Evaluation of Terrorist Improvised Nuclear Device Detonation in U.S. Urban Areas

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The Nuclear Threat
What is an IND?

- **Improvised Nuclear Device (IND)**
  - A crude nuclear device built from the components of a stolen weapon or from scratch using nuclear material (plutonium or highly enriched uranium). – *U.S. Department of Homeland Security*
  - An IND is not a Radiological Dispersion Device (‘dirty bomb’), but rather a device capable of full nuclear explosive detonation.

Slovak police experts hold open one of two shells containing 481.4 grams of enriched uranium powder seized in east Slovakia on Wednesday, Nov. 28, 2007.

*Source: AP/Harvard Kennedy School*
IND vs. State-Sponsored Devices

- **Improvised Nuclear Device (IND)**
  - Crude device (not professionally designed or manufactured)
  - Low-yield device is assumed
  - Likely to be large in physical size (not man-portable)

- **State-Sponsored Device**
  - Military-grade device
  - Broad range of yield (low- to high-yield devices)
  - Broad range of physical sizes ('backpack'-size up to warhead delivered)

The first portable nuclear device, the Special Atomic Demolition Munition. Source: AP/The Moscow Times
IND Delivery Methods and Effects

- **Air Burst (achieves maximum damage)**
  - Aircraft Delivery
    - Can achieve optimum altitude for maximum effect
  - Delivery atop a high-rise structure
    - Unlikely scenario due to size and weight

- **Surface Burst**
  - Auto
    - Truck or SUV needed due to size and weight
  - Watercraft
    - Cargo ships and small vessels
  - Rail
    - Freight and passenger rail lines run through most major cities
IND Delivery Methods and Effects

- **Air Burst** (achieves maximum damage)
  - Each structure is impacted separately (minimum shielding)
  - Ground reflections amplify effects

Source: Harney, 2009

Airburst – Buildings provide little mutual shielding from blast. Surface reflection enhances the overpressure.
IND Delivery Methods and Effects

- **Surface Burst**
  - Structures are impacted sequentially
  - Effects from ground reflections are minimized

Source: Harney, 2009
Nuclear Effects

Nuclear Detonation Environments
Nuclear Detonation Environments

- Prompt Radiation
- Electromagnetic Pulse (EMP)
- Thermal Radiation
- Ground Shock
- Blast
- Fallout
Prompt Radiation

- Intense ionizing radiation released within minutes
  - Primarily composed of gamma, x-rays, and neutrons
- Protection factors for prompt radiation:
  - Distance
  - Shielding: concrete, steel/iron, earth
- Acute Radiation Syndrome (ARS)
  - Illness caused by irradiation of the entire body by a high dose of penetrating radiation in a very short period of time
  - Three stages of ARS symptoms include prodromal, latent, and manifest
Electromagnetic Pulse (EMP)

- **EMP Types:**
  - High-Altitude EMP (HEMP) – upper atmosphere detonation (regional/continental effects)
  - Source-Region EMP (SREMP) - surface/near surface detonations (localized effects)
- Induces damaging high-voltage surge in electronics
- EMP impact typically not considered for surface burst scenarios


Source: Glasstone 1977
Thermal Radiation

- 35-45% of the yield of an IND will be thermal energy
- Direct line-of-sight impact (significant shadowing in urban areas)
- Thermal effects include:
  - Potential for firestorm development (increases with HOB)
  - Incineration at close proximity to detonation
  - Ignition of flammable materials, exterior and interior (via window openings)
  - Direct and indirect burn injuries and eye injuries (permanent and temporary)
- General rules of thumb for thermal radiation:
  - Flammable material ignition \(20 \text{ cal/cm}^2\)
  - Light flammable material ignition and severe burns \(8 \text{ cal/cm}^2\)
  - Light burn injuries \(2 \text{ cal/cm}^2\)
Thermal Effects in Urban Areas
Airblast and Ground Shock

