Domestic Nuclear Detection Office (DNDO)

DNDO Algorithmic Needs and University Engagements

Briefing for the 9th Algorithm Development for Security Applications Workshop

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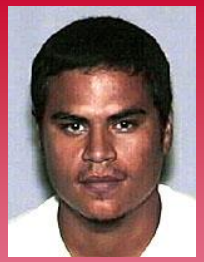
The Nuclear and Radiological Threat

"I continue to believe that nuclear terrorism remains one of the greatest threats to global security. That's why working to prevent nuclear terrorism is going to remain one of my top national security priorities …"
– President Obama (National Defense University, December 3, 2012)

- Types of threats:
  - Nuclear Weapon
  - Improvised Nuclear Device (IND)
  - Radiological Dispersal Device (RDD) – (also referred to as "Dirty Bomb")
  - Radiation Exposure Device (RED)

HEU intercepted by Republic of Georgia in smuggling sting



Jose Padilla – convicted of plotting RDD attack

RDD response exercise in New York

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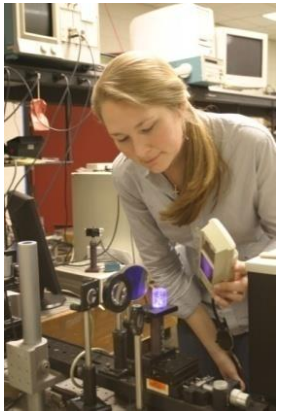
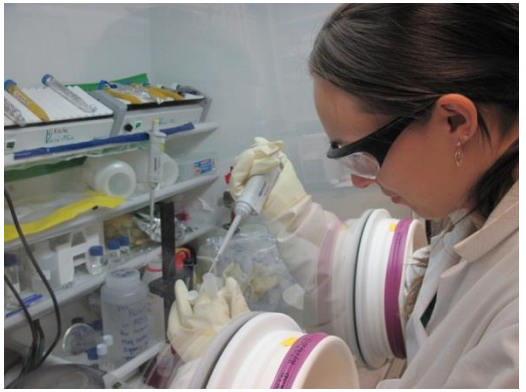
Outline

- **Mission and Objectives**
  - Domestic Nuclear Detection Office (DNDO)
  - Transformational and Applied Research (TAR)
  - Algorithm Research Role
- **Algorithm Role in Grand Challenges**
  - On Going Efforts
  - Future Needs





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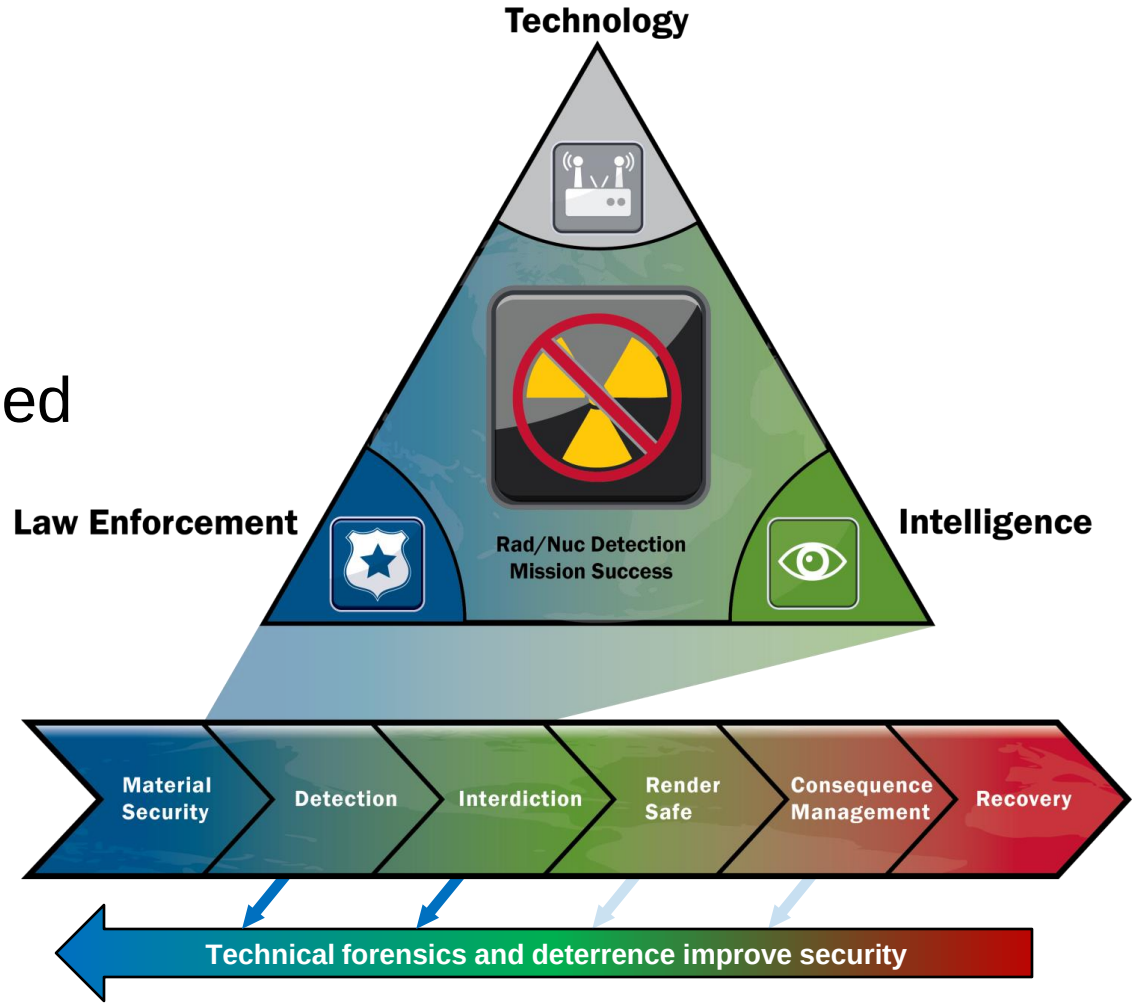
DNDO Mission

