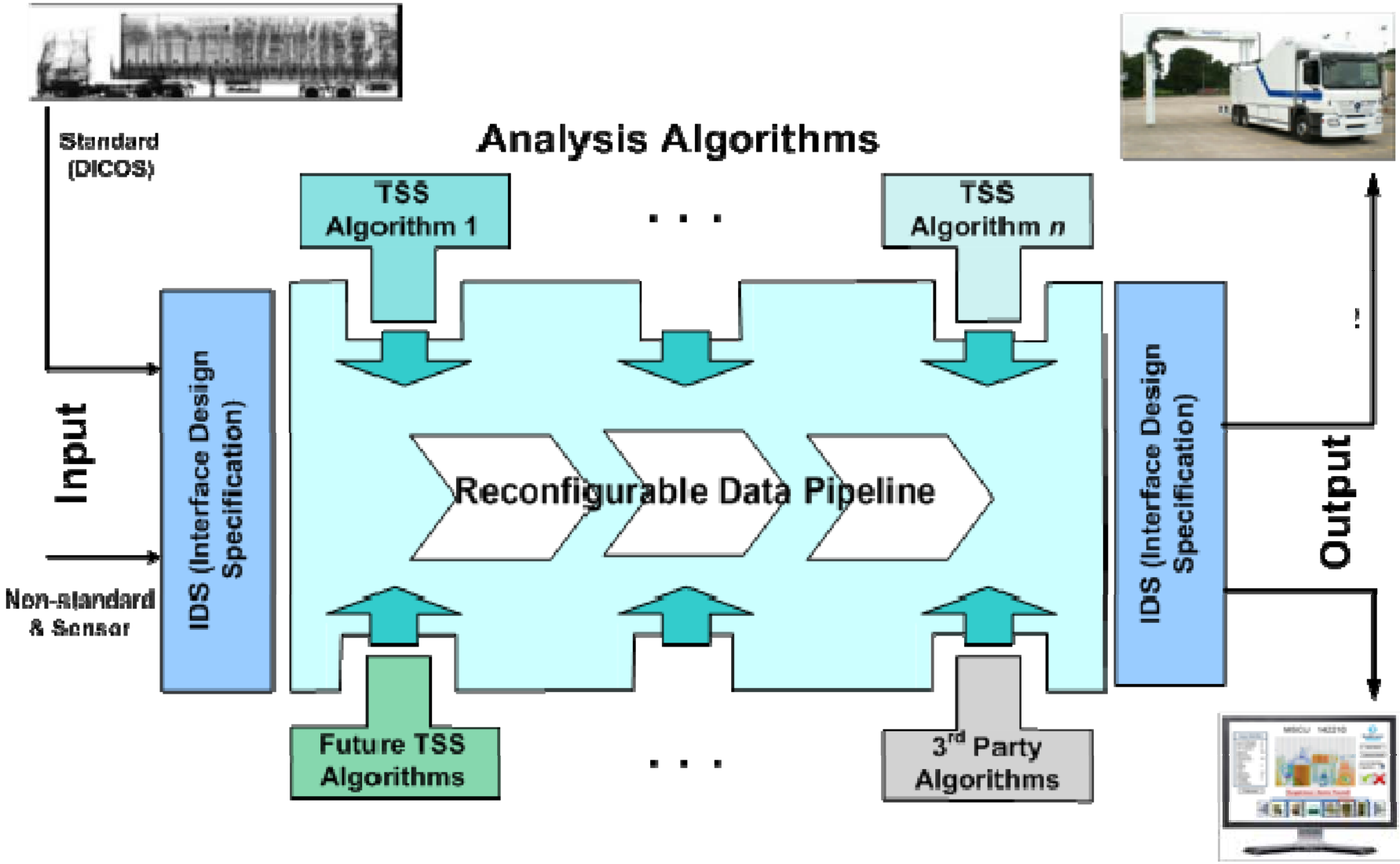
$$X_P = \alpha r_0^2 Z^2 \left[\frac{28}{9}\ell n(\gamma) - 5.91 + 3.76\exp\left(\frac{-(\gamma-2)}{2.42}\right)\right]$$

