Overview of LLNL Support for CWMD: Nuclear and Radiological Imaging Platform (NRIP) and Passive And X-ray Imaging Scanning (PAXIS)

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Advanced Development for Security Applications (ADSA) Workshop - Customs and Border Protection
20 June 2018

This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract/IAA HSHQDC-12-X-00341. This support does not constitute an express or implied endorsement on the part of the Government.

LLNL-PRES-753298
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

Nondestructive Characterization Institute

Lawrence Livermore National Laboratory

So what? Who cares?

- Space: Cargo inspection for Rad/Nuc at POE's
- Problem: Inspection performance needs to be characterized and paths forward need to be identified
- Solution: Directly measure detection performance
  - 6 currently-deployed NII and RPM systems characterized to date
  - 2 advanced technology inspection systems characterized to date
- Some areas where LLNL can help CBP
  - Characterization of NII and RPM performance
    - design tests, interpret results, and recommend system improvements
    - operationally-relevant conditions and controlled experiments for basic science & modelling
  - Image quality metrics
    - Software applications and algorithms
    - Design of measurement fixtures, etc.
  - Operator training for image inspection
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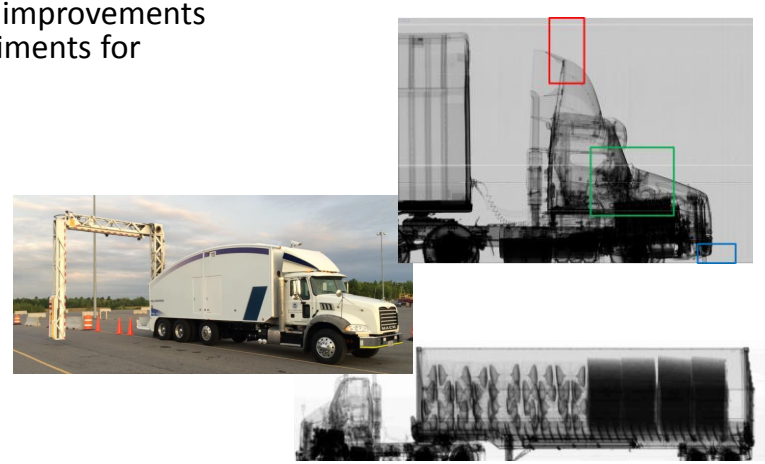
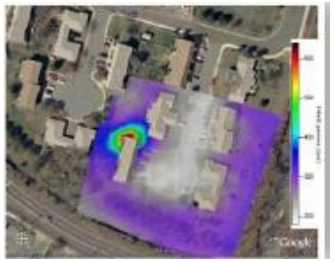
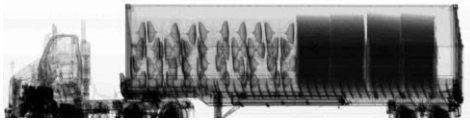


LLNL has supported a variety of DNDO/CWMD programs

- Advanced Scintillator Detector Development
- Algorithms
  - Portal Monitors
  - Mobile search
  - NII ATD
- Vehicle Monitoring
- Cargo Inspection





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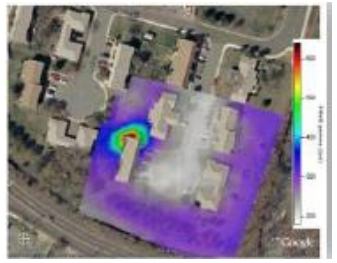
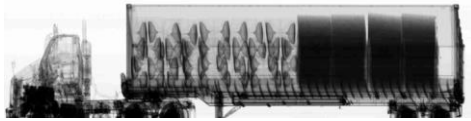


- Vehicle Monitoring

- Cargo Inspection
  - Nuclear and Radiological Imaging Platform (NRIP)
  - Passive and X-ray Imaging Scanning (PAXIS)



Phases of an Advanced Technology Demonstration (ATD)

