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# The development of x-ray imaging for airport security, defence and medical markets

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9th International Conference on
POSITION SENSITIVE DETECTORS
Aberystwyth
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# Mission

To be the leading provider of digital colour x-ray imaging enabling direct materials identification in the security, medical, industrial inspection and defence markets

# Profile

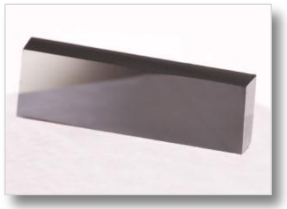
- Founded in 2003 as spin out from Durham University
- Based in North East England, UK and California, USA
- More than 140 families of patents over entire value stream
- Acquired Nova R&D Inc, a Californian corporation in June 2010
- Employ over 60 people in US and UK including 19 PhD's
- ISO 9001 accreditation for all internal design and manufacturing processes
- **Business Model** : End user products for niche applications and technology solution provider to OEM's in conventional markets

# Product strategy

End user products for niche applications and technology solution provider to OEM's in conventional markets

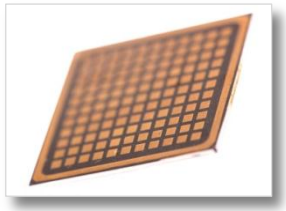
## Materials

Substrates and detector grade material



## Detectors

Pixellated and planar detectors with electronics



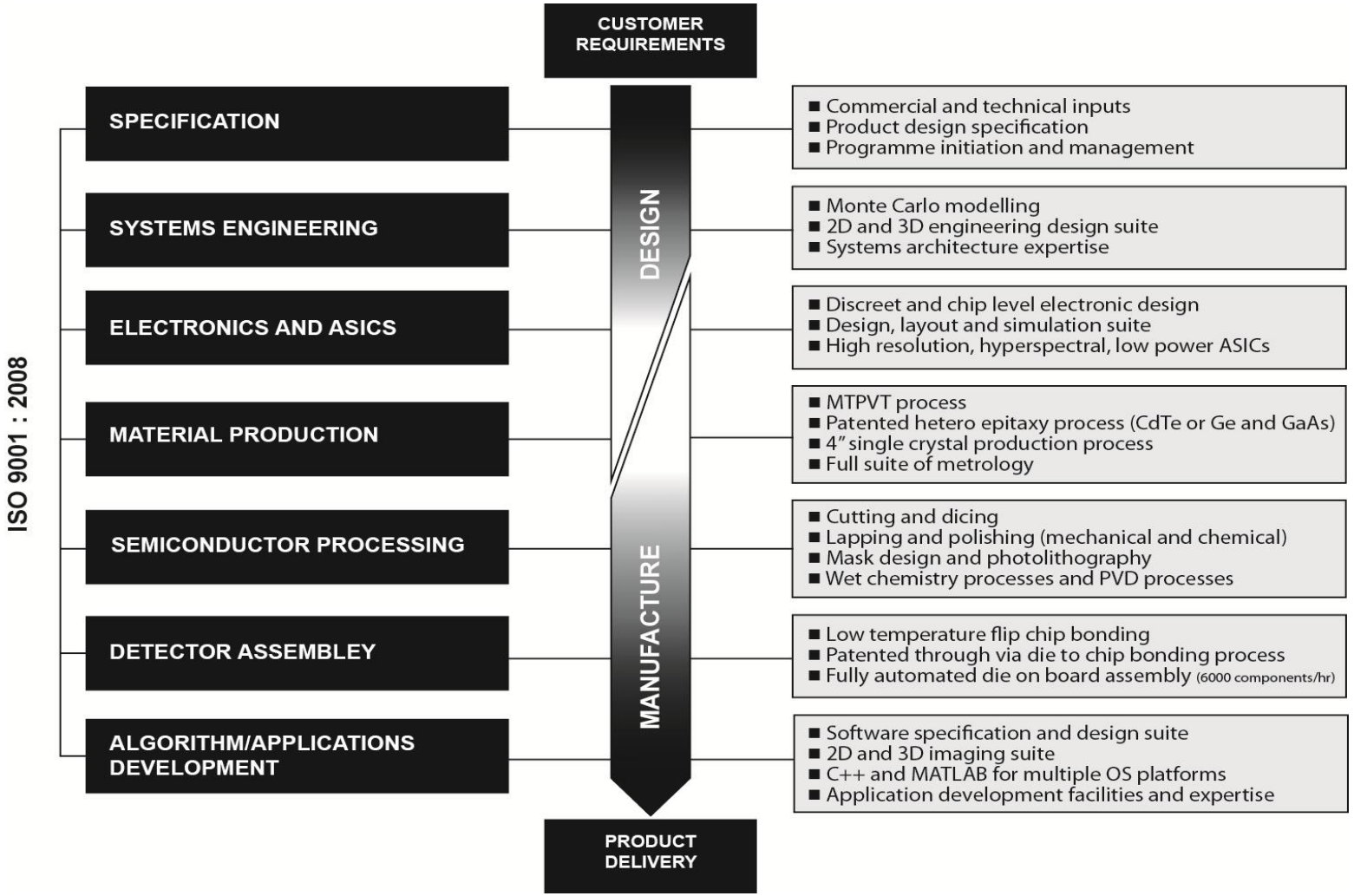
## Sub-systems

Application specific sub-system assemblies with Kromek detectors

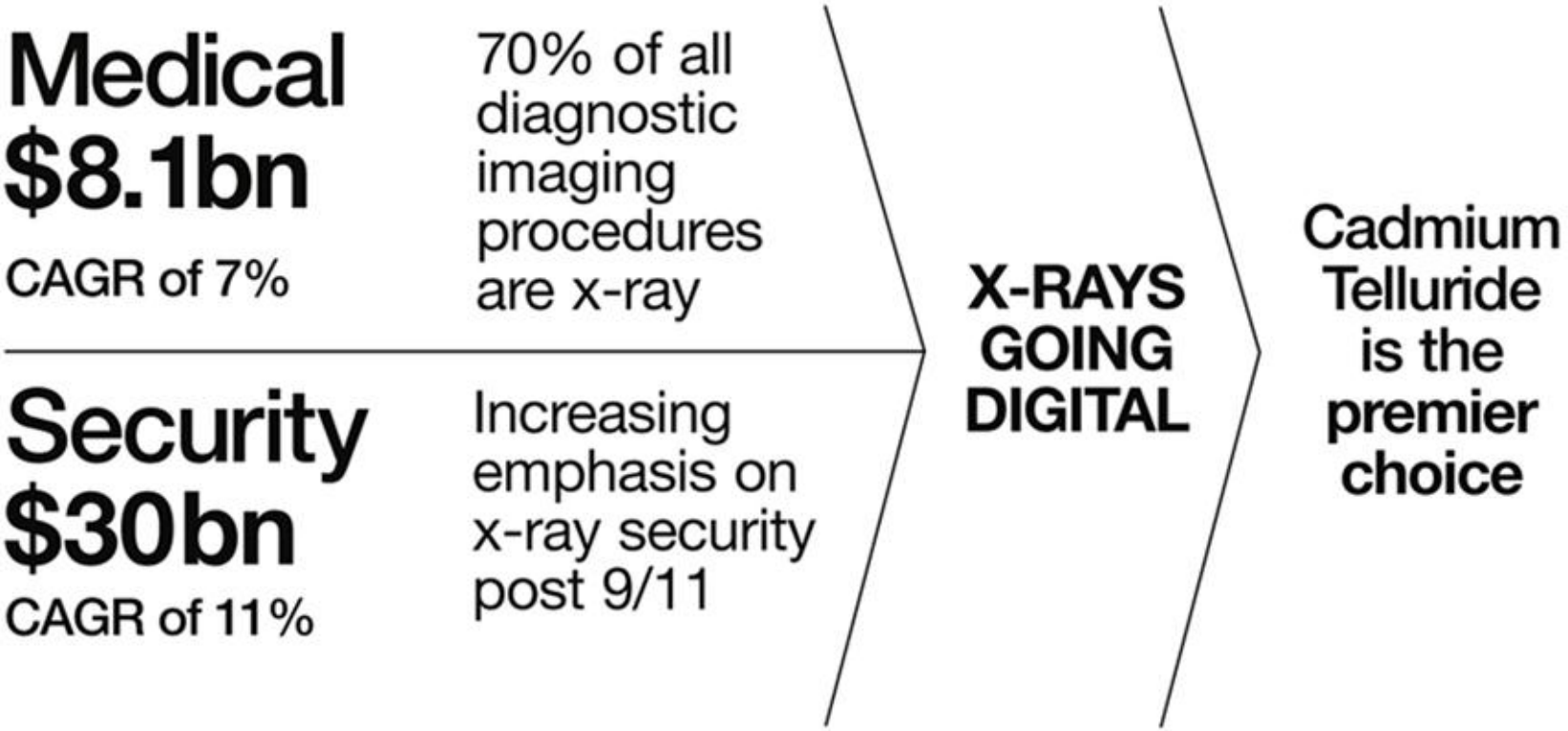
## Platform Integration + Products

Selective high value-added system prototypes exploiting advantages of Kromek detectors

