Contraband Detection in Air Cargo Containers

Algorithm Development for Security Applications 2014

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Passport Systems, Inc.

What Could TSA Obtain?

- Integrated solution to detect explosives, nuclear material and other contraband

- Automated detection – Think CT machine for air cargo

- 3D volumetric data of density and effective Z for region of interests
  - Available for operator review
  - Locates any potential threat

- Ability to resolve regions of interest to the elemental level

- Increased throughput due to larger scan volume (LD size)

- Low False Alarms due to orthogonal information
  - Alarms match in density, effective Z, and elemental ratios

- Ability to clear containers with confidence

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EZ-3D Volumetric Data of Density and Effective Z

Color Scale = Zeff Range   Transparency = Density

Targets

■ Organic   ■ Tobacco

■ Inorganic   ■ C4 Explosive

■ Metals   ■ Cocaine

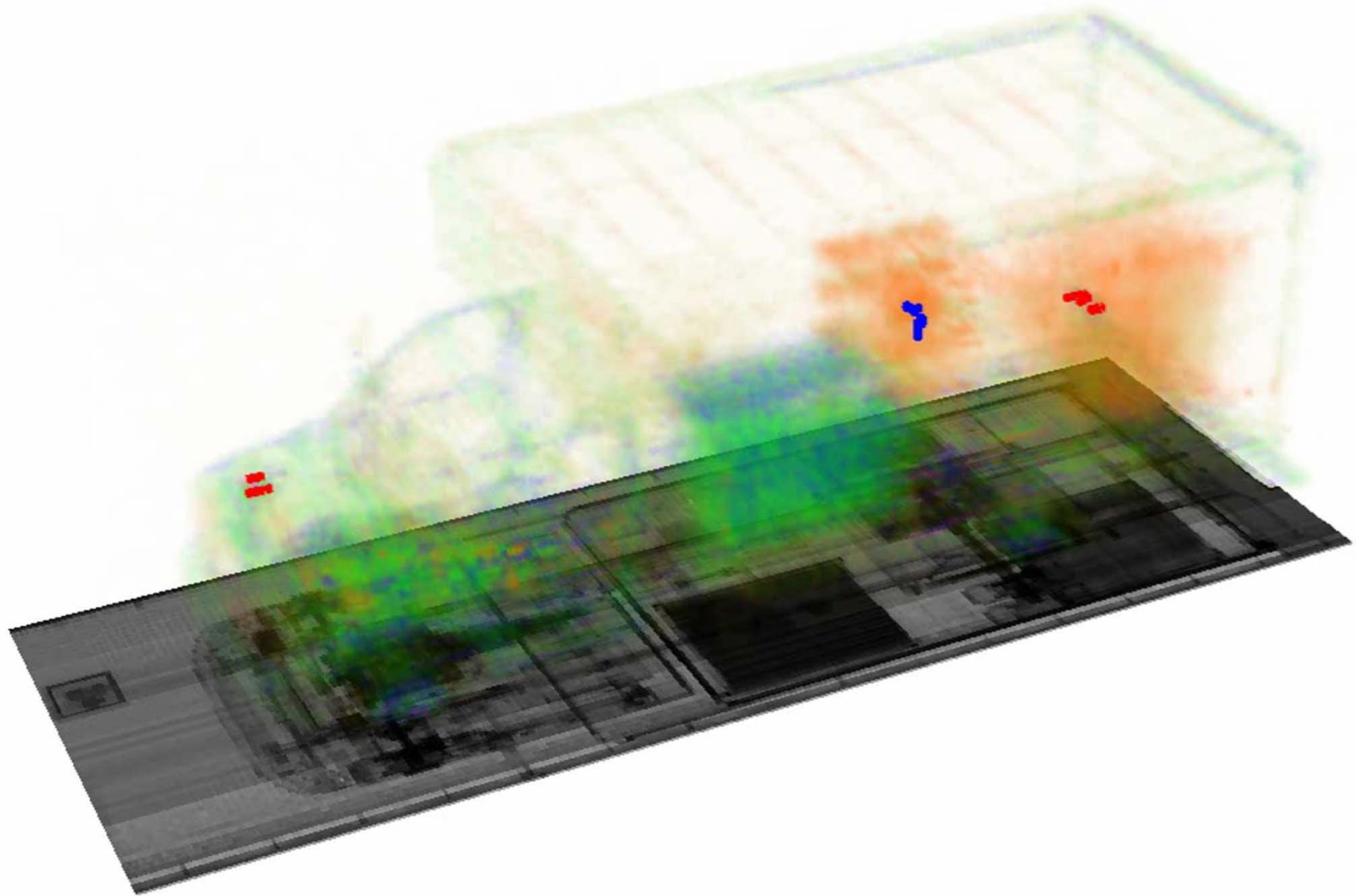■ Dense Metals   ■ High - Z

- ■ Cargo is scanned slice-by-slice and reconstructed in 3D
- ■ The voxels are aggregated into regions-of-interest
- ■ These ROI's are analyzed for targeted materials at elemental level