- Phase I: Conduct the necessary R&D (experiments, modeling, analysis, trade studies) and design to validate a PTU
  - Complete PDR and report
  - DNDO will develop characterization objectives and, with Offerors, draft analysis and characterization plans for Phase IV.
- Phase II: Conduct the necessary engr and dev't for Critical Design Review (CDR)
  - Complete CDR and report.
  - In coordination with DNDO, develop final vendor analysis and characterization plans.
- Phase III: Development, fab, assembly, and contractor characterization of the PTU
  - Characterization of the underlying detector modules
  - Complete Characterization Readiness Review (CRR) – mandatory for all vendors
- Phase IV: Support Characterization and Evaluation (C&E) of the PTU device
  - Performed by DNDO in a realistic simulated environment
  - Following a successful C&E, define and perform upgrades as approved by DNDO for Phase V
  - Complete Characterization Readiness Review (CRR) for Phase V
- Phase V: Support C&E of the same or revised PTU
  - Perform a second C&E in an operationally-relevant environment.
  - Complete Final Report

Phases of an Advanced Technology Demonstration (ATD)

Vendors

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NRIP

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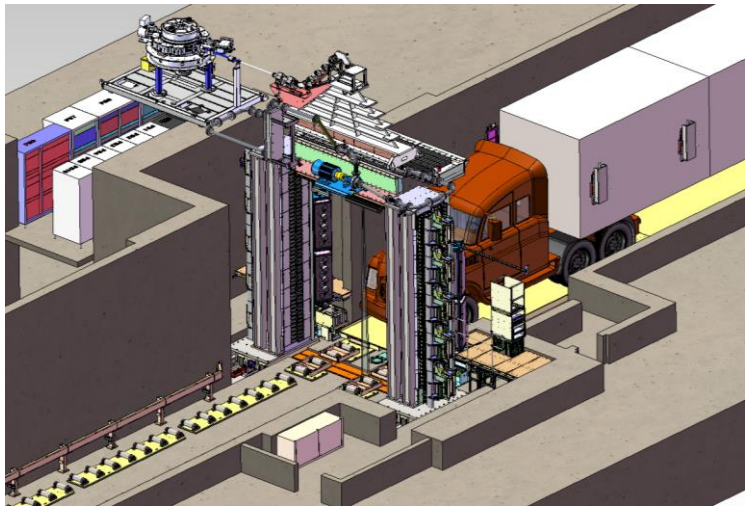
The Technical Support Team has a wide range of experience in relevant subject areas

- Physics and Accelerators
- X-ray Radiography and Tomography
- Active Interrogation, NRF, Systems
- Muon and proton tomography
- Gamma and Neutron Detectors
- Volumetric Imaging
- Simulation/Modeling
- Data Fusion
- Automatic Threat Detection

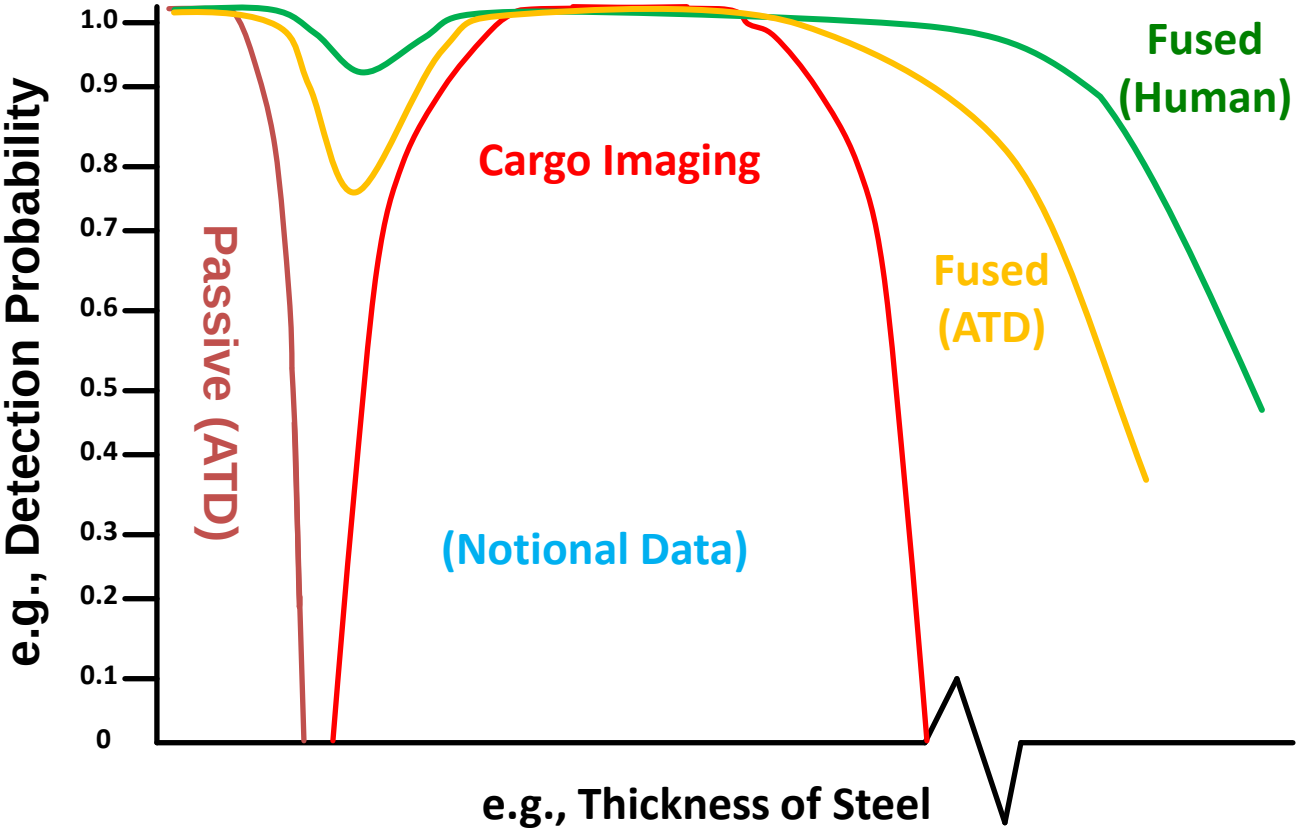
Passive Gamma & Neutron, and X-ray Radiography

