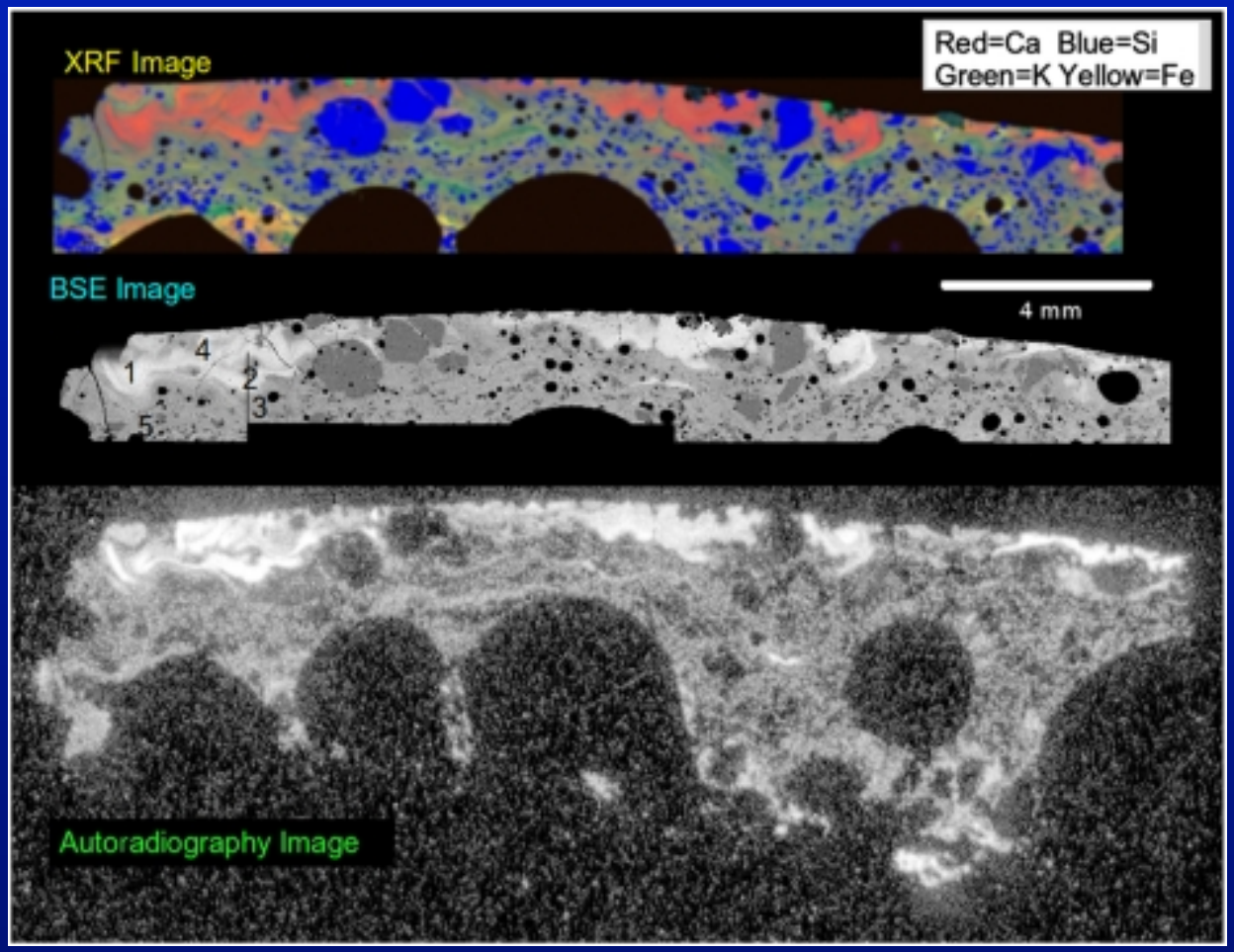
Nuclear Forensics



W Dorland
Univ of Maryland

Trinitite from 1945

Fahey, et al., Proc Natl Acad Sci U S A. 2010 Nov 23; 107(47): 20207–20212.

