Reliably Detecting Nuclear Weapons in Transit

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Science, Technology and Security Seminar

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"Closing Loopholes in Domestic Detection of Uranium using Reliable Detection Portals"

http://www.devabhaktuni.us/research/RDP-paper.pdf
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Reliably Detecting Nuclear Weapons in Transit

- What is the threat model?
  - Distributed Fractional Transport
  - Dozens of pathways on which small quantities of HEU can be delivered into a metro
- How to deploy portals?
  - Use multiple redundant “rings “ around metros (MSAs) to complement national border
- What technology to use for portals?
  - Design passive gamma/neutron, passive muons, and active neutron interrogation in conjunction so their strengths make up for each other’s weaknesses

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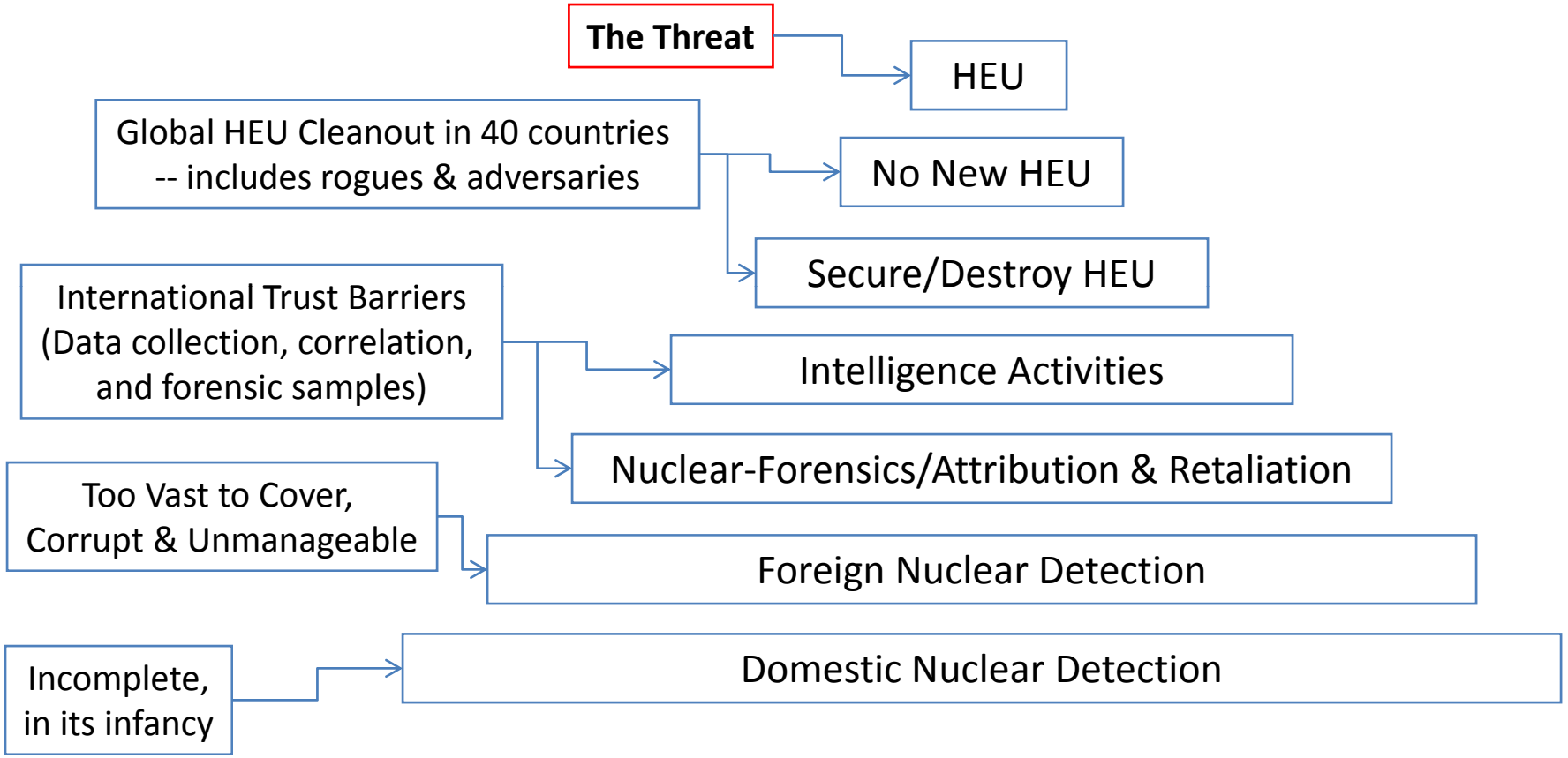
Reliably Detecting Nuclear Weapons in Transit

