Multi-Spectral 3D Reconstruction and Data Fusion for Contraband Detection in Cargo Containers

Algorithm Development for Security Applications 2013

Steve Korbly, Ph.D.
Passport Systems, Inc.

Work Supported by U.S. Department of Homeland Security Domestic Nuclear Detection under competitively awarded Contract No. HSHQDC-08-C-00124. This support does not constitute an express or implied endorsement on the part of the government. All claims and representations contained herein are those of Passport Systems, Inc. alone

Copyright ©2013 Passport Systems, Inc.

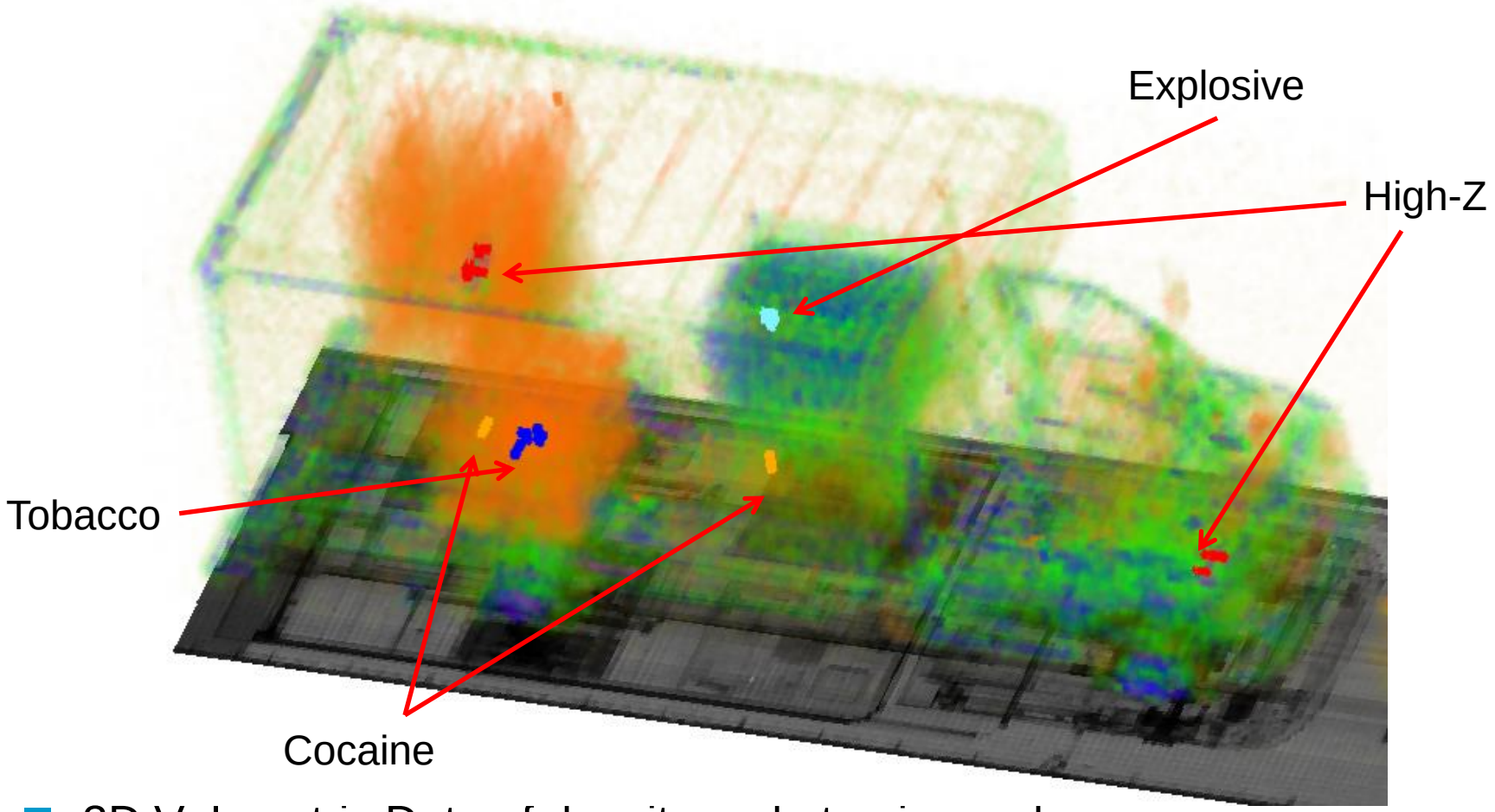
Passport Systems Inc.

Passport Systems Company Overview

- Private U.S. company founded in 2002 to address cargo security
  - Passport's technology allows prompt, thorough, and precise cargo screening
  - Identifies cargo by what is inside - not by how it 'looks'
- Passport has strong intellectual property position
  - Passport patents on core detection technologies, HW and applications
  - Unique automated threat detection algorithms
- $80 million invested in Passport to date
  - Major funding from U.S. Department of Homeland Security ($42M)
- Passport products
  - Cargo Scanner
  - Networked Sensor Systems (NetS2) SmartShield™ G300

Copyright ©2013 Passport Systems, Inc.