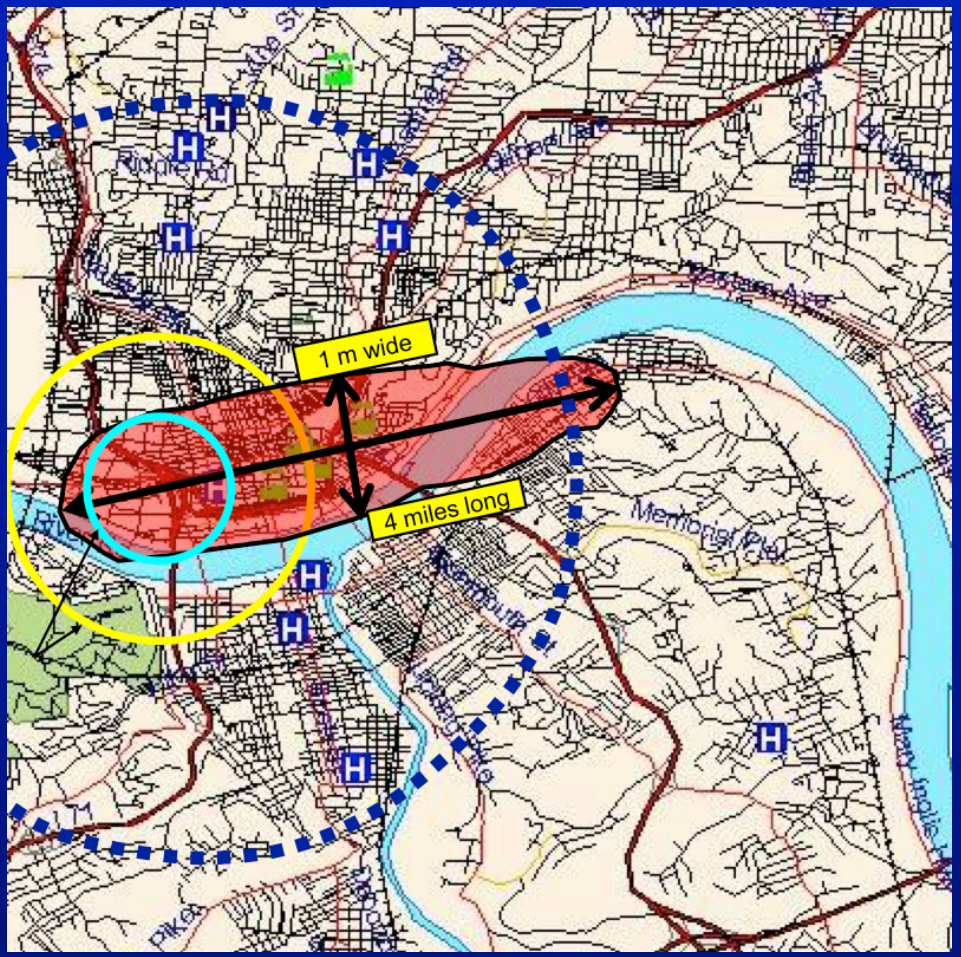
Key Concepts

1. Interdicted materials vs. post-detonation debris
2. Dirty bombs vs. fizzle vs. nuclear detonation
3. Forensic analysis
   - Nuclear forensics determines the composition, physical condition, age, provenance, and history of materials
   - Together with information from intelligence and law enforcement, nuclear forensics can suggest or exclude the origin of materials and of nuclear devices
4. Attribution
   - Much harder!
   - Timeline would be “screaming panic” (J. Davis)
   - Who did it vs. what happened

Interdiction

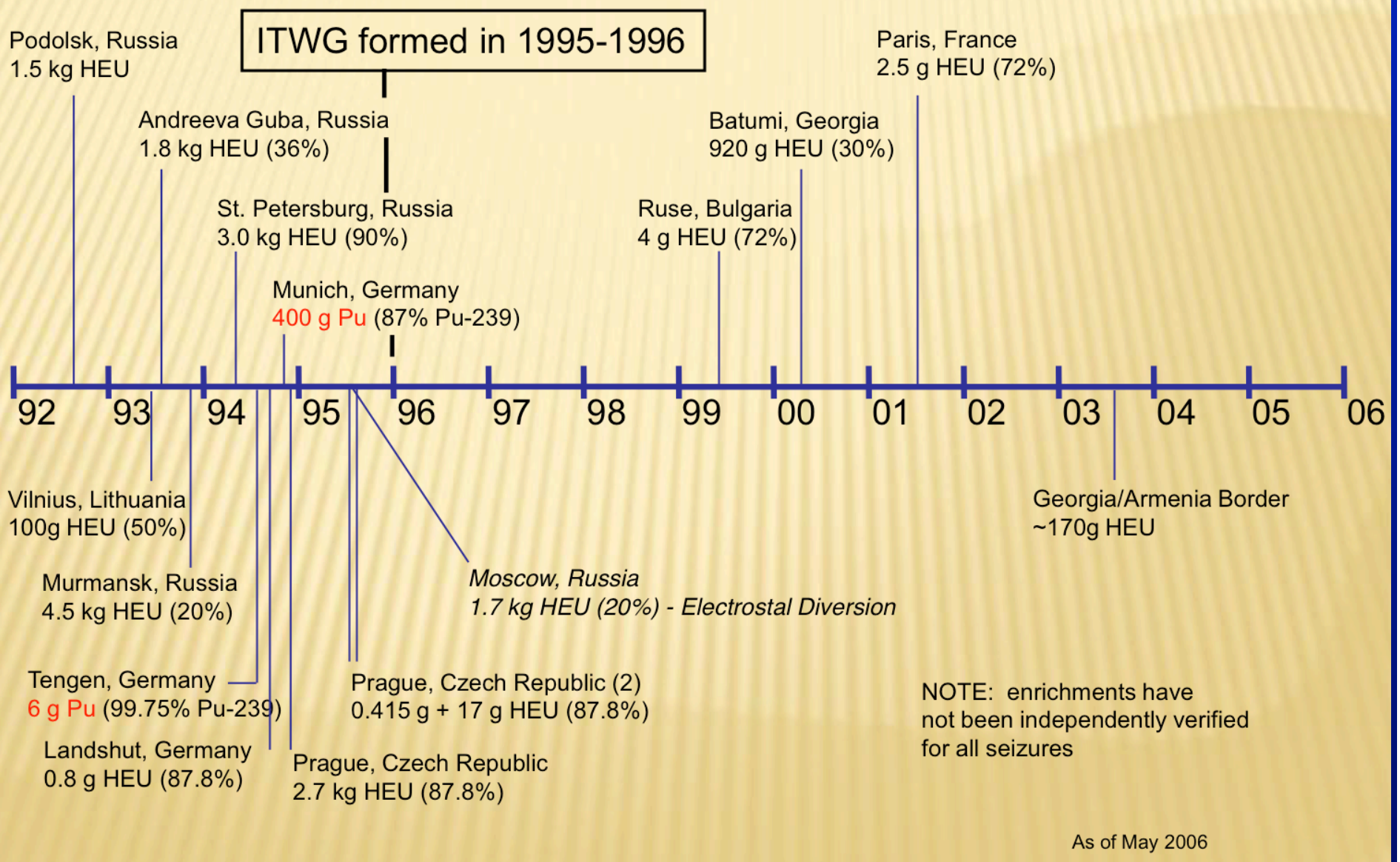
- High false positive rate, but many successful finds
- Technology evolving