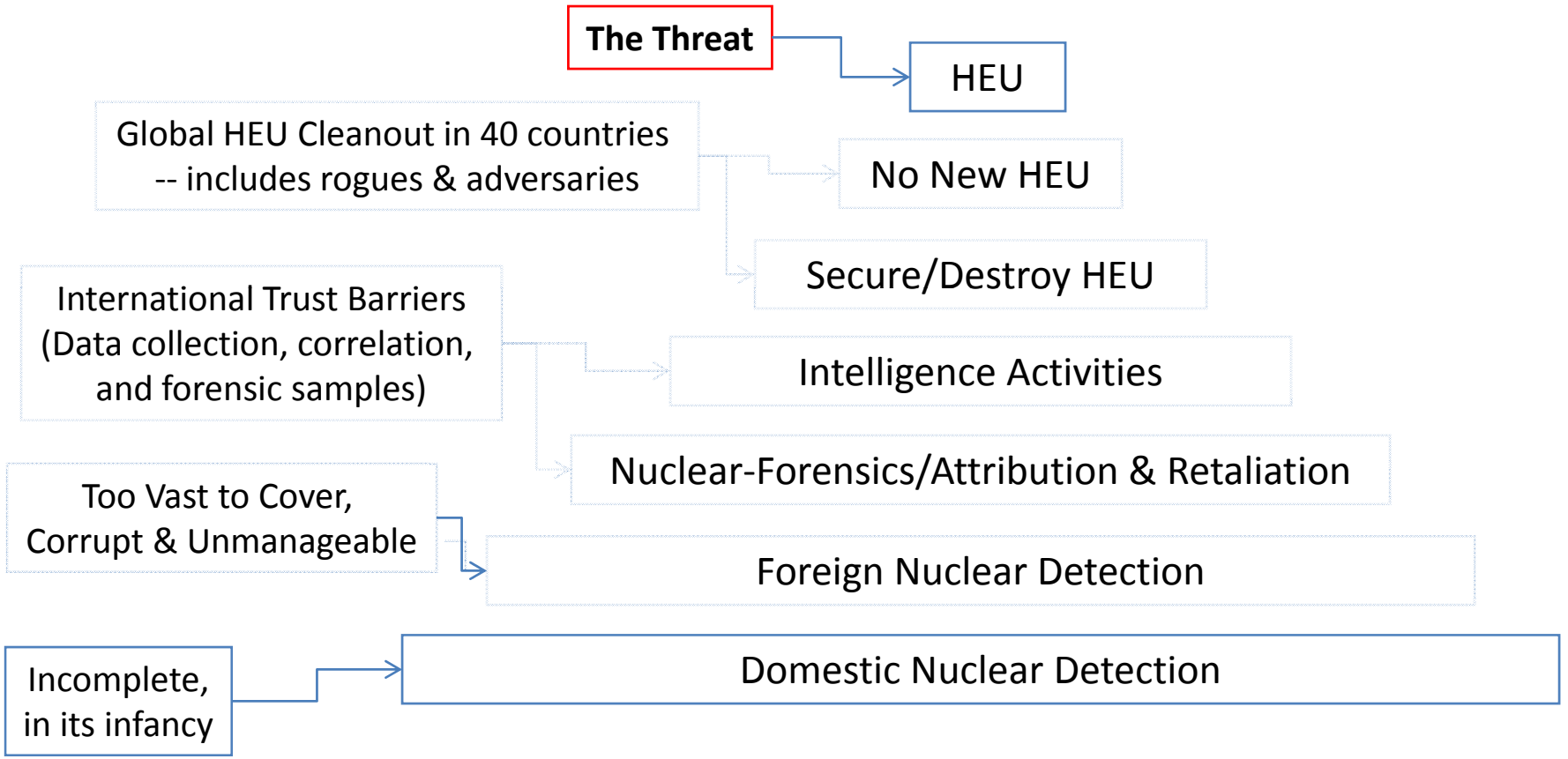
- Best case: **Assembled Weapon (Hiroshima) with U-232 traces**
  - Greater than 20 kg of metallic HEU
  - Heavy gun barrel
  - Unshielded, uncluttered, easiest to detect with highly penetrating 2.4 MeV gamma radioactive signature (from U-232)
- Worst case: **Disassembled Weapon, no U-232**
  - Reassembled domestically by attacker in a secret location
  - Shielded to eliminate radioactive signatures, no U-232
  - Fractionized into multiple arbitrary small shipments (perhaps as low as hundreds of grams)
  - HEU metal crushed and dispersed into small particles or powder
  - Spread out thin within the same shipment under some minimum thickness that is undetectable
  - HEU transported in lower density oxide forms of uranium

Today's Layered Defense Strategies



Could an attack slip through once in 10 years? 20 years?...