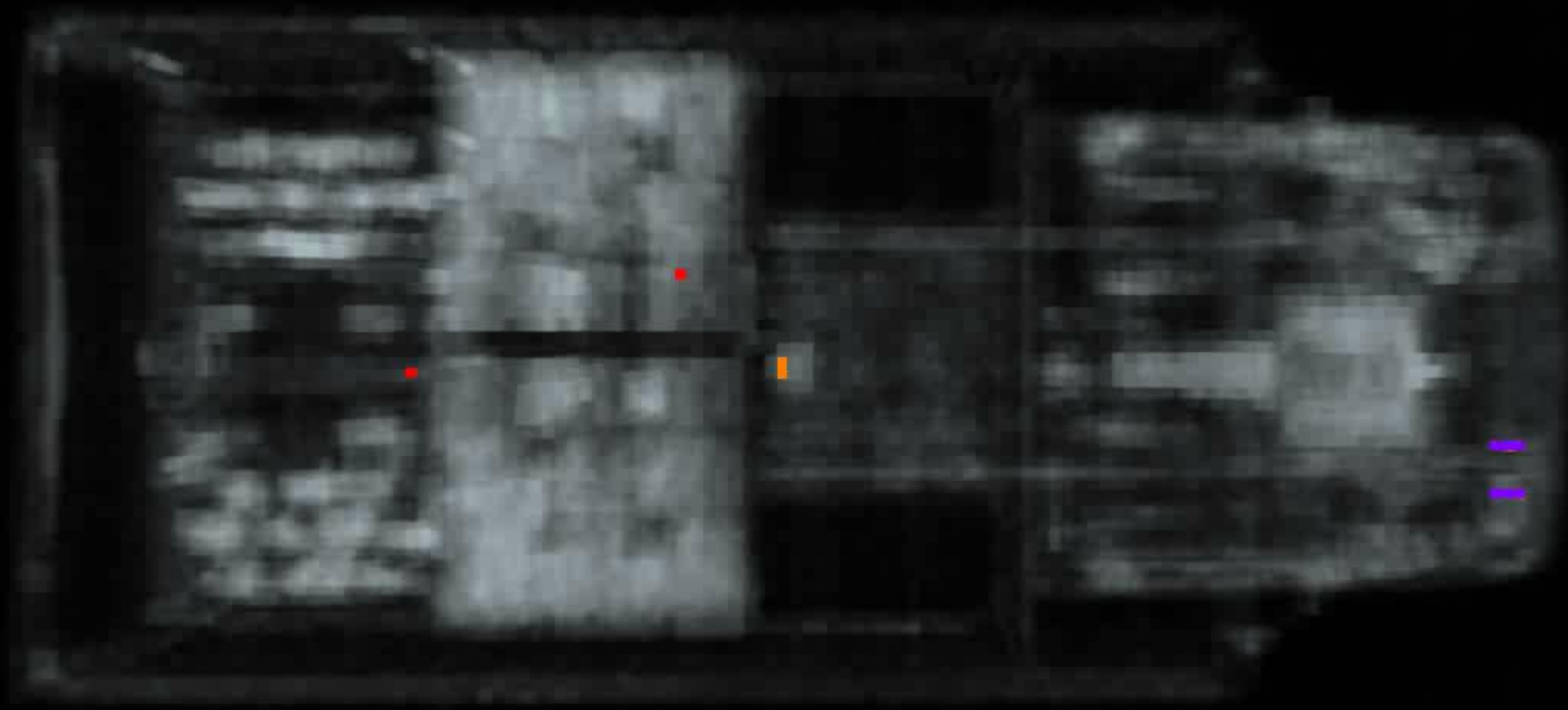
3D Volumetric Data: Density, Effective Z



- 3D Volumetric Data of density and atomic number
  - Provides regions/windows automated threat detection
- Regions of interest resolved to the elemental composition level

Copyright ©2013 Passport Systems, Inc.
Passport Systems Inc.

High-Z Fissionable Potential Explosive (ρ, Z) High-Z Non-Fissionable



Copyright © 2012 Passport Systems, Inc. www.passportsystems.com

Passport Scanner Advantages

- Every one of the 700,000 Tennis ball-sized pieces of the 3D vehicle image contains discrete and independent data
- Image analysts: rotate, zoom, slice, and set alarms
  - Just like doctors with an MRI
- Operator-assist algorithms alarm automatically in the background
  - matches to preset density & atomic number
  - anomalies in cargo which should be uniform
  - cargo which does not match the manifest
- Material identification in minutes or seconds without opening the vehicle
  - Materials have unique signature
  - Continuously monitors confidence levels and forecasts time to ID
  - Confidence thresholds fully customizable to support shifting CONOPS
- Confirmed innocent cargo is on its way in minutes
- Dangerous material identified?
  - High resolution image and 3D coordinates inform the response
    - Just explosives? – Devanning team trained to handle explosives
    - Explosives with wires? – Bomb squad

Copyright ©2013 Passport Systems, Inc.
Passport Systems Inc.

Standalone Cargo Scanning Facility

Conceptual design for facility to be installed at Massport (Boston, MA)

Copyright ©2013 Passport Systems, Inc.

Passport Systems Inc.

Passport Scanner Technologies

Beam

9 MeV Bremstrahlung
Photons

Measured Particle

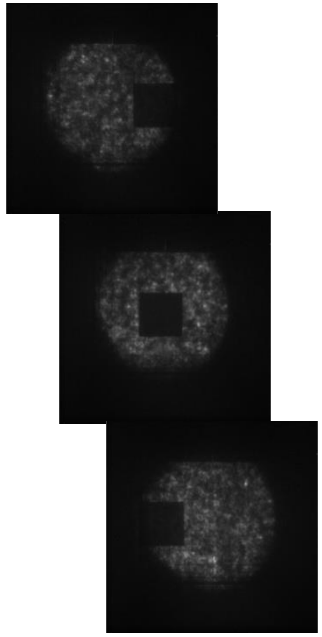
Photons: Effective-Z (EZ-3D™)
Photofission (prompt and delayed)
Nuclear Resonance Fluorescence (NRF)
Neutrons: Photofission (prompt)