- Interagency
- Interdisciplinary
- Integration
- Interdiction-focused



Nuclear Defense Spectrum

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DNDO Transformational R&D Program

Develop break-through technologies that will have a dramatic impact on capabilities to prevent nuclear and radiological terrorism through an aggressive and expedited R&D program.

What we do …

- ***Address*** gaps in Global Nuclear Detection Architecture
- ***Improve*** performance, cost, and operational burden of nuclear detection and forensics technologies
- ***Transition*** successful technologies to system development, acquisition, and deployment or commercialization

How we do it …

- ***Include*** industry, national laboratories and academia; encourage teaming
- ***Coordinate*** with intra/interagency R&D organizations (e.g., S&T, DOE, DOD, DNI)
- ***Follow*** a sensible process that provides the transparency and agility needed for expedited R&D

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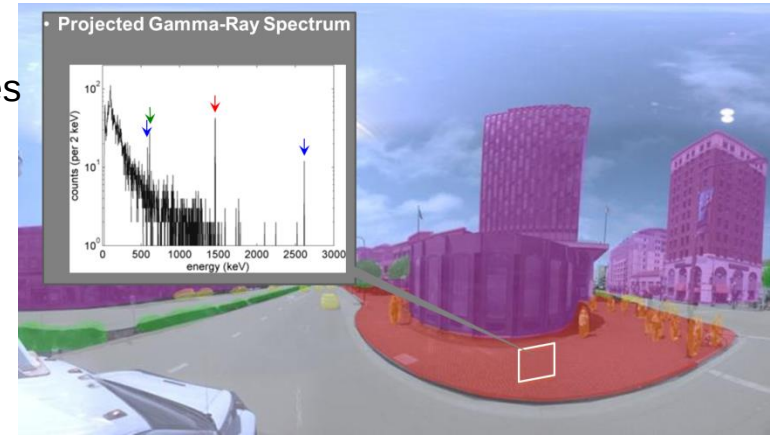
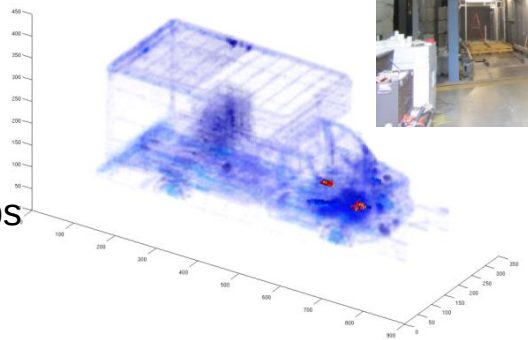
TAR Programs

- Exploratory Research Program (ERP)
  - Research by Industry, National Labs, or Universities
  - Portfolios
    - Materials
    - Neutron Replacement
    - Shielded SNM
    - Radiation Detection Techniques
    - ***Algorithms & Modeling***
    - Nuclear Forensics
- Academic Research Initiative (ARI)
  - University Grant Program coordinated through NSF
  - Create **next generation** of scientists and engineers
- Advanced Technology Demonstration (ATD)
  - Further develop technology concepts applied to GNDA gaps
  - Characterize in a **simulated operational environment**
- Small Business Innovative Research (SBIR)
  - Agile R&D to support rapid prototyping