Today's Layered Defense Strategies



Only layer within 100% US control is Domestic Nuclear Detection

Dissuasion versus Interception

- Dissuasion: Use nuclear detection to convince (dissuade) the adversary not to carry out a nuclear terrorism attack by developing a capability to detect an attack early enough to stop it (defeat).
- Interception: Use nuclear detection to catch nuclear material or weapons being smuggled on transportation pathways.

They are similar in spirit, but are very different in practice

9/11 Commission legislation

- Public Law 110–53 passed (August 3, 2007) requires cargo containers to be scanned at ports of origin for nuclear devices.
- Ignores possible mid-ocean transfers by attackers using helicopter or ships.
- Leaves pathways insecured. It does not address:
  - oil tankers, cruise ships, sailboats, yachts
  - private jets, passenger airplanes, helicopters
  - underground tunnels or sewage pipes
  - Automobiles
- Today's plans for nuclear detection would be like securing the international terminals while permitting holes in the perimeter around the airport and leaving the domestic terminals unsecured.

Consistent with Interception – not Dissuasion

Countermeasure: Ocean ships passing by SF Post-Inspection Vulnerability

After mid-ocean transfer, the attacker could detonate the device before it reaches the port

Countermeasure: Luxury Liner docked in SF
Post-Inspection Vulnerability

Tourist Attraction or Trojan Horse?

Adversary's Decision to Attack

- Know-How: With the detection system in place, can they figure out how to execute the countermeasure to transport the device or material while evading detection in a "reliable enough" way -- say better than 95%? (yes/no)
- Resources: Do they have access to the resources required to execute this countermeasure with sufficient confidence -- say better than 95%? (yes/no)

“Yes” to both? – if so adversary can attack at will.
Cannot close some loopholes leaving others wide open

HEU Transport Security Standard

A chain is as strong as its weakest link. A reliable nuclear detection network should be impenetrable to all HEU smuggling plots that fall within some minimum criteria:

- Know-How:
  - **science, engineering, logistics, detector specifics**
  - **Example 1: Open source literature (Internet/libraries)**
  - **Example 2: All knowledge including closed source**
- Resources:
  - **"smart" team of people and cash**
  - **Example 1: $50K cash + team of 2 people**
  - **Example 2: $500,000K cash + team of 10 people**

If not, a loophole exists, i.e. over-engineered system. Security = 0. Securing to minimum thresholds may also increase risk of failure in more complex plots.

