A Systems Framework for Modeling the Detection of Smuggled Nuclear Materials

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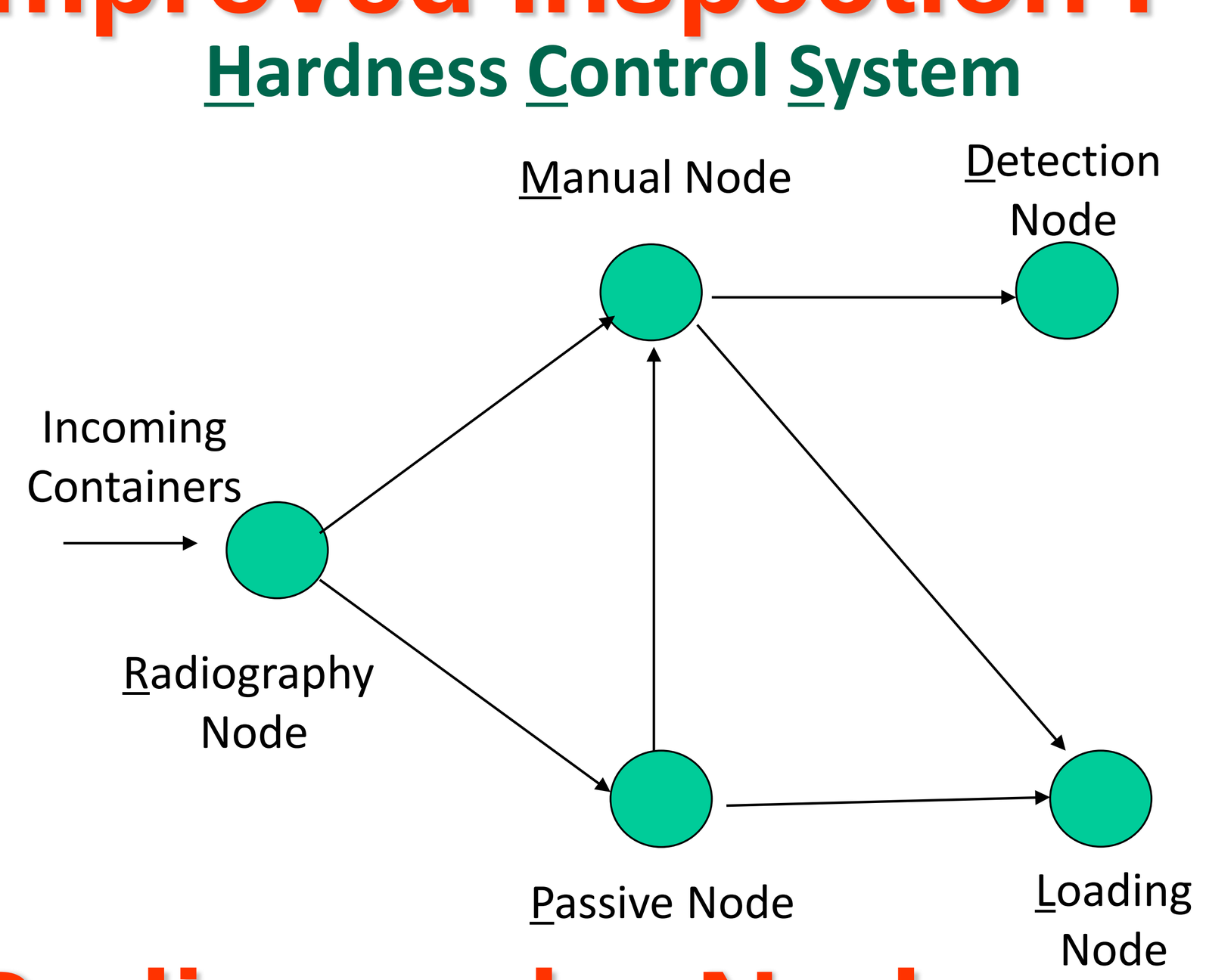
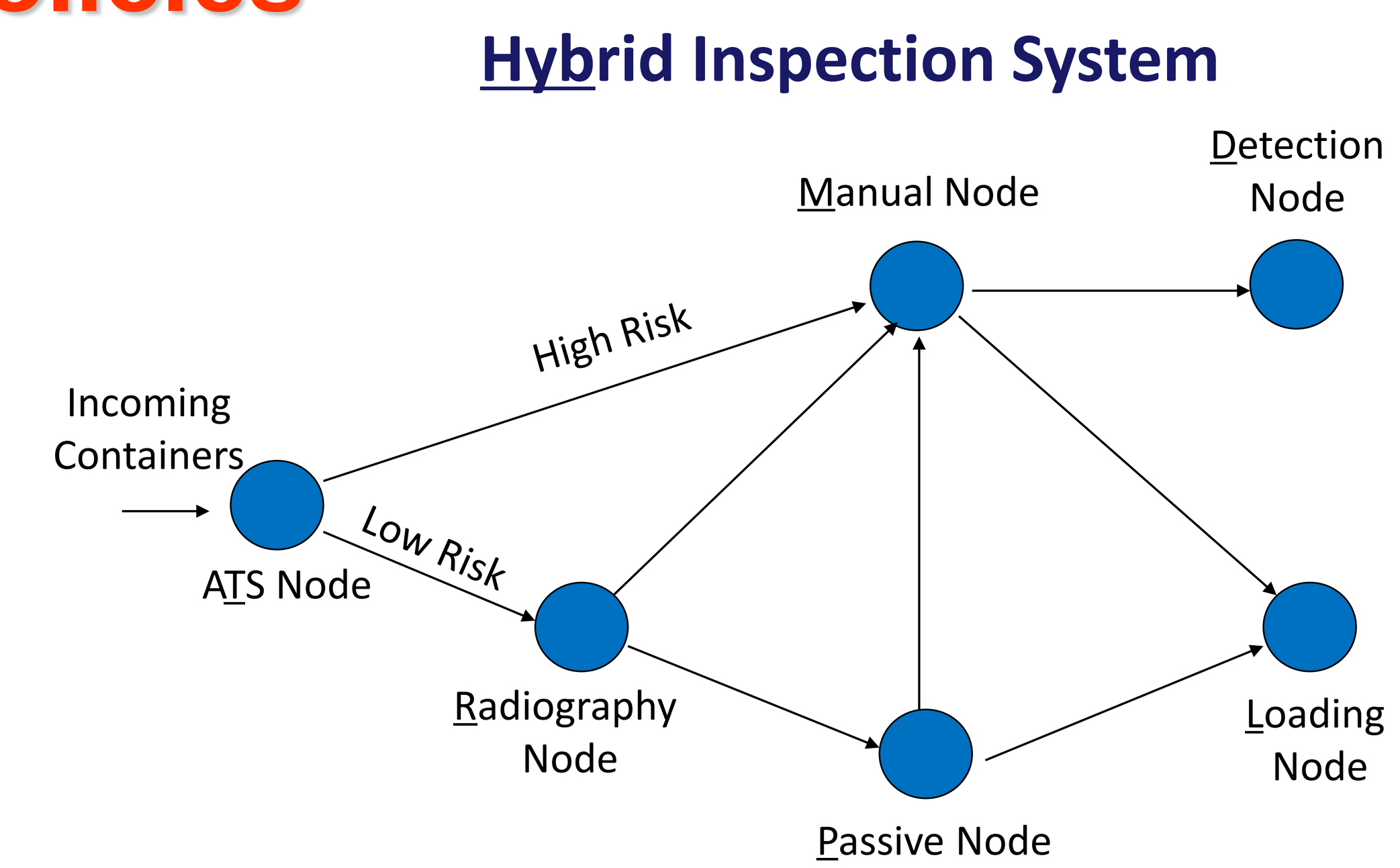
Objectives