Scan	Algorithm	Input	Functionality / Output
Initial	EZ-3D™ Reconstruction	Medium-resolution energy spectrum	3-D density and Effective-Z map Anomaly identification/3D location
Initial	Transmission X-ray	Medium/High spatial resolution transmission image	Anomaly 2D location & density Shape/edge recognition
Initial	Portal Networked Detection System	Medium-resolution passive spectrum	Identification and localization of radioactive sources
Initial & Prolonged	Photofission	Digitized pulses from liquid organic scintillator	Identifies presence of fissionable material
Prolonged	NRF 3D	High-resolution energy spectrum	Complete isotopic composition in the region-of-interest
	Anomaly Classification	Output of NRF 3D, PNPF, EZ-3D™ and transmission algorithms	Performs data fusion, classifies anomaly as threat or innocuous, predicts detect/clear time

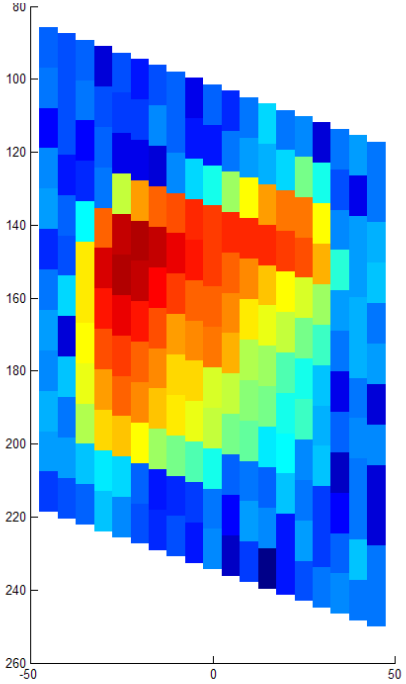
Copyright ©2013 Passport Systems, Inc.
Passport Systems Inc.

