Multi-Energy X-Ray Detection Applied to Liquid and Solid Explosives

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Moirans MultiX plant

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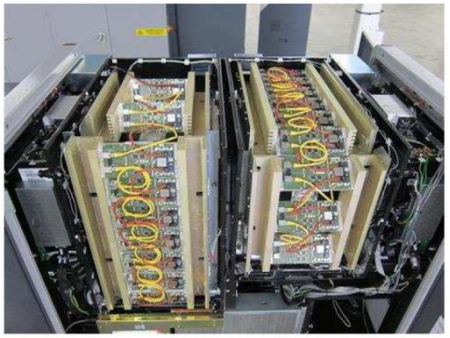
> So What? Who Cares?

> The Technology:

- Multi-energy (ME) x-ray detection and processing

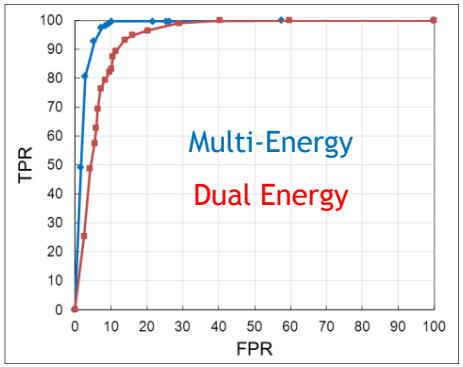
> What benefit could TSA (and RoW) obtain from my technology?

- Improved threat detection
- Improved throughput and passenger facilitation
- Capable of being retrofit to existing equipment



> So What?

- Increase security and lower operating costs (retrofit)



> Who Cares?

- Passengers: Faster checkpoints, less aggravation
- TSA: More efficient checkpoints, lower staffing levels, can be done now

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More on “So What?”

- **To improve threat detection performance for ALL x-ray based detection systems**
- **How: Use a new metric for discrimination with high resolution multi-energy detection**
- **Now: COTS ME detector for conventional line-scan X-rays**
  - Hardware: ME100 V3 DAS, retrofit capable
  - **Software: ME Image Processing Algorithms (Zeff)**
- **Future: 2 Directions**
  1. High Flux Applications: High Flux ME capability for CT applications
  2. High Energy Resolution: High Energy Resolution for low flux scatter applications

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Now: Conventional X-Ray

- **The goal is to support platform performance improvements and lifecycle extension**
  - Ensure that conventional x-ray system platforms can continue to improve in performance.
- **Fill the performance gap between current dual energy (DE), multi-view and CT technology:**
  - Low FAR on dual view systems, low cost (<$150K), compact size and easy operation
- **Multi-Energy**
  - Improved threat identification (especially HMEs)
  - Improved spatial resolution
  - Retrofit capable
  - Low cost alternative

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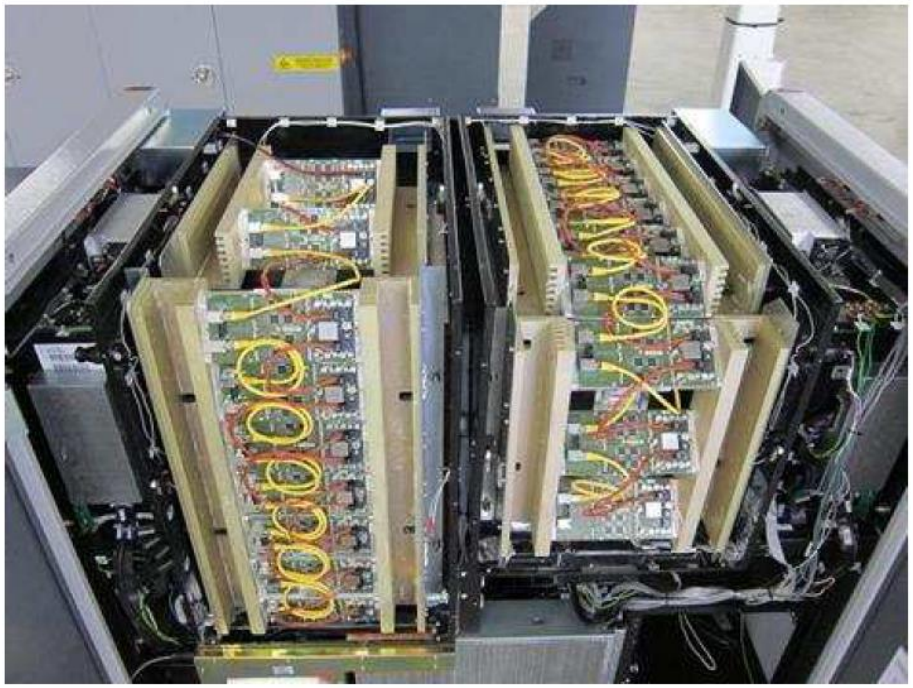
Hardware

- ***Form Fit and Function***
- The ME100 DAS is designed to replace the conventional DAS
- Same size DAS enclosure
  - Retrofit
  - New design
- DAS boards shown in detector box in a conventional dual view linescan x-ray system
  - Improved rigidity and adjustment makes installation simple and improves reliability and stability
- Other parts include interface board and power supply