Countermeasure: SF Bay Pre-inspection Vulnerability

DHS pilots inspections for private boat near cities

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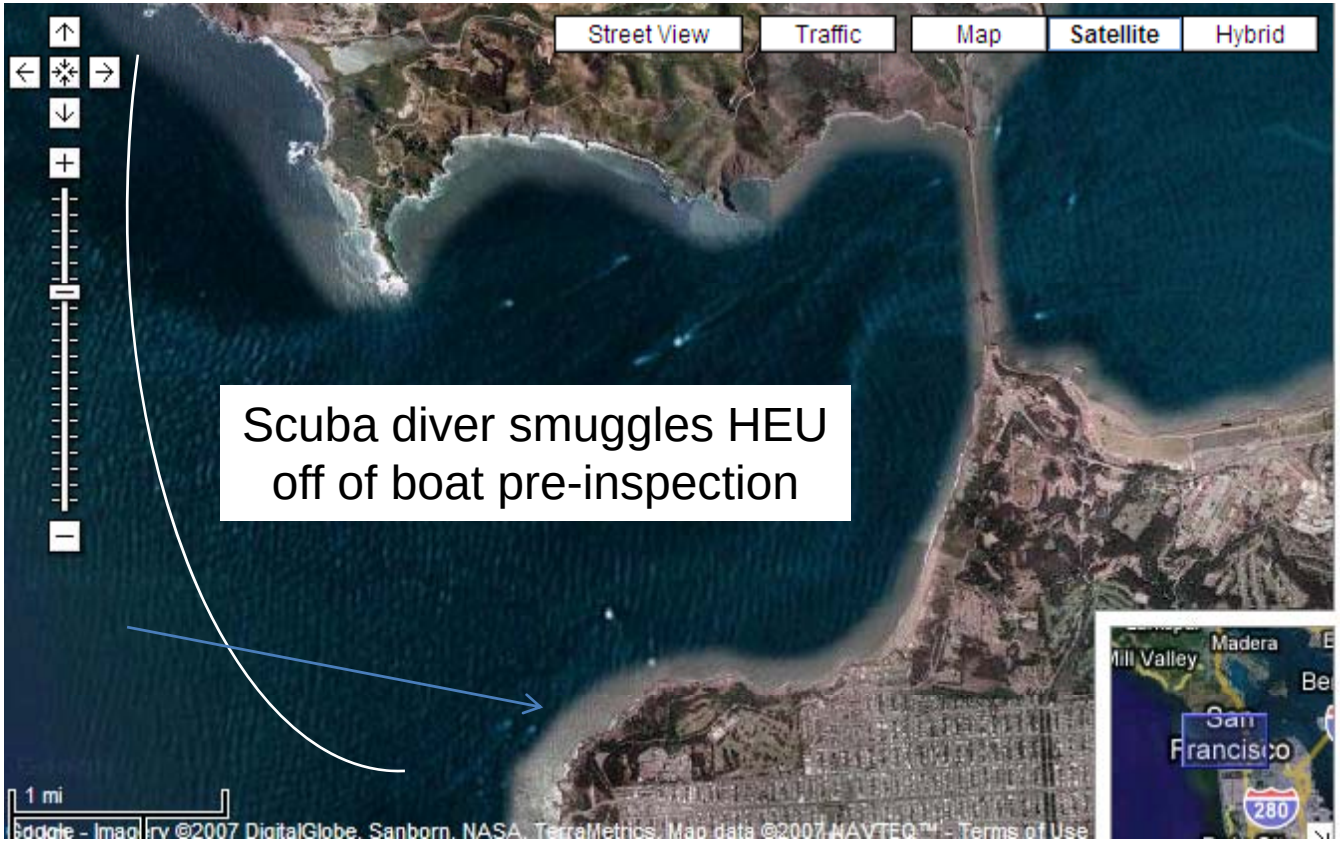

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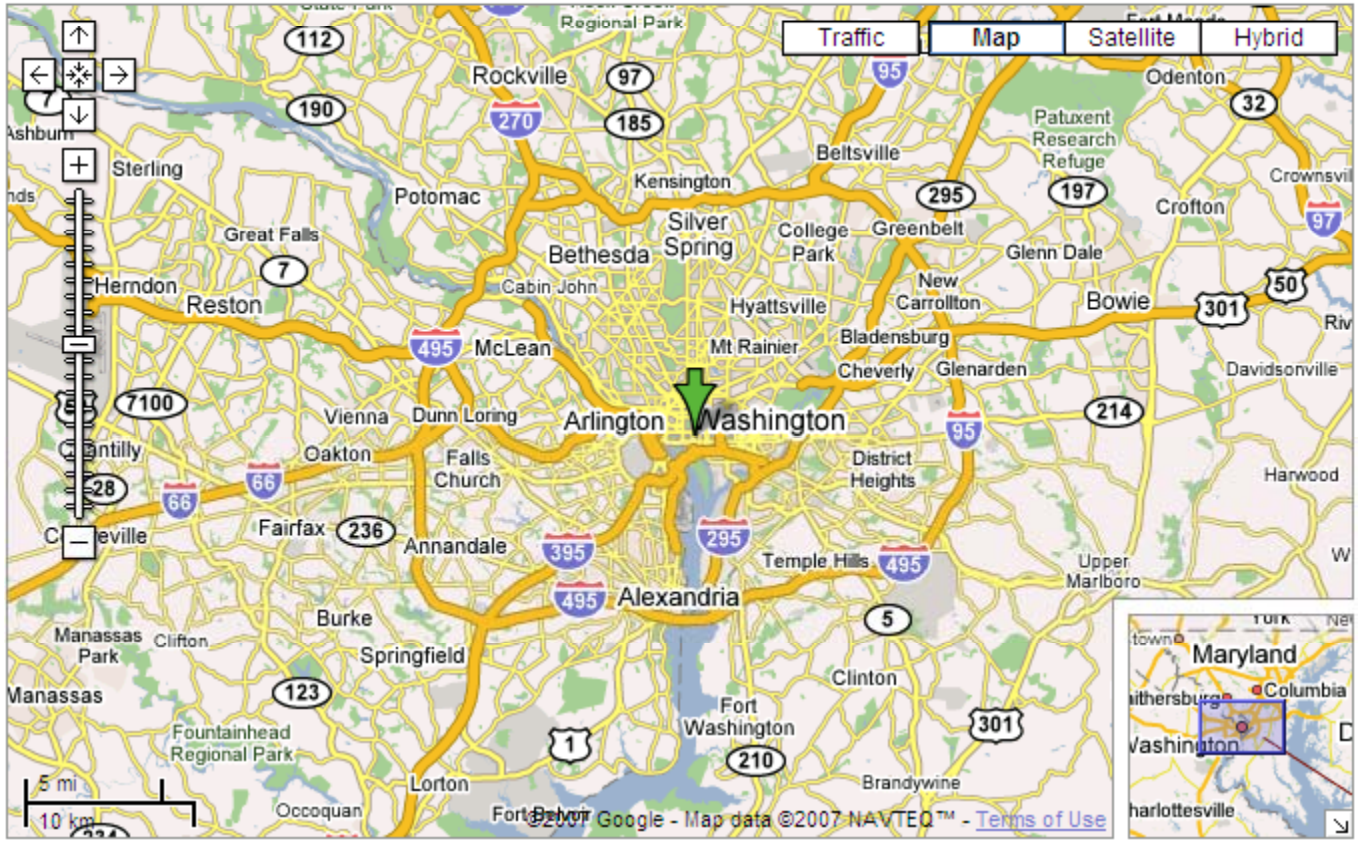
Dozens of approach pathways

