Transportation Research Forum:

Survey of Proposed Cargo Inspection Technologies

Presentation to TRF Plenary Panel Session on Transportation Security

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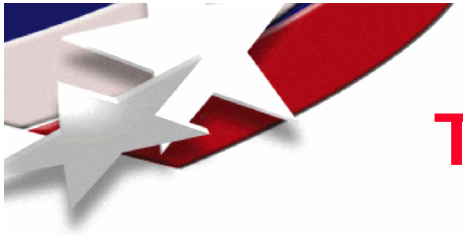
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

Agenda for Presentation

- **Importance of the Problem Definition**
  - **Threat (type, quantity)**
  - **Operational/logistical requirements (time, cost)**
- **Survey of Non-intrusive Detection Technologies**
  - **Bulk (PFNA, PFNTS, NRA, NRF)**
  - **Trace**
  - **Nuclear**
- **Detectors**
- **What is the next step?**



The Problem MUST be Defined Before Looking at Promising Technologies

- **Different technologies have different strengths and limitations**
  - **Define problem before screening of technologies**
  - **If you ask for everything (better, faster, cheaper) – no technology will pass the initial screen!**
- **Most critical parameters**
  - **Threat materials**
  - **Threat quantity**
  - **Operational environment**

Sample Problem Definitions

- **Air cargo inspection (very very difficult)**
  - **Very small threat quantities**
  - **Cluttered test objects**
  - **Stressing operational requirements**
  - **Large penalty for false positives, even more so for false negatives**
- **Border smuggling of drugs**
  - **Large threat quantity is acceptable**
  - **Missed detections can be tolerated**
  - **Very adaptive threat vector**

Bulk Detection Technologies

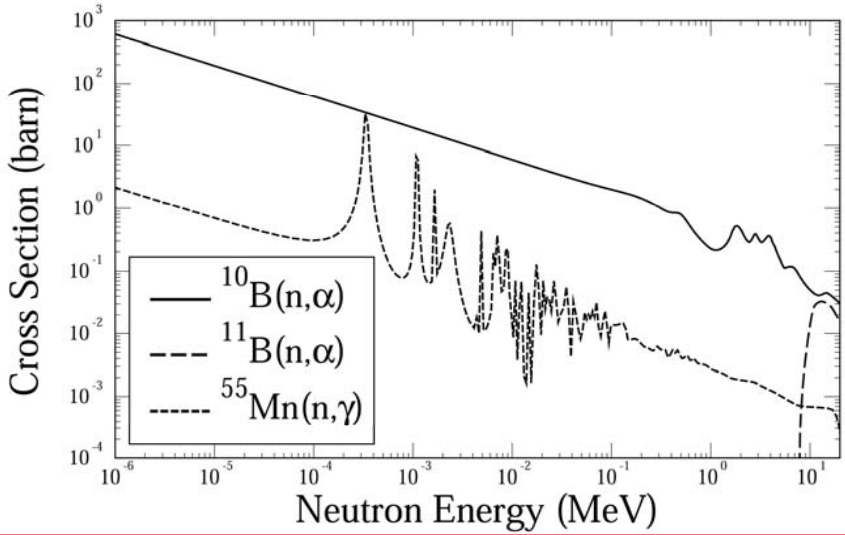
- **Photon**
  - High energy probes – anomaly detectors only
  - CT inspection on pieceparts – labor/time intensive if cargo broken down, tested, re-assembled
  - Nuclear Resonance Absorption (NRA/GRA) – monoenergetic photon source, effectively nitrogen only
  - Nuclear Resonance Fluorescence (NRF)
- **Neutron**
  - Pulsed Fast Neutron Transmission Specroscopy (PFNTS)
  - Pulsed Fast Neutron Analysis (PFNA), large accelerator source
  - 14-MeV NG often using Associated Particle technique
- **Electromagnetic Interrogation**