Post-detonation



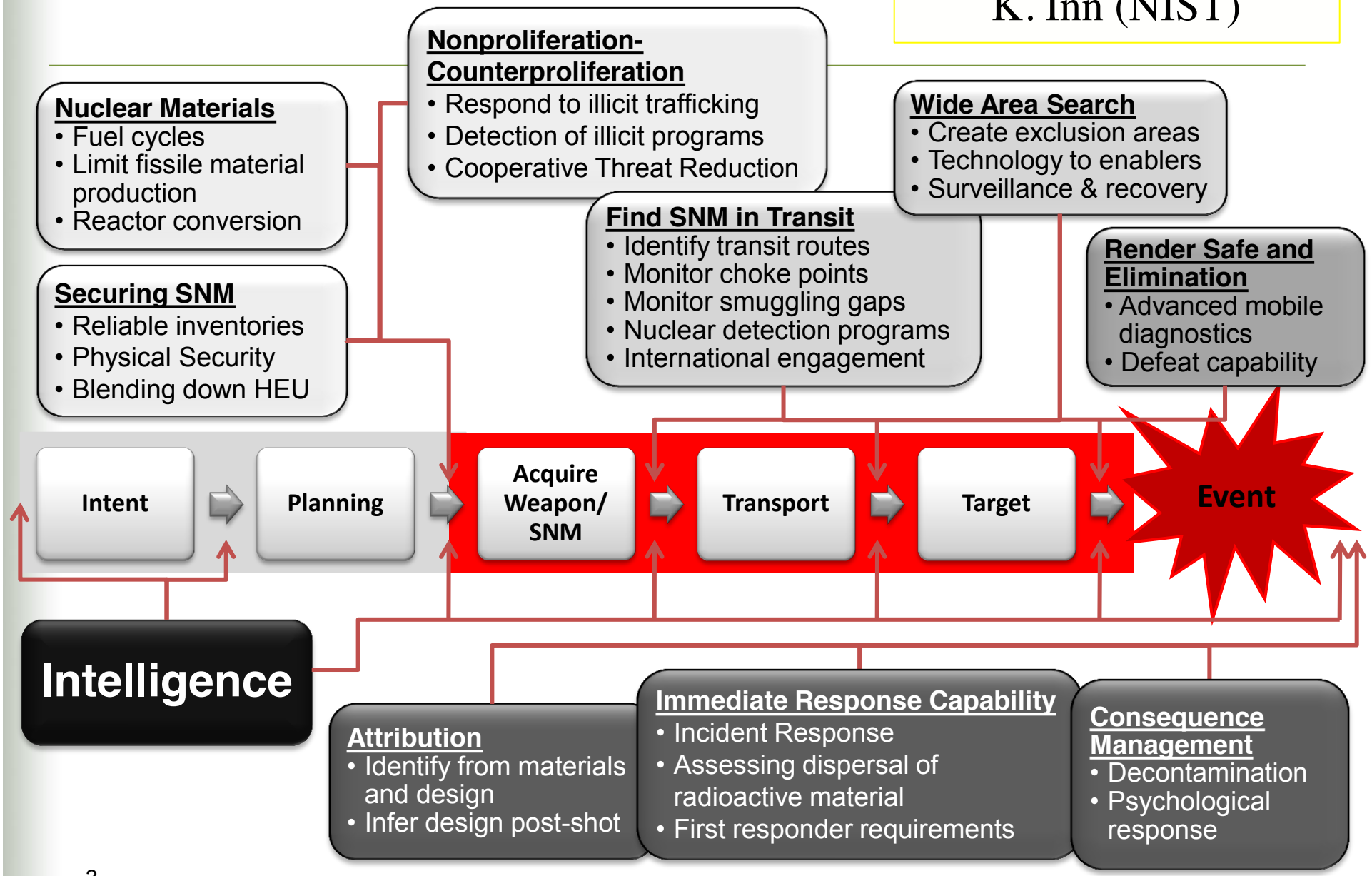
- **Analyses must then be unclassified…*why?***
- **Pace of response cannot be frantic…*why?***
- **Who is involved?**

Timeline of some known interdictions



From Jay Davis, talk given at Imperial

K. Inn (NIST)


Nonproliferation-Counterproliferation
• Respond to illicit trafficking
• Detection of illicit programs
• Cooperative Threat Reduction
Nuclear Materials
• Fuel cycles
• Limit fissile material production
• Reactor conversion
Wide Area Search
• Create exclusion areas
• Technology to enablers
• Surveillance & recovery
Find SNM in Transit
• Identify transit routes
• Monitor choke points
• Monitor smuggling gaps
• Nuclear detection programs
• International engagement
Render Safe and Elimination
• Advanced mobile diagnostics
• Defeat capability
Securing SNM
• Reliable inventories
• Physical Security
• Blending down HEU
Intent
Planning
Acquire Weapon/ SNM
Transport
Target
Event
Intelligence
Attribution
• Identify from materials and design
• Infer design post-shot
Immediate Response Capability
• Incident Response
• Assessing dispersal of radioactive material
• First responder requirements
Consequence Management
• Decontamination
• Psychological response