# Kromek's core capability offering



# The importance of x-rays



# Large markets

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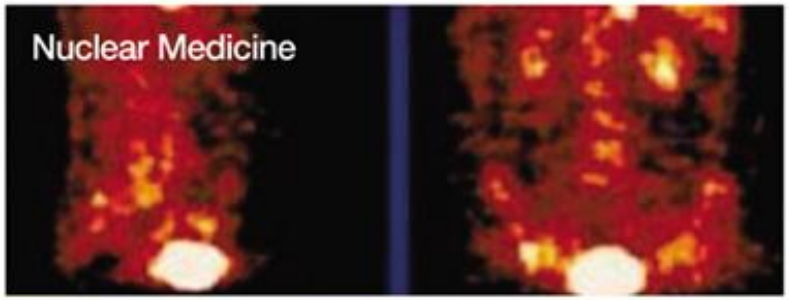
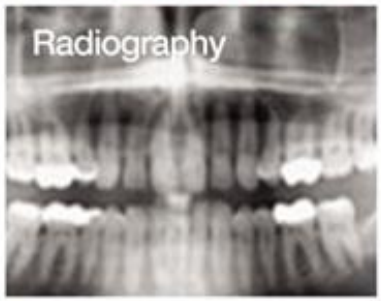
## Medical Imaging
## $8.1bn








## Security
## $1bn

Security Screening

## Inspection
## $1.5bn+

Industrial Inspection

## Defence
## $750m

Night Vision
IR Substrate

# Current programmes

**Medical**

- Multispectral CT detector subassembly development **(OEM)**
- Detection module for non-invasive colorectal scanning capsule **(OEM)**
- Multimodal x-ray imaging and breast CT **(UMASS – NIH, USA )**

**Security**

- Liquid explosive detection system **(ECAC Type B)**
- Spectral imaging system for baggage screening **(Type C&D)**
- Sheet explosive and powder detection system

**Industrial**

- 3D imaging for large object scanning **(OEM)**
- High resolution x-ray imaging camera for semiconductor inspection **(OEM)**

**Defense**

- Large volume CZT detector development for gamma ray detection
- Low power high resolution spectroscopic ASIC for gamma ray detection **(OEM)**
- 2 Phase II SBIR programmes

# Illustrations of Kromek technologies

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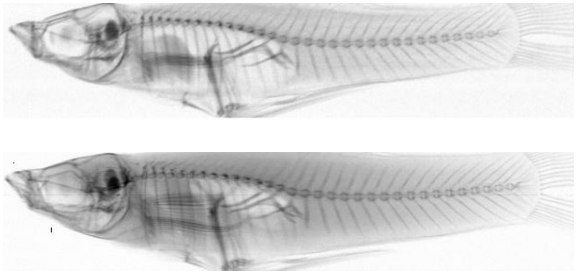
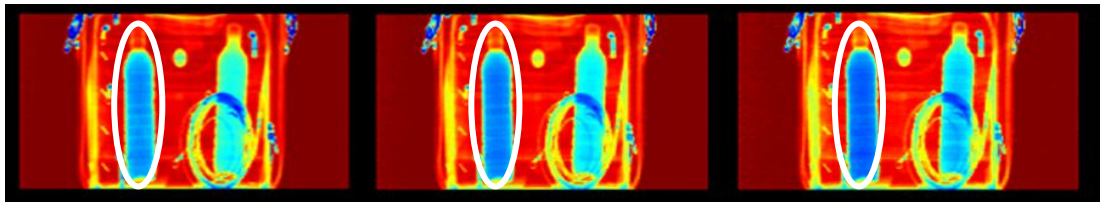
## Small Animal Imaging