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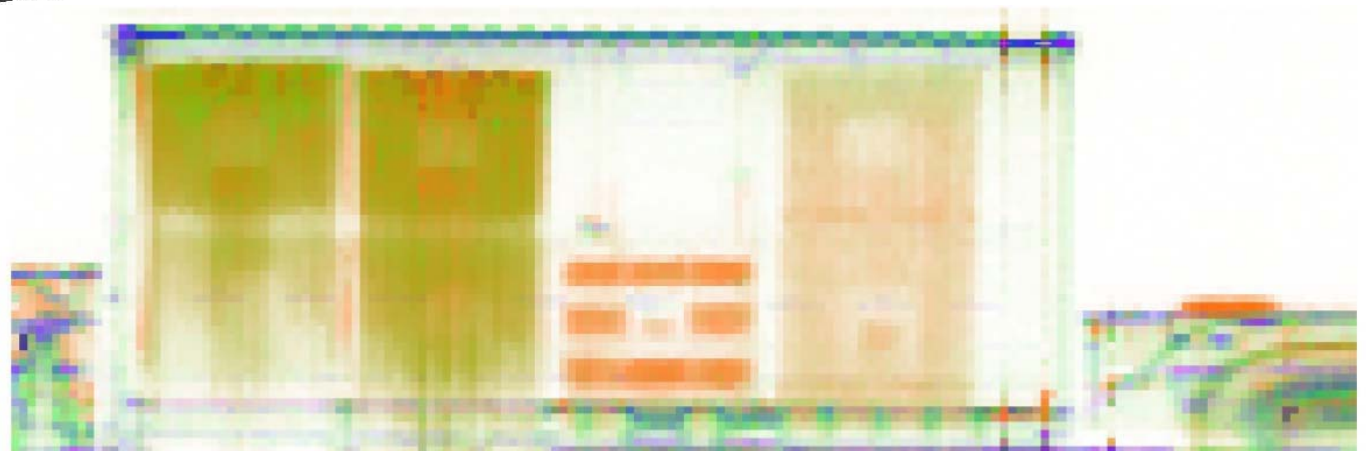
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EZ-3D Volumetric Data of Density and Effective Z with Targeted Materials

Cargo measurements

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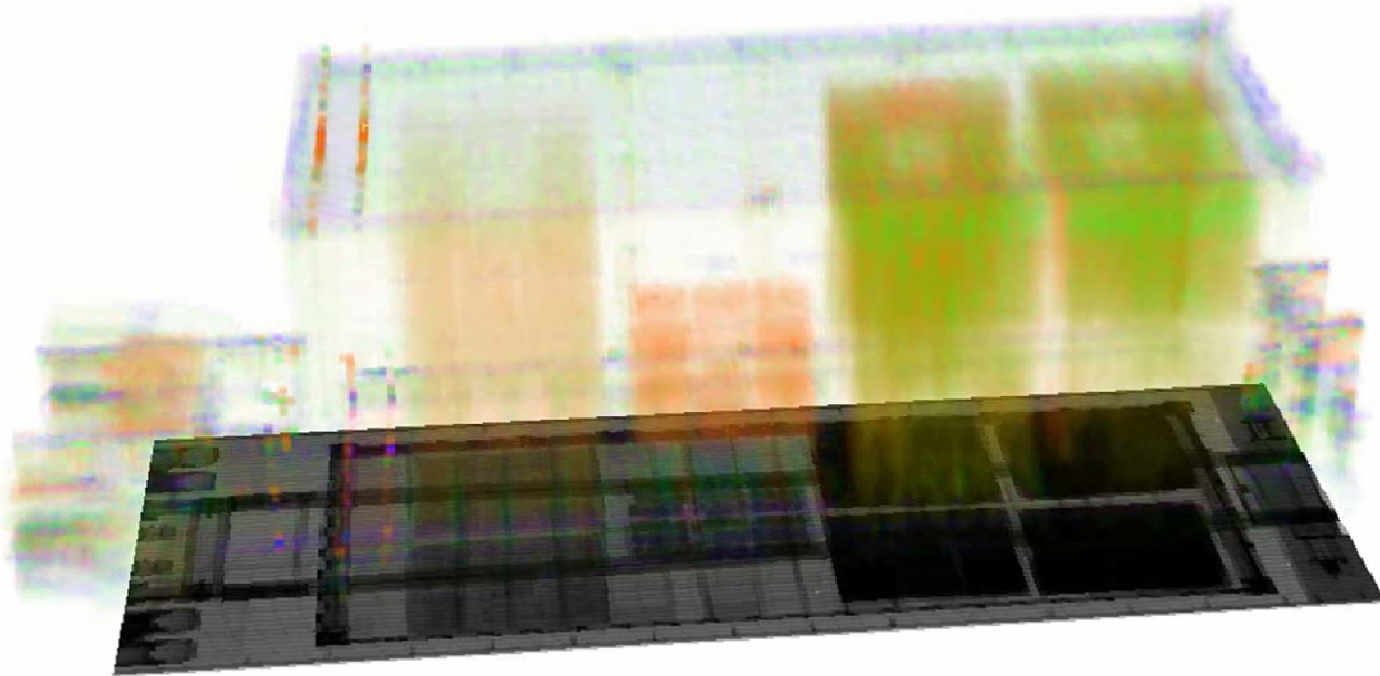Systems Inc.
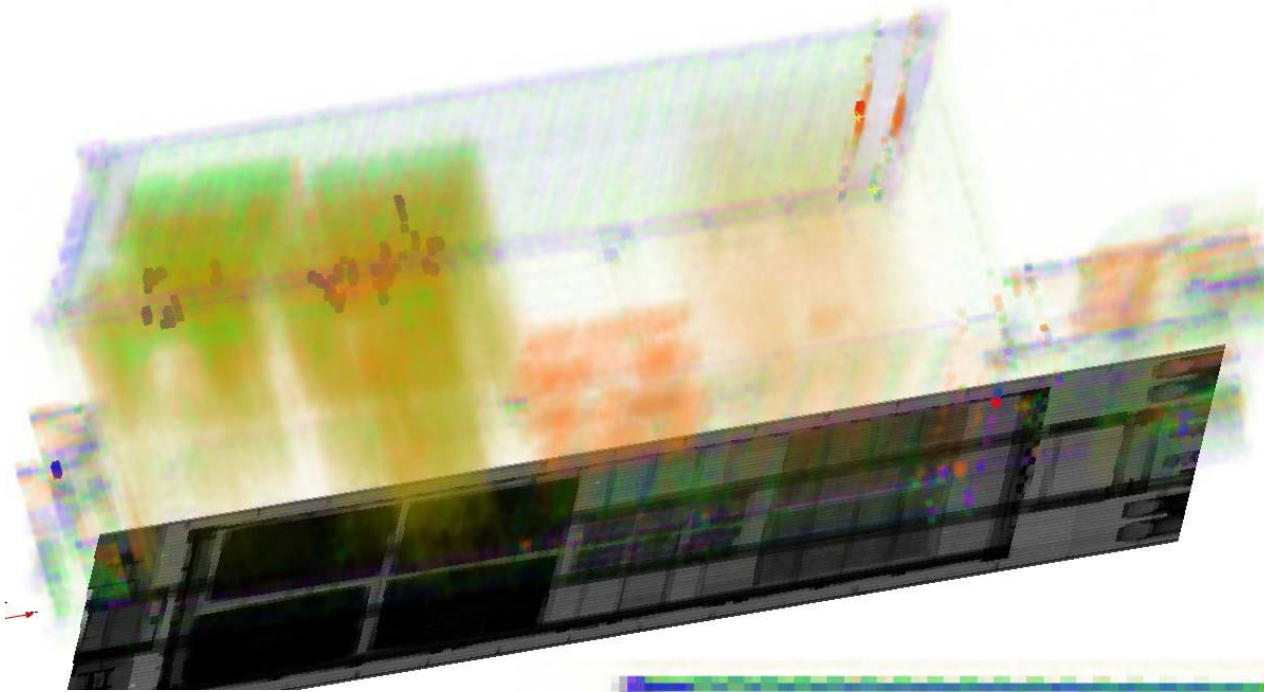
Cargo measurements

