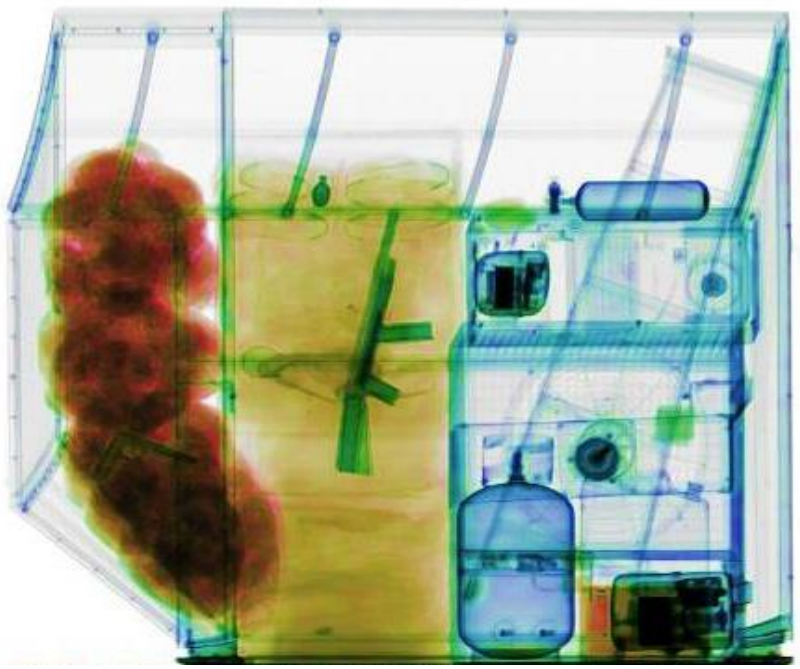
ICARST 2017
1st International Conference on Applications of Radiation Science and Technology



Next-generation Fast-Neutron/X-ray Scanner for Air Cargo Interrogation

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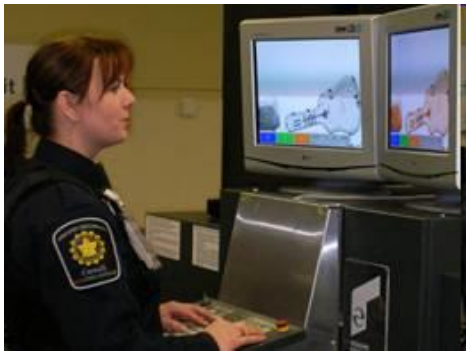
CSIRO