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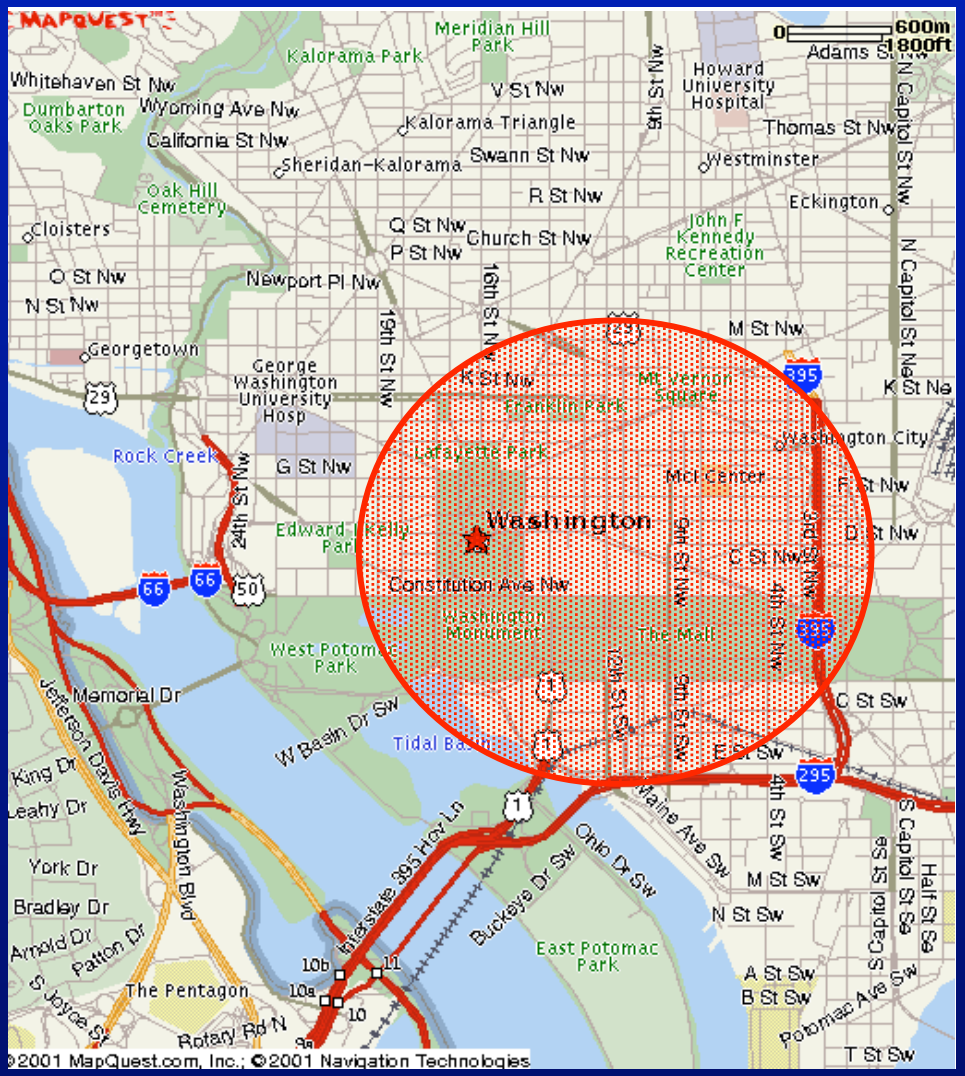
Scenarios

- Dirty bomb – explosive device designed to spread medical isotopes, for example
  - Most likely/easiest
  - Few casualties
  - Expensive cleanup
- Fizzle – nuclear device that fails to work
  - Next most likely
  - Hundreds of casualties
  - Forensic opportunities
- Nuclear explosion
  - Least likely (but…)
  - Large number of casualties; city devastated
  - Greatest forensics challenge