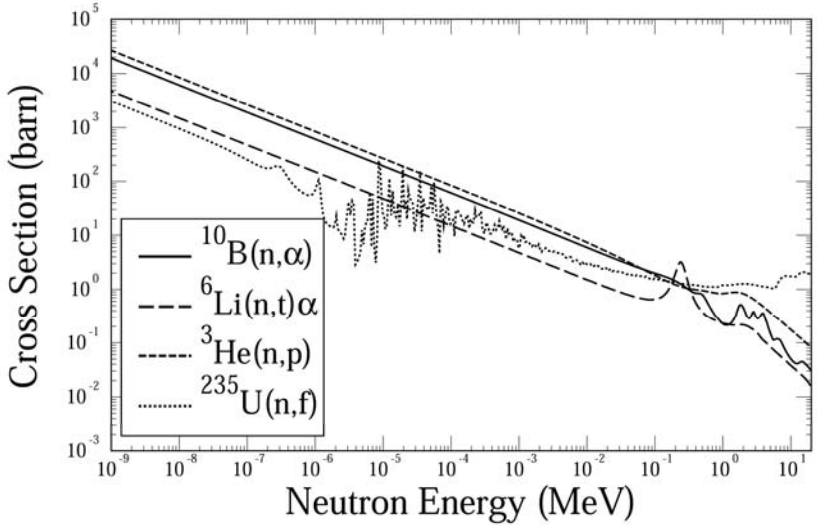
Representative Photon Inspection Systems

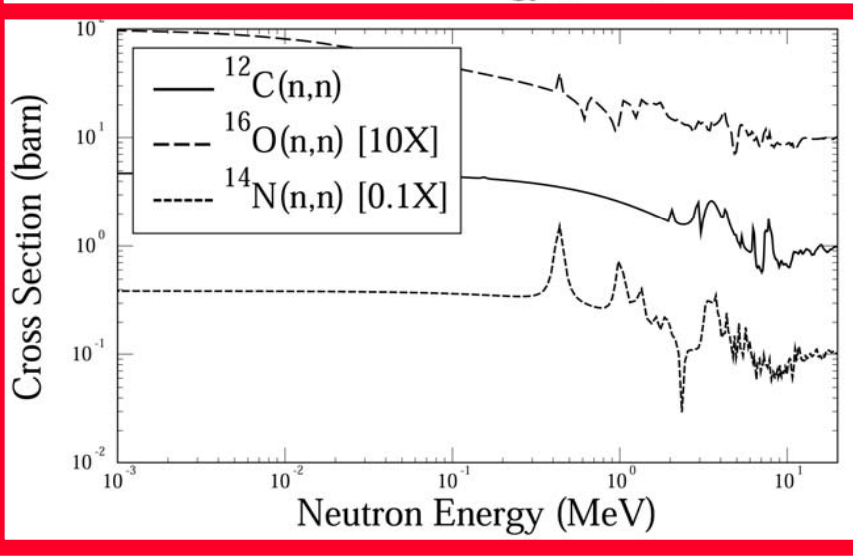
System	Passage Size	Source/ Current	Technology	User Agency	Location
AS&E Cargo Search	15.25' x 9.5'	450keV/10 mA	TR&BS	USCS	Otay Mesa, CA Calexico, CA
AS&E Pallet Search	14' x 6'	450keV/10 mA	TR&BS	USCS	Anacostia, MD
AS&E Mobile Search	14' x 8.5'	450keV/10 mA	TR&BS	DOD	Ft. Huachuca, AZ
SAIC VADIS	N/A	662keV	TR	USCS	SW Border
EG&G 232	59" x 59"	320keV/10 mA	DeTR&BS	DOD	Ft. Huachuca, AZ
Rapiscan 532/532H	59" x 59"	160keV*	DeTR&BS	Commercial	Several U.S.
Rapiscan 545	Large	450keV	DeTR&BS	N/A	Israel

Notes:

Physics of Neutron Interactions







- **Cross sections vary in magnitude, structure, and threshold**
- **1/v shape at low energy behavior of lowest reaction channel**

How Does PFNA Work

- **PFNA uses a neutron probe**
  - **Use ns-pulsed mono-energetic neutron source**
  - **Source (10^{10} n/s) produced by accelerator driven DT or DD reaction**
  - **Neutrons collimated and scanned over cargo**
- **Detects secondary gammas from neutron interactions with cargo contents**
  - **Signature is unique to the isotopes in the target material**
  - **Ratios of H/C/O/N distinguish explosives from other cargo**

Generic PFNA Technical Characteristics for Air Cargo Inspection

- Tandem Van de Graff accelerator
- >6 MeV DD reaction
- ~150 μAmp beam current
- <1 ns pulse width
- MHz pulse rep. Rate
- $>10^{10}$ neutrons into 4π
- $>10^{5}$ neutrons/cm^2 at center of LD3
- Collimator of borated polyethylene
- Small voxel size < 5-cm x 5-cm x 5-cm