Fast neutron and X-ray imaging

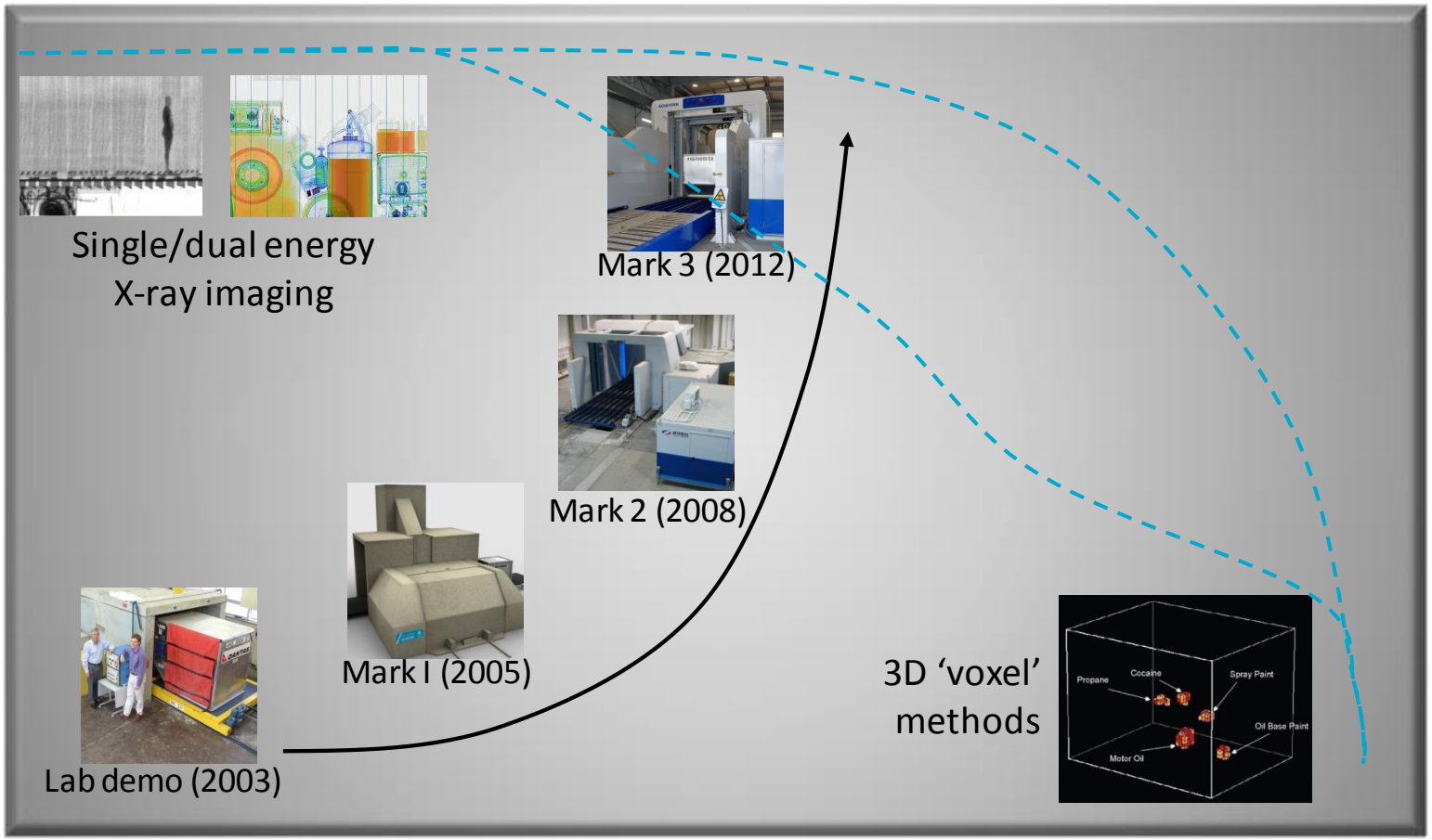
- **Developed between CSIRO and Nuctech for scanning large cargo**
  - *Suited to large structures, but scalable to smaller items*
- **Cargo is highly variable and heterogeneous making it complex to interpret a single X-ray image**
  - *Combined x-ray and neutron data simplifies the interpretation of complex images involving multiple material types such as mixed inorganic and organic compounds*
- **Strong constraints on scanning time, footprint and ease-of-use**
  - *Evolved a compact high speed imaging solution with sophisticated imaging tools for interpretation of complex data*



Implications for technology solutions in consolidated cargo inspection

- Need material discrimination capability
  - For a wide range of material types
  - With resolution of a few mm's
- Use commercial radiation sources
  - Radioisotopes (not preferred)
  - X-ray tubes or X-ray LINACs
  - Neutron generators
- Image analysis:
  - Overlay material information onto high resolution X-ray images for mm resolution
  - Sophisticated and rapid image manipulation tools developed
  - Automated and semi-automated image analysis tools developed