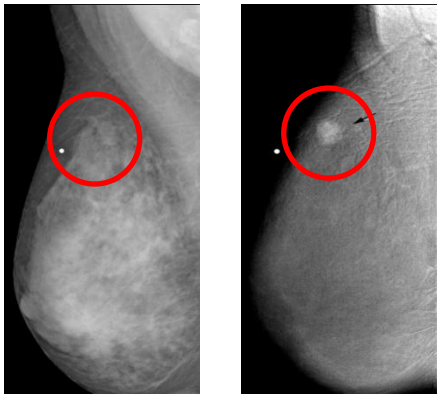


## Multispectral x-ray images for explosive detection



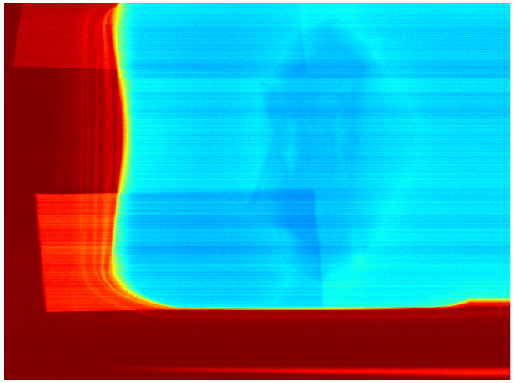
50keV 80keV 100keV

## Cancer Detection

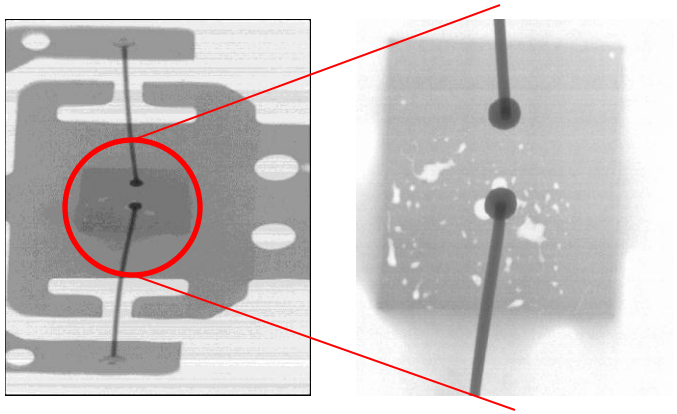


Contrast Enhanced Breast Imaging

## Hyper-spectral Imaging for defect and anomaly detection

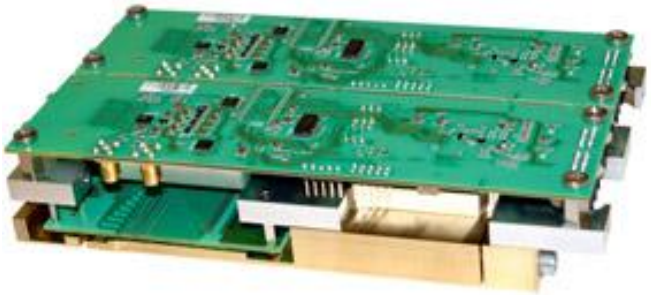
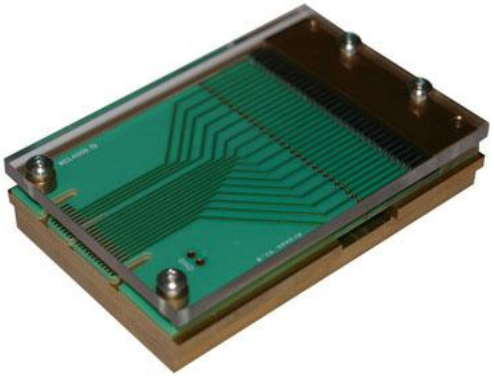