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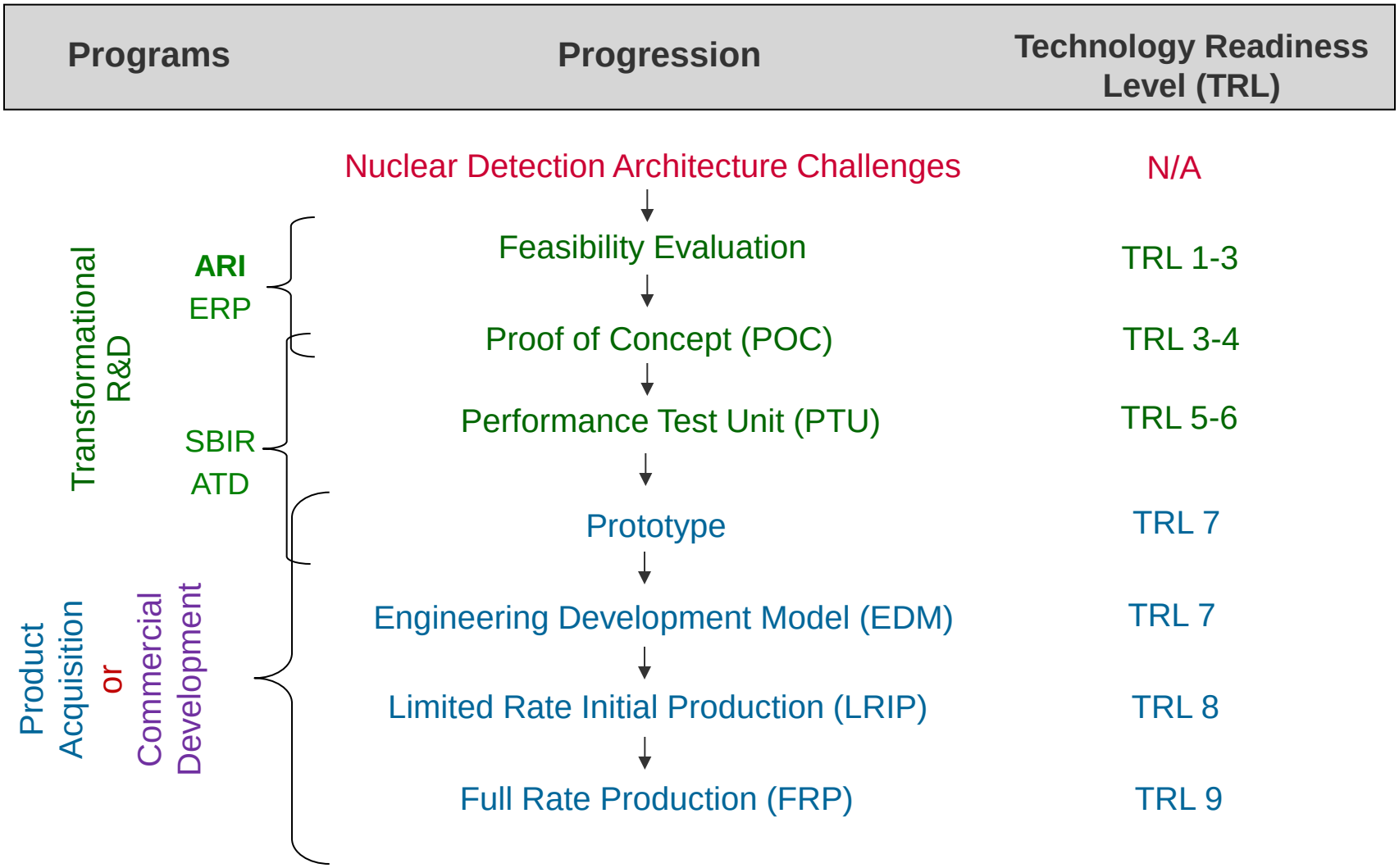
DNDO R&D Program Progression



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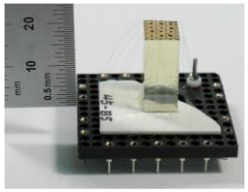
Grand R&D Challenges

- ***Cost effective equipment*** with sufficient performance to ensure wide spread deployment



- ***Detection of special nuclear material*** even when heavily shielded

- ***Enhanced wide area search*** in a variety of scenarios, to include urban and highly cluttered environment

- Monitoring along ***challenging GNDA pathways***, to include general aviation, small vessels, and in between ports of entry

- Forensic ***determination of origin*** and/or route of interdicted materials

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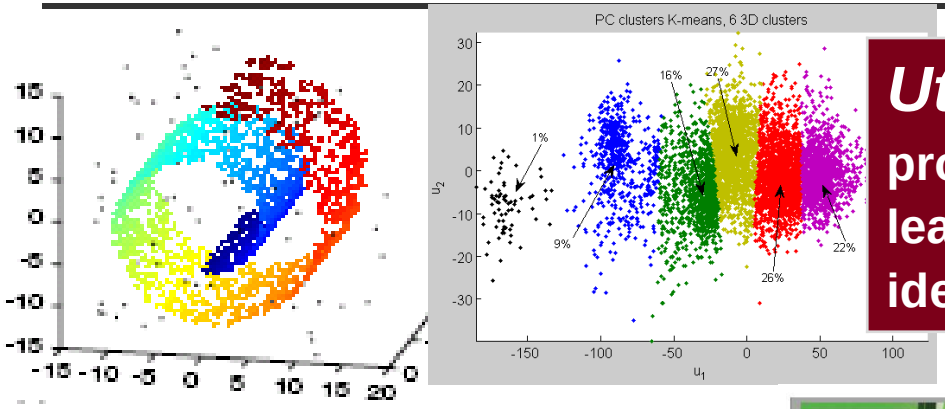
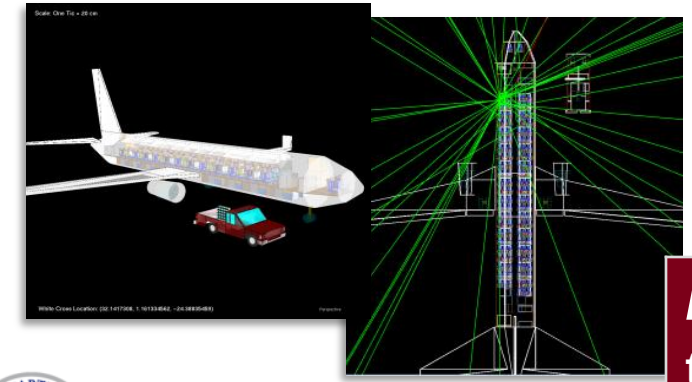
Algorithm Portfolio Mission and Overview