ME100 retrofitted to a AT2 System

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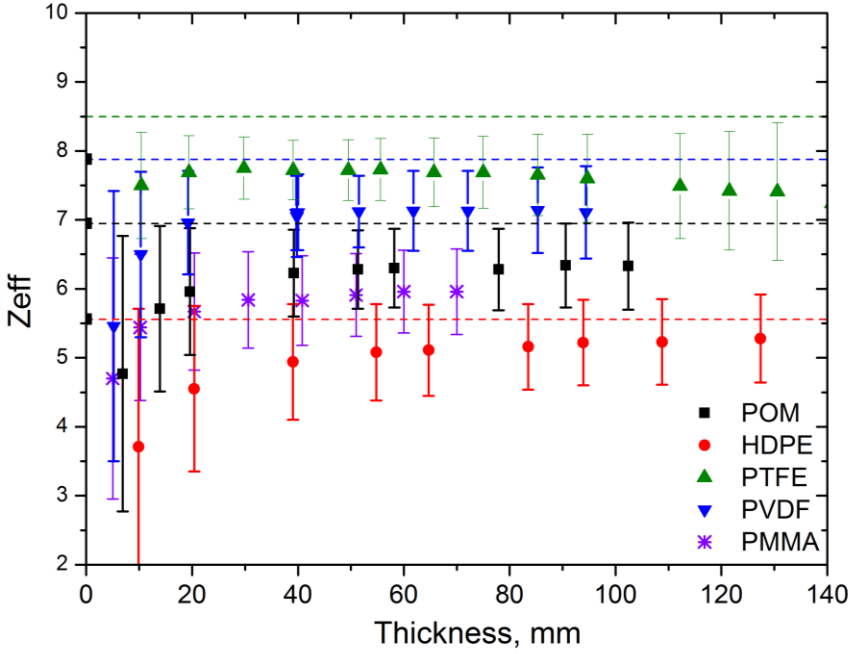
Initial Retrofit Results: Zeff Comparison

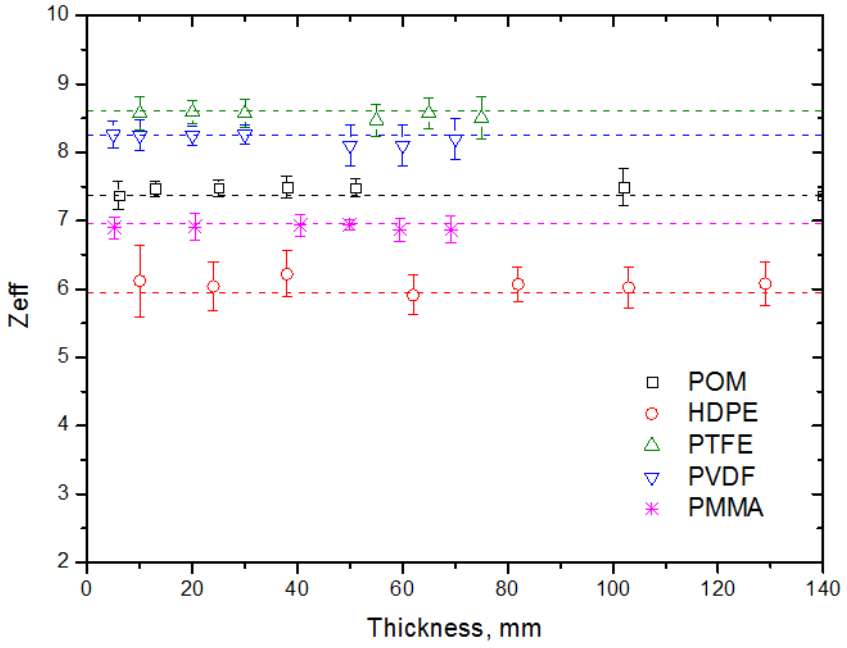
Zeff for some explosive simulants as a function of thickness :

- Dot Lines on the graphs represent tabulated values
- ME brings higher accuracy (bias) and precision (σ) : factor 4 to 5(both cumulated)

Dual Energy DE



Multi-Energy ME



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More on “Who Cares?”

- **The main reason to deploy the ME100 is for improved threat identification.**
  - This is achieved through better material discrimination
  - Which leads to lower false alarm rates
  - Which leads to higher throughput, reduced staffing levels and lower cost
  - Which leads to improved passenger facilitation
- **Progress:**
  - ME integration within various leading OEM conventional x-ray equipment
- **Results**
  - Liquid Explosives: Divested LAGs (a good example)
  - Solid Explosives: Complex imaging situations and Personal Electronic Devices (PEDs)
  - Alarm Resolution