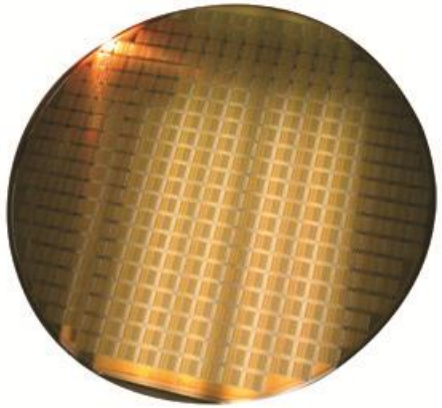
Plastic strips in butter tub

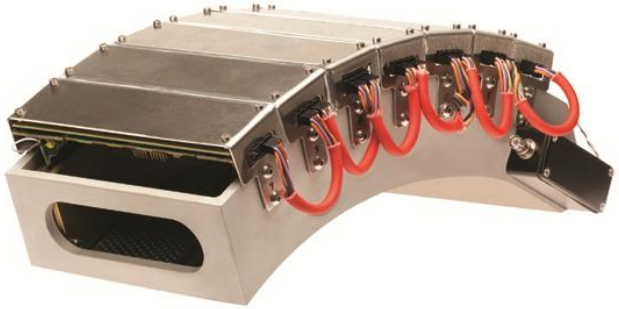


Electronic connection showing solder voids visible through connectors

# Examples of Kromek OEM products





# Advantages of CdTe systems

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**High Resolution**

output at low radiation doses

**High Speed**

real-time imaging

**Colour x-ray**

energy discrimination

**Portable & Simple**

no cooling

**10x**

more sensitive than silicon

- **Better**
- **Cheaper**
- **Larger**

# Advantages of Kromek materials

**Current Materials**
Variable quality

**Kromek's Process**
High quality + optimised by application

- Lower cost
- Larger wafers
- Better quality
- Reliable supply chain

# State-of-the-art operations

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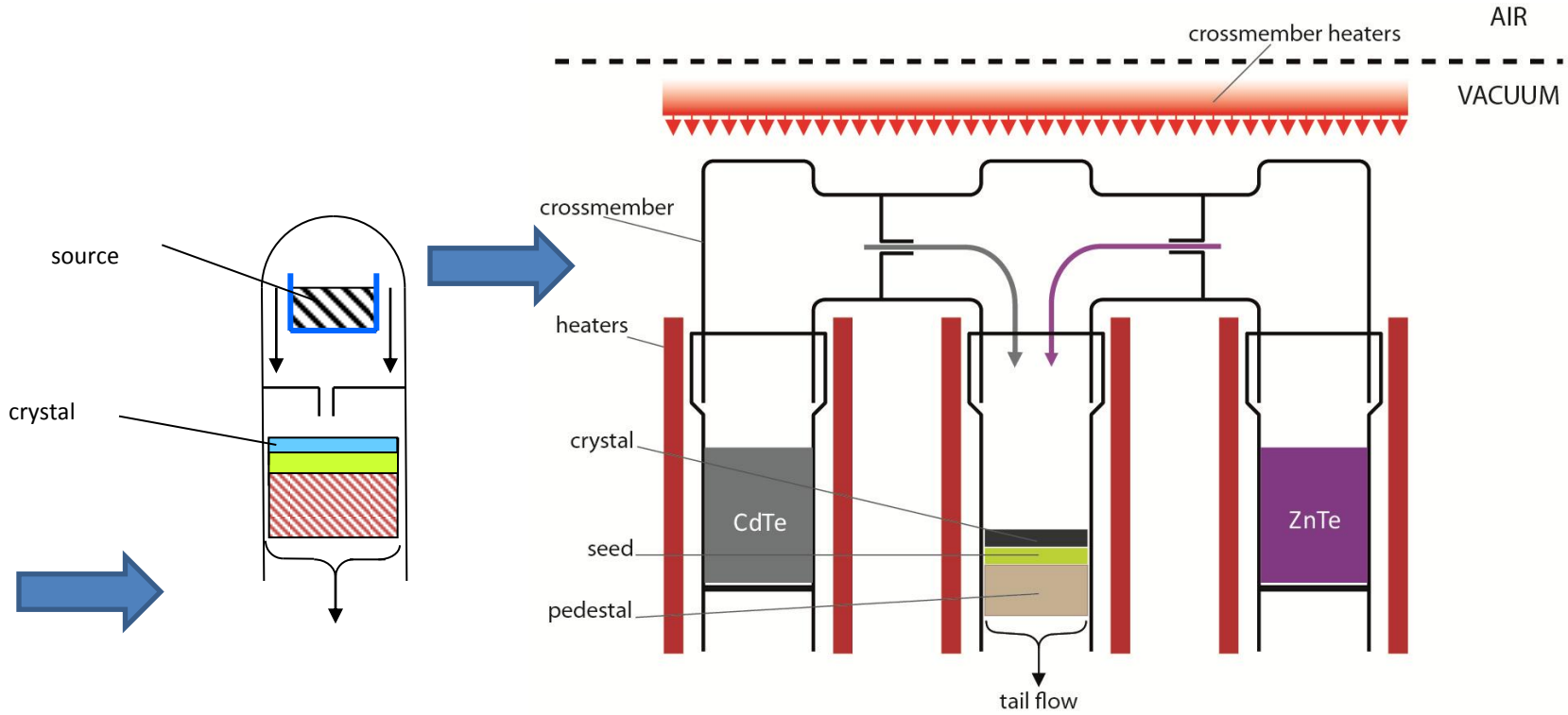
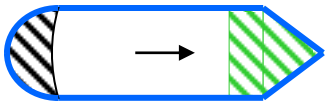
# Multi-tube Physical Vapour Transport



source crystal

# Modelling – Monte Carlo and FEM

A comprehensive modelling tool that can be used for detector design and analysis.

1. Production and Transport of Radiation
2. Ionisation of the Semiconductor
3. Separation and Acceleration of Electrons and Holes by the Electric Field
4. Transport of Charge Carriers within the semiconductor and induction of charge on the electrodes ( formation of charge pulse)
5. Amplification and Processing of the Charge Pulse

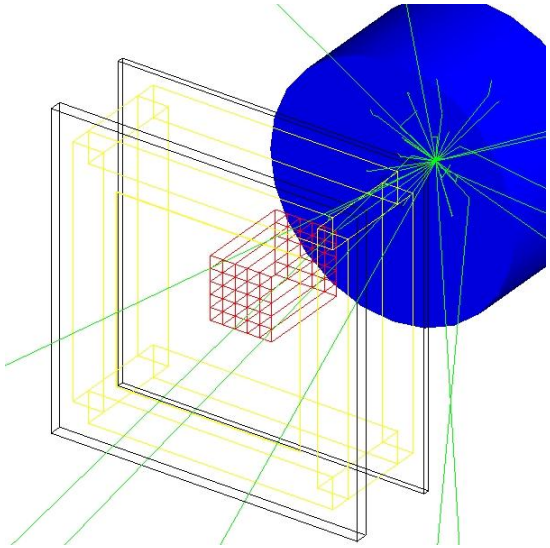
This can be achieved in 3 steps;