EZ-3D™ Anomaly Detection
Lead cube in steel chain example

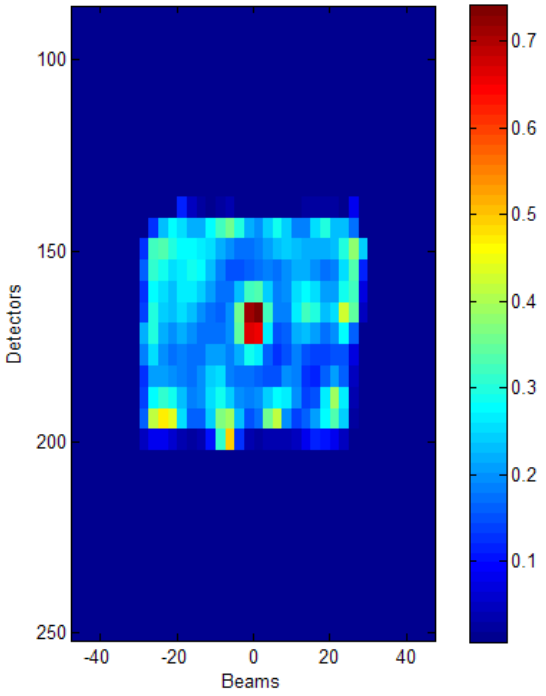
Transmitted Flux



Raw EZ-3D™ Data



EZ-3D™ Signature

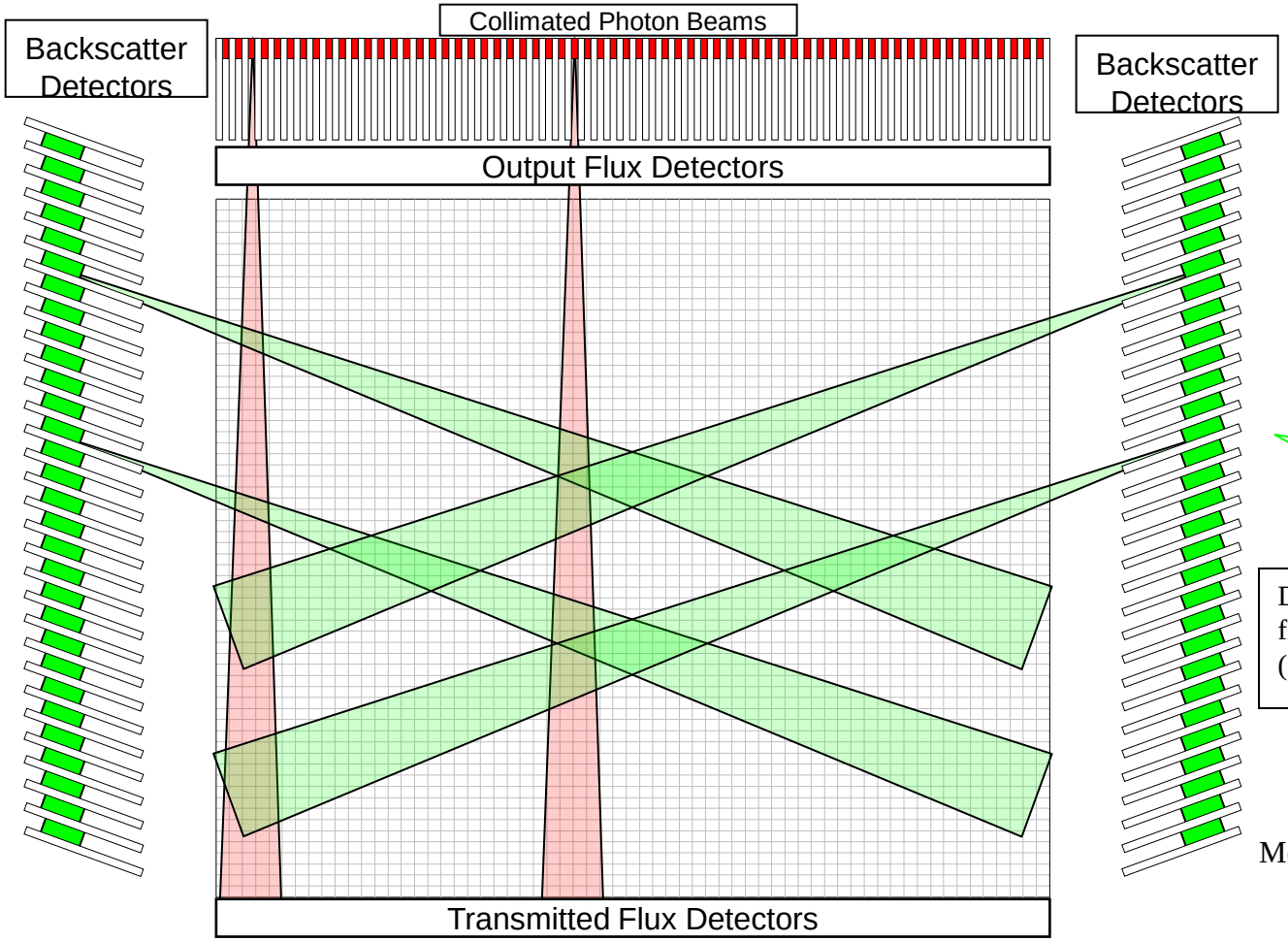


- Combine Transmitted Flux and Raw EZ-3D™ data
- Reconstruct EZ-3D™ signature
- Determine anomaly locations for threat ID

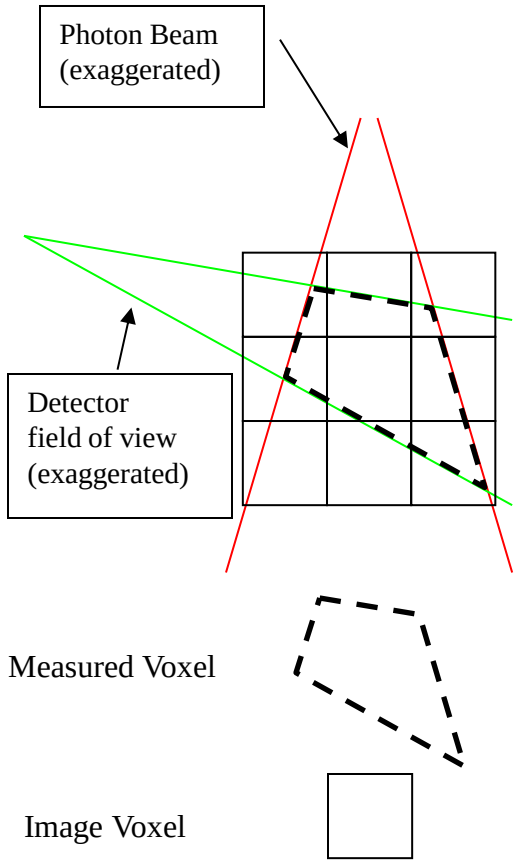
Copyright ©2013 Passport Systems, Inc.

Passport Systems Inc.