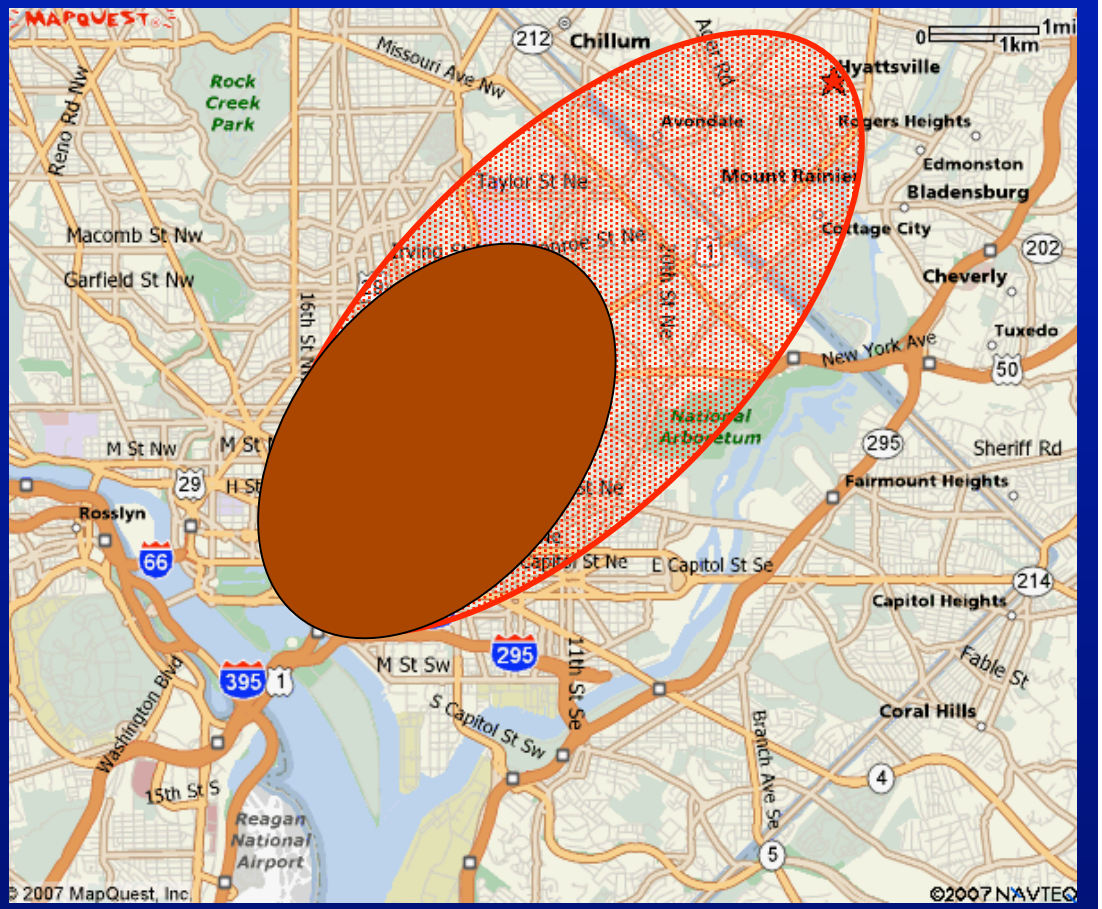
10 kt explosion in Washington, DC

- From “Day After” report
- 50% of population in 2-mile radius would suffer immediate major injuries or fatalities
- Assumed groundburst with typical weather conditions and no warning



10 kt explosion in Washington, DC

- Fallout pattern would include my house!
- 10-50% of the people in the larger, lighter oval would receive non-fatal injuries in the first day
- Overwhelming con-clusion: prevent this from happening in the first place



- So: what strategies did you come up with for preventing this?

10 kt explosion in Washington, DC

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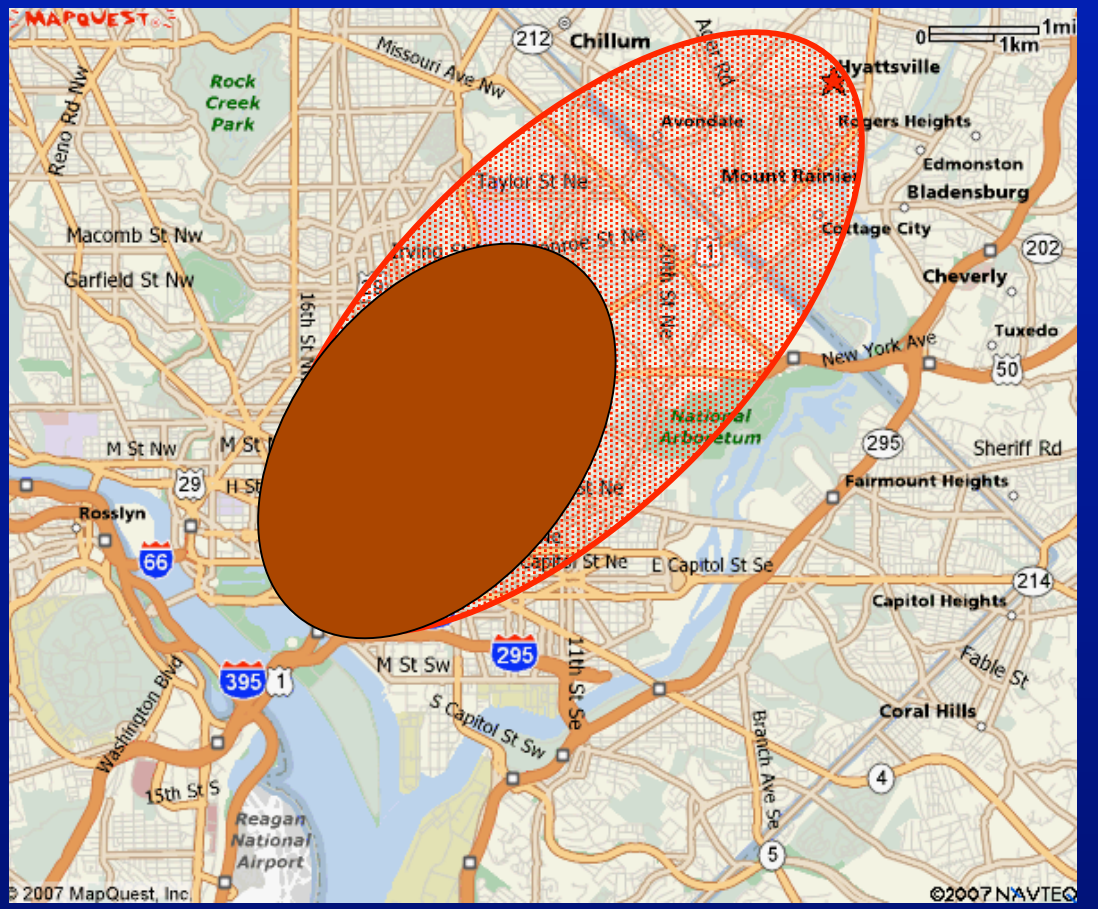
- 10-50% of the people in the larger, lighter oval would receive non-fatal injuries in the first day
- Overwhelming con-clusion: prevent this from happening in the first place
- But what would happen next? What can the physics community offer?