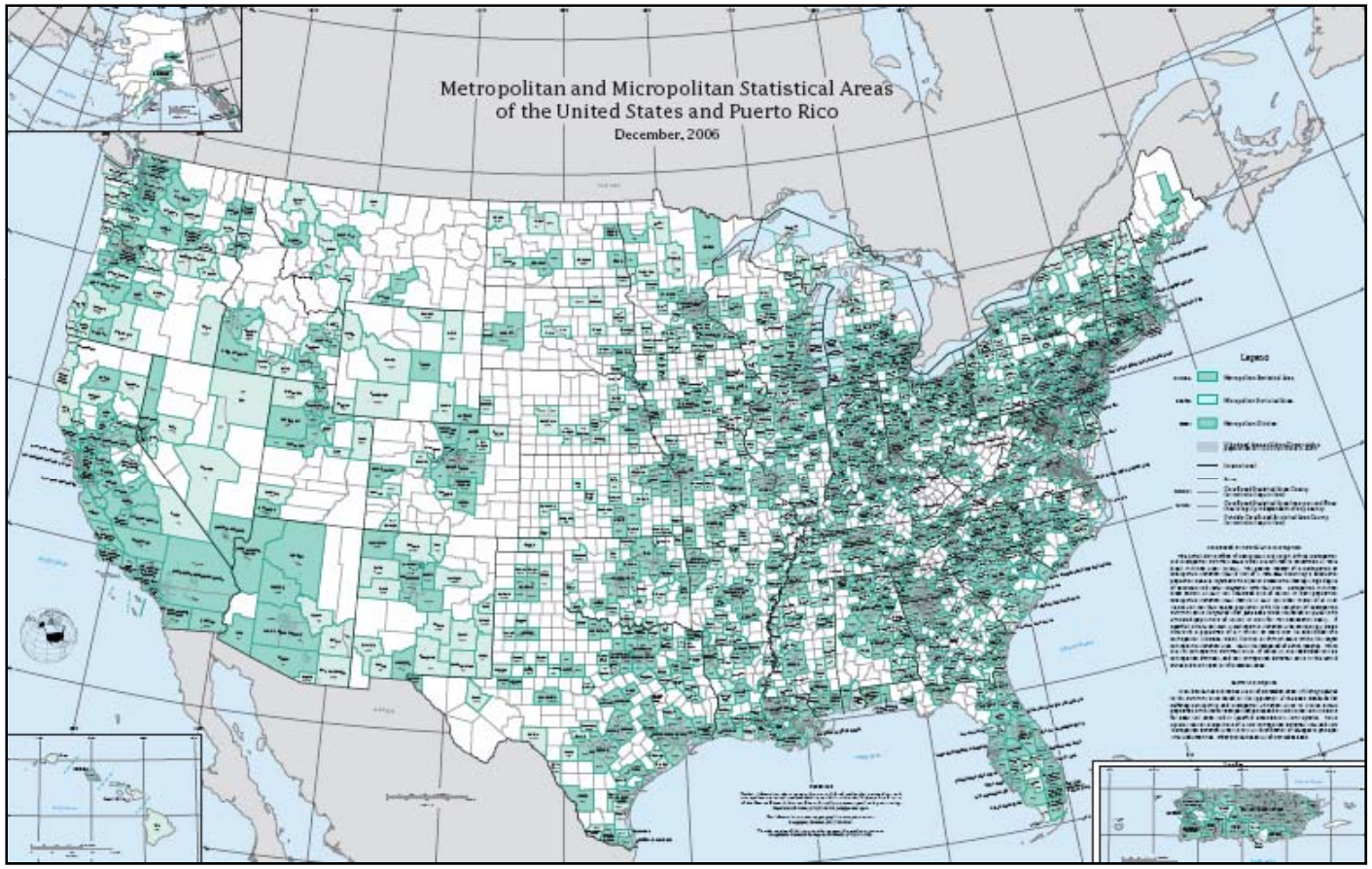


Dozens of approach pathways

- Ground
- Underground
- Water
- Underwater
- Air

Some may be secured using nuclear detection.
The remaining have to be prohibited.

National vs Metro Detection Rings



National vs Metro Detection Rings

- Long US border: 20,000 miles of land/sea borders
  - 5000 miles US-Canada
  - 1900 miles US-Mexico
- Extremely porous: Weak spots, millions of illegal immigrants, hundreds of tons of cocaine annually
- Single Points of Failure: Single linear border has no redundancy – once attacker punches through they're "home free" and there is little time to react

Reliability achievable via multiple redundant borders around Metropolitan Statistical Areas (MSAs)

Building Block of Nuclear Detection: the Drive-Thru Portal

- To screen all transport for HEU
  - Pedestrians
  - Automobiles
  - Trains
  - Cargo
- Portal Detection Techniques