Technology landscape

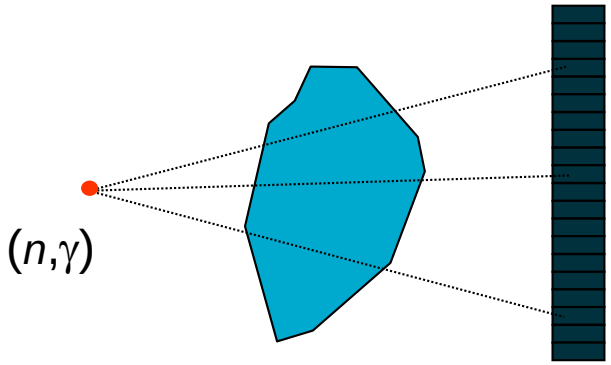


Prototype to product

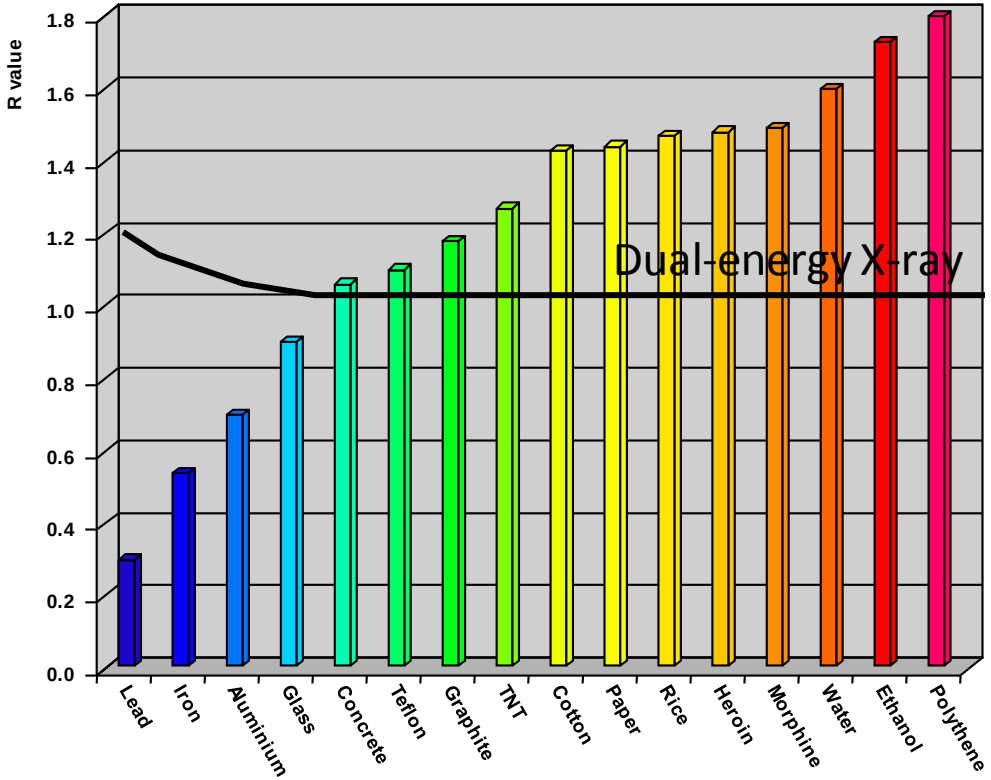
- Prototype system evolved over 4 years
- Commercial partner selection - 2 years
- Product development - 3 years
- Complex landscape of products – where do we fit?
- Competitive tension between technology and process driven industry

Our approach

- Collect high resolution neutron and X-ray radiographic images
- X-ray data provides information about density of material in beam
- Neutron/X-ray interaction cross-section ratio provides information about the average composition of the material in the beam
- Vastly more sensitive than dual-energy X-ray approach