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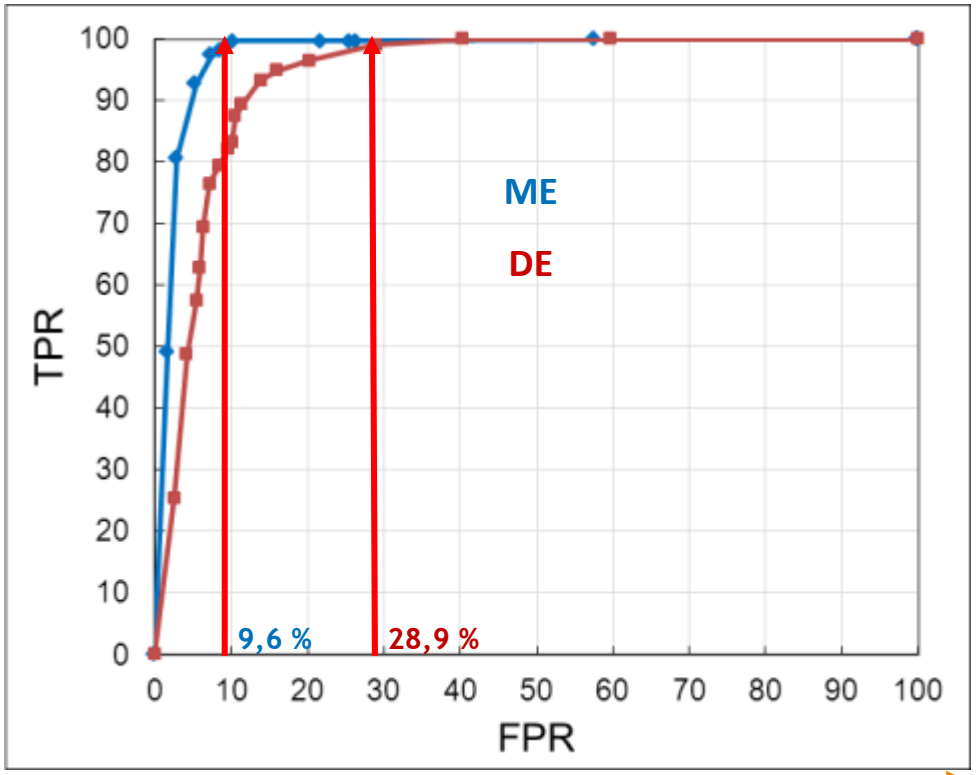
Liquid Explosives: Divested LAGs (OEM 1)

- **Objects**
  - 24 benign items in plastic containers,
  - 3 threats, ab 100 scans each : NM-real, HP-sim, NG-sim

- **Criteria**
  - Mean Zeff values for each of the 3 threats

- **PFR of 99%**
  - **ME=> FAR 9,6 %**
  - **DE=> FAR 28,9 %**

FAR reduction by factor 3



- **NM: Nitromethane (500ml),**
- **HP: Hydrogen Peroxide 70% simulant (500ml),**
- **NG: Nitroglycerine simulant (500ml)**

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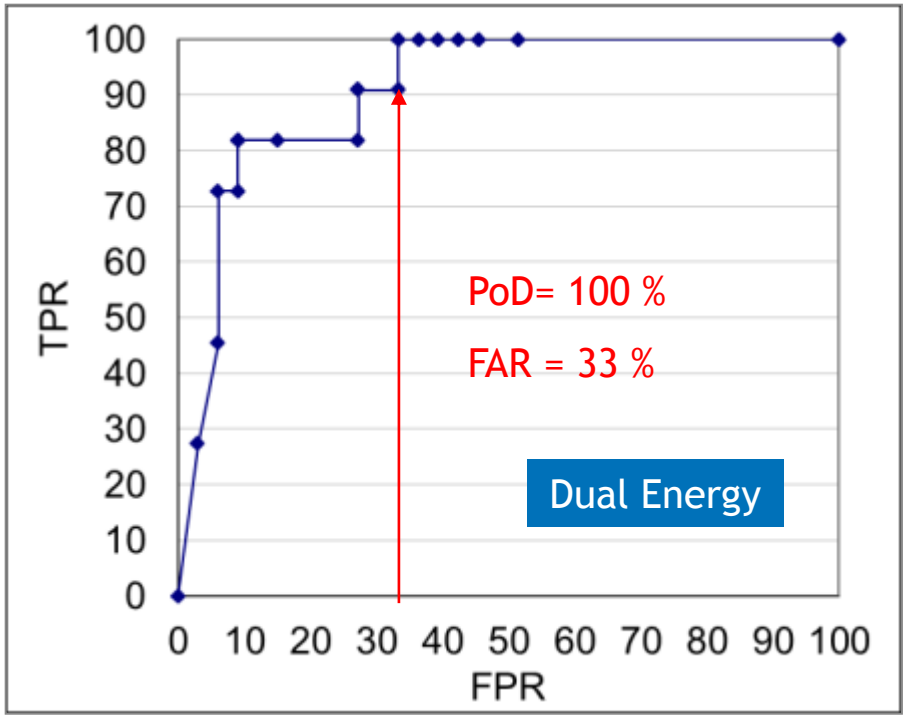
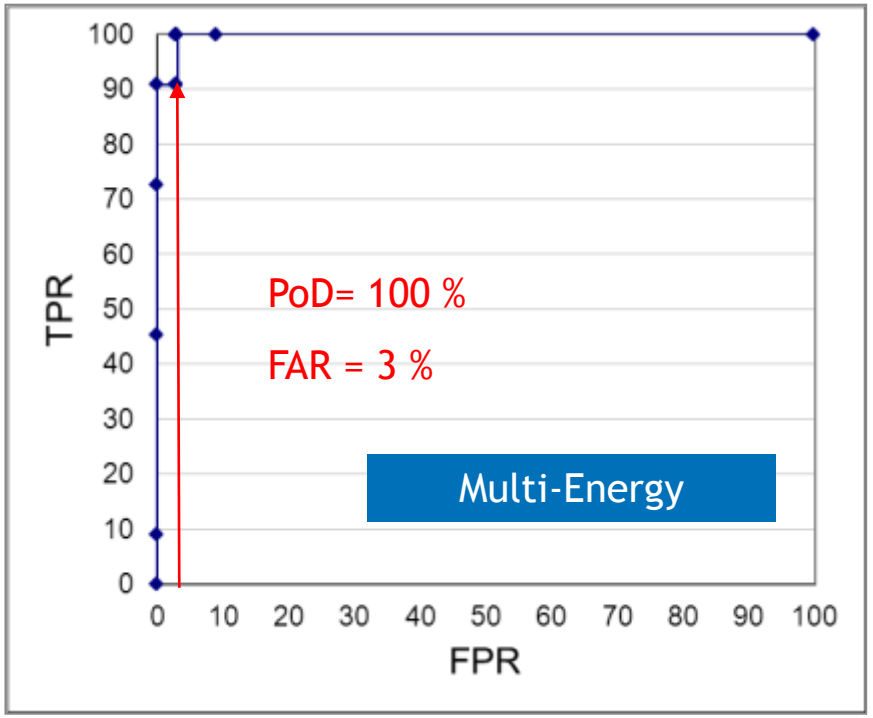
Liquid Explosives: Divested LAGs (OEM 2)