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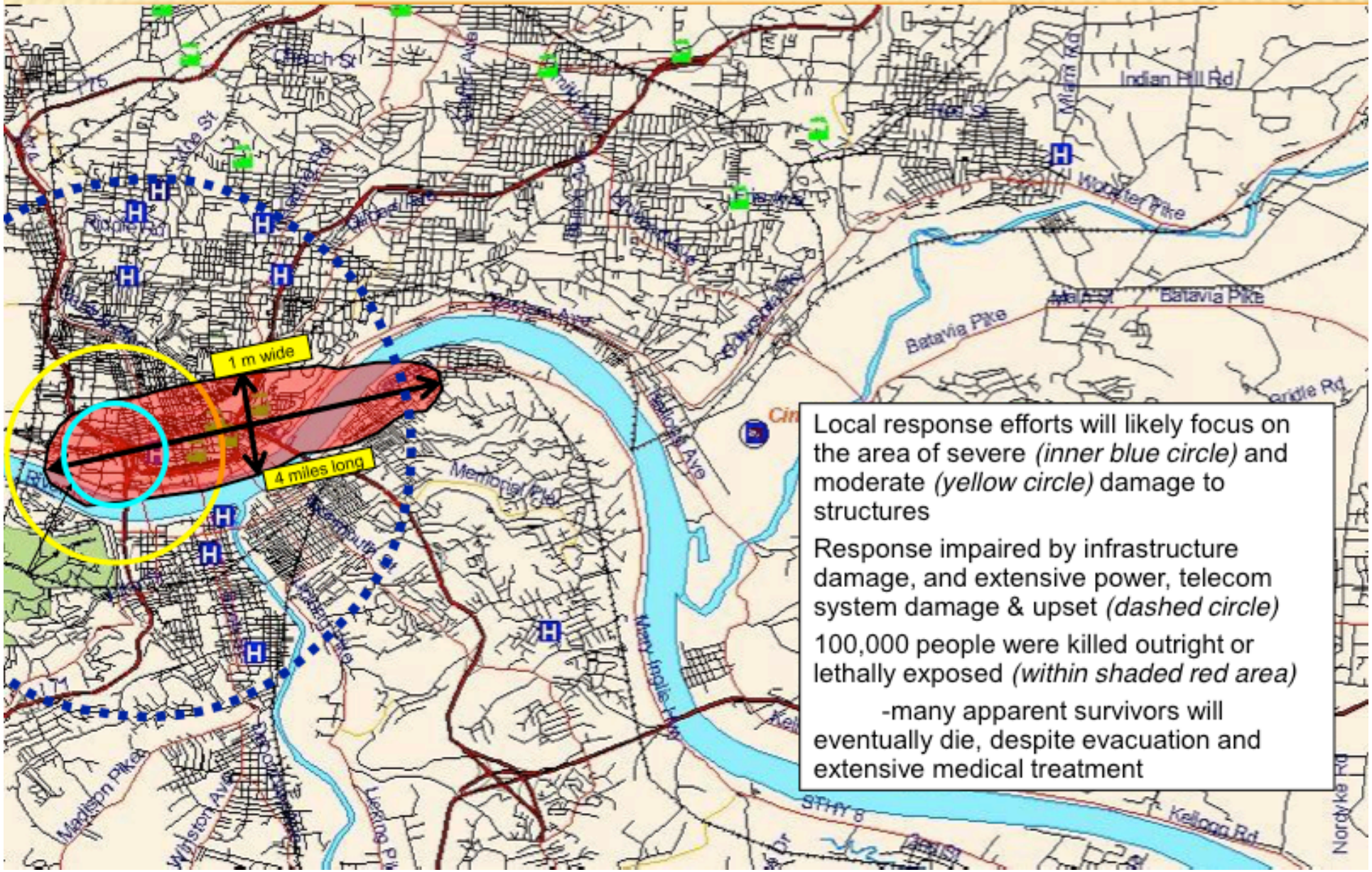
- What kinds of questions would be asked?
  - What just happened?
  - Will there be another one?
  - Who did it?
- Where might the weapon have come from?
  - Intentionally smuggled in by another nation
  - Lost by a peer state and used by terrorist
  - Built by rogue state with covert program
  - Built by terrorists using materials from NW state
  - Sold by a NW state
  - Diverted from inventory of a collapsing NW state