Passive Gamma Detection & Muon Tomography



Passive Gamma & Neutron, Photofission,
X-ray Backscatter, Nuclear Resonance Fluorescence (NRF), etc.

The goal of the analysis is to generate a Summary Performance Plot



The actual plot is more complicated than this one, but measuring it is the goal

Example Test Design

Scenario 1 – Muon Tomographic Testing (3 days) 1A – Effects of Steel Shielding 1B – Modulation Transfer Function (MTF) from Edge Response 1C – MTF from Periodic Patterns 1D – Muon Tracking Errors 1E – Material Response 1F – Material Discrimination Scenario 1 – Gamma Response Testing (2 day) 1G – Gamma Detection Efficiency 1H – Gamma Detection Limit 1I – Gamma Localization 1J– Effects of High Gamma Rates 1K– Gamma Backgrounds Measurements 1L – Test Object Orientation 1M– Neutron Masking 1N– IQI of Smiths HCVM	Physics
Scenario 2 – Isolated Signatures (5 days) 2A – Isolated Signatures 2B – Object Signatures in Engineered Shielding 2C – Tunnel Mapping	Modeling & Simulation
Scenario 3 – Detection Performance in Cargo (20 days) 3A – Detection Performance in Homogeneous Cargo 3B – Detection Performance in Representative Cargo 3C – Detection Performance in SOC Cargo	P_D Representative Cargo
Scenario 4 – Miscellaneous Tests 4A – Health Physics 4B – Repeatability	Misc.

There are a lot of tests to be performed in a limited amount of time

NRIP and PAXIS Technologies

Summary

- LLNL has provided technical support for a number of DNDO/CWMD programs that affect CBP
- Examples are the Nuclear and Radiological Imaging Platform (NRIP) and Passive and X-ray Imaging Scanning (PAXIS) programs
  - Assess capabilities of existing CBP-deployed inspection systems
  - Assess advanced technologies for future inspection systems
  - LLNL-led technical support teams:
    - Monitor and advise vendors
    - Design characterization tests
    - Verify data quality
    - Analyze and reduce test data
    - Create final reports for CWMD/DNDO

BACKUP MATERIAL

NRIP BAA Targets and Goals

Parameter	Target	Goal
Nuclear	4 kg SNM	2 kg SNM
Radiological	IAEA Cat. 1	IAEA Cat. 2
Initial Inspection		
Time for Initial Inspection	<2 min	<30 sec
Referral Fraction: % of benign conveyances that cannot be cleared and are referred to a prolonged inspection	<5%	<1%
Missed Detections: Probability of False Negative (P_{FN}) on initial inspection	<1%	<0.1%
Prolonged Inspection		
Duration of Prolonged Inspection	<10 min	<2 min
Clearance Fraction: % of benign vehicles that are cleared during prolonged inspection	>99%	>99.9%
False Alarms: Probability of False Positive (P_{FP}) during prolonged inspection	<0.5%	<0.1%
Missed Detection: Probability of False Negative (P_{FN}) for threat objects on prolonged inspection	<5%	<0.5%