- **Objects:**
  - 3 Benign items (baby milk, hair gel and mouthwash)
  - 1 “Threat” item (water)
- **Criteria:** Mean Zeff values for each of the 3 threats





FAR reduction by factor 10

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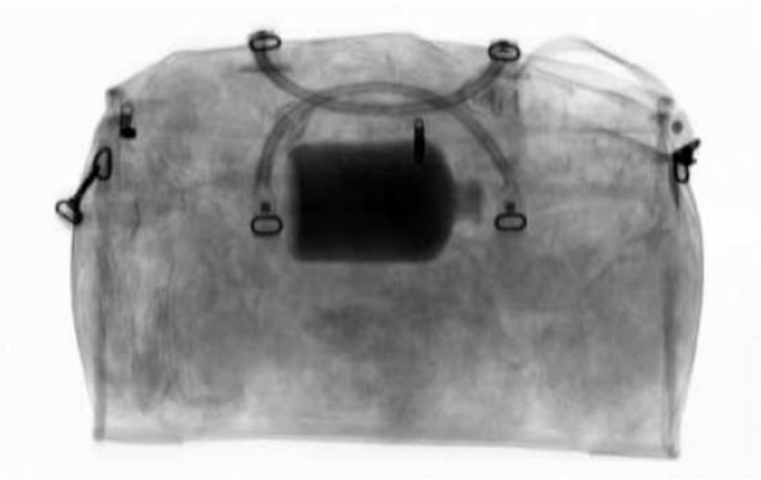
Liquid Explosives: LAGs in Bags with Overlap



with Clothing

with Aluminum

Sample	Zeff after correction	Stdev	With Overlap	Stdev	Zeff after correction	Stdev	With Overlap	Stdev
70% NA	7.51	0.06	7.68	0.04	7.56	0.12	8.20	0.03
50% HP	7.41	0.09	7.72	0.03	7.45	0.02	8.07	0.04
water	7.35	0.11	7.76	0.20	7.37	0.03	8.15	0.09
NM	7.24	0.16	7.62	0.03	7.19	0.05	8.08	0.03
50% Ethanol	6.78	0.05	7.25	0.06	6.98	0.03	7.91	0.04