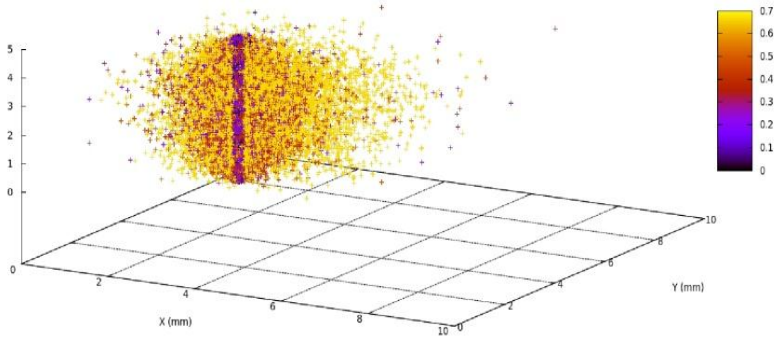
1. **Geant4**

2. **COMSOL (Finite Element Method for Device Modelling)**

3. **LABVIEW (Post Signal Processing)**

# Modelling – Monte Carlo and FEM





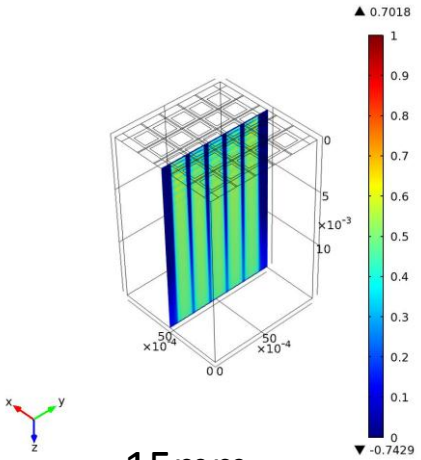

- Monte Carlo Modelling for Detector modules
- For full dectector designs- industrial, medical and security.
- Energy Deposition
- Interaction positions

Because of the complexity of these devices direct mapping of pulse shapes is impractical. The charge-carrier continuity equation must be solved for each point, this becomes prohibitive for complex electrode structures.

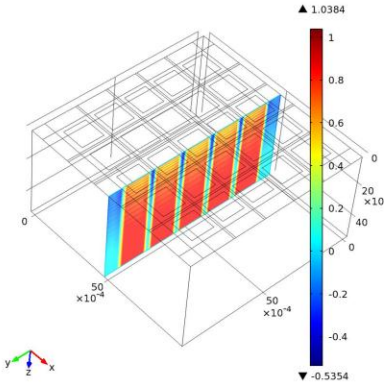
$$\frac{\partial n^+}{dt} = \mu_n \nabla \varphi \cdot \nabla n^+ + \nabla \cdot (D_n \nabla n^+) - n^+ / \tau_n + G_n^+$$

Prettyman introduced a new method for mapping charge pulses by solving the adjoint carrier equation which yields a time and position dependent map that contains all possible charge pulses that can be produced by the detector for charge generated at discrete locations.