PFNA Truck Cargo Inspection at Port of Ysleta

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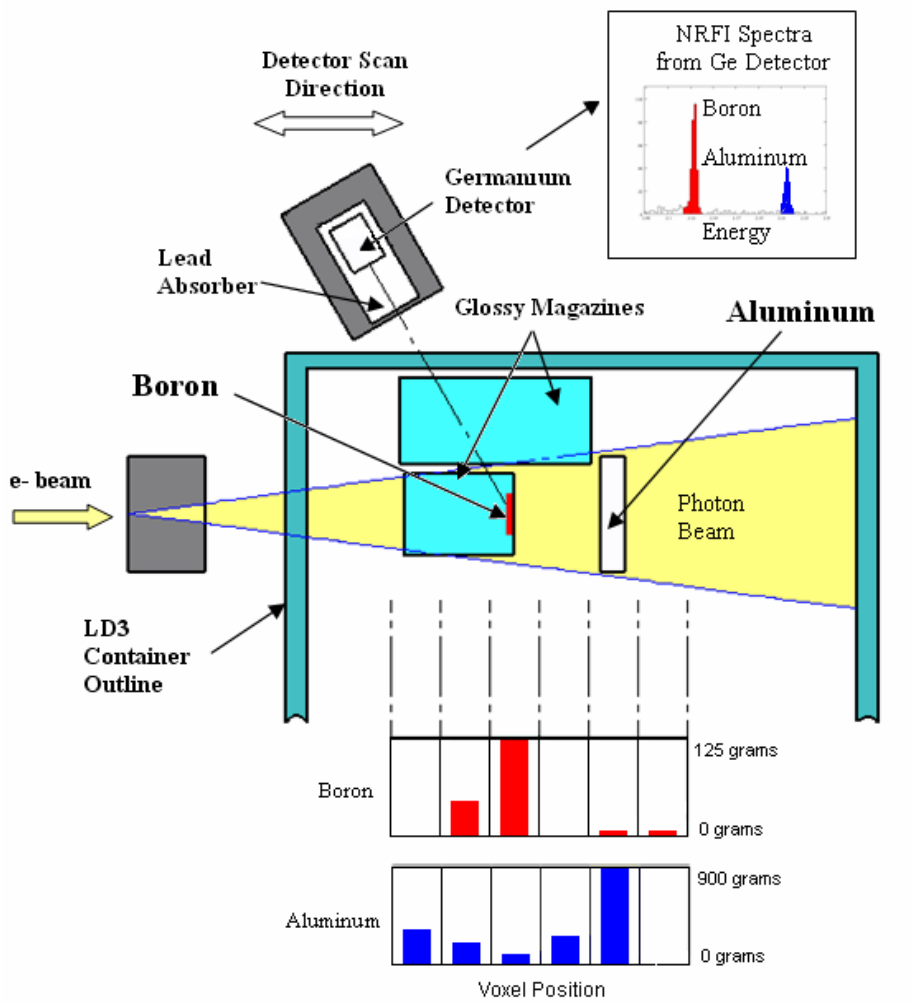
PFNA Air Cargo Blind Test Results

- **FAA Threat Quantities (Explosives)**
  - October 2000 Ancore tests best performance metric
  - PFNA fails to meet FAA explosive detection requirements
  - PFNA failed to detect one important class of explosives
- **Large Quantity Cargo Threats**
  - Eurotunnel test very successful for detection of large quantities of explosives and drugs
  - El Paso Port of Ysleta testing in progress

Nuclear Resonance Fluorescence (NRF)