Standalone Cargo Scanning Facility

Design for facility to be installed at Port of Boston

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Passport's Cargo Scanner

Beam Scanner

EZ-3D™ Detectors

Cargo

Electron Beam Generator

NRF Detectors

Photofission Detectors

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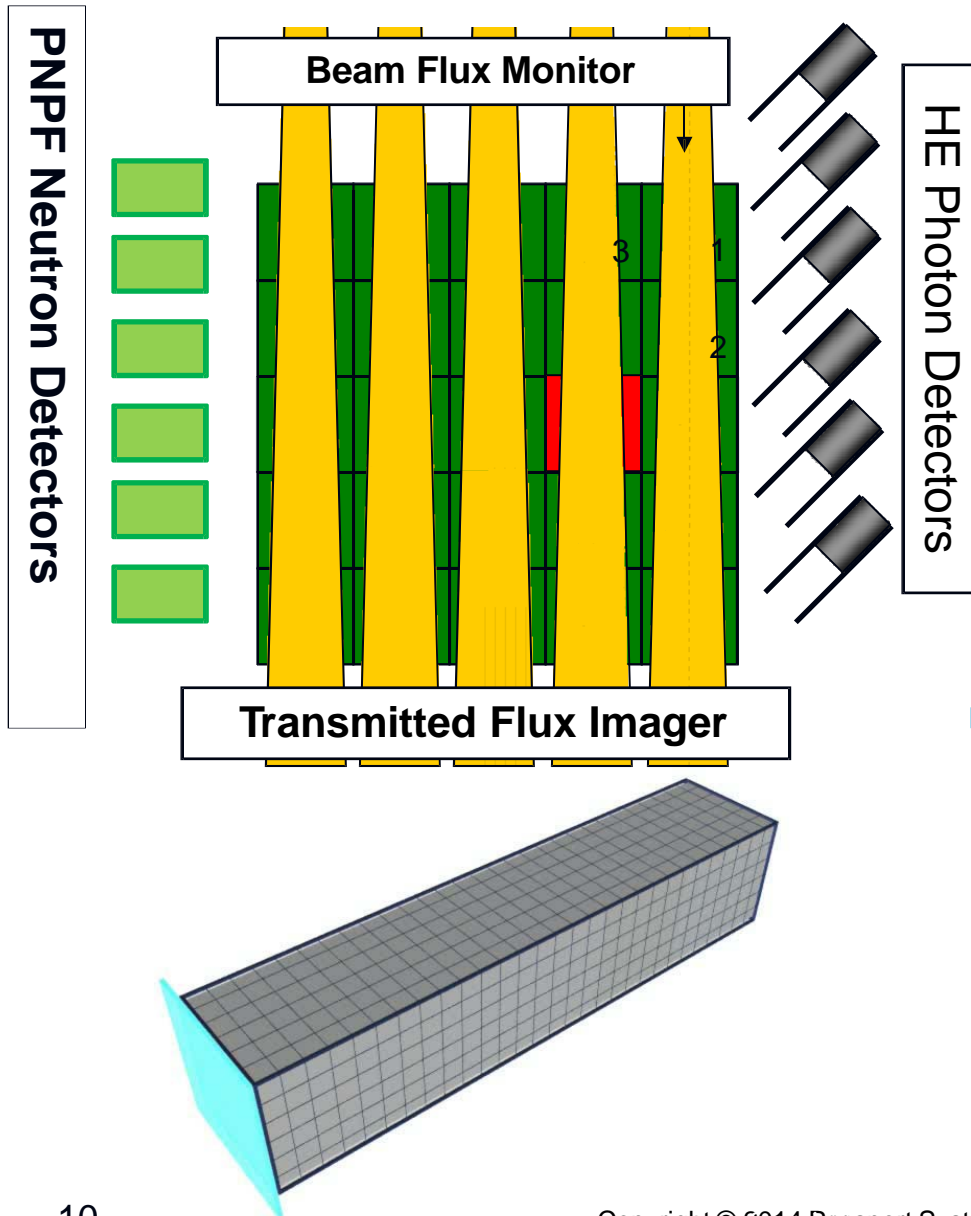Systems Inc.
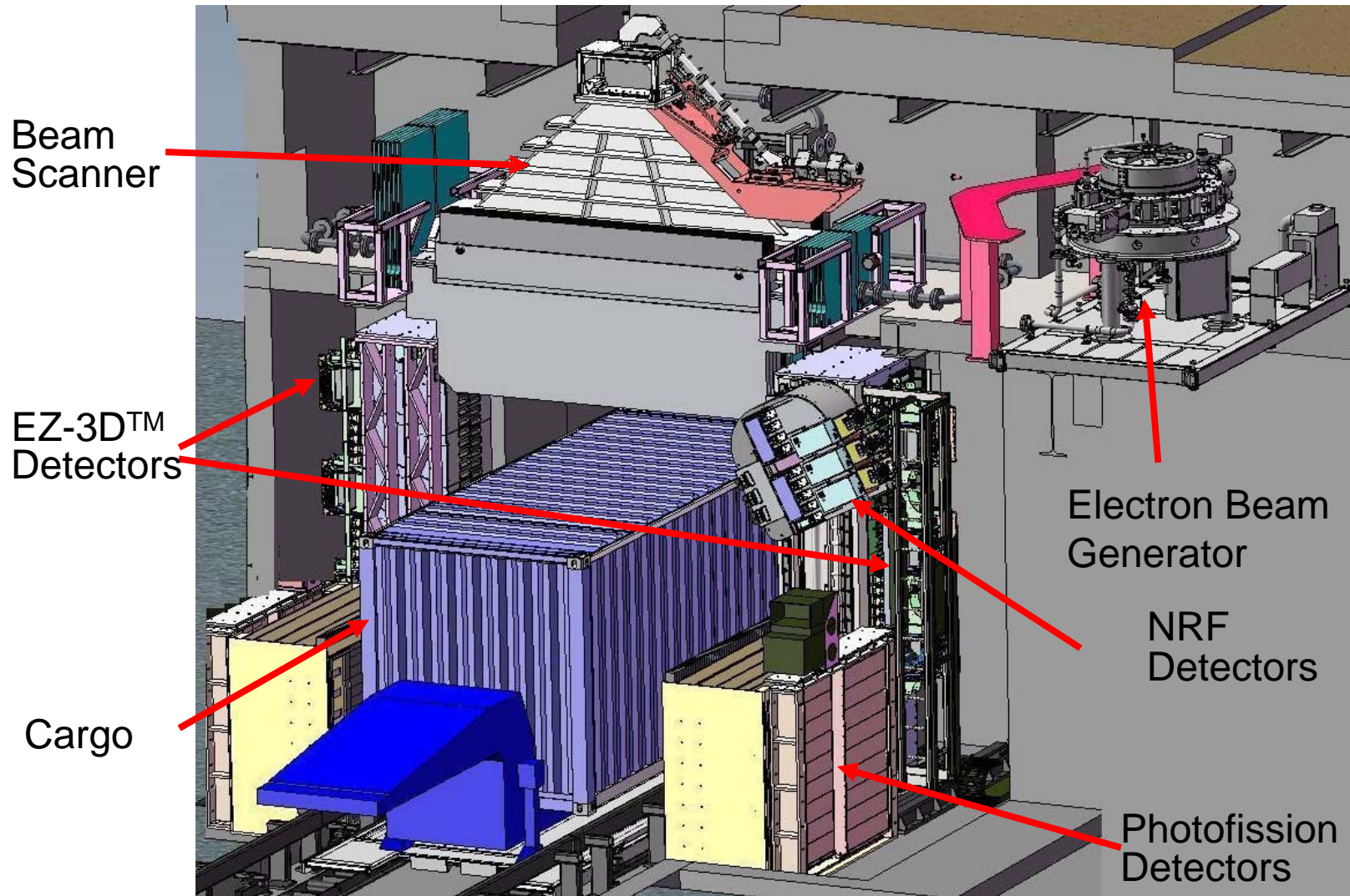
Passport Scanner Technologies

Beam

9 MeV Bremstrahlung
Photons

Measured Particle

Photons: Effective-Z (EZ-3D™)
Nuclear Resonance Fluorescence (NRF)
Neutrons: Photofission (prompt)