Parameters	Target	Goal
Other Parameters		
Interrogation Volume	40-ft ISO container on truck chassis	Truck cab and container
Dose to inadvertent stowaway in initial inspection	<500 mrem	None
Dose to cargo in prolonged inspection	<20 rem	None
Dose Rate to Driver (if applicable)	10 µrem/scan	None
Threat Localization	<30 cm	<10 cm
Contraband Detection		
Footprint/ Exclusion Zone		
Life Cycle Cost		

Summary of NRIP and PAXIS projects

- NRIP Benchmarking
  - CBP-owned systems at PNNL
  - Co-located Radiation Portal Monitor (RPM) and Non-Intrusive Inspection (NII)
- Technology Demonstration and Characterization (TD&C)
  - DSIC MMPDS—Multi-Mode Passive Detection System
    - Muon tomography combined with passive gamma detectors allow for a no-dose scanning approach
    - Modeling and Simulation of DSIC MMPDS
  - Passport NRIP system
    - EZ-3D and photofission primary scanning, photofission and NRF secondary scanning, and passive detection based on IRSS technology
  - Leidos Automatic Integrated Platform Threat Detection
    - Integrates components of NII with RPM technologies to enable the fusion of passive, radiographic, and fission-induced signatures
- PAXIS Data Collection
  - Deployed NII systems at Champlain POE

NRIP Program Goals and Objectives

- Overall Goal: Characterize the ability of emerging technology to clear and detect threats in vehicles and containerized cargo of nuclear and radiological threats regardless of the shielding level.

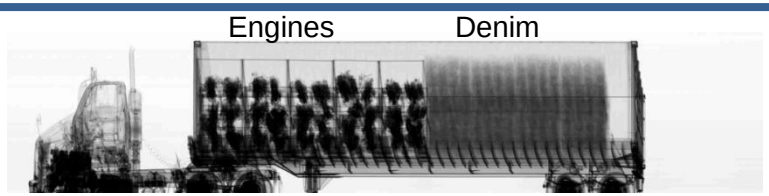
- Application Space
  - Ports of entry, ports of departure, and other choke point applications for vehicles
  - Lessons learned can be applied to more challenging applications

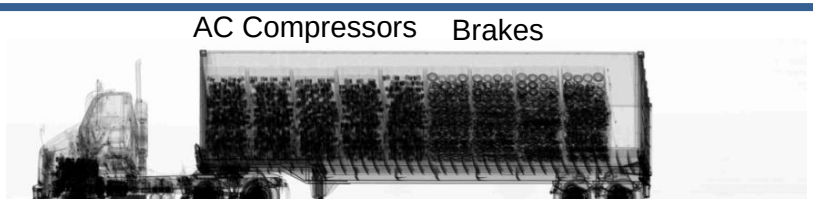
- Technical Objectives
  - Rapid cargo and conveyance throughput (short scan time and short decision time)
  - High probability of detection of threats in cargo regardless of clutter and degree of shielding (very low false negatives)
  - Very low false alarm rates regardless of clutter (very low false positives)
  - Utility to detect other contraband is desired but not required
  - Maximize operational viability (size, footprint, radiation exposure, cost)