Test in LD3 container for 130 g of boron behind 30-cm of glossy magazines

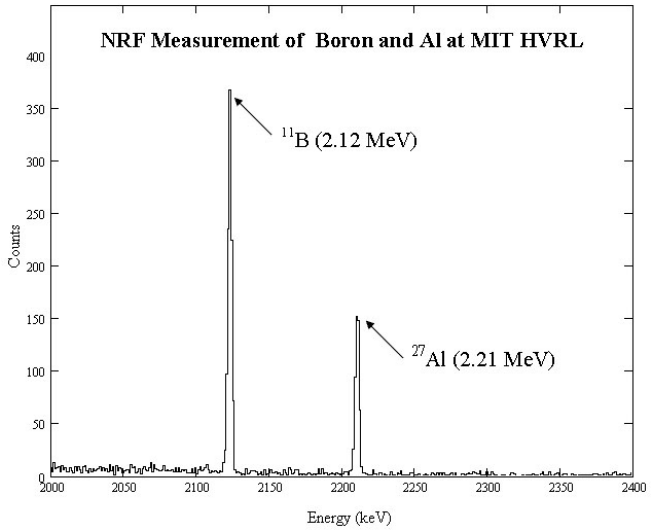


Figure from CAARI conference presentation by W. Bertozzi

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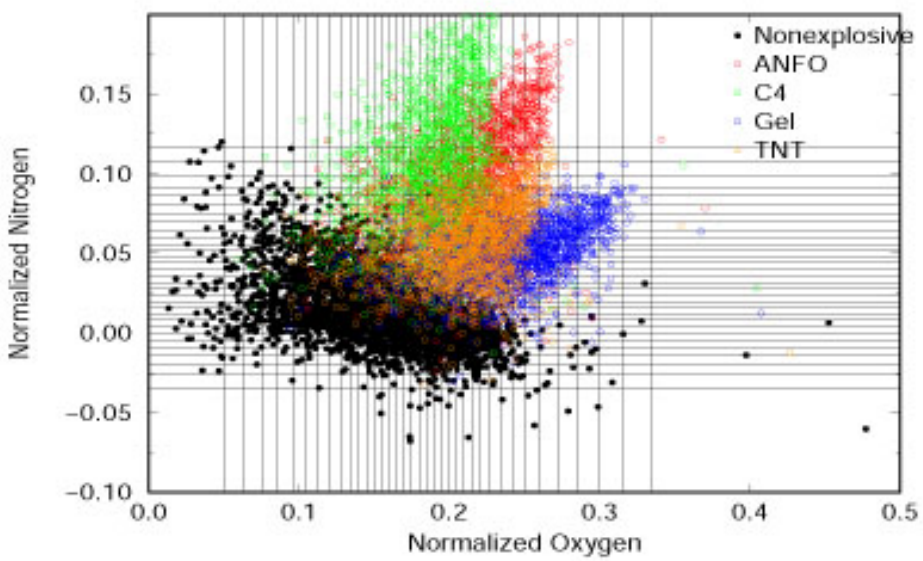
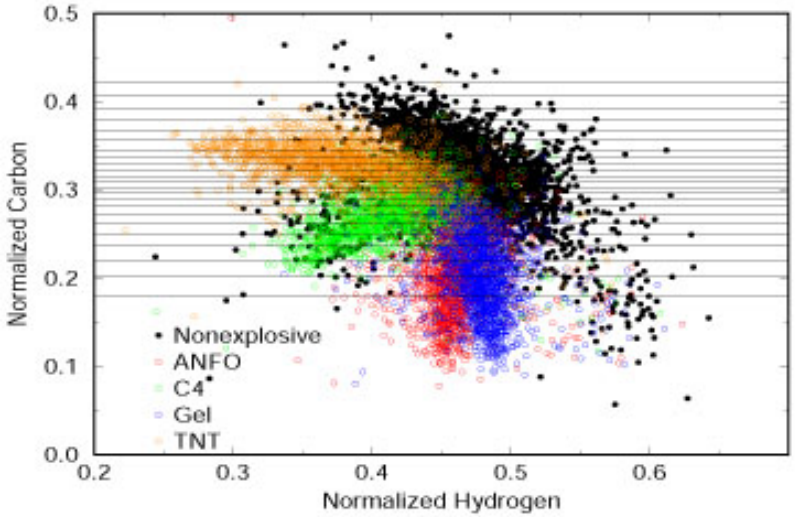
Container Clutter is Critical!

Some mappings show clear elemental ratios for contraband – BUT clutter in a voxel may change the picture!