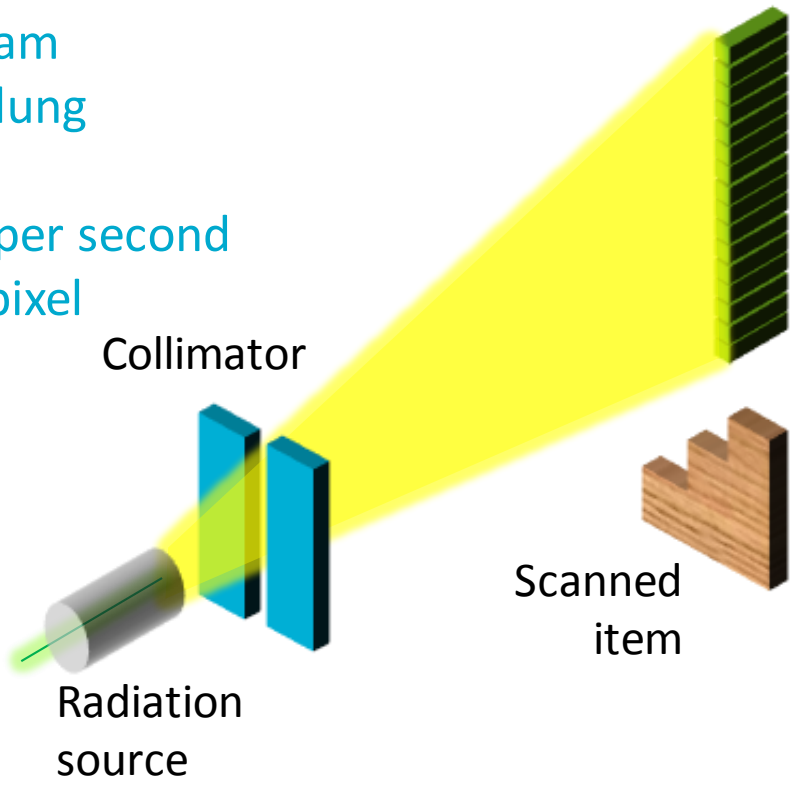
Combined X-ray/neutron imaging



Collecting X-ray and neutron images

X-rays:

- Electron beam
- Bremsstrahlung radiation
- 10^{13} X-rays per second
- 10^{5} X-rays/pixel



Neutrons:

- Deuterium-tritium beam
- Fusion reaction
- 3×10^{8} neutrons per sec
- 15 (!) neutrons/pixel

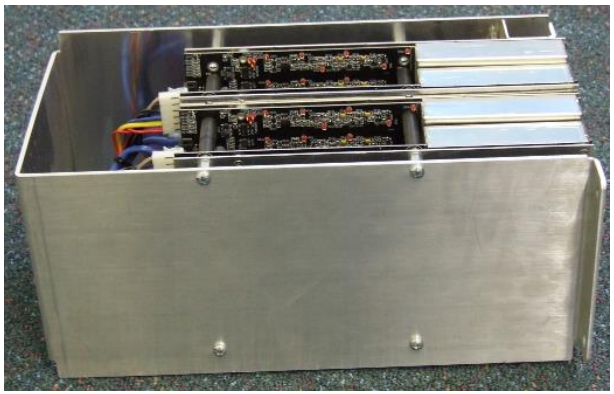
Compact neutron generator

- Electronic generator produces 14 MeV neutrons only when energised
- Medium-output (3×10^8 n/s) [pulsed generator]
  - *Low capital and operational cost*
  - *Digital control*
  - *"Return to base" maintainence*
  - *Reduced shielding footprint – easier to deploy*
  - *Long tube life at 3×10^8 n/s*

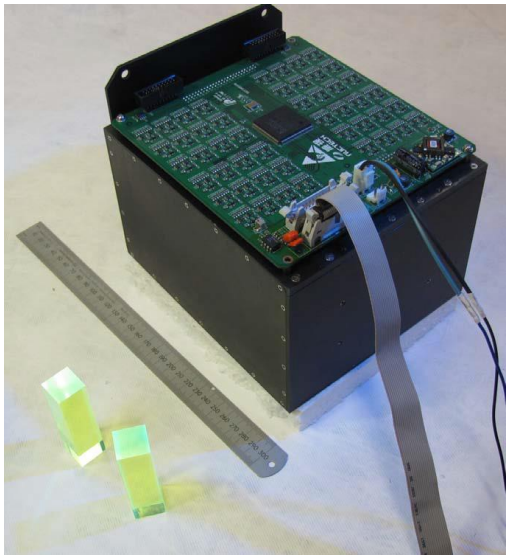
Improved neutron detectors

Effective and fast imaging required an improved neutron detector

- CSIRO/Nuctech technology development over past decade
- Basic detector element comprises plastic-scintillator, solid-state photodetector, discriminators and counting electronics
- Main drivers were increasing efficiency and reduced cost