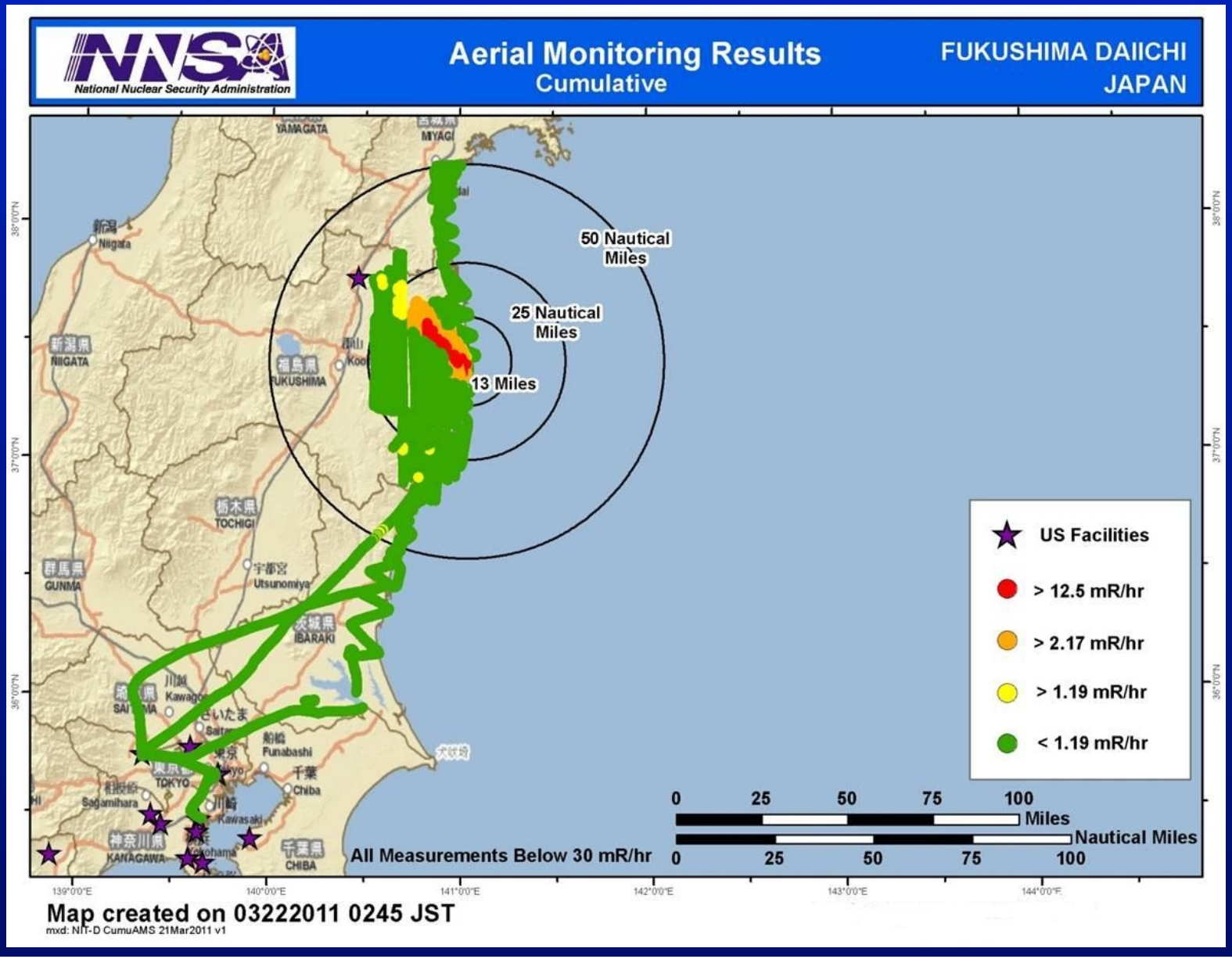
SITUATION - 4 HOURS AFTER DETONATION

SOME REGIONAL FEDERAL ASSETS POSSIBLY ON-SCENE



What was it? (Was it nuclear?)

- National assets developed for Cold War and NPT are always watching
- GPS satellites carry optical nuclear detectors
- How sensitive, how accurate, how quick the response?
  - Classified
  - Varies by country
  - Most countries will depend on announcements
- Local samples, fallout sampling
  - Takes longer
  - Gives more detailed information
  - Requires readiness – the world is a big place


National Nuclear Security Administration
Aerial Monitoring Results
Cumulative
FUKUSHIMA DAIICHI
JAPAN
50 Nautical Miles
25 Nautical Miles
13 Miles
US Facilities
> 12.5 mR/hr
> 2.17 mR/hr
> 1.19 mR/hr
< 1.19 mR/hr
0 25 50 75 100
Miles
Nautical Miles
0 25 50 75 100
All Measurements Below 30 mR/hr
Map created on 03222011 0245 JST
mxd: NIT-D CumuAMS 21Mar2011 v1

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  - Requires readiness – the world is a big place
- Answers must be shared quickly to prevent even worse outcomes but some actors will not wish to reveal what they know

Global information

- What would other countries know? What would they share quickly?
- Need confirmation from other countries because response would be globally destabilizing
- Attribution would probably be slow. Retribution would be…?

- Technology for detailed analyses is known and evolving
  - Requires robust investment in tech and people
- Our report also called for gaming exercises involving as many national agencies and national leaders as possible

Forensics on Explosive Debris

- **Within an hour, event can be identified as a nuclear explosion or otherwise**
- **Within a day or so, nature of fissile materials can be identified**
- **Within 1-3 weeks, probable device design can be inferred**
- **All *IF* the forensics teams have access in the midst of the chaos**

- **Fukushima accident was excellent test of international response to potential international nuclear emergency. Generally failed the test**

Deterrence

- What are the motivations of the various actors in the terrorist chain and what can deter or dissuade them?
- Do these actors believe the US/international attribution capability (including nuclear forensiccs) is enough to lead to retribution/action against them?