Utilize **cutting-edge signal processing, data fusion, and machine learning to detect, locate, track, and identify potential threats**

Develop **capability to effectively model radiation detection and environments to test algorithm performance**



Implement **advanced simulation tools to support personnel training, threat awareness, or visualization**

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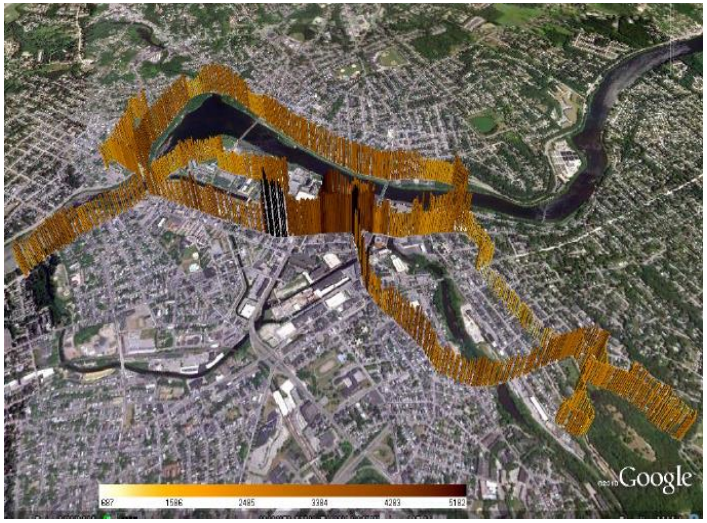
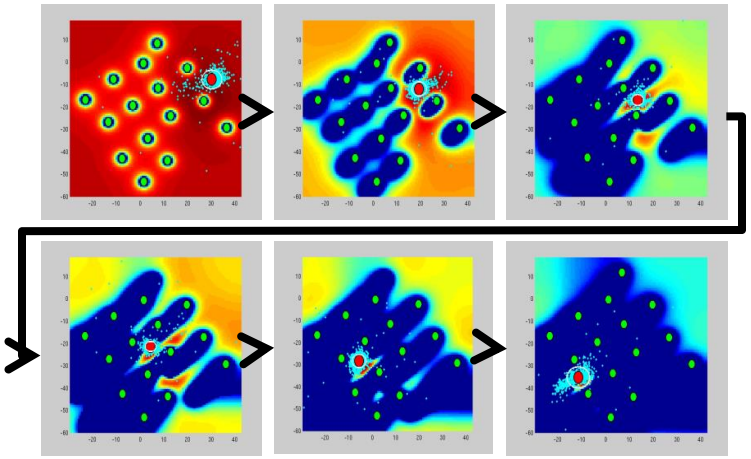
Algorithms for Detect, Locate, and Track

Goal 1: *Increase Detector Sensitivity* by capturing background uncertainty

- High Gain vs. Low Gain Tradeoff
- Detect→Locate→Track
- Track→Locate→Detect





Goal 2: *Agile Architecture* by networking, data fusion, and mobile search enhancements

- Context-Aware Systems
- Distributed Sensor Fusion
- Video-enhanced tracking

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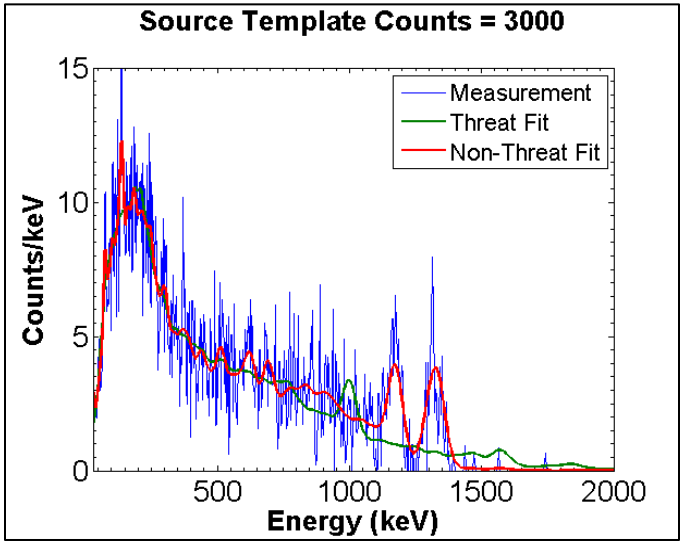
Algorithms for Identification