  - Passive gamma/neutron
  - Passive muon tomography
  - Gamma/X-ray radiography
  - Active neutron interrogation (Nuclear Car Wash)

Portals required for DC metro area

Average Annualized Daily Traffic Volume (AADT) in vehicles	Lanes	Maximum Daily Traffic Volume (assuming 1-second spacing between cars)	**Number of portals required**							
			1 min scan/delay needed per vehicle inside portal		2 min scan/delay needed per vehicle inside portal		5 min scan/delay needed per vehicle inside portal		10 min scan/delay needed per vehicle inside portal	
			Avg	Peak	Avg	Peak	Avg	Peak	Avg	Peak
1,096,000	50	4,320,000	381	1500	761	3000	1903	7500	3806	15000

1M million vehicles in and out of DC metro area daily
Depending on scan delay, several 1000s of portals are required

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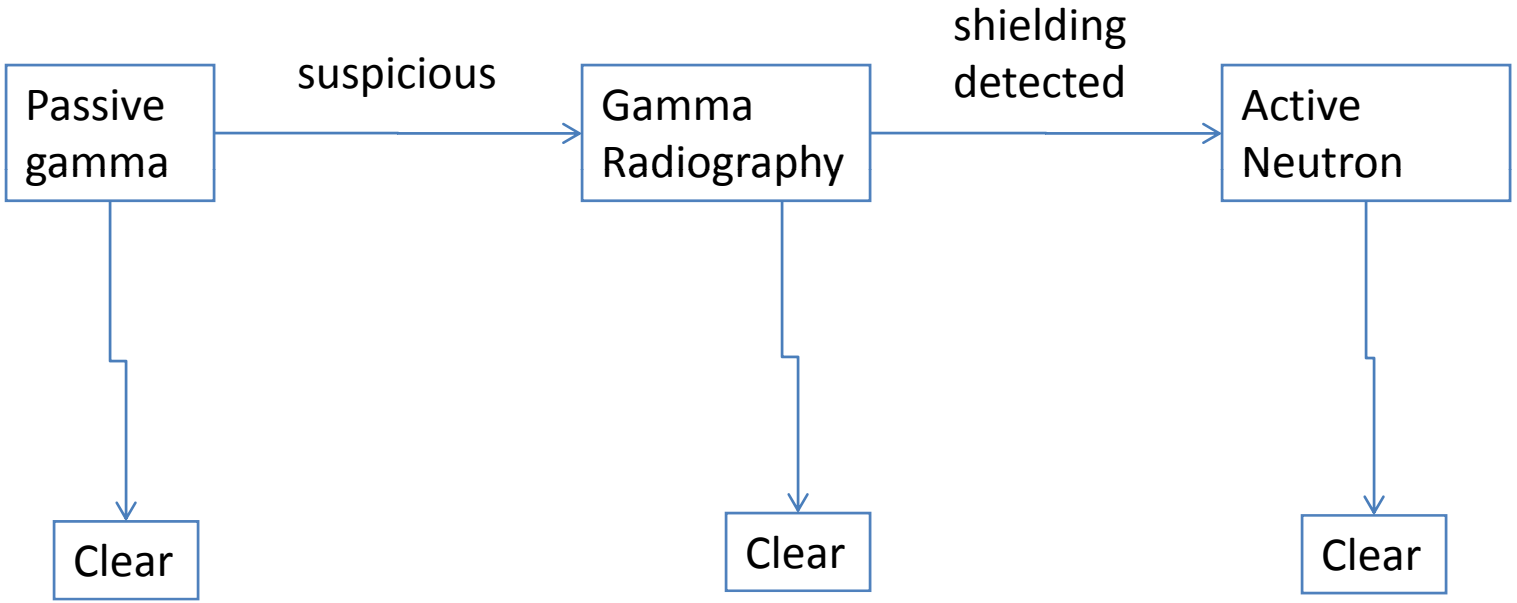
Countermeasures of Portal Technologies