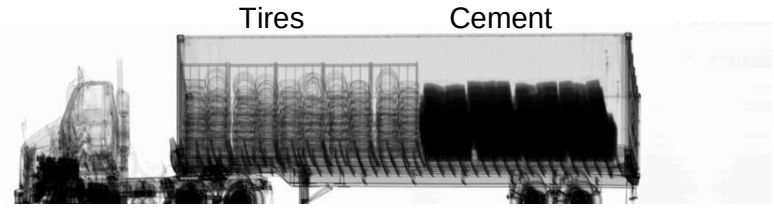
PAXIS Program Objectives

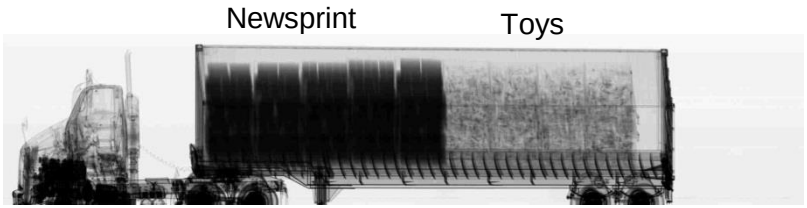
- Collect data from commerce when operating the operationally deployed systems in the combined mode, as well as benchmark images using DNDO non-stream-of-commerce cargos and objects, to confirm and improve algorithms for the Auto-Z and dual energy system capabilities in order to detect high-Z materials that are consistent with shielding and/or special nuclear materials.
- Increase DNDO's understanding of CBP CONOPs and assist CBP with development of high-Z (i.e., Auto-Z) detection and Material Discrimination CONOPs.
- Refine combined and integrated X-ray imaging and RPM system requirements to support future acquisition efforts.
- Establish recommended path forward for related R&D.

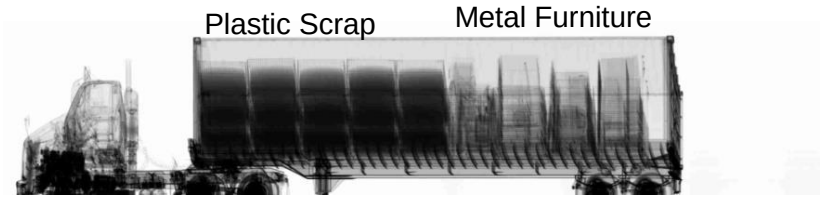
Example radiographs

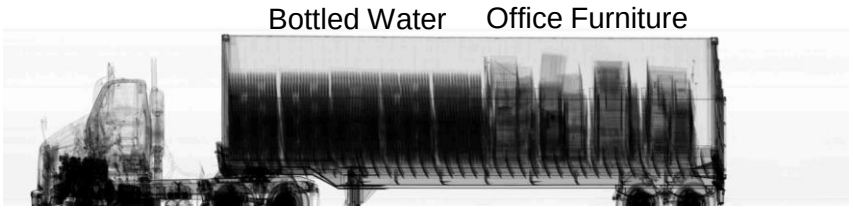


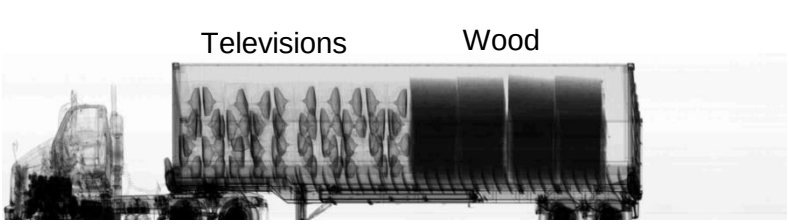


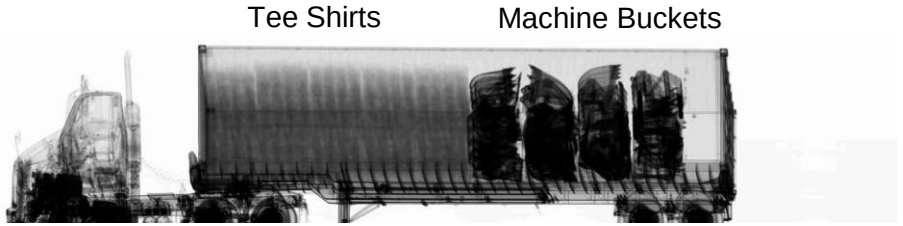












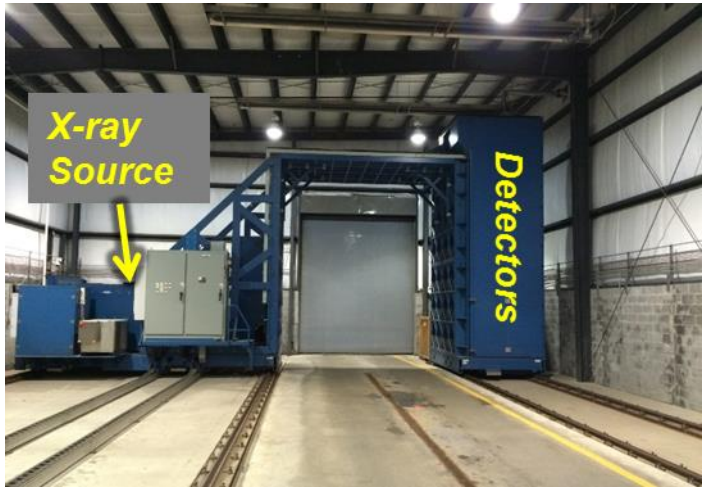
Cargos span a range of densities and complexities