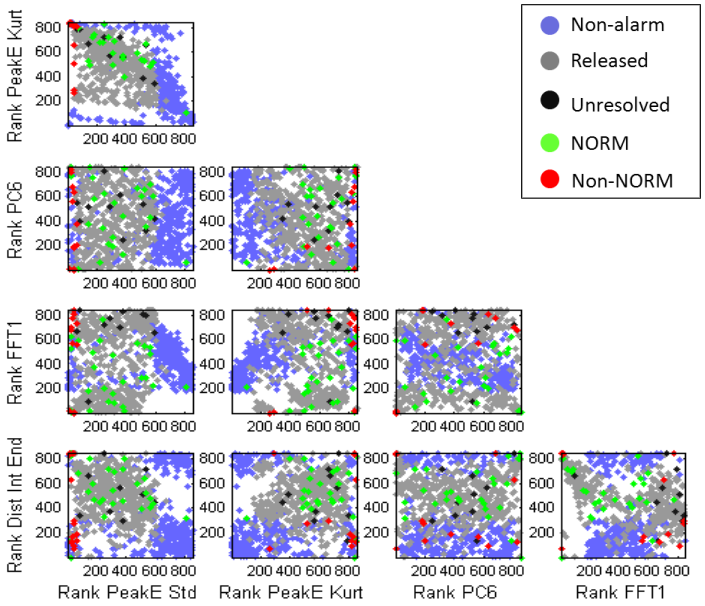


Goal 1: *Low Cost SNM Detection* by developing ID algorithms on new materials or improved threat discrimination on current systems

- Template Matching
  - Variance weighting
- Peak-Finding
- Adaptive Learning
  - Bayesian Branch and Bound

Goal 2: *Reduce Operational Burden* by screening non-threat alarms

- Adaptive Learning Algorithms
  - Random Forest best performance
- Inclusion of non-radiological information
- Augmentation with Advanced Sensors
  - Hyperspectral, LIDAR, EO/IR, & gravity



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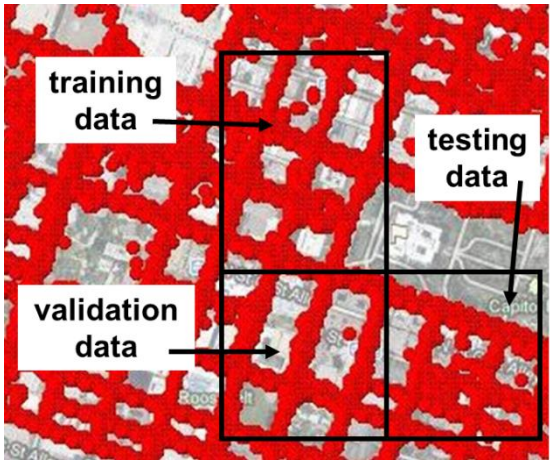
Examples of TAR Research Efforts

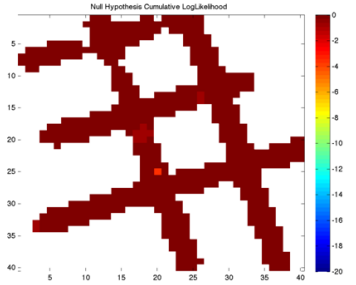
- University led with National Lab support (**Machine Learning for Search**)
- Industry-led (performer) with National Lab (gov-team) (**IRSS**)
  - Follow-up to include National Lab and University support
- National Lab led with University support with Industry developed technology (**Background Estimation**)
- National Lab led with Small-business spin-off from University Research (**gravity gradiometry**)

Machine Learning for Search –CMU (ARI)

- Machine Learning for Effective Nuclear Search and Broad-Area Monitoring
- Goal: Use supervised learning for detection and classification of threats for spatial/temporal/spectral information for mobile search
- Injection Study using large mobile data set
- LLNL Partnership with RNAK tool
  - Bayesian-based
  - Branch and Bound
  - Genetic Algorithm

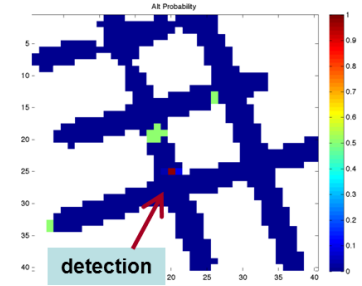


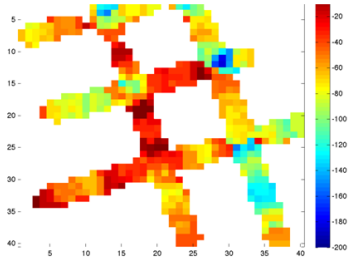
(1) Locations where spectra were measured