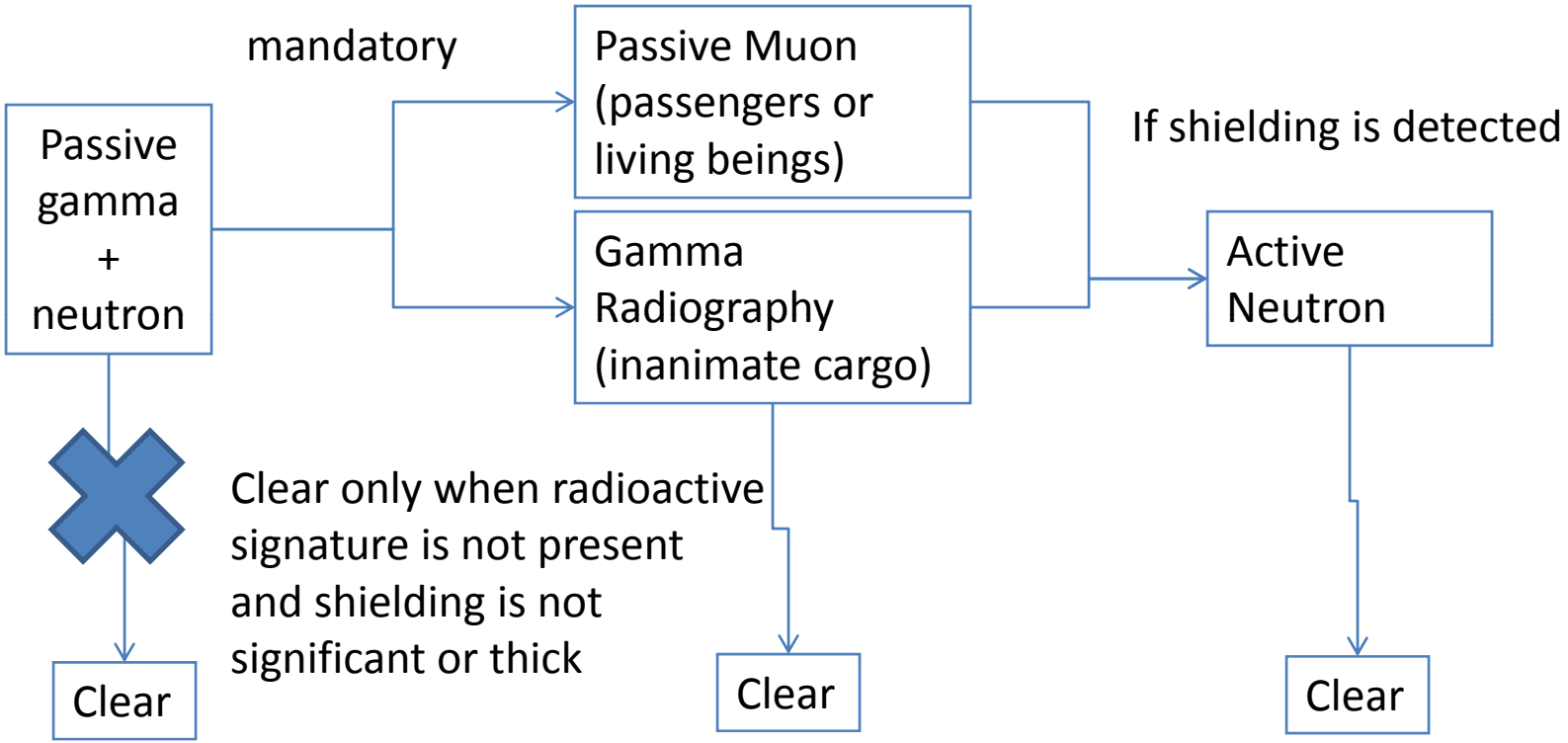
Portal Technology	Harmful to humans and living beings	Susceptible to shielding by lead, steel, concrete, etc	Susceptible to neutron shielding	Susceptible to Spreading, Dispersion, Oxides, etc
Passive gamma	No	Yes	No	No
Passive neutron	No	No	Yes	No
Passive muon tomography	No	No—detects dense shielding	No	Yes
Gamma/X-ray radiography	Yes	Yes—detects dense shielding	No	Yes
Active neutron (6 MeV)	Yes	No	Yes	No
Active neutron (14 MeV)	Yes	No	No—detects neutron shielding	No