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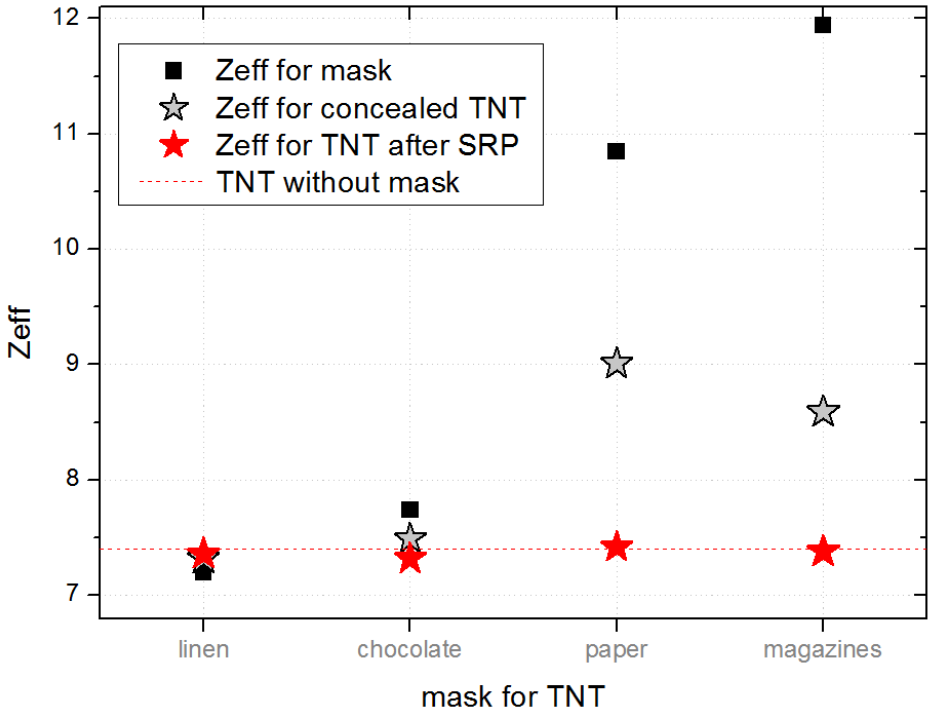
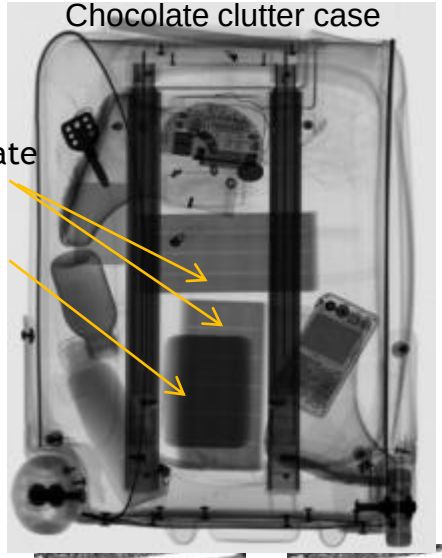
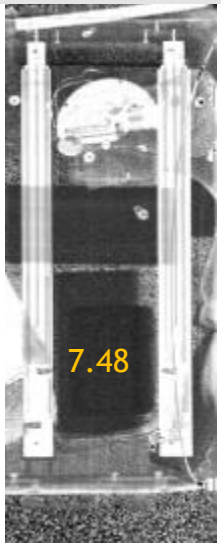
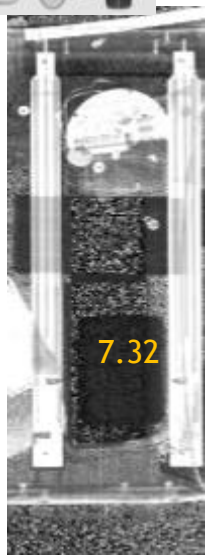
Solid Explosives: Cluttered Bag Overlap Experiments

- TNT overlap recovery from various objects found in bags:
  - chocolate (35 mm), paper (50 mm), magazines (13 mm) and bed linen (22 mm)









- Processing allows recovery of the TNT Zeff (within 0.1)

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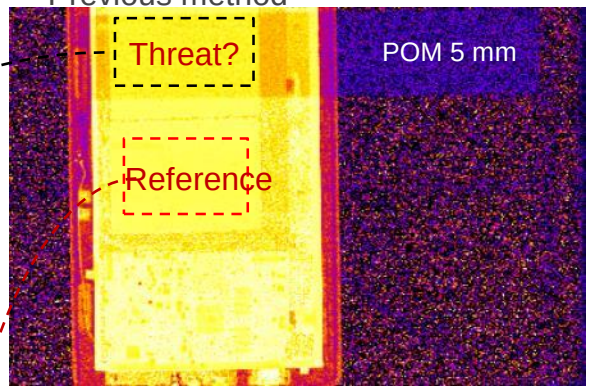
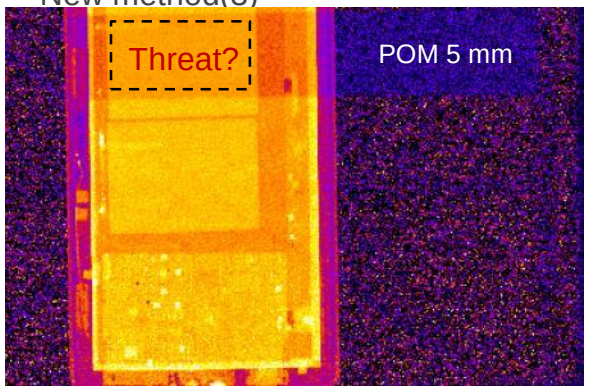
Solid Explosives 2: Sheet Explosive + Tablet

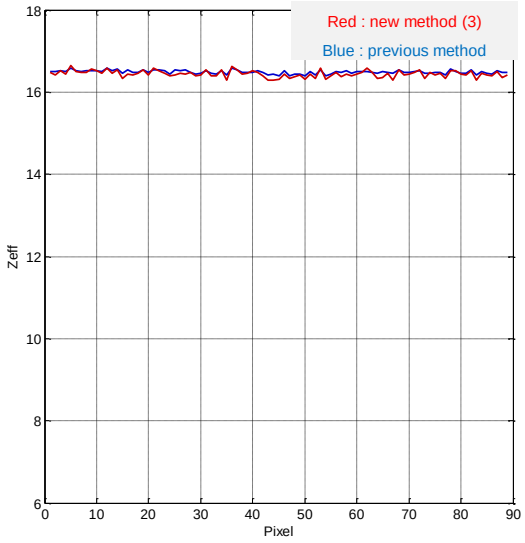
- **Objects:**
  - Explosive sheet simulant (5mm)
  - Tablet
- **Processing:**
  - Zeff recovery methods
  - Comparison of new and old methods