(2) Null hypotheses cumulative log likelihood map

(4) Resulting threat probability map





(3) Alternative hypotheses cumulative log likelihood map

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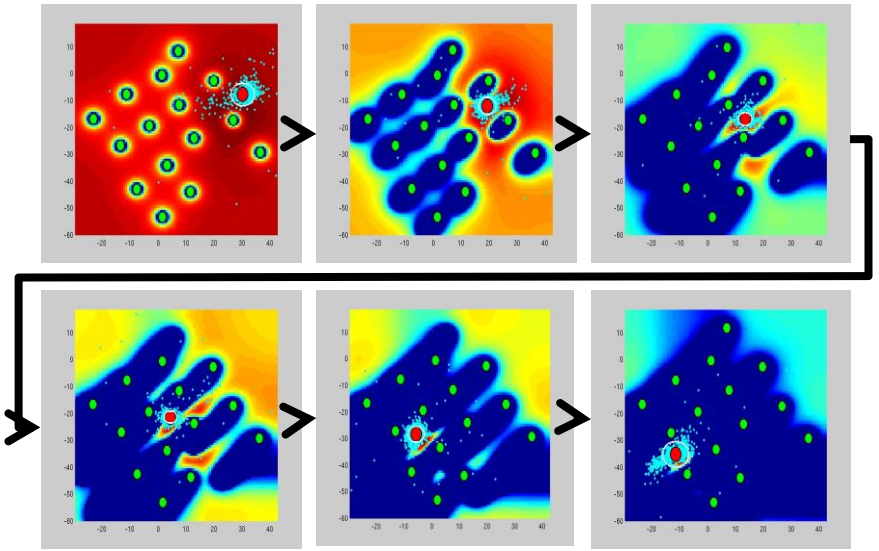
Intelligent Radiation Sensing System (IRSS)

- Advanced Technology Demonstration of 20 mobile detectors searching a wide area
  - Fuse detectors in real-time for increase ability to detect, locate, and track
  - Extensive span of independent variables including:
    - Detector (number, type, geometrical configuration)
    - Source (type, intensity, location, and vector)
    - Background (uniformity, variability)
    - Algorithms (ex. particle filter numbers)
    - Networking (method, data loss)
  - Provide data to Academic Researchers



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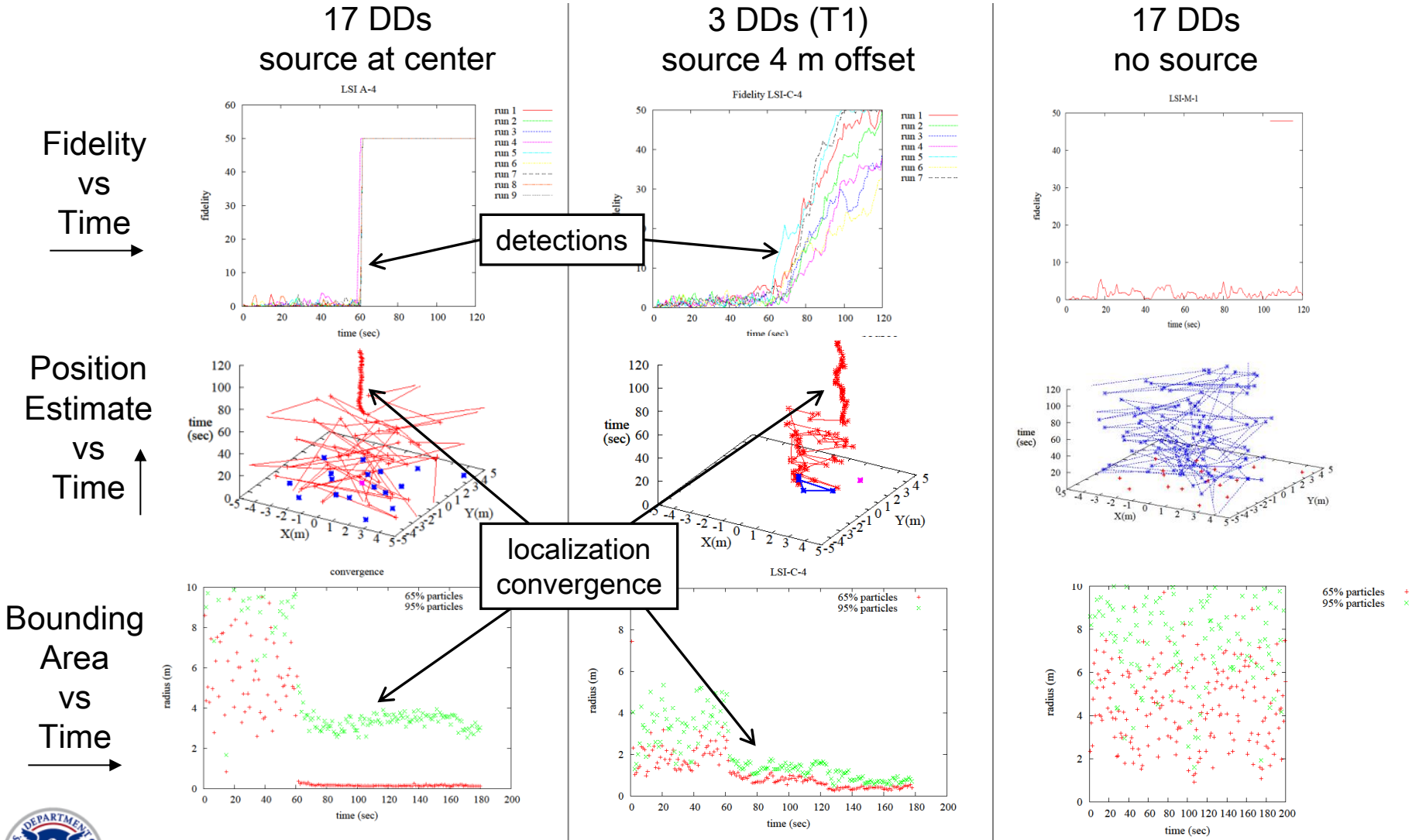
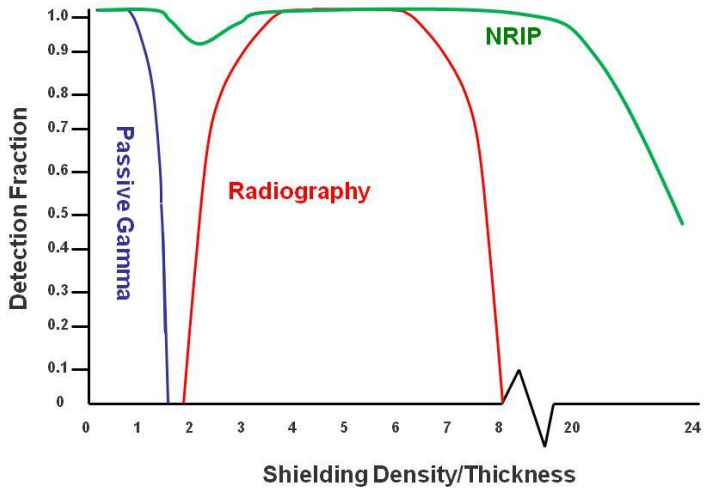
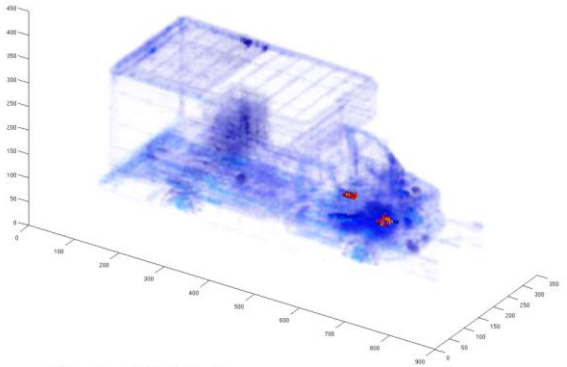
Convergence of IRSS Position Estimates