Today's Inspection Paradigm – Unreliable



Shielding needs to be detected in all, not only suspicious vehicles. Gamma radiography is harmful to humans

The Reliable Detection Portal (RDP)



All vehicles can be screened using passive gammas, neutrons, and muons. Muon tomography does not harm humans or living beings

RDP Requirements

- **Minimum Detectable Quantity:** Detection > 300 grams of highly enriched uranium metal (1 cubic inch), uranium oxides, or plutonium in any shape or form, not limited to solid spheres or cubes.
- **False negatives:** A false negative rate less than 5% . No simple countermeasures
- **False positives:** A false positive rate of less than or equal to $10^{-6.}$ Require manual search to resolve questions in less than 10^{-6} of normal vehicles.
- **Detection Time:** Similarly, maximum detection time of 10 minutes, with average detection time less than two minutes. Average detection time of one minute or less is desirable.
- **Portal Size:** Size of the system should be scalable based on the dimensions of the types of vehicle scanned, with all equipment required not exceeding twice the size of the vehicle. Capable of operated by a single operator
- **MTBF:** The system has a mean time before failure (MTBF) of 10 years. Higher is better.

RDPs: Are they feasible?

- What is the optimal combination of passive gamma/neutron, passive muon, and active neutron techniques? Where does one technique leave off and the other begin?
- What are the possible countermeasures? How does this compare to other approaches?
- What is the minimum detectable quantity of HEU? What are the false negative rates?
- What are the false positive rates? (less than 1 in a million needed)
- What are the delay/dwell times for the portal for various types of vehicles, and on average?
- Can these be operated in securely, in large-scale?

RDPs: Passive Gamma Feasibility?

- What size detector is necessary?
- At which thickness of shielding does it become ineffective and passive muon must take over?
- What energy resolution is required to distinguish 1MeV HEU signal from background or clutter in vehicle? 1%, 2%, 5%, 10%?
- What detector technology works in operational environments? HPGe requires cryogenic cooling. Will LaBr suffice? NaI?

RDPs: Passive Muon Feasibility?

- What minimum size HEU can be detected without incurring large false negative rates?
- What minimum horizontal thickness is required to detect HEU?
- What minimum thicknesses of shield can it detect? How does this compare to objects in typical vehicles?
- What are the countermeasures that will cause it to fail…spreading, dispersion, oxides, etc?
- What will the false positive rates be?
- At what point will the vehicle need to be referred to active neutron interrogation?

RDPs: Active Neutron Feasibility?

- If shield detected by passive muon or radiography, what design is necessary to detect HEU within shields using 6MeV neutrons? What thicknesses of shields?
- Can neutron shields be effectively detected using 14 MeV neutrons?
- What are the specifications of neutron sources and gamma detectors required?

RDPs: Research Agenda

- Phase 1: Answer open questions based on theory and simulation using full spectrum of inputs
- Phase 2: Construct prototypes and demonstrate proof-of-principle
- Phase 3: Test with "real world" inputs and measure/qualify their effectiveness

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Further Reading

- **these slides** http://www.devabhaktuni.us/research/RDP.pdf
- **"Closing Loopholes in Domestic Detection of Uranium using Reliable Detection Portals"** (2008) http://www.devabhaktuni.us/research/RDP-paper.pdf
- **"Nuclear Detection: History and Facts"** (2008) http://www.devabhaktuni.us/research/history-facts.pdf
- **"DHS' Domestic Nuclear Detection Office Progress in Integrating Detection Capabilities and Response Protocols"** (Office of the Inspector General, Department of Homeland Security, December 11, 2007) http://www.dhs.gov/xoig/assets/mgmtrpts/OIG_08-19_Dec07.pdf
- **"Nuclear Detection: Fixed detectors, portals, and NEST teams won't work for shielded HEU on a national scale; a distributed network of in-vehicle detectors is also necessary to deter nuclear terrorism"** (2005) http://www.devabhaktuni.us/research/disarm.pdf

Hundreds of references cited in these papers