Scan	Algorithm	Functionality / Output
Primary	EZ-3D™ Reconstruction	3-D density and Effective-Z map Anomaly identification/3D location
Primary	Transmission X-ray	Anomaly 2D location & density Shape/edge recognition
Primary	Portal Networked Detection System	Identification and localization of radioactive sources
Primary & Secondary	Photofission	Identifies presence of fissionable material
Secondary	NRF 3D	Complete isotopic composition in the region-of-interest
	Anomaly Classification	Performs data fusion, classifies anomaly as threat or innocuous, predicts detect/clear time

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Scan Geometry and Process

PNPF Neutron Detectors

Beam Flux Monitor

3   1

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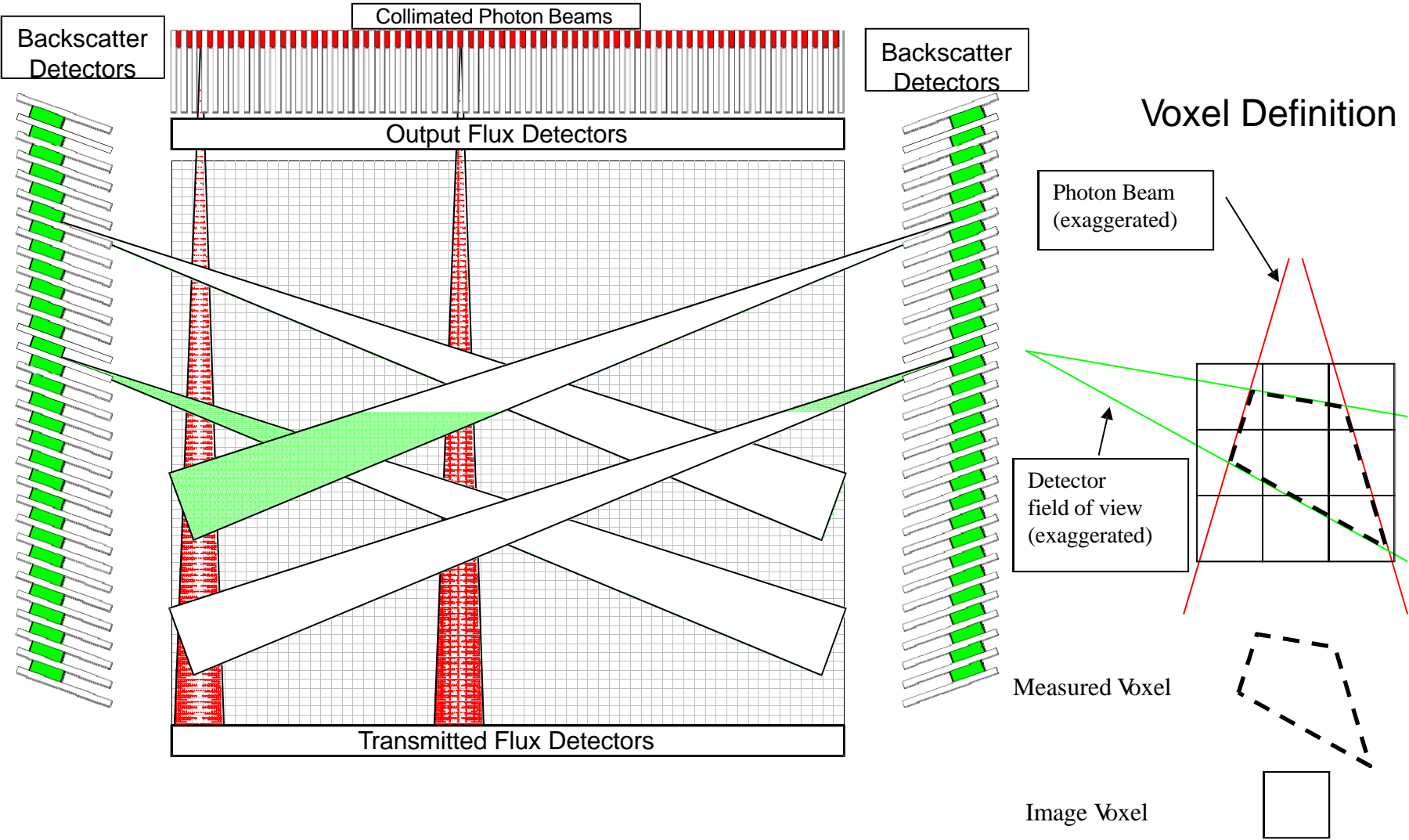**HE Photon Detectors**