The Rapiscan M60 tested at Champlain (PAXIS)

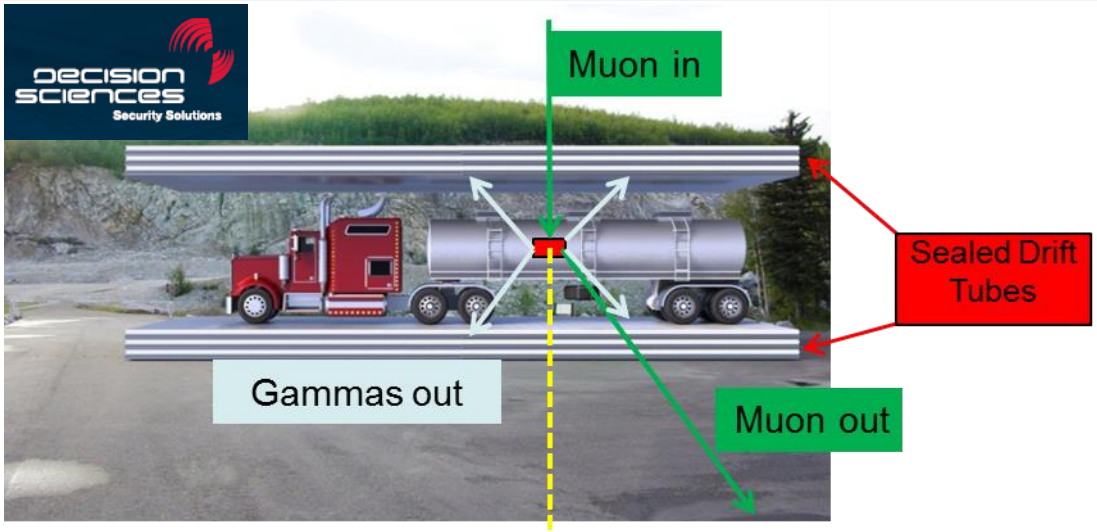
- Dual-Energy (4/6 MeV) X-ray Mobile NII System
- Color-coded images showing organic/intermediate/metallic materials
- Gamma and neutron detectors (RDE=Radiation Detection Equipment)
- Automatic threat detection called Auto-Z
- Required a crew of 3
  - Traffic director
  - Driver
  - Operator

The Varian IntellX3 tested at Champlain (PAXIS)

- Dual-Energy (4/6 MeV) X-ray Gantry NII System
- Color-coded images showing organic/intermediate/ metallic/High-Z materials
- NucSafe RPM at building entrance
- Required a crew of 2 operators



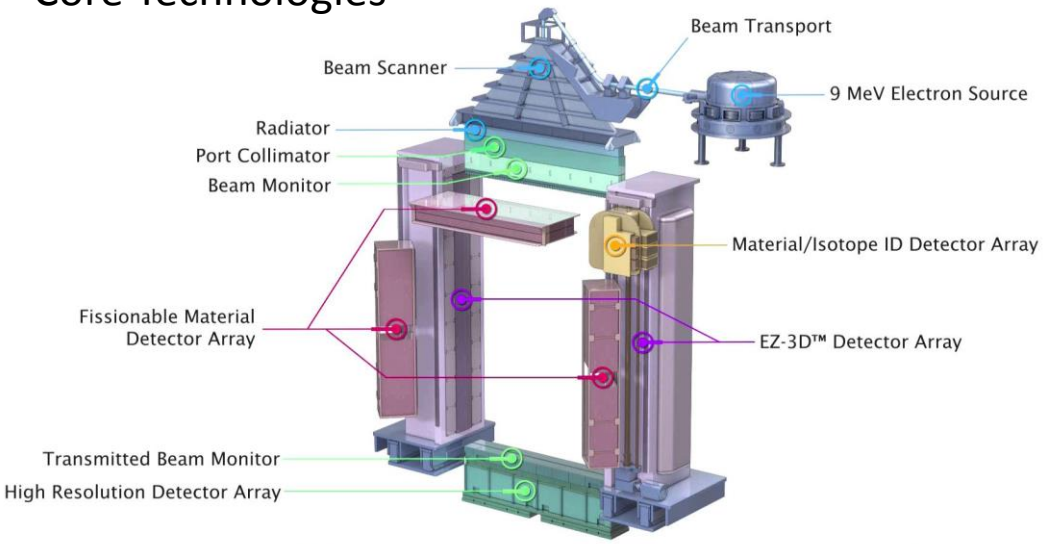
NRIP Multi-Modal Passive Detection System (MMPDS)