Material Discrimination by Dual-Energy in the MeV range



Dual-energy processing can help classify many materials of interest

A common workstation for many types of truck and cargo scanners



Whole Body Imaging for Passenger Screening

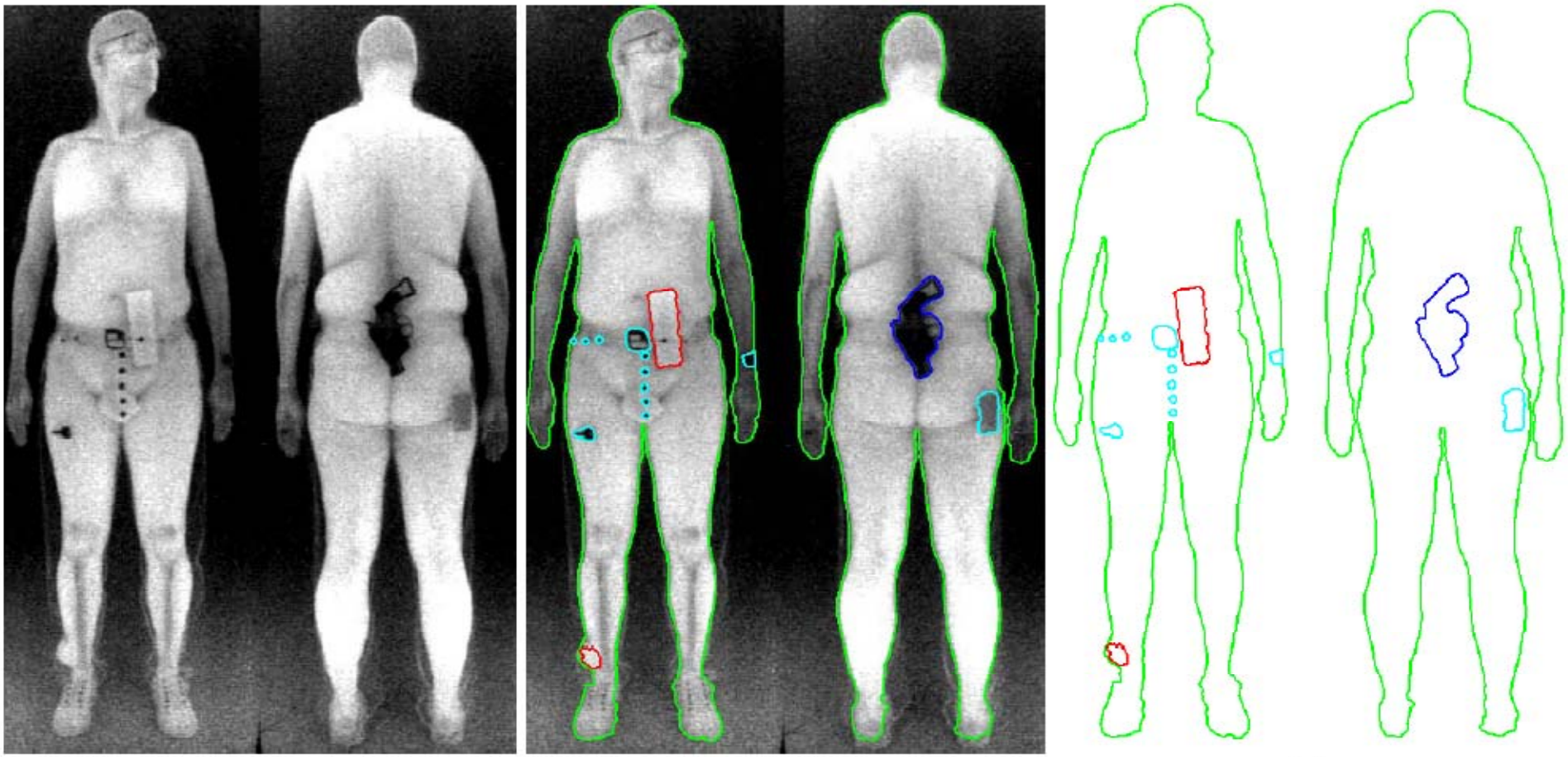
L-3 Communications Provision System

Illustration from L-3 website

Millimeter Wave Passenger Screening

These systems reconstruct a holographic display of the body surface using a rotating millimeter wave antenna system. (Images from internet)