Previous method



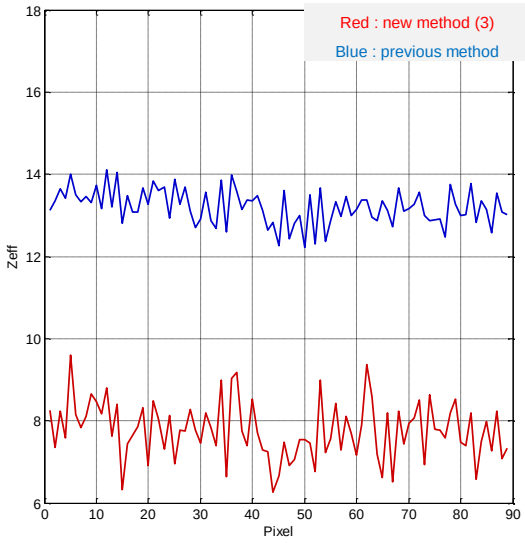
New method(3)





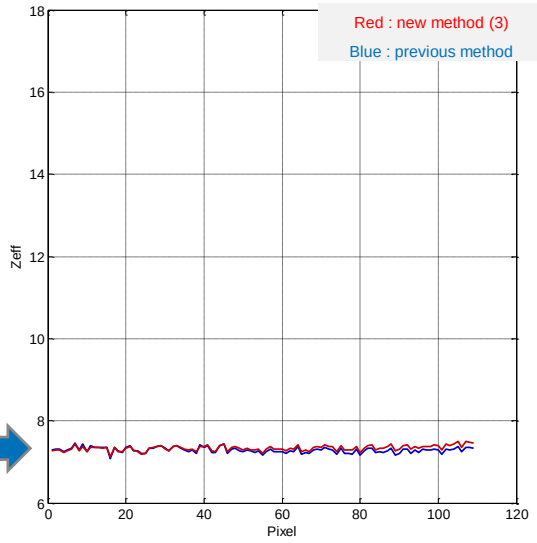
Z_{eff} PED + 5 mm POM.

Background substraction



Recovered Z_{eff} (POM) with background substraction

POM reference



Z_{eff} 5 mm POM.

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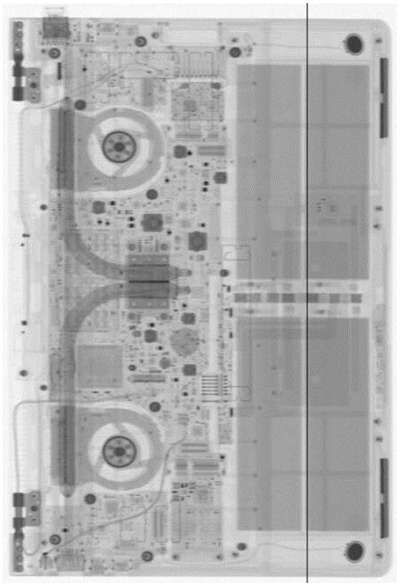
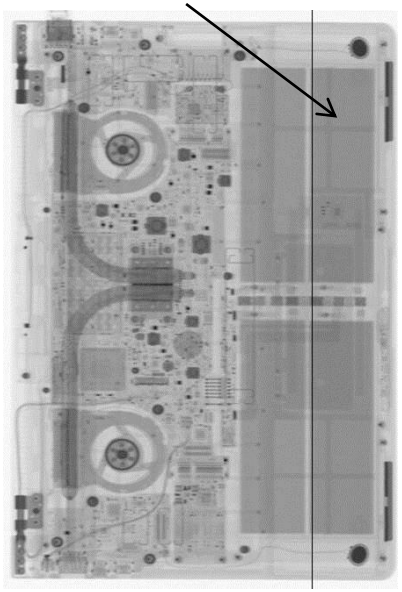
Solid Explosives 3: Sheet Explosive + Laptop/Tablet

- **Objects:**
  - Explosive sheet simulant (5mm)
  - Laptop
- **Processing:**
  - Zeff recovery methods
  - Comparison of new and old methods

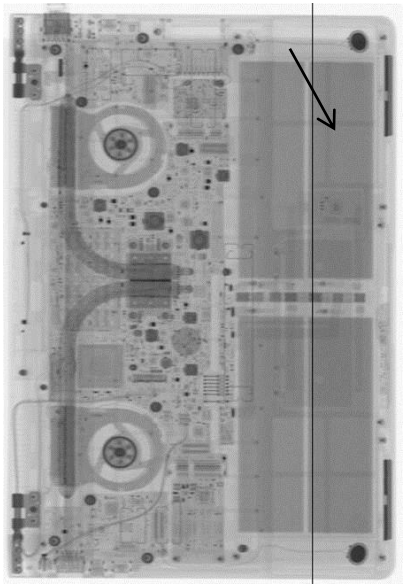
Computer



Computer + Sheet 5mm C4



Computer + Sheet 11mm C4



Actual Zeff (C4)	Recovered Zeff (C4 11mm sheet)behind laptop	Recovered Zeff (C4, 5mm sheet) behind tablet
7.23	7.38	7.52