The Nuclear Terrorism Chain

- **Four groups would be involved:**
  1. **The terrorist group itself (planning and execution of attack)**
  2. **Specialists who may not be in the terrorist group but who cooperate, wittingly or not**
  3. **A supplier state, to provide the fissile material, wittingly or not**
  4. **Intermediaries for funding, transport, cover, etc.**

Deterring the Terrorist Group

- Perhaps not deterred by threat of discovery
- Most terrorist group leaders are risk-averse – want long-term activity
- Intercepting and tracing nuclear material to its source can jeopardize not only the source but also the terrorist organization itself
- Effective forensics on intercepts may thereby contribute to preventing a later nuclear attack.
  - Need international cooperation and standards

Deterring Specialists

- Specialized skills are needed at many levels: scientists, engineers, machinists
- These specialists form a much smaller group worldwide than specialists needed for other terrorist acts
- The threat of identification may deter them
- Nuclear forensics augments this threat by helping to trace design origin and processing plants

Deterring and Encouraging States

- All nuclear weapon material is owned by states and states are responsible for securing it
- States are subject to incentives of all kinds, positive and negative
- A strong attribution capability (including forensics) increases the risks of cooperation with terrorists and of negligence, and encourages good practices
- It is difficult for another state to determine exactly how effective US/UK/etc nuclear forensics can be, enhancing the deterrent power

Deterring Intermediaries

- Intermediaries are needed to provide money, materials, a safe space to work for weeks or months, basic instrumentation, transport across guarded borders, freight forwarders, people in the target country who speak its language, and other tasks
- Some are in it for the money, some out of conviction
- The main deterrent here is effective law enforcement and intelligence rather than nuclear forensics…

Who Can Be Deterred?

- Attribution can help to deter all links in the chain, to varying degrees
- Nuclear forensics specifically most threatens needed specialists and states
- Effective forensics on intercepts can also help prevent a later nuclear attack

Nuclear Forensics, Post-Detonation

Four urgent tasks, to be executed simultaneously:

- **Prevent additional detonations**
- **Identify the chain of actors responsible**
- **Lead response and recovery if in the US, assisting the affected country if not**
- **Provide leadership to the public and to other countries**

Preventing Additional Detonations

- Forensics information can help assess the likelihood, location and size of a possible additional nuclear device
- However, device signatures are short range so the search will mainly have to be carried out by intelligence and law enforcement personnel
- The time scales for forensics:
  - Nuclear? Visual, seismic, radioactivity measures
  - Fuel type? Lab analysis (mobile labs, probably)
  - Device design? Lab analysis (non-mobile, probably)
  - Provenance? Pace determined by decay rates, isotopic mixes

The Forensics Time Scale

- Access and transport to labs
- Availability of equipment and personnel
- Size and number of samples
- Radioactive decay rates

- Implications: Information will come gradually, will require revision, will be exclusive first. Need to develop "fingerprints" (via international collaboration)

Response and Recovery

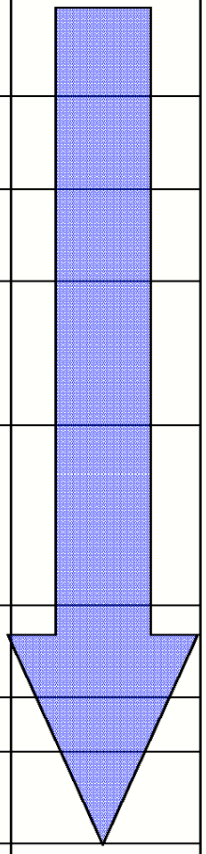
- Extent and nature of the affected area and identify where post-response resources are most needed
- Requires first-responders and nuclear forensics teams to share information – hard!
- Nuclear forensics teams will not be able to move as fast as desired. Will add information over time.

Collection of Information

- Fissile material is turned into a plasma by temperatures as hot as those in a star
- Debris collected is a condensation of this very hot plasma
- Some will be in the crater, some in the air, condensing around dust, some stays in the wind
- At early times, the crater would be too hot to access and collection will be from fallout and from the cloud

- How much is needed? One billionth of the total fission fragments is more than enough
- Samples needed from different times – essential
- Hope exists for trace materials for provenance. Harder.

Activity *(arranged in order of increasing time since an event)*	Information Gained	
"Prompt" analysis by γ-ray spectrometry; tritium detection; satellite and seismic sensing/data	Initial "picture", i.e., snapshot, of the device; yield	
Receipt and chain of custody	Starting point for laboratory analyses	
γ-ray spectrometry of bulk samples	Initial look at fuel type (U or Pu) and device sophistication	
Sample processing (dissolution/ashing/particle and solids separation/isolation of non-nuclear debris)		
Whole solution assays by high resolution γ-ray spectrometry	Improved knowledge of fuel type (U or Pu) and device sophistication	
Chemical separations to isolate individual elements		
Mass spectrometric analysis of U, Pu, other actinides	Fuel characterization; age; device sophistication	
High resolution alpha particle and gamma ray spectrometry of individual isotopes/elements	Device design; fuel materials; original isotopics; fuel mass	
Particle analysis by SEM/electron microprobe/mass spectrometry		
Gas analysis	Burn-up; fuel origin	
Non-nuclear (collateral) forensics	Pathways traveled by materials and individuals	
Interpretation and all-source fusion for attribution assessment	Origin; comparison with known designs	



Much information exists on the web

- If you find this interesting, there are many career options. This is typically “part-time” work
- Very important, even for deterrent value
- Game theory is as important as physics in this arena

Thank you!