Transmitted Flux Imager

- **Primary Scan:**
  - Beam scans in the beam plane
  - Container traverses the beam
  - → 3D backscatter image (EZ-3D™)
    - ~15 s/20' container
    - 3D map of effective Z & density
  - → 2D transmission image
  - → 2D neutron image
    - Fissionable Material Alarm
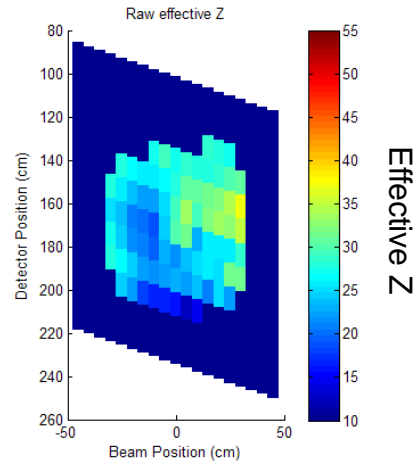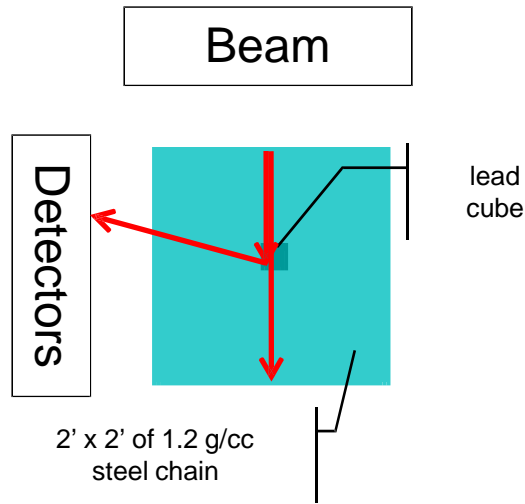 - → ROIs for secondary scan

- **Secondary Scan – ROI inspection:**
  - PNPF, beam dwell on ROIs (~seconds)
    - Fissionable Material Alarm
  - NRF, beam dwell on ROIs (~minutes)
    - Elemental Composition

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EZ-3D™ Geometry

Collimated Photon Beams

Backscatter Detectors

Backscatter Detectors

Output Flux Detectors

Transmitted Flux Detectors

Voxel Definition

Photon Beam (exaggerated)

Detector field of view (exaggerated)

Measured Voxel

Image Voxel

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EZ-3D™ Reconstruction

Beam

Detectors

lead cube

2' x 2' of 1.2 g/cc steel chain

Raw Data from Passport test bed
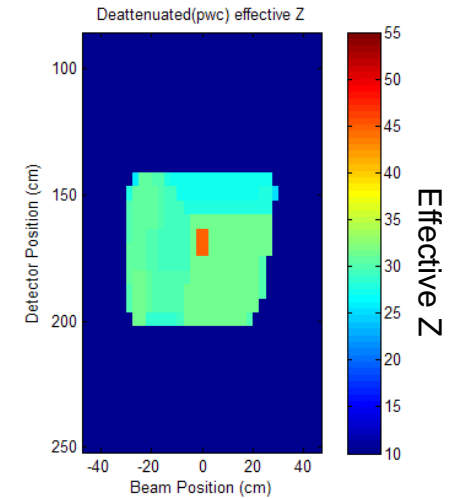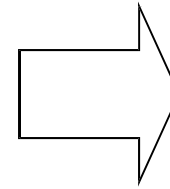
Reconstructed Image

- **Constraints**
  - Transmission
  - Attenuation In
  - Attenuation Out
  - Regularizer – Biases toward "likely" solutions

Output for Data Fusion

- Position
- Surface area
- Attenuation In
- Photon Attenuation Out
- Neutron Attenuation Out
- Density
- Effective Z

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EZ-3D™ Detection Algorithm

- Utilize Z_{eff} and density image produced by Reconstruction
- Detection: use simple axis aligned upper and lower thresholds on Z_{eff} and density
- Thresholds determined by using reconstructed image voxels from training scans