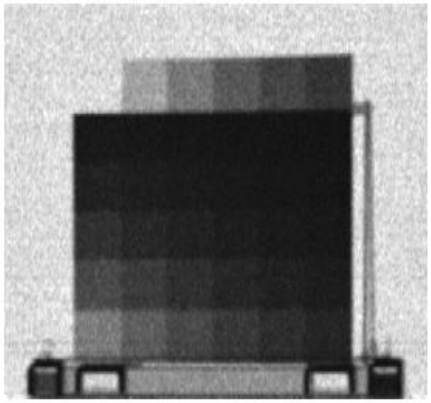


Mark 2	Mark 3
960 detectors	1440 detectors
10% efficiency	30% efficiency
	×5 overall gain

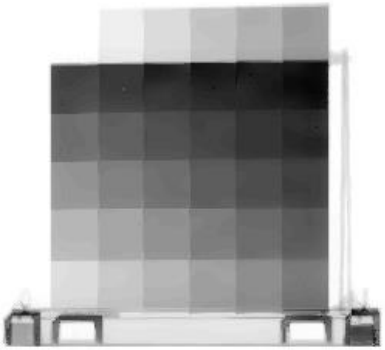


X-ray/neutron image processing

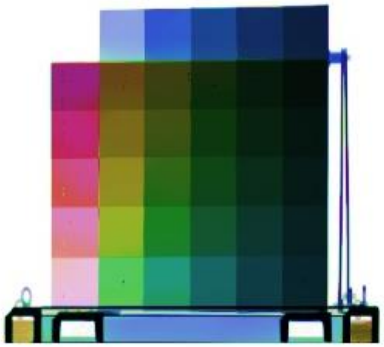
- Raw neutron images have significant artefacts:
  - *Noise, due to low neutron intensity*
  - *Cross-talk due to scattering, which reduced contrast*
- CSIRO has developed new, non-linear filtering techniques to decrease noise and increase image definition
- Latest generation of filters allow us to increase imaging speeds 5-10 times whilst preserving image quality



Raw neutron image



Filtered neutron image



Combined neutron/ X-ray image

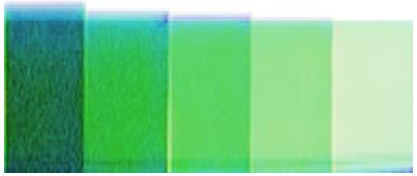
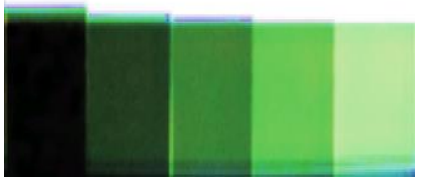