EZ-3D™ Geometry



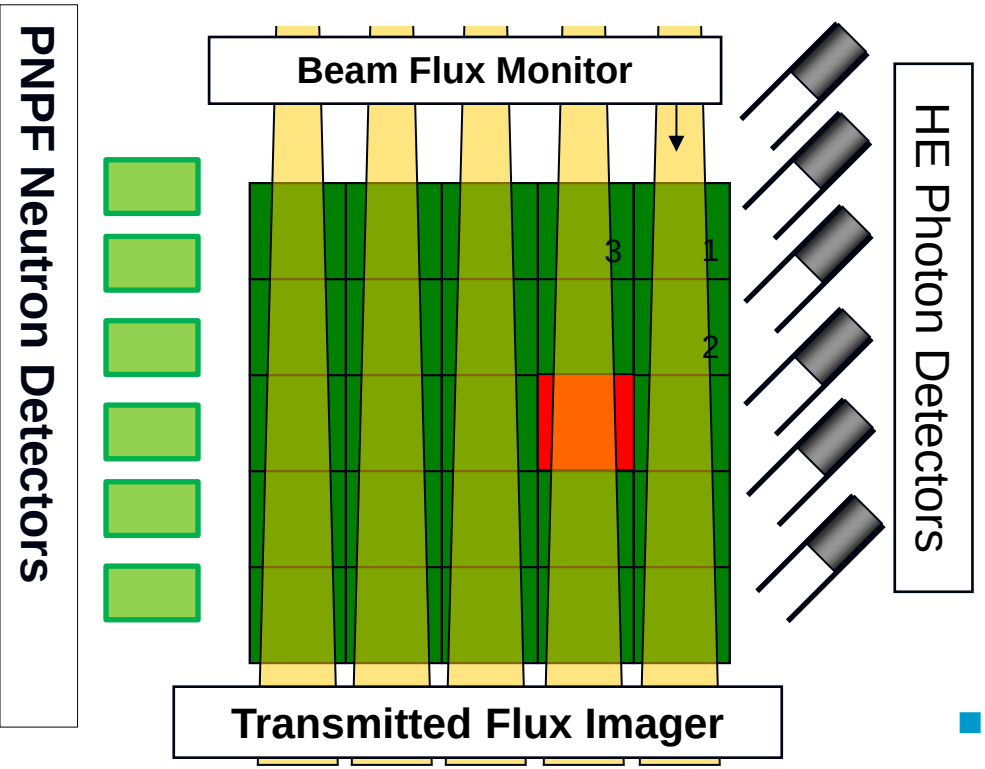
Voxel Definition

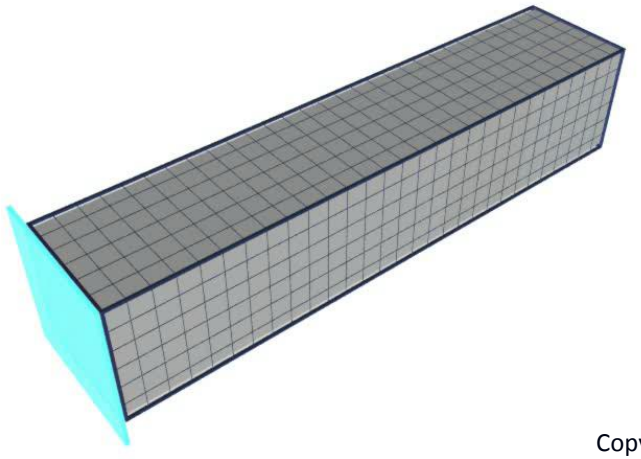


Copyright ©2013 Passport Systems, Inc.

Passport Systems Inc.

Scan Geometry and Process



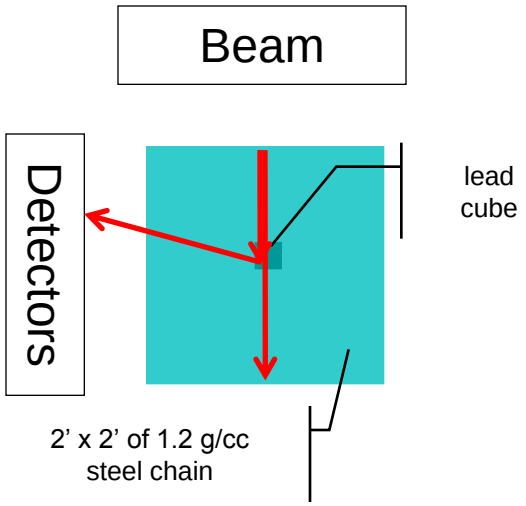


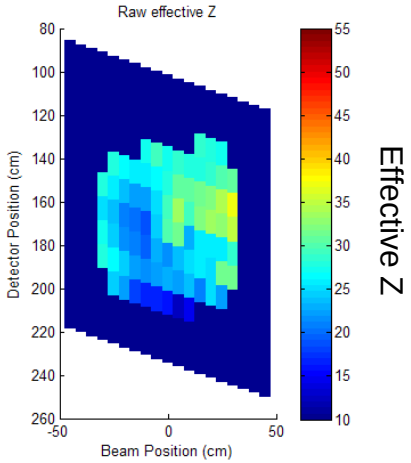
- **Primary Scan:**
  - Beam scans in the beam plane
  - Container traverses the beam
  - → 3D backscatter image (EZ-3D™)
    - ~15 s/20' container
    - 3D map of effective Z & density
  - → 2D transmission image
  - → 2D neutron image
    - Fissionable Material Alarm
  - → ROIs for secondary scan

- **Secondary Scan – ROI inspection:**
  - PNPF, beam dwell on ROIs (~seconds)
    - Fissionable Material Alarm
  - NRF, beam dwell on ROIs (~minutes)
    - Isotopic ID:
    - HEU, explosives, cocaine

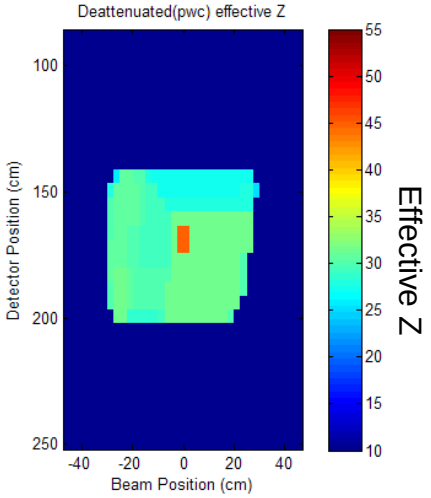
Copyright ©2013 Passport Systems, Inc.
Passport Systems Inc.