N vs O Map



C vs H Map



Data from Lefever and Overley, University of Oregon, using PFNTS system on cluttered airline bags

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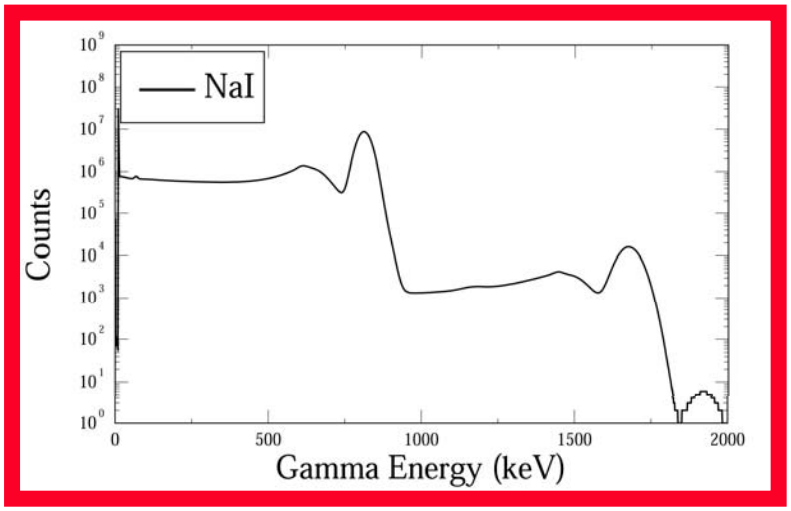
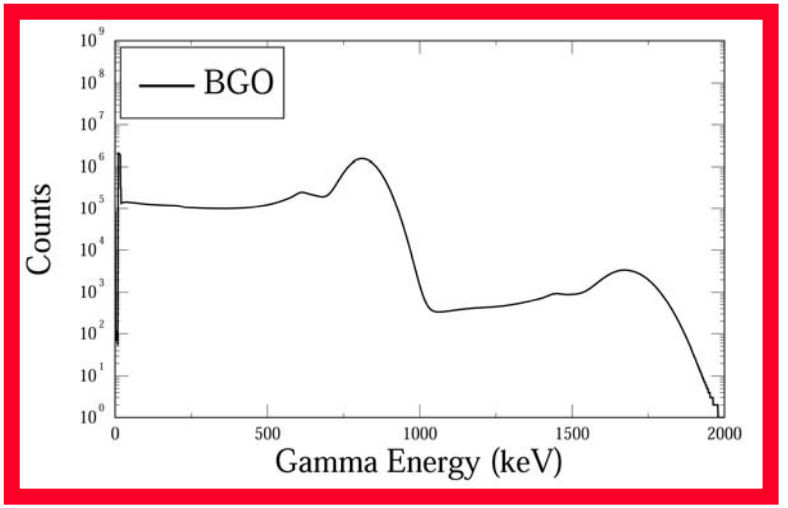
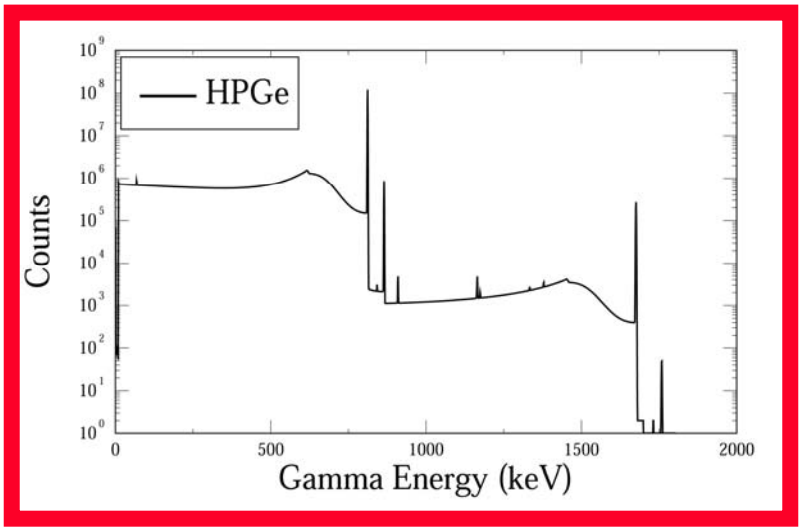
What is the Criteria for Selecting a Photon Detector?