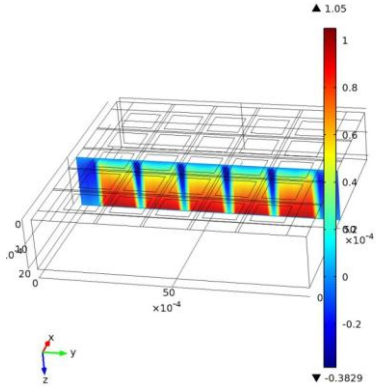
# Charge Induction Efficiency Maps



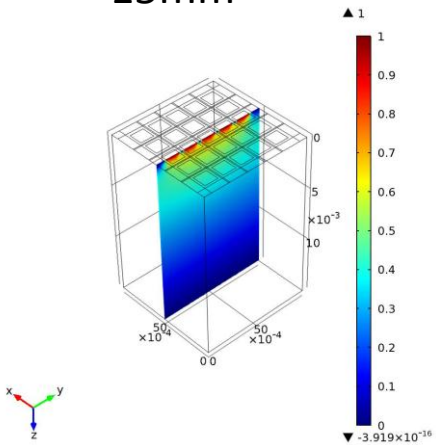

15mm

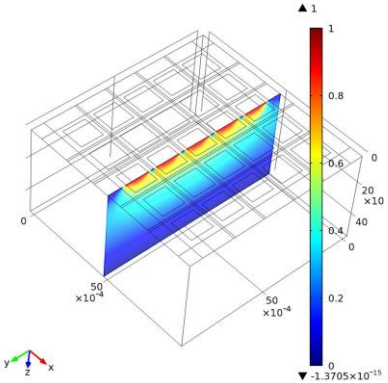


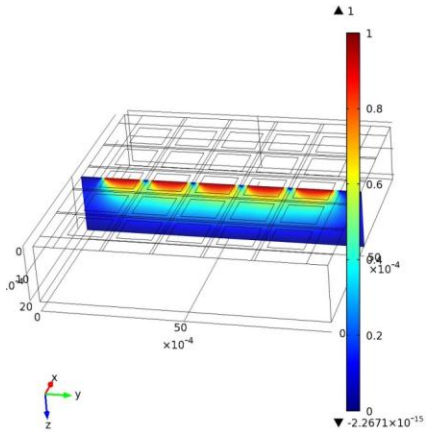

5mm




2mm

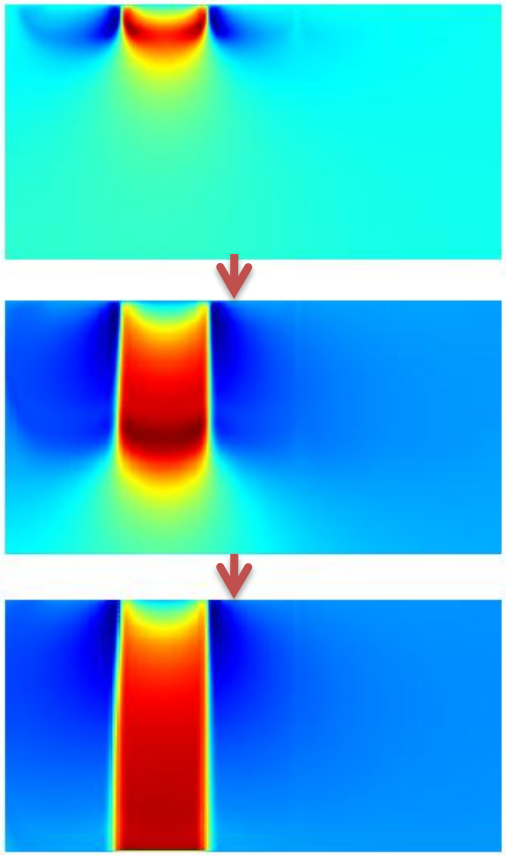


# Experiment vs Simulation

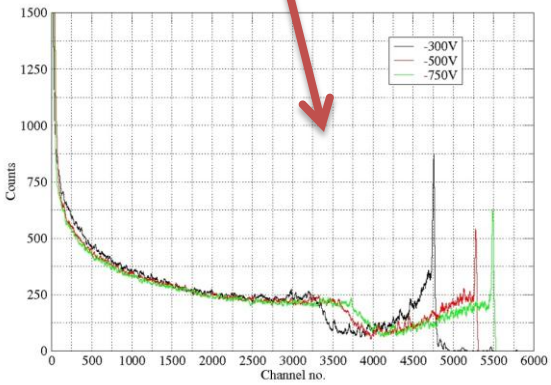
- 2mm, 5mm and 15mm thick detectors
- Largest at present 20x20x15mm
- 15mm needs DOI correction because of limited electron lifetime and diffusion
- 5mm needs DOI because of Weighting Potential effects
- Using RENA ASICs from Nova – good for spectroscopy



CIE at -300V, 0.1, 0.5, 1µs

As reverse bias is increased, the CIE gets closer to 1 hence the photopeak moves right.

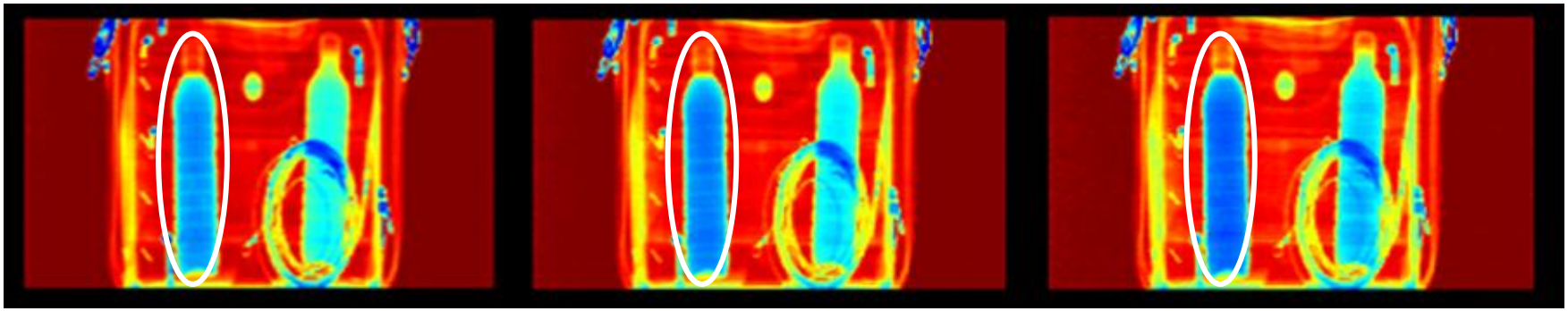
Large depth dependency in the CIE remains, hence there is a long tail on the photopeak.