EZ-3D™ Reconstruction





Raw Data from Passport test bed



Reconstructed Image

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

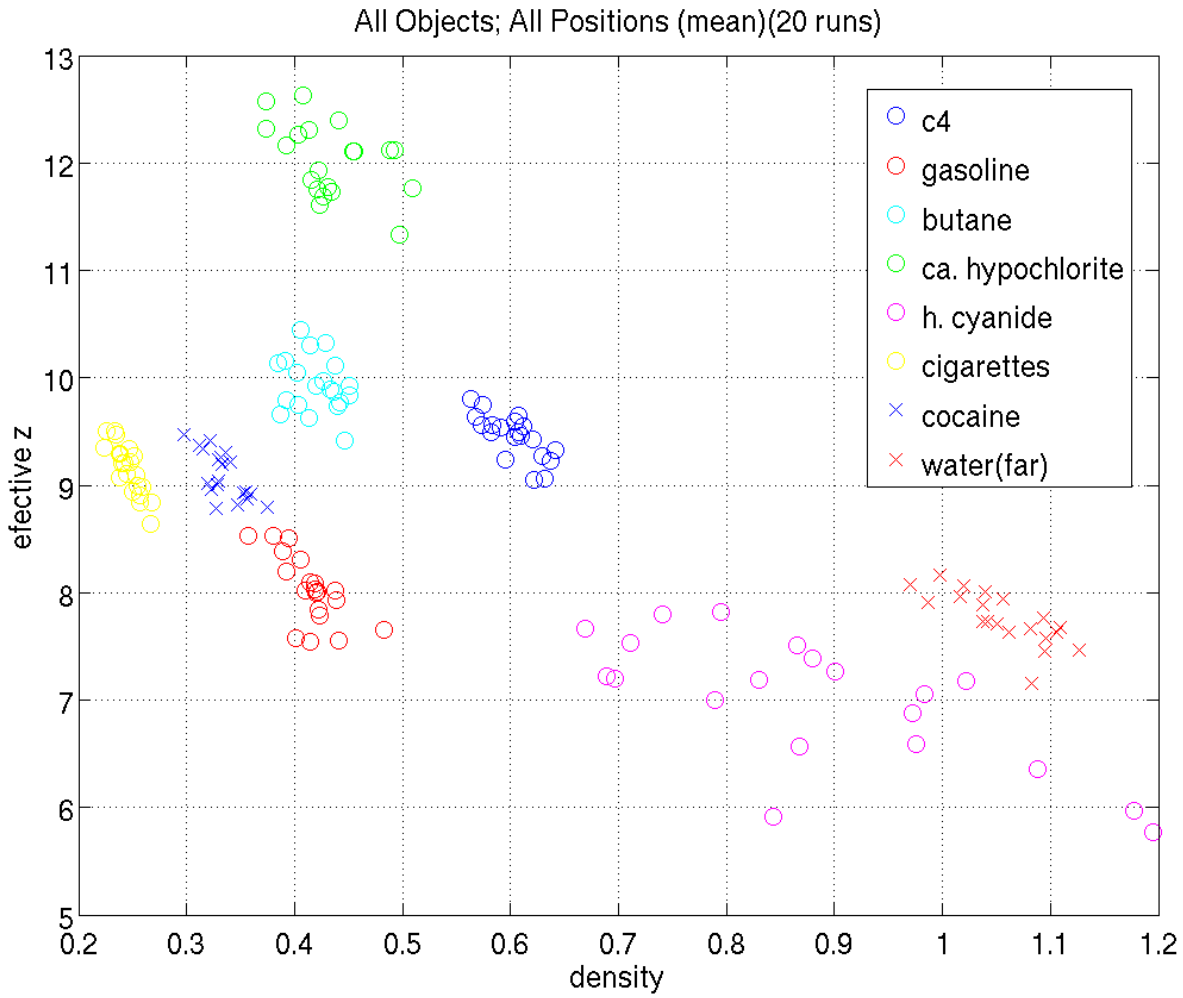
Output for Data Fusion

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

Copyright ©2013 Passport Systems, Inc.

Passport Systems Inc.

Discrimination via EZ-3D™

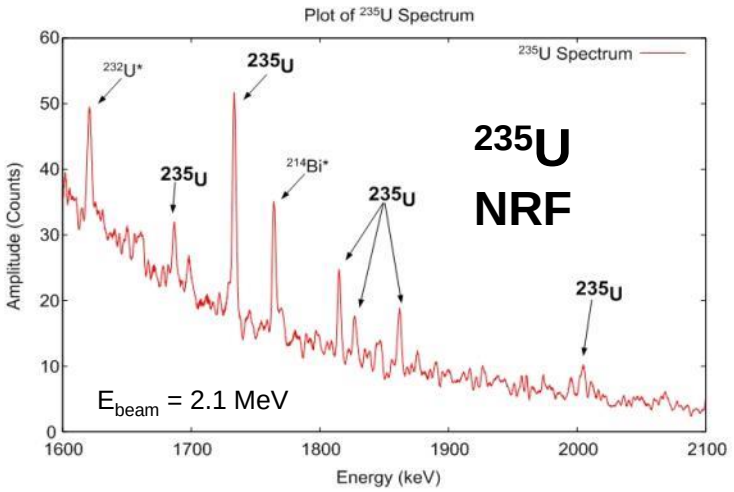


- Improving reconstruction to reduce spread in density and EZ

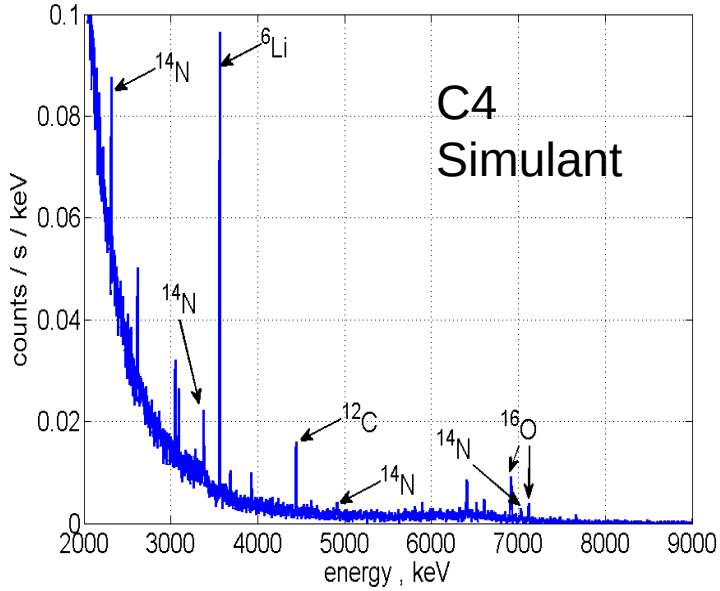
Copyright ©2013 Passport Systems, Inc.

Passport Systems Inc.