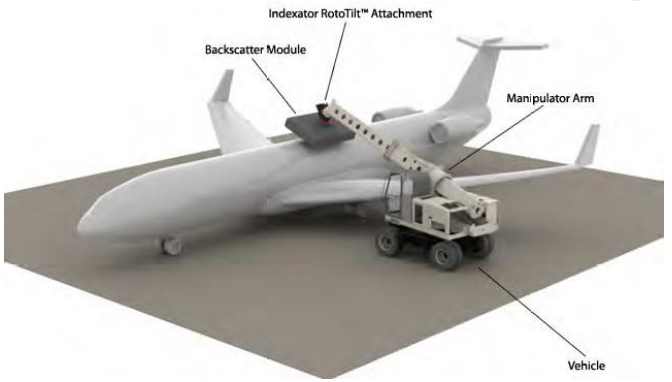


Transformational Screening Applications

- Goal is to detect Shielded Special Nuclear Material in Relevant Environments
  - Technology may also detect explosives and other materials
- Multiple (18) and Large Projects tackling the shielded SNM challenge
  - Passport NRIP (high-energy backscatter)
  - Rapiscan (high-energy backscatter)
    - Aircraft Inspection System
    - Neutron Differential Die-away
  - Algorithm Development on Novel Data
    - Telesecurity Sciences 2-energy algorithm







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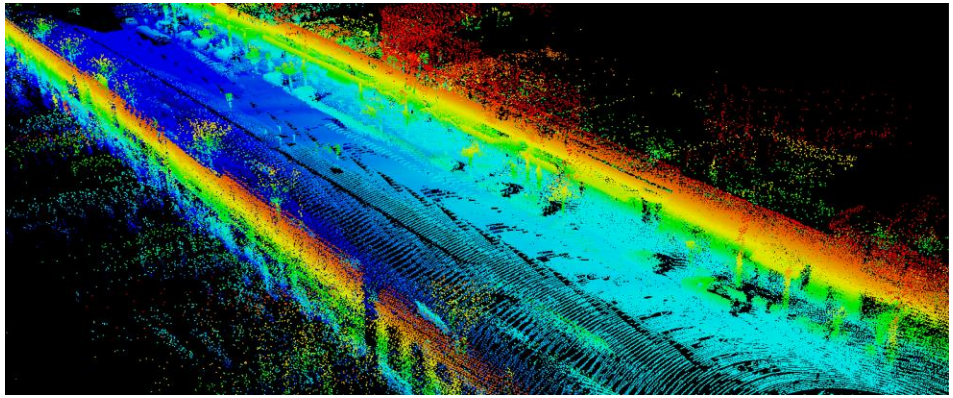
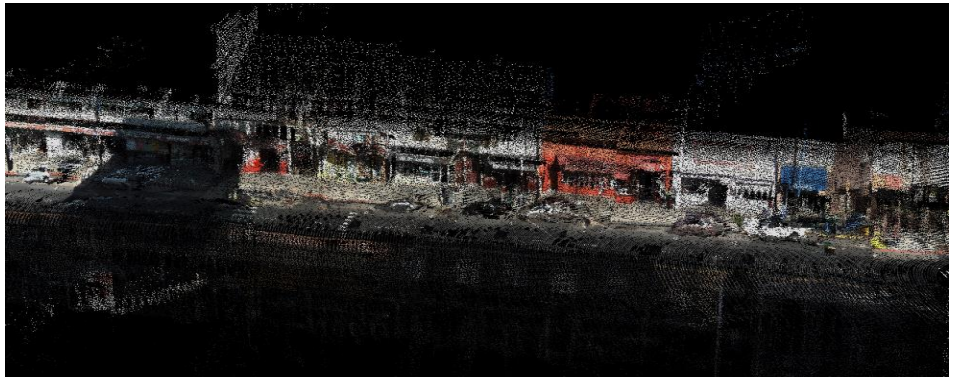
Background Estimation Algorithms