**Airblast**
- The primary damage mechanism for surface detonation scenario
  - Collapsed and damaged structures and infrastructure
  - Non-uniform damage and anomalies in urban areas
  - Primary source of injuries due to collapsing structures, glass fragments, and direct airblast
- Includes two load environments:
  - Overpressure
  - Dynamic pressure (drag)

**Ground Shock**
- May damage specialized structures, infrastructure or sensitive equipment
- Shock propagation varies as it passes through different types of media
- Buried infrastructure such as utilities and tunnels are vulnerable
Radioactive Fallout

- Nuclear Fallout
  - Radioactive by-products (fission products) of a nuclear detonation
  - Fission products mix with dirt, building debris, water, etc.
  - Radioactive particles are transported by winds and fall to the ground

- External Radiation Hazard
  - Hot Zone
  - Dangerous Fallout Zone

- Internal Radiation Hazard
  - Inhalation
  - Ingestion

- Radiation Hazard Timescale
  - Hours to Days
  - Weeks to Years

Grable (Upshot-Knothole), 1953
10kT IND Rules of Thumb

- Severe Damage Zone (~0.5 mile)
  - Cratering
  - Prompt
  - Thermal
  - Blast
- Moderate Damage Zone (~1 mile)
  - Thermal
  - Blast
- Light Damage Zone (~3 mile)
  - Prompt Radiation
  - Thermal Radiation
- Electromagnetic Pulse (~5 miles)
  - SREMP

Source: remm.nlm.gov
Example

- Hiroshima and Nagasaki
  - Prompt
  - Thermal
  - Blast

Source: Independent Online News
Cascading Infrastructure Effects
Cascading Effects

- Population Effects
  - Shelter-in-place
  - Evacuation

- Critical Infrastructure Effects
  - Electrical Power
  - Petroleum
  - Natural Gas
  - Water and Wastewater
  - Communications
  - Emergency Services

Source: LandScan, ORNL
Source: Infragard Los Angeles
Population Effects

- Regional population
  - Fatalities and Injuries
  - Evacuated
  - Relocated
- Short-term considerations
  - Alternate housing
  - Loss of manpower/expertise
- Long-term considerations
  - Reclamation of land and infrastructure
  - Repopulation

Source: Worldnuclear.org
Electrical Power Infrastructure

- Physical Damage
  - Generation Plants
  - Transmission Lines
  - Substations
  - Distribution Networks
  - SCADA
- Radioactive Fallout
  - Shutdown of Power Plants
  - Delayed Repairs or Maintenance
- Cascading Effects
  - Disruption of Potable Water Supply
  - Transportation (e.g., subway, trains, traffic lights)
  - Communications (rely on back-up power generators)
  - Hospitals (rely on back-up power generators)
Petroleum Infrastructure

- Physical Damage
  - Transmission Pipelines
  - Storage/Distribution Facilities
  - Retail Locations
  - SCADA

- Radioactive Fallout
  - Shutdown Storage/Distribution Facilities
  - Shutdown Import/Export Facilities
  - Shutdown Refineries
  - Delay Repairs and Maintenance

- Cascading Effects
  - Disruption of Fuel Supply for Transportation
  - Disruption of Fuel Supply for Electrical Power Plants
  - Disruption of Fuel Supply for Backup Power Generators
Natural Gas Infrastructure

- Physical Damage
  - Transmission Pipelines
  - Storage
  - Distribution Systems
  - SCADA

- Radioactive Fallout
  - Shutdown Storage/Distribution Facilities
  - Shutdown Import/Export Facilities
  - Delay Repairs and Maintenance

- Cascading Effects
  - Disruption of Fuel Supply for Electrical Power Plants
  - Disruption of Fuel Supply for Backup Power Generators
  - Increased Risk of Natural Gas Fires or Explosions
  - Disruption of Residential Gas Supply
Communications Infrastructure

- **Physical Damage**
  - Wireless Transmitters and Receivers
  - Radio and TV Broadcast Transmitters
  - Colocation Communications Facilities
  - Wire and Fiber Optic Lines
  - Damaged or Upset Electronics

- **Radioactive Fallout**
  - Delay Repairs and Maintenance
  - Delay Refueling of Backup Generators