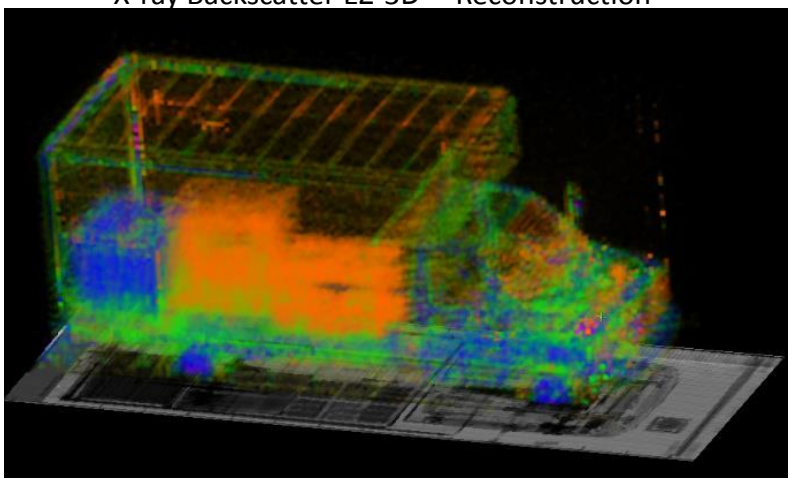
- Cosmic-ray muon tomography takes advantage of naturally occurring cosmic ray muons to probe the inspection volume
- The MMPDS detects muons that are deflected as they pass through high-Z and/or high-density materials
- Drift tubes used for muon tracking also serve as passive gamma detectors
- Containers were also scanned by CBP-owned Smiths HCVM to verify contents
  - 100+ specially-configured containers scanned for controlled tests
  - 600+ stream of commerce containers scanned
- Final report issued 2016

Passport's NRIP System

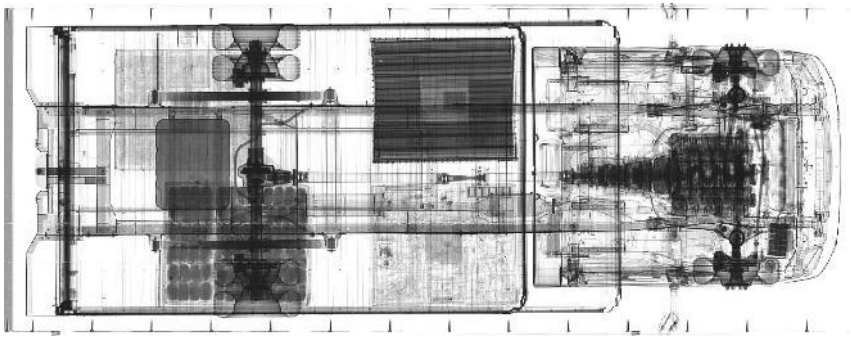
Core Technologies



X-ray Backscatter EZ-3D™ Reconstruction



Top-Down Transmission Radiography



- Passive detection of gamma-rays/neutrons
- High-Energy x-ray (9 MeV) backscatter imaging
- Prompt Neutrons from Photo-Fission (PNPF)
- Nuclear Resonance Florescence (NRF)
- Characterization data have been acquired. Analysis in progress.

Validation and Verification

- Validation
  - Addresses the question “are we measuring the right things?”
  - Is specified in the Analysis Plan
- Verification
  - Addresses the question “are we getting good data?”
  - Is summarized in the Characterization Plan and detailed in a separate document called the verification plan

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