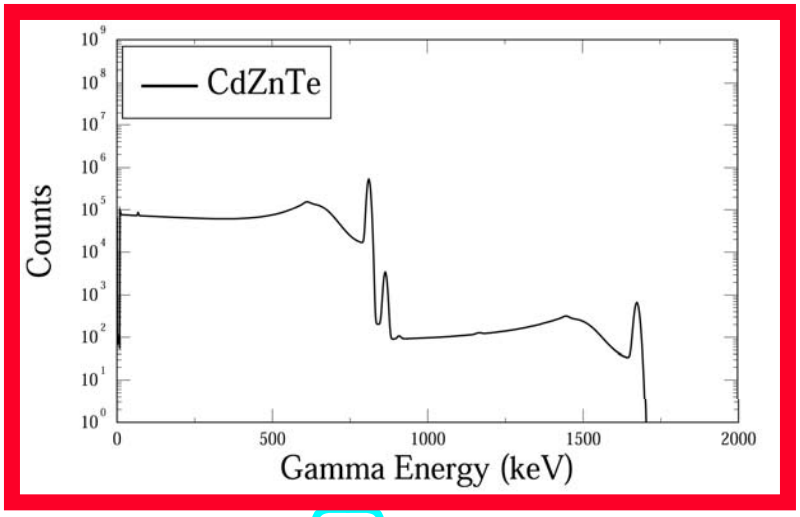
- **Line Resolution**
  - **HPGe is highest resolution**
- **Efficiency (energy-dependent)**
  - **NaI is a very efficient detector**
- **Radiation Hardness**
  - **BGO and NaI have good neutron hardness**
  - **HPGe is very neutron sensitive - soft to neutrons**
- **Cost**
- **Operational Logistics**
  - **HPGe requires cooling, typically liquid nitrogen**

Various Gamma Detectors Can Be Used









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Trace Detection Technologies

- **"Sniff" cargo vapor for explosives or drugs**
  - **Not useful for some contraband, such as currency and ^{235}U**
- **Produce vapor**
  - **Draw vacuum (early model used for altitude sensitive detonators)**
  - **Pressurize and release**
  - **"Shake and Bake"**
- **Not quantitative indicator**
  - **Danger of high false positive**
  - **Danger of false negatives**
  - **Danger of deliberate contamination of cargo stream, denial of service attack**

Important Differences in Purpose of Trace Detection

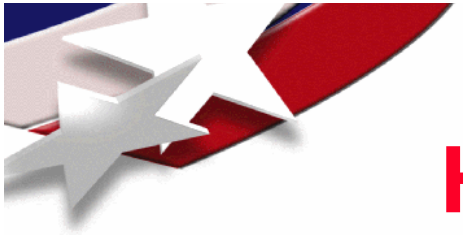
- "Detect to avoid" for explosives
  - Keep threats off the plane
- "Detect to warn" for fast acting chemical agents
  - Steer airport evacuation, graded approach
  - Modify facility air circulation system
- "Detect to treat" for some delayed response biological agents
  - e.g. Bacillus anthracis, treatment after exposure for noninfectious agents
  - e.g. smallpox, track and quarantine of exposed population for infectious agents

Detection of Nuclear Threats

- **Types of nuclear threats:**
  - Nuclear weapons (e.g. typically stolen)
  - Improvised nuclear device (IND)
  - Special nuclear material (SNM)
  - Radiological dispersion devices (RDD)
- **Detection:**
  - Active interrogation
  - Passive detection
    - » Activity
    - » Isotope identification
- **Issues:**
  - False alarm rate (medical treatments, natural sources)
  - Privacy issues (medical treatments)

What Do I Field for Security?

- **Make sure the security reflects a balanced hardening for all threat vectors**
  - **e.g. do not harden passenger screening without a consideration of food services and maintenance access**
  - **include probability and consequence**
- **Use a high quality threat analysis**
  - **Update threat analysis regularly**
  - **Coordinate with other targets and other countries security personnel**
- **Cost/benefit analysis**
  - **Very difficult with high consequence low probability occurrences**
  - **Must factor in public response to an event (not necessarily rational)**
  - **Consider deterrence value, public perception, liability**



How Should One Proceed?

- Select the problem of highest interest – do not try to do everything!
- See if there are any potential technologies that could solve the detection problem selected
- Determine the critical experiments needed to validate investment in the technology
  - Relax time/flux constraints, validate detection approach
- Only then provide seed money for technology development of critical components (learn from NRA)
- Determine an approach that motivates the investment of private industry in the security issue while promoting technology development
  - Learn lessons from the CT EDS experience

Considerations for Any New Detection Systems

- **Must have complete ROC curves**
  - **P_d and P_{fa} are coupled – must be considered that way**
  - **Based on measured data, not intuition or a single point**
  - **Provide as a function of threat quantity**
- **Build for testability**
  - **Support in-situ daily calibration testing (more than red/green, need quantitative indicator)**
- **Certification/acceptance testing must use <u>real</u> explosives**
  - **Learn from previous history with EDS**

Questions???