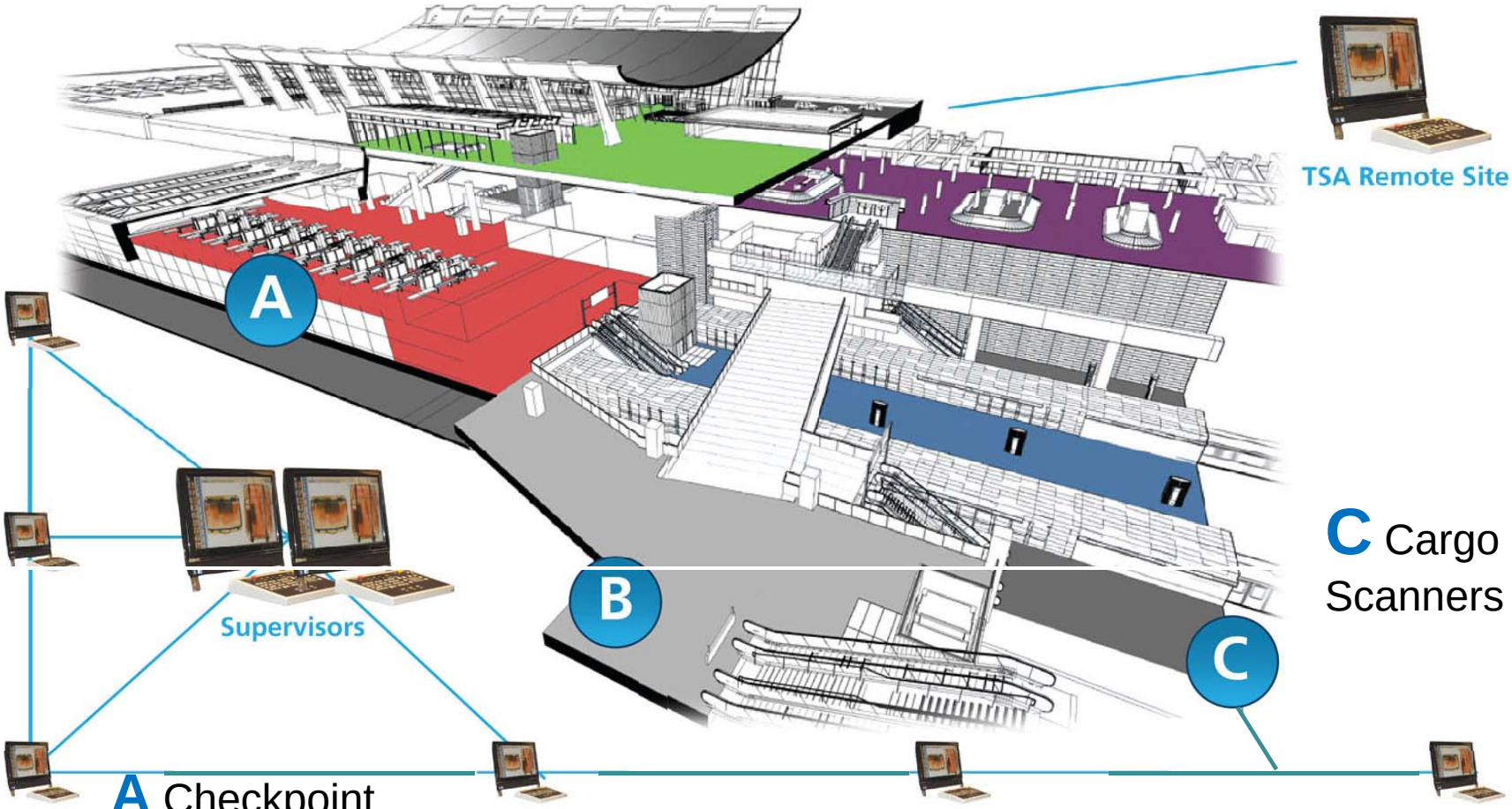
ATR for Whole Body Imaging



(a) (b) (c)

A schematic illustration of automated threat recognition and reporting of the location and type of threat without intrusion on passenger privacy. This would be a common workstation module for passenger screening. (Image from Internet)

The Common Workstation throughout the Airport



C Cargo Scanners

A Checkpoint Scanners

B Checked Luggage Scanners

Digital Image Communication for Security

- DICOS is a image and network standard for connectivity with security images
- The DICOS specification will enable interconnectivity of security scanners with common workstations
- The DICOS specification is under development by NEMA in collaboration with industry and government scientists
  - Phase I. This phase covers carry-on and checked luggage scanners and is complete
  - Phase 2. This is an extension for target reporting and to cover whole body scanners

Conclusions

- ATR solutions for all airport and security imaging devices are under development
- ATR has the potential to improve security and reduce costs for manual inspection procedures
- The Common Workstation will greatly enhance the efficiency of airport screening operations
  - Cost Reduction
  - Improved secondary screening
  - Simplified operations