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Alarm Resolution

- Checkpoint alarm resolution is an important step.
- Due to there being a non-zero false alarm rate there is always a need to do alarm resolution
- Current checkpoints cannot handle current AT2 false alarm rates with secondary search
- It is inevitable that On Screen Resolution will be employed to match the secondary search rate capability
- On Screen Resolution Requirements:
  - High spatial resolution
  - Good contrast
  - Good penetration
  - Efficient image processing tools

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Alarm Resolution 1: ASTM Image Quality

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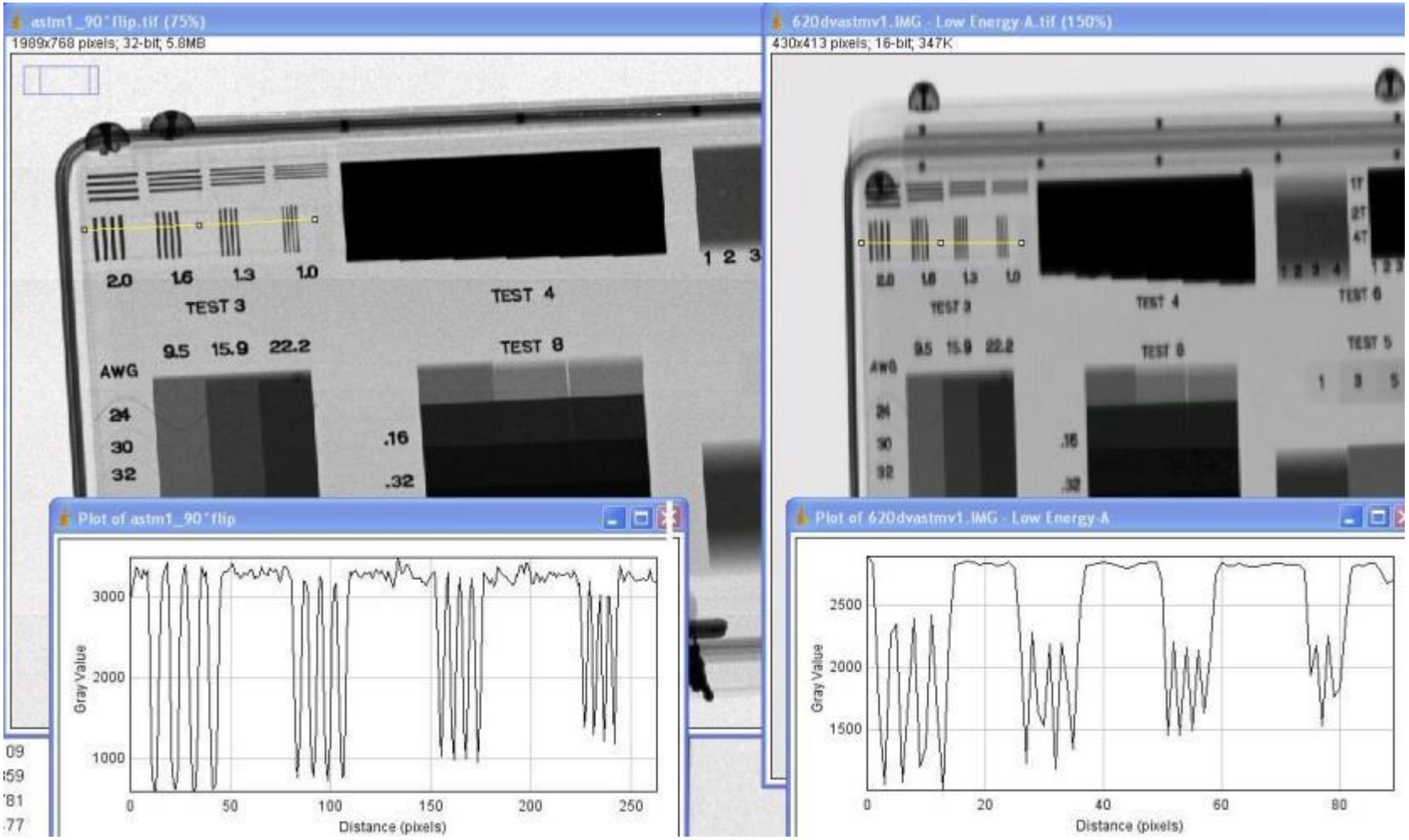
Dual Energy