NRF Algorithms Overview



* Measurements performed with PNNL

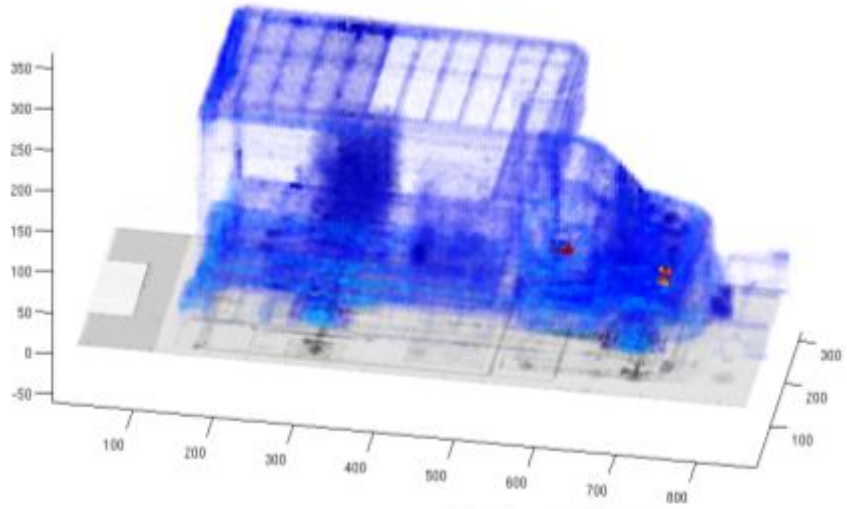


- NRF Data
  - Integrated counts for each line / detector
  - Background rate for each line / detector
- Anomaly identification
  - Calculate expected signal count rate for threat hypothesis
  - Calculate likelihood of measured NRF counts for hypothesis
  - Determine if anomalies from user-defined list are present / absent at defined level of PD / FP
- Supporting functions
  - Background estimation
  - Spectrum smoothing

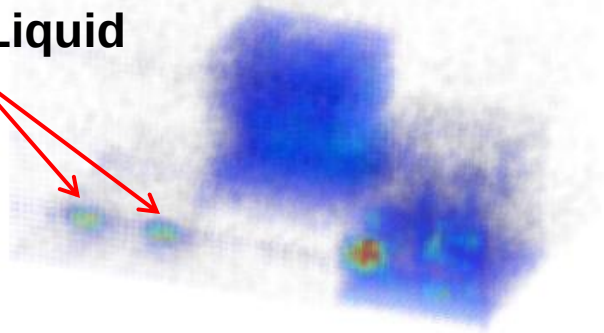
Copyright ©2013 Passport Systems, Inc.

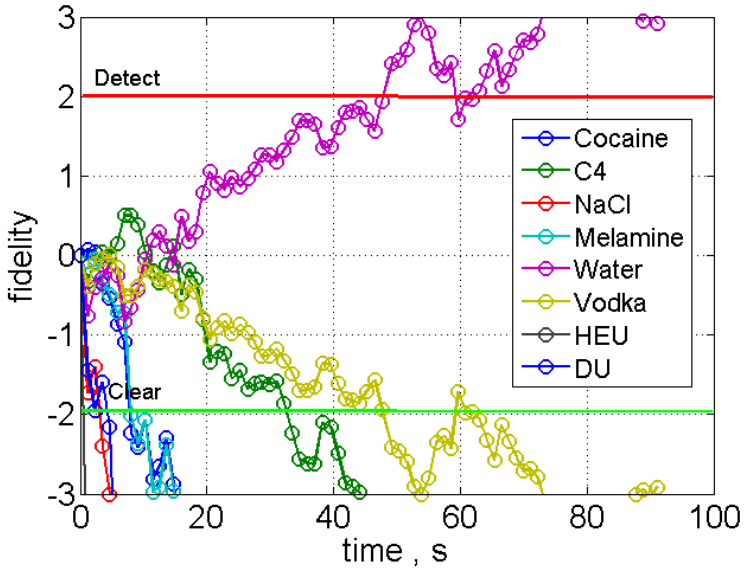
Passport Systems Inc.