Mean Properties of Single Targets in Air; 20 scans
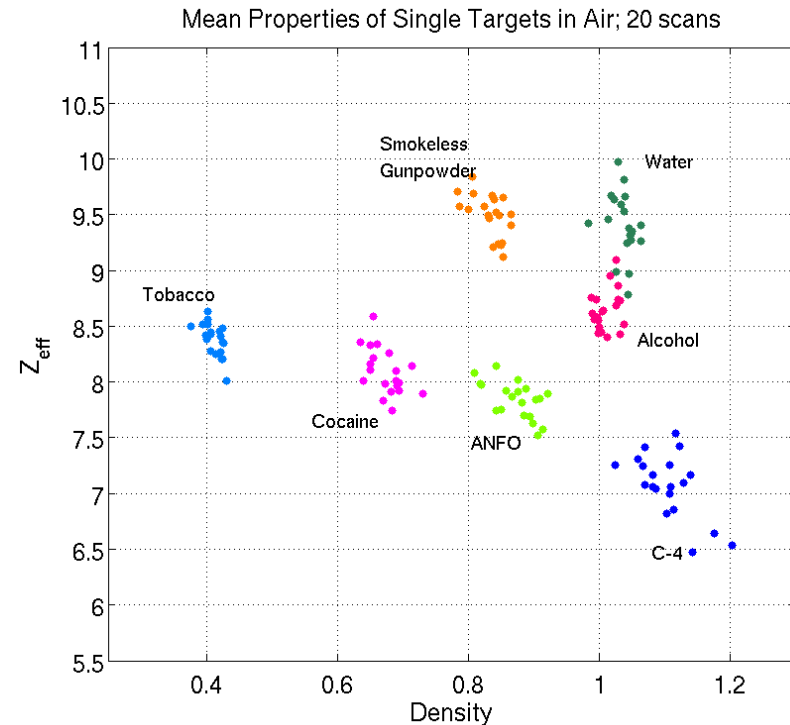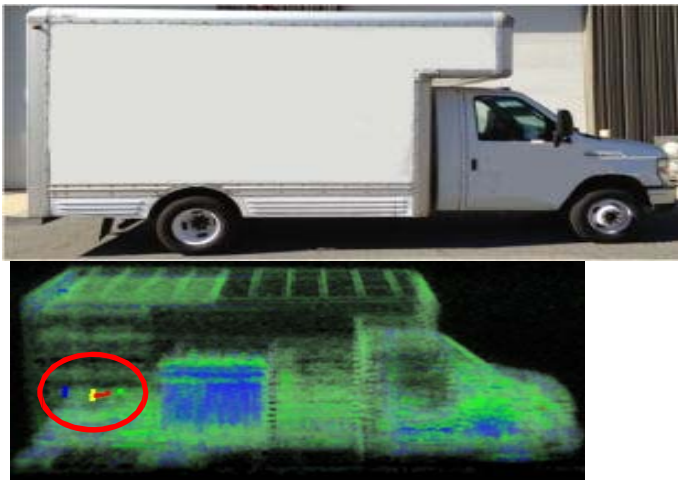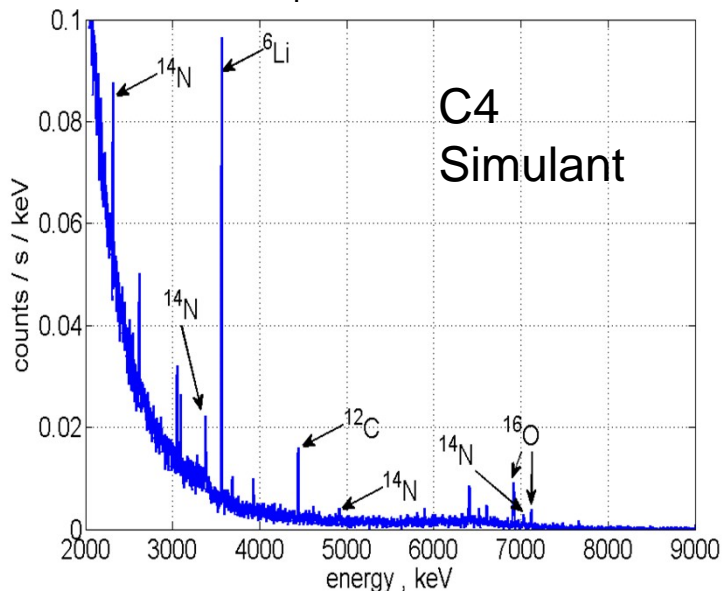

Threat Object	Type	Color
Calcium Hypochlorite	Oxidizer	Blue
Butane	Flammable Gas	Yellow
Gasoline	Flammable Liquid	Red
Hydrogen Cyanide	Toxic	Green

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NRF Algorithms Overview

Plot of ^{235}U Spectrum

^{235}U NRF

E_{beam} = 2.1 MeV
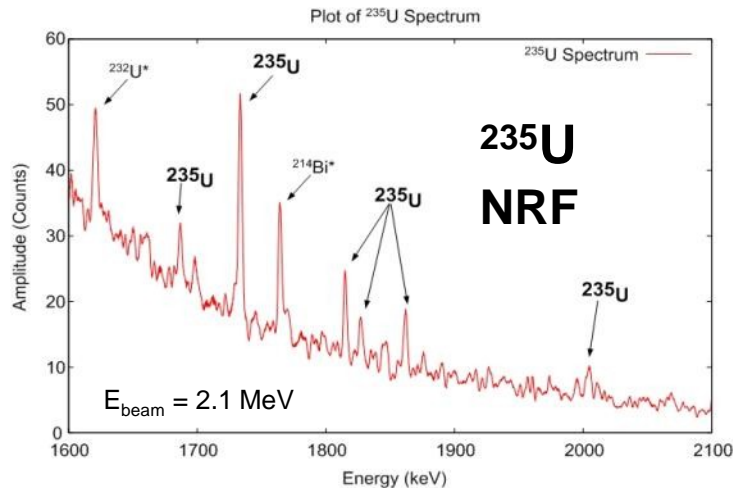
* Measurements performed with PNNL

C4 Simulant

- **NRF Data**
  - Integrated counts for each line / detector
  - Background rate for each line / detector

- **Anomaly identification**
  - Calculate expected signal count rate for threat hypothesis
  - Calculate likelihood of measured NRF counts for hypothesis
  - Determine if anomalies from user-defined list are present / absent at defined level of PD / FP