- Model a set of layered container inspection policies
- Investigate the benefits of having a radiography node
- Provide a general framework for nuclear materials
- Discuss how information from upstream inspection sites can be used to improve detection at downstream sites

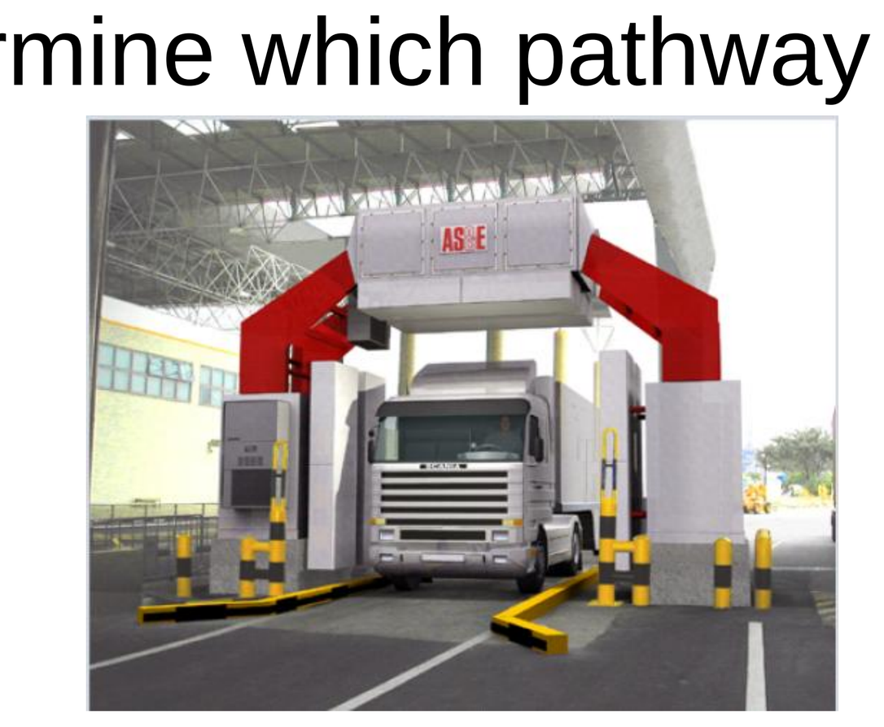
Improved Inspection Policies





Radiography Node

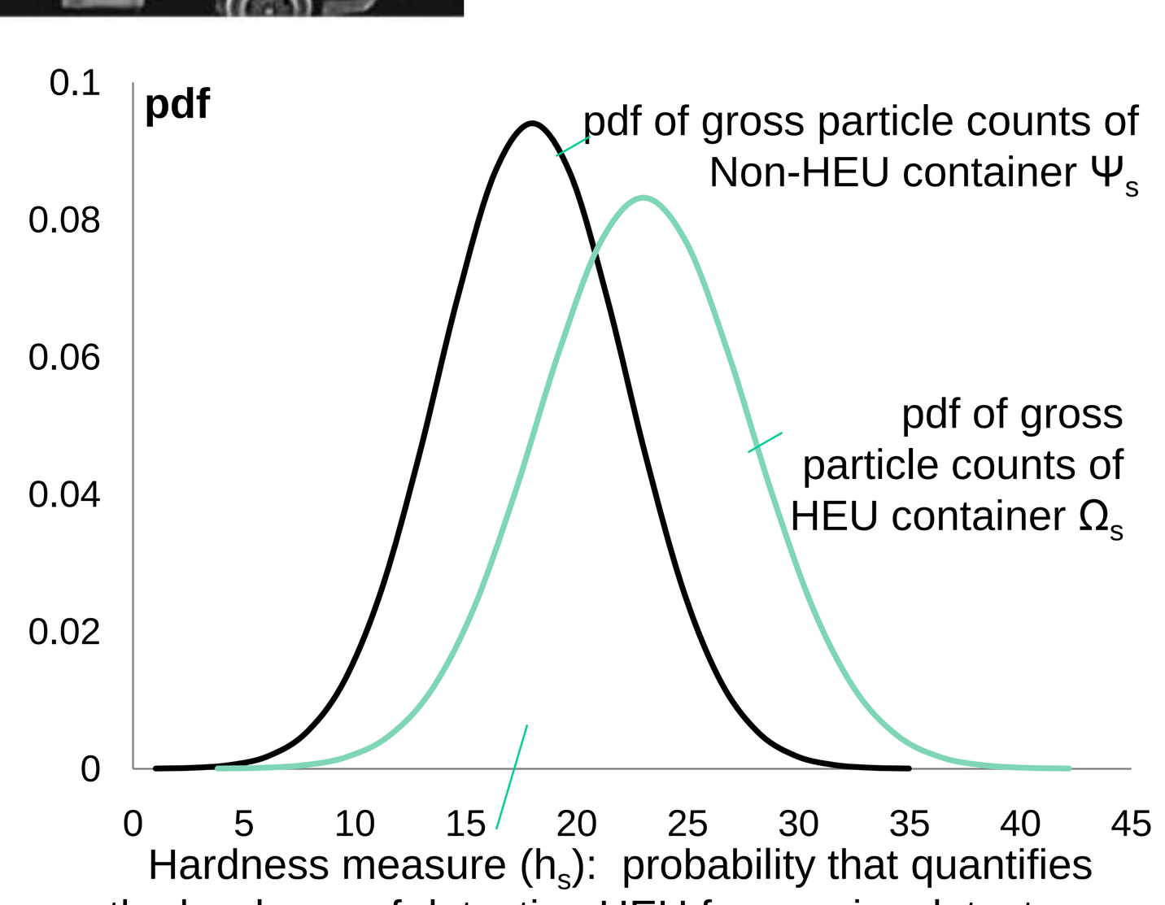
- Introduce a radiography node, which provides an X-ray imaging of what is inside the container, called a container type.
- Based on a given container type, calculate a hardness measure and determine which pathway the scenario will go through.