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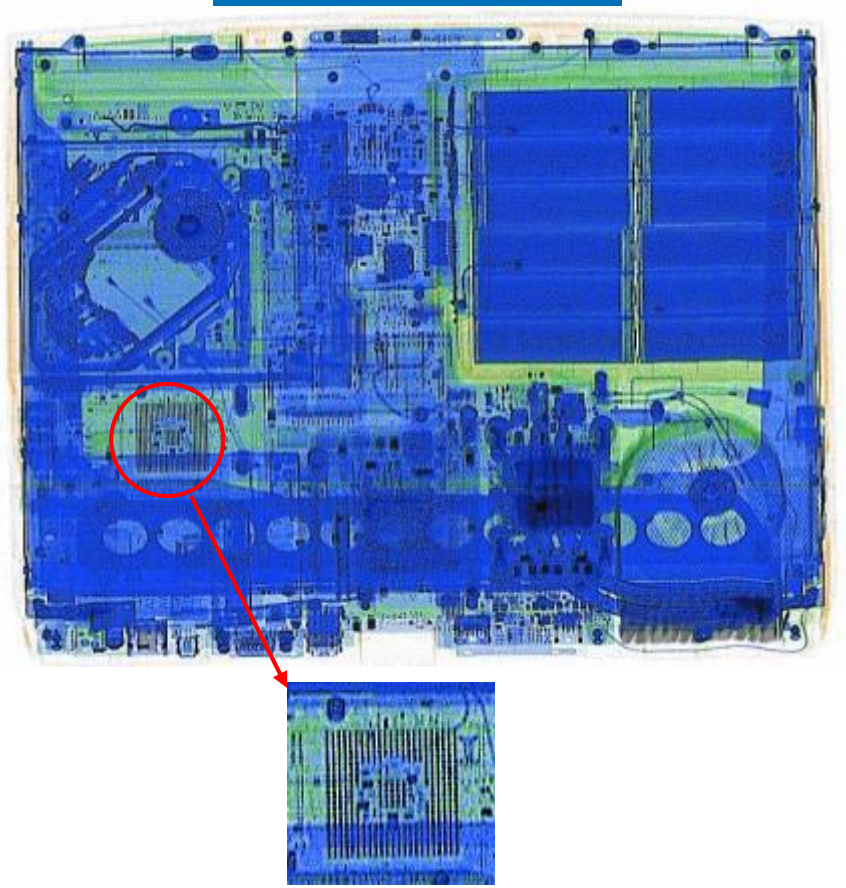
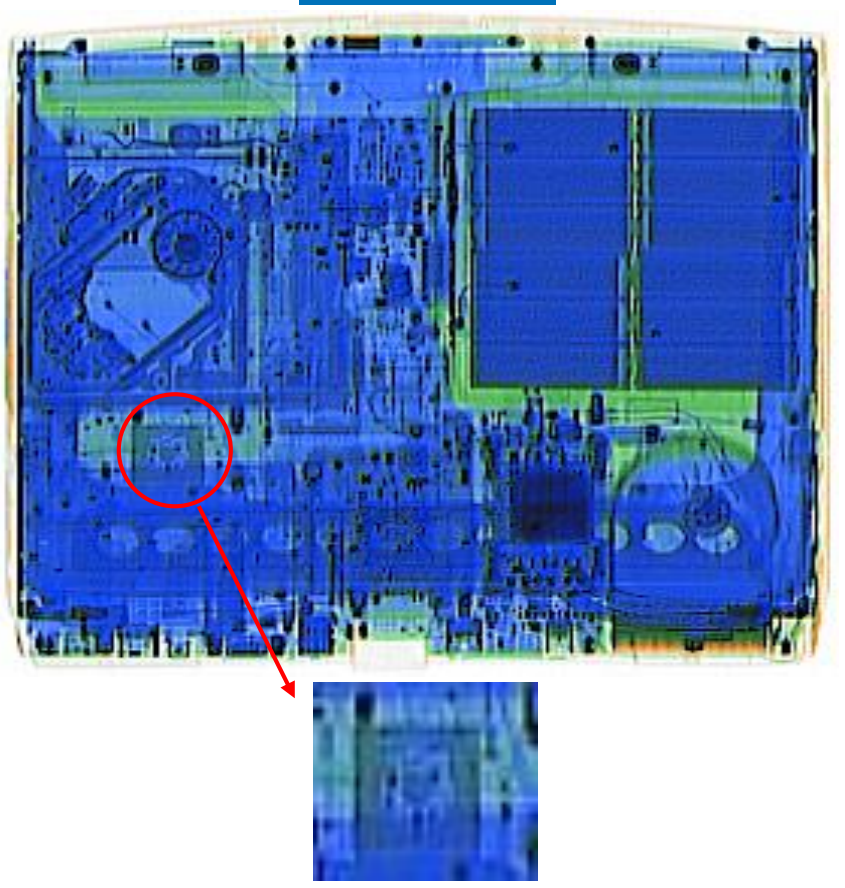
Alarm Resolution 2: Complex Images

Multi-Energy



Dual Energy



Improved Spatial Resolution with ME Detectors

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Conclusion

ME detection:

The next step in empowering the conventional x-ray platform to meet emerging security regulations and airports requirements:

- Automatic, real-time identification of all illicit materials including explosives,
- Significant decrease of FAR versus dual energy technologies,
- Increased throughput,
- Retrofitable,

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