- **Supporting functions**
  - Background estimation
  - Spectrum smoothing

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Explosive Detection Example
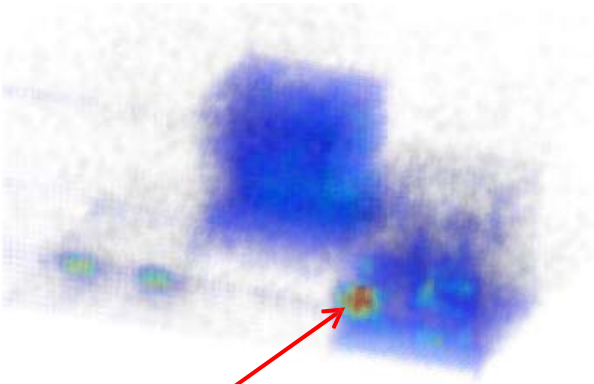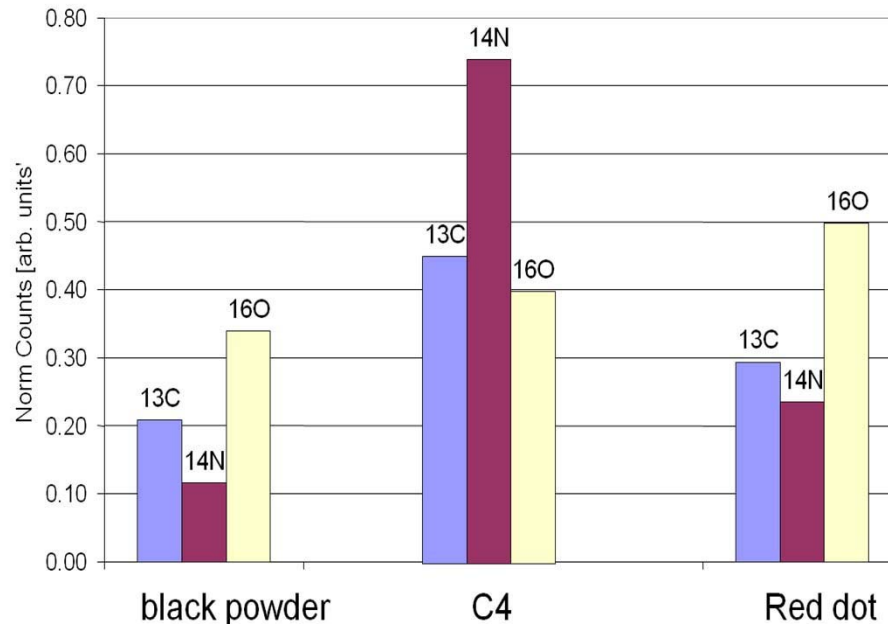

'Explosive' Anomaly
detected by density & EZ
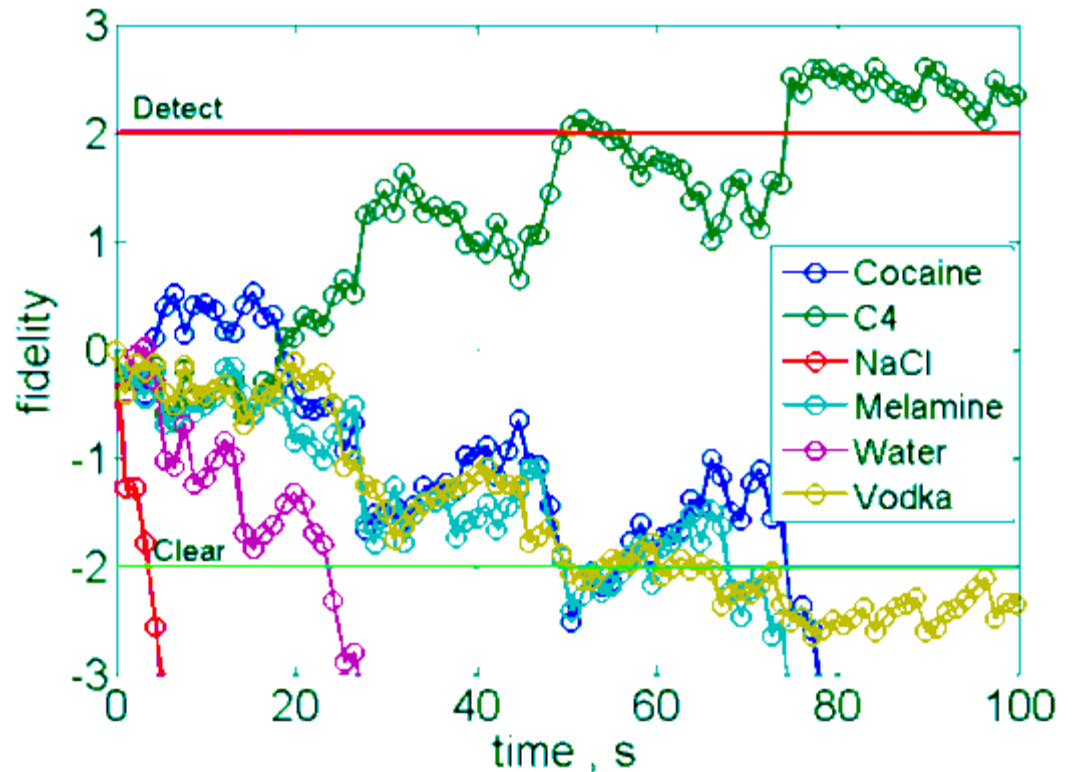
- Potential explosive anomaly detected by density, EZ
- Identified as C4 in minutes

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Nitrogen, Oxygen, and Carbon as Signatures

10 MeV Simulant Measurements

	C4 (%)		Red Dot (%)		Black Powder (%)	
El.	Mass Spec	NRF	Mass Spec	NRF	Mass Spec	NRF
C	23.0	21.6±2.7	25.2	27.4±3.4	14.8	15.2±2.2
N	32.9	41.0±6.7	13.9	11.2±1.8	11.2	11.5±1.9
O	38.8	37.4±3.6	58	61.4±5.9	33.7	41.4±4.3

■ Isotopic identification offers clear discrimination between other materials

■ NRF technique agrees well with other techniques

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Summary

- EZ-3D™ reconstruction - novel imaging technique for automated contraband detection

- NRF provides isotopic/elemental identification

- Passport's scanner provides unique solution for
    - Explosives
    - Nuclear Material
    - Contraband
    - Material Identification

- Passport building land/sea cargo container scanner at port of Boston

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