- **Cascading Effects**
  - Disruption of Emergency Communications
  - Disruption of Broadcast Communications
  - Disruption of SCADA
Transportation Infrastructure

- Physical Damage
  - Tunnels and Bridges
  - Ports and Ferries
  - Airports
  - Rubble Obstructing Roadways
- Radioactive Fallout
  - Health Hazards in High Radiation Areas
  - Aircraft Avoidance of Airborne Fallout
- Cascading Effects
  - Disruption of Emergency Responders
  - Disruption of Evacuation Efforts
  - Disruption of Fuel Resupply
  - Disruption of Supply Chains
Water and Wastewater Infrastructure

- Physical Damage
  - Transmission and Distribution Pipelines
  - Pumping Stations
  - Treatment Plants
  - SCADA Systems
- Radioactive Fallout
  - Delay Resupply, Repairs, and Maintenance
  - Evacuate Facilities
  - Contaminate Reservoirs and Watersheds
- Cascading Effects
  - Disruption of Firefighting
  - Disruption of Healthcare
  - Disruption of Communications (e.g., HVAC Systems)
  - Disruption of Drinking Water
Interdependencies

- Interdependent Infrastructure
- Interdependent World (PMESII)
  - Political – diplomatic
  - Military – security
  - Economic – trade of goods and services
  - Social – family and friends
  - Information – news, data, and business
  - Infrastructure – physical world
- How far and fast can the effects of an IND cascade?
- How quickly can recovery occur?
Community Resilience and Recovery

Components of Resilience and Recovery

Source: Architectural Graphic Standards (AGS), Chapter 3: Building Resilience (DRAFT)
Potential Implications

Cost estimates of large-scale natural disasters compared with IND attack on a major U.S. city (DHS National Response Scenario Number One)


Economic impact from an IND Attack has been estimated to be in the Hundreds of Billions of Dollars
Questions?

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A Senior Engineer and U.S. Air Force Gulf War Veteran, Mr. Herrle has held key roles in numerous blast and security vulnerability assessments and designs supporting nearly 20 different U.S. Government Departments and Agencies, and has directly supported the U.S. Government in analyzing improvised nuclear device (IND) detonation in urban areas and corresponding damage to facilities and infrastructure throughout the impacted zones. He has conducted over 70 large-scale explosive tests with devices ranging up to thousands of pounds TNT equivalent, and has served as national Vice-Chair of a DHS working group for explosive modeling, simulation and testing. A licensed Professional Engineer in nine states, Mr. Herrle holds an M.S. in Civil Engineering from Auburn University, and a B.S. in Civil Engineering from the University of New Orleans.

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Joseph Smith, PSP is a security and blast protection consultant with over 30 years of experience in security engineering and explosion effects from conventional, nuclear and improvised (terrorist) explosions. He holds Civil Engineering degrees from the U.S. Air Force Academy and Columbia University. Mr. Smith serves as a Director and Senior V.P. of Applied Research Associates, a 1,000 person engineering & sciences consulting firm where he leads the company’s Security Engineering & Applied Sciences business. He has developed and tested hardening technologies to protect against nuclear weapons while serving at the Air Force Weapons Laboratory. He has led teams for security assessments of many national monuments, icons and critical infrastructure. Mr. Smith is a frequent speaker and has spoken at numerous national conferences and seminars.

Alec Thurman
Mr. Thurman has worked within the defense and homeland security communities for the last decade, focused on the development and application of CBRNE consequence assessment models and the use of geospatial data to enhance their operational value. Prior to joining ARA he worked at the Defense Threat Reduction Agency (DTRA) within their Reachback WMD Analysis Group and later as a technical manager of several DoD nuclear weapon effects codes. Since joining ARA, he has divided his time between chem/bio and nuclear weapon effects projects. On the nuclear side, he has focused on supporting FEMA emergency response planning efforts with urban critical infrastructure and cascading effects analyses incorporating high-fidelity geospatial data. Mr. Thurman holds a B.S. in Chemistry from Emory University.