# Kromek Identifier™ – liquid explosive bottle scanner


- Identifies the presence of hazardous liquids in containers (liquids, aerosols and gels)
- Industry's lowest false alarm rate
- Scans all type/shapes container (coloured, clear and opaque glass, plastic, metal and cardboard)
- Scans in less than 20 secs
- Easy to use one-touch operation
- Simple PASS/FAIL display
- Threat database easily upgraded

# Automatic liquid recognition



50keV 80keV 100keV

- Multispectral x-ray image of 2 bottles inside a bag at three different energy levels
- One bottle contains hydrogen peroxide (white circled) and other alcohol
- ADMiT™ algorithm can accurately identify material independent of the volume or thickness in convoluted and multilayered environments

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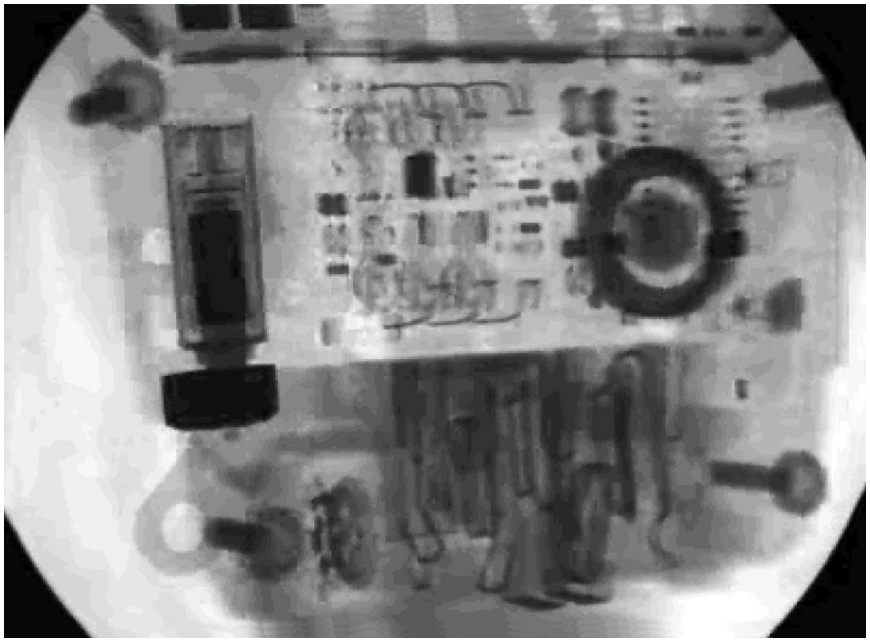
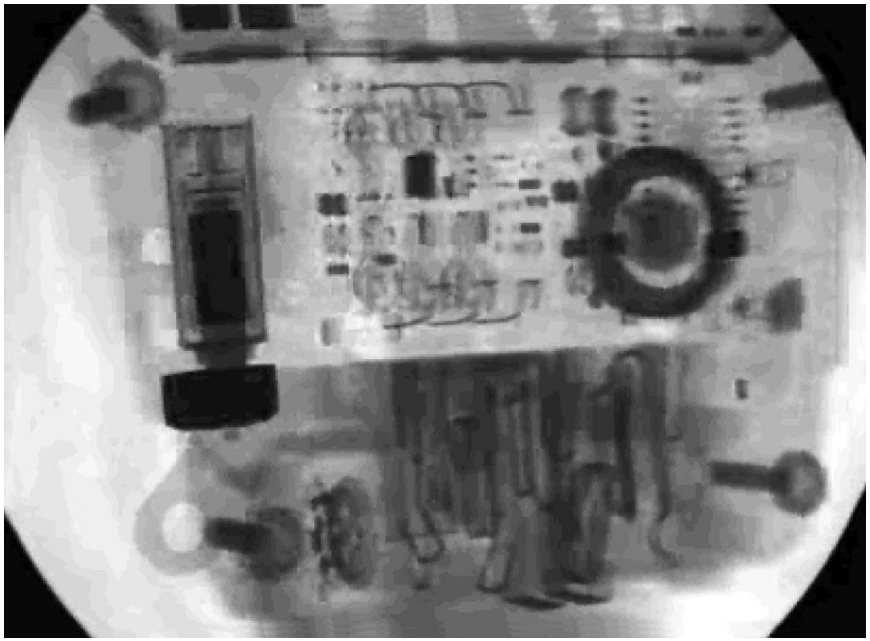
# XRA TM multi-view platform



**X-Ray Animation (XRA) new imaging IP will radically improve threat detection**

# XRA TM multi-view platform



- 3D Imaging with materials recognition
- Multiple fan beams from a single source
- Exploits the physiological phenomenon of monocular movement parallax to create three dimensional view of object.
- Allows separation of layered or hidden parts
- Images combined to produce an animated 3D view of the object
- Gathers spectral x-ray information, uses Kromek proprietary algorithms to determine material constituents of the object & correlates material assignments via voxel analysis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