Image with scatter

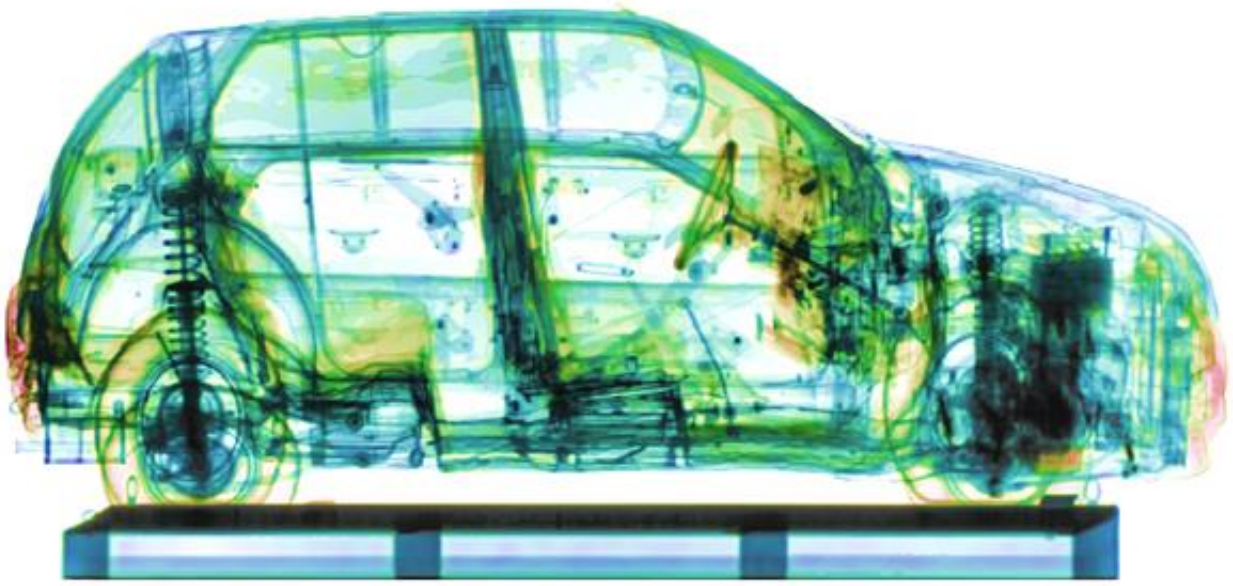


Corrected image

Mark 3 scanner footprint

- Incorporates 6 MV X-ray LINAC and 14 MeV neutron source
- Modular lower cost shielding (steel and recycled materials)
- Integration of X-ray and neutron systems in operation and image analysis
- No exclusion zones exterior to scanner footprint