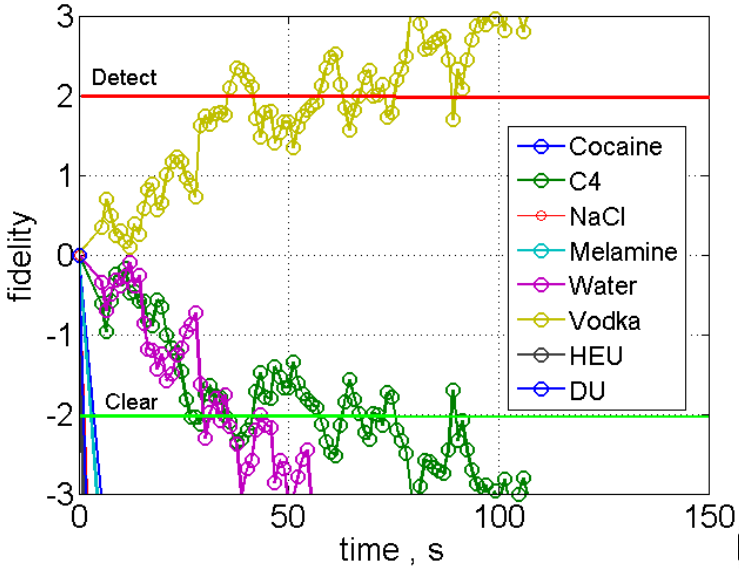
Material Identification via NRF



Bottles of Liquid



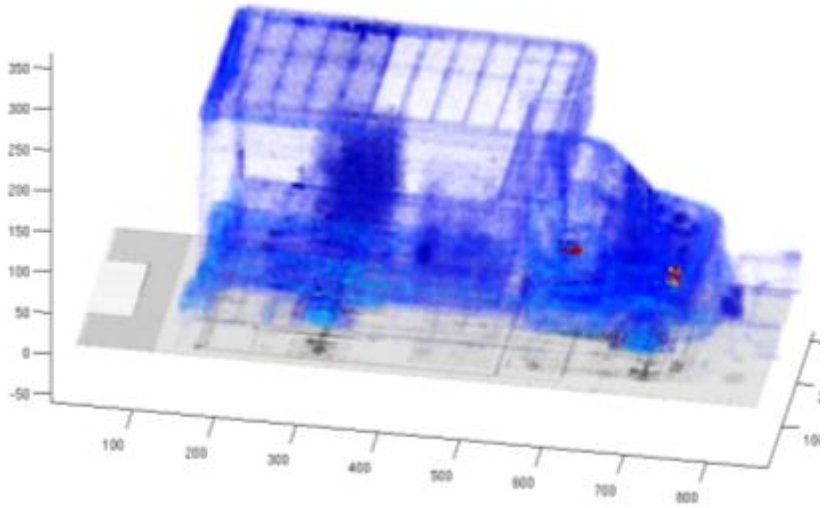


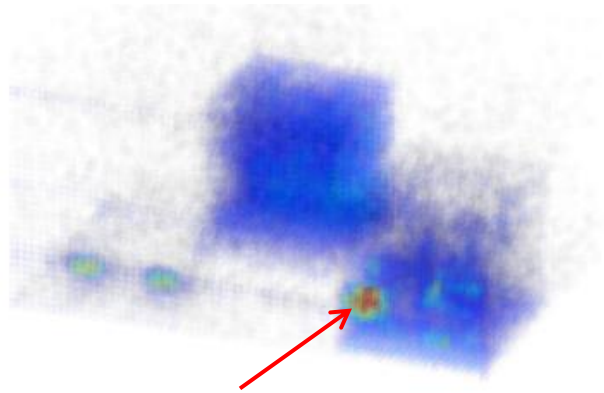


- Time to identify each: <1.5 minutes

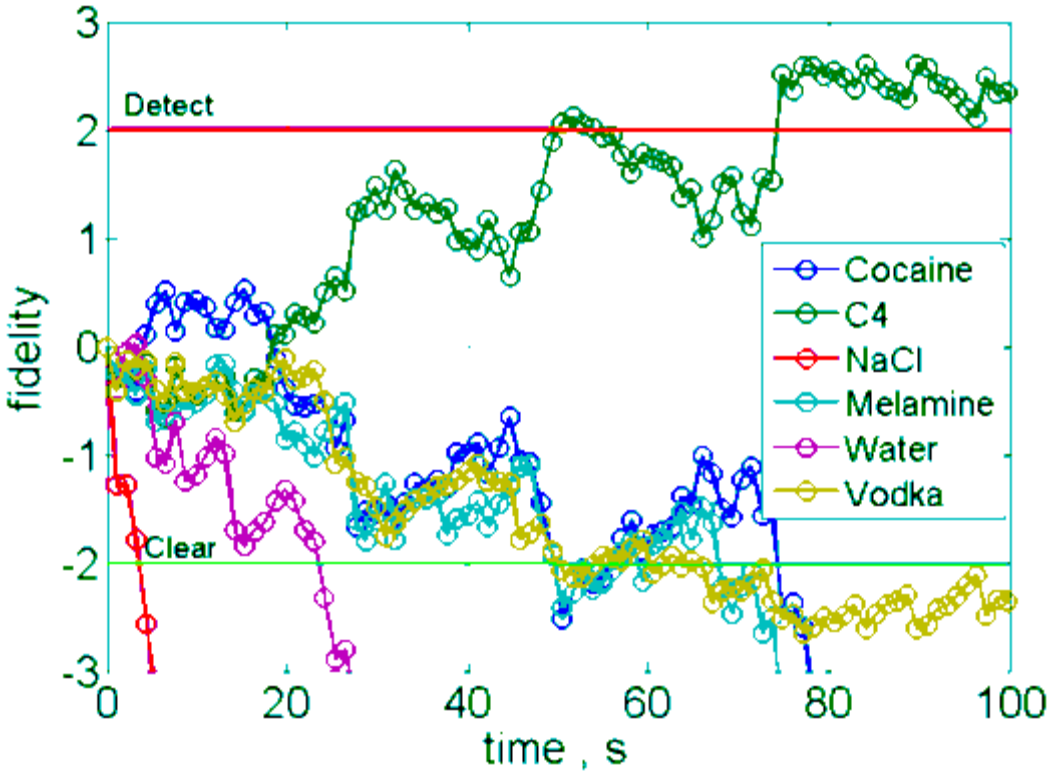
Copyright ©2013 Passport Systems, Inc.

Explosive Detection Example





'Explosive' Anomaly detected by density & EZ



- Potential explosive anomaly detected by density, EZ
- Identified as C4 in <1.5 minutes

Copyright ©2013 Passport Systems, Inc.

Passport Systems Inc.

Summary

- Passport building land/sea cargo container scanner at port of Boston
- EZ-3D™ reconstruction - novel imaging technique for automated contraband detection
- NRF provides isotopic/elemental identification
- Data fusion provides predictive detection/clear times
- Passport's scanner provides unique solution for
  - SNM detection
  - Contraband
  - Material Identification

Copyright ©2013 Passport Systems, Inc.
Passport Systems Inc.

Thank You

Passport Systems Inc.