Goal is to discover and quantify the non-radiological observables that correlate to the radiation signatures and improve detection algorithms

- Potentially compare these results with existing materials databases
- Mobile EO/IR, LIDAR, & Adv. Radiation Spectral Imaging Detectors

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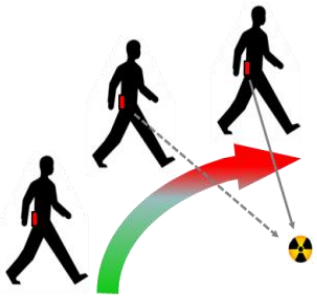
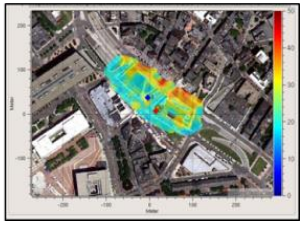
Other On-Going Effort Examples

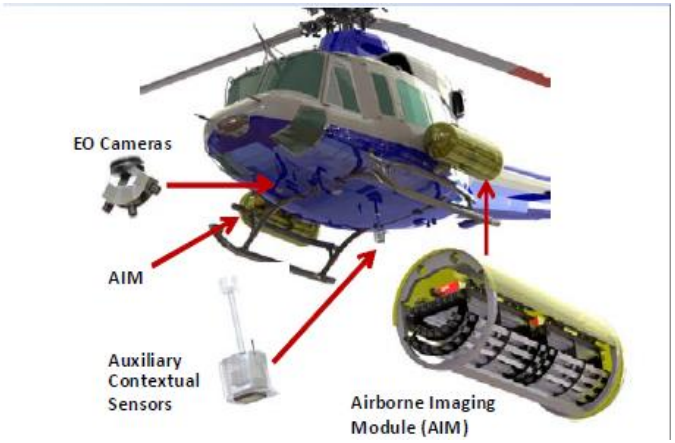
- Algorithms to Improve Discrimination of Threats and Non-threats
  - Systematic mapping of background radiation in 3D: "Nuclear Street View"
  - Algorithms to detect at low signal to background ratios
  - Advanced search techniques with low-cost detectors integrated with smartphones
- Radiation Imaging and Tracking
  - Moving and mobile choke point systems with the ability to detect, identify, locate, and track threats: Long Range Radiation Detection (LRRD) ATD
  - Airborne Radiological Enhanced-sensor System (ARES) ATD
  - Dual gamma ray and neutron imaging and spectroscopy
  - Advanced imaging technologies (electron tracking, liquid imagers)
  - Non-visible roadside tracking (different infrared wavelengths, short range radar)

Nuclear Street View





Smart Phone Integration



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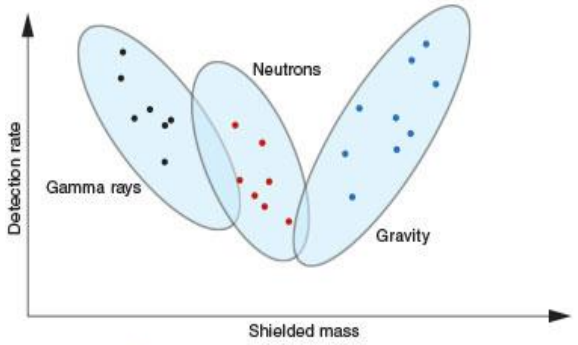
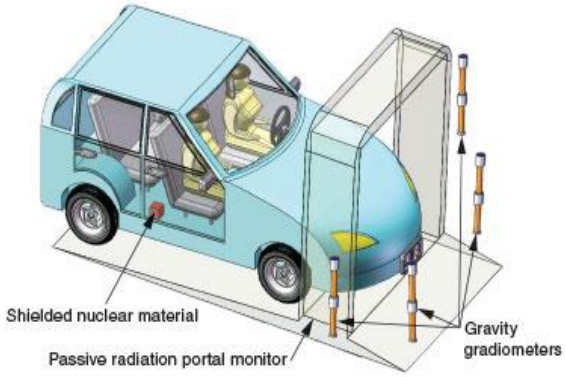
Pathforward for Aviation Algorithms

- Partnerships crucial to gather representative data
  - Operational Knowledge
  - Reasonable Threat Objects
- Leverage modeling to bootstrap data
  - Improve Algorithms as well as Visualization

- Apply novel sensors to support detection in dose-constrained pathways
  - Gravity Gradiometry or Muon Deflection
- Augment systems with low-cost sensors
  - Contextual Information (weight, size, proximity)
- Multi-threat integration with CBRNE spectrum
- Algorithms: Spatial Mapping & Adaptive Learning





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