

for Detecting HEU in Seaborne Containers

DNDO Grant Project

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TAMU DNDO Research

- Effort combines
 - Nuclear detector research
 - Inverse and forward transportation calculation
 - Public Policy
 - Systems Engineering
- Systems Engineering Team
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Research Focus



- Establish a system to prevent terrorists f rom smuggling HEU into the United States
- Strategic level:
 - International transportation network
 - Nodes: e.g., foreign and domestic ports
- Tactical level:
 - Analyze specific node in the international network
 - Determine appropriate inspection policies to decide the level of scrutiny to use for any given shipment
- Initially, scope limited to commercial seaborne container shipping



Strategic Level



- Given a limited budget, at which domestic and foreign ports should detectors be deployed? Which types of detection should be deployed?
- Threat origination:
 - Nuclear rogue state
 - Known HEU deposit sites
 - Unknown origination
- Target:
 - Probabilistically known





Detection Network





- Each of these nodes requires a solution to the tactical problem
- We focus on the tactical problem first



d Targeting System



Identify ±high-riskqcontainers

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(ATS)

- Customs established criteria and automated targeting tools for identifying ±high-riskqshipments
- Ships are assessed for risk using general intelli gence information and advance mani fest data
- Treat ±high-riskqcontainers different from ±owriskqcontainers
 - e.g. different detection technology, requirement to passively scan at foreign port, etc.



General Nuclear Detection

- Passive interrogation
 - Passively detect level of neutrons and gamma rays
- Active interrogation
 - X-ray: image cargo; detect shielding
 - Neutron/Photon: cause SNM to react and emit more neutrons/gamma rays
 - Drawback: time consuming, high level of false positive, possible activation to the material and exposure to persons in the container.
- Manual inspection
 - Multi-person team open a container and inspect manually
 - High cost of manual labor, time consuming
 - Residual risk







- Model current practice:
 - High-risk / low-risk containers in ATS
 - Escalation system of passive / active / manual
- Explore changes to the system:
 - Containers classified based on contents
 - Arbitrary detection technologies
 - Using BOL or imaging information
- Develop useful inspection policies:
 - Based on available detection technology, decide:
 - Which technology to use for which container
 - Sequence of detector use
 - Detector operational thresholds





Model Input & Output

- Input:
 - Scenario parameter sets
 - Containers are classified based on the contents, denoted by scenario q_s
 - Threshold t_{H} , t_{p} , t_{A}
- Output:
 - Detection probability for each scenario
 - Overall detection probability
 - Sojourn time for each path
 - Queue length at each node

Different Scenarios







MCNP Code

- General-purpose Monte Carlo N-Particle code
- Used for neutron, photon, electron, or coupled neutron/photon/electron transport
- Treats an arbitrary three-dimensional configuration of materials in geometric cells
- Suited to the needs performing radiation shielding, detector simulation studies, and etc.
- Input: Z value matrix
- Output: distribution of the amount of photons we expect to detect at given scenario q_s with HEU and without HEU







Thank you for using PDF Complete. By Shielded HEU: Hardness Measure

- A scenario can be defined based on the X-ray image or BOL of a cargo container
- The hardness of detection is the probability of not being able to detect a certain amount of shielded HEU for a given scenario. The probability is calculated as in the following







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- Define a hardness measurement for each of the container scenario q_s , based on MCNP code
- Choose the threshold for hardness, t_H
 - $h_s > t_{H'}$, sent to A-node
 - $h_s < t_{H}$, sent to P-node
- HC-node queue: M/M/C
 - Arrival rate λ : the arrival rate of the incoming containers
 - Service rate: μ_x
 - Number of servers: m_x







- Set up threshold value (t_P) to split the stream to A -node or L-node:
 - $X_i > t_{P'}$ -> sent to active node
 - $X_i < t_{P}$, -> sent to loading node
- P-node queue: *M/M/C*
 - Arrival rate $\lambda_P = \lambda * (1 f_H)$
 - Service rate: μ_P
 - Number of passive servers: *m_P*



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- A-node receives two streams:
 - One directly from HC-node; the other from P-node
- Set up a threshold t_A , to split the stream:
 - $X_i > t_A$, -> sent to M-node
 - $X_i < t_A$, -> sent to L-node
- A-node queue: M/G/C
 - Arrival rate $\lambda_A = \lambda * f_H + \lambda * (1 f_H) * f_P$
 - Service rate: μ_A
 - Number of active servers: m_A









- Assumption: If HEU is present, it is detected at M -Node with probability 1.
 - For simplicity only; can incorporate any choice of residual risk
- M-node queue: G/G/C
 - Arrival rate $\lambda_M = (\lambda * f_H + \lambda * (1 f_H) * f_P) * f_A$
 - Service rate: μ_M
 - Number of manual servers: m_M
- Define q_s^{HEU} to be a container scenario with a known quantity of HEU:

Scenario q_S^{HEU}



• Detection probability = $Pr\{q_s^{HEU} \text{ arrives at } M\}$



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Time in System



- Path: e.g. P-node \rightarrow A-node \rightarrow L-node
- For each path, calculate the expected time in system: T_w
- For each container scenario q_s , calculate the probability that the container follows any given path
- \rightarrow Calculate expected time for a given scenario q_s
- Model yields:
 - Expected time in system for a given container
 - Expected time in system for a %andom+container



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Current Model Capabilities

Can calculate:

- Expected queue lengths at nodes
- Detection probability

 - For each container type (scenario)
- Expected time in system
 - For ‰verage+containers
 - For each container type (scenario)





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Optimizing the System



For a given technology set:

- Choose operational thresholds t_{H} , t_{P} , t_{A}
- Tradeoff between detection probability and time in system for containers
- Constrained optimization, or efficient frontier generation





Sojourn Time



Current and Future Research

- Sensitivity Analysis
 - Impact of different detector technologies
 - Which technologies should we develop further?
 - Minimum set of detector technologies to reach a certain detection probability
 - Value of x-ray imaging vs. using BOL for scenario generation





Current and Future Research

- Terrorist Decision
 - If the terrorist knows how our system is structured, what is his optimal response?
 - E.g. prefer high or low hardness containers to infiltrate?
 - Better chance for terrorist with containers that offer natural shielding, or those without?
 - Based on optimal terrorist behavior, can anticipate and strengthen our system





Current and Future Research

- Strategic level
 - Once we deal with multiple nodes, what changes?
 - Detector type deployment: where to deploy what type of detectors
 - Passive at foreign ports, active at domestic ports?
 - Detector operational parameters
 - Thresholds, sensitivity
 - Potential to use container history
 - Prior measurements, detection results
 - Breach of containers





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Questions?