Image example



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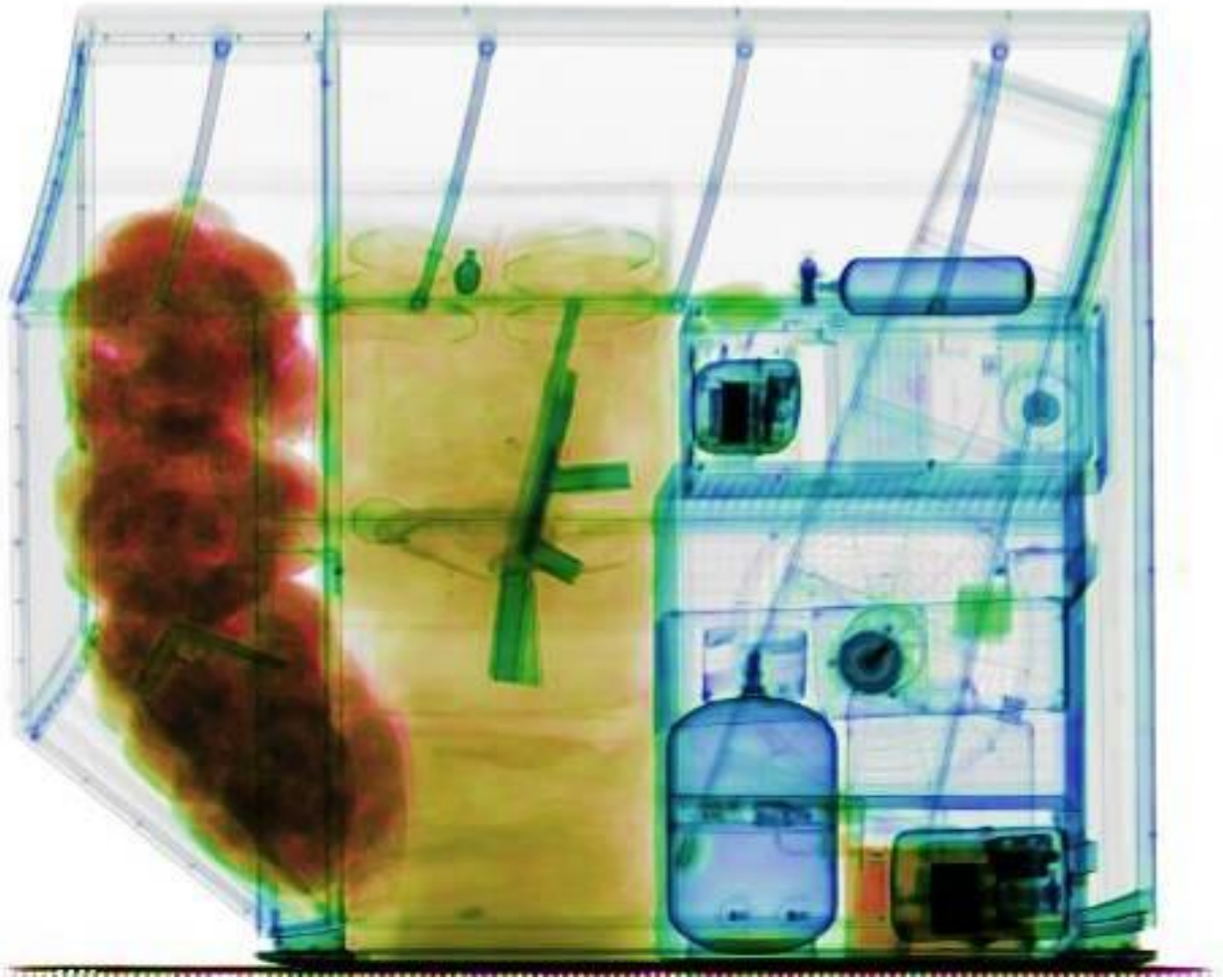
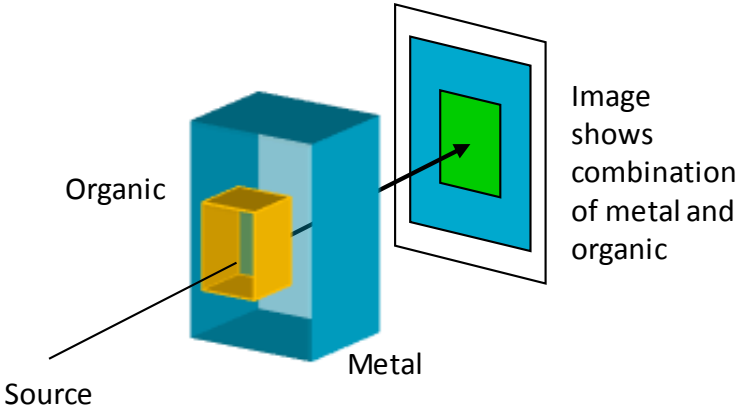
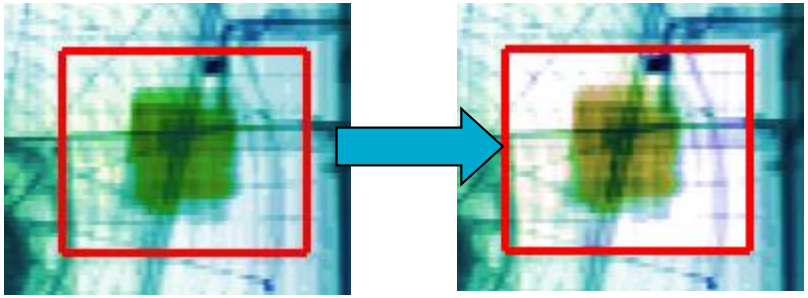


Material identification

- ‘unique’ R-value based image analysis relies upon:
  - High-resolution images
  - Good penetration
  - Good image filtering (uniform colour for uniform materials)
  - Image manipulation tools
  - Background-stripping can correct for overlap to reveal true composition





Operational experience

- Provides additional information that more quickly defines the makeup of complex bulk cargo
- Overlapping of the transmission images is not always adequately resolved for complex cargo
- Further refinements such as additional views providing limited CT would enhance current technology
  - *Limited View / Angle CT Reconstruction*
  - *3D reconstruction of limited view and/or limited angle CT data, reduce current CT scanning time and dosage*

Industrial Process Imaging?

Neutron/X-ray imaging, developed over more than 10 years, is potentially applicable to industrial applications and provides advantages over X-ray imaging alone

- Material recognition allows recognition and mapping of multicomponent (organic/inorganic) systems at high resolutions (mm's)
- High rate imaging is compatible with the imaging of rapidly changing systems
- Developments in neutron source optimisation, detectors, shielding and image analysis equally apply in industrial applications
- Developed concepts are scalable and could be deployed in a much smaller footprint suited to specific industrial applications

Thank you

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