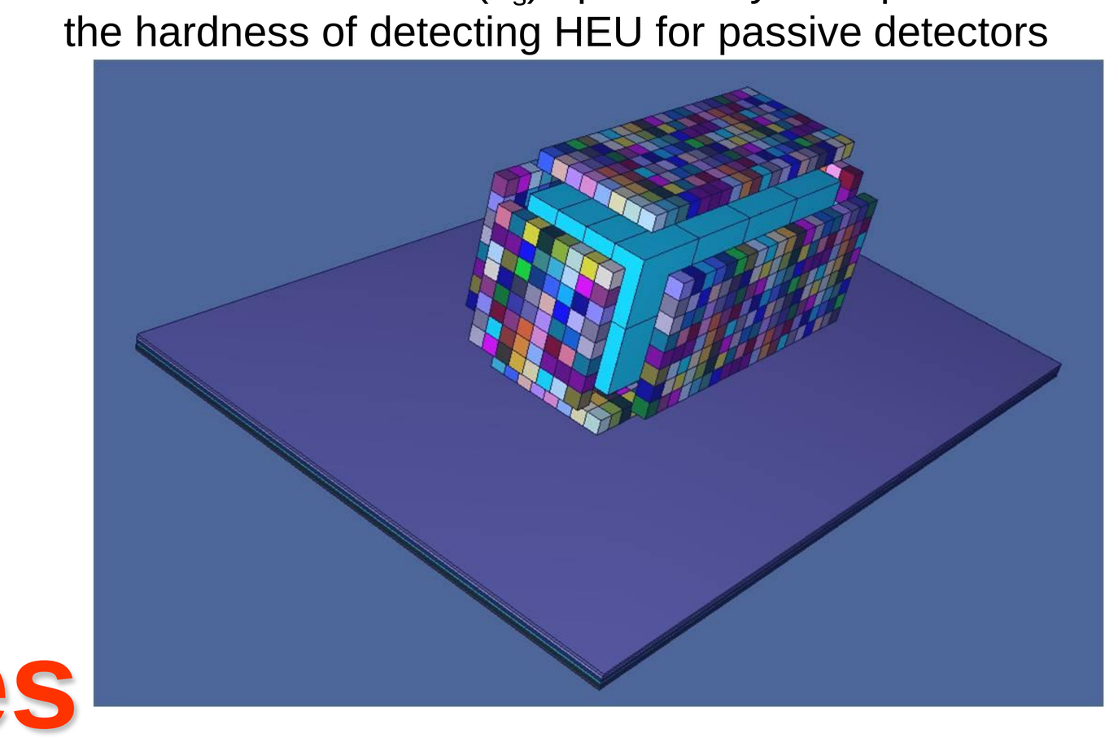


Medium energy X-ray machine: Z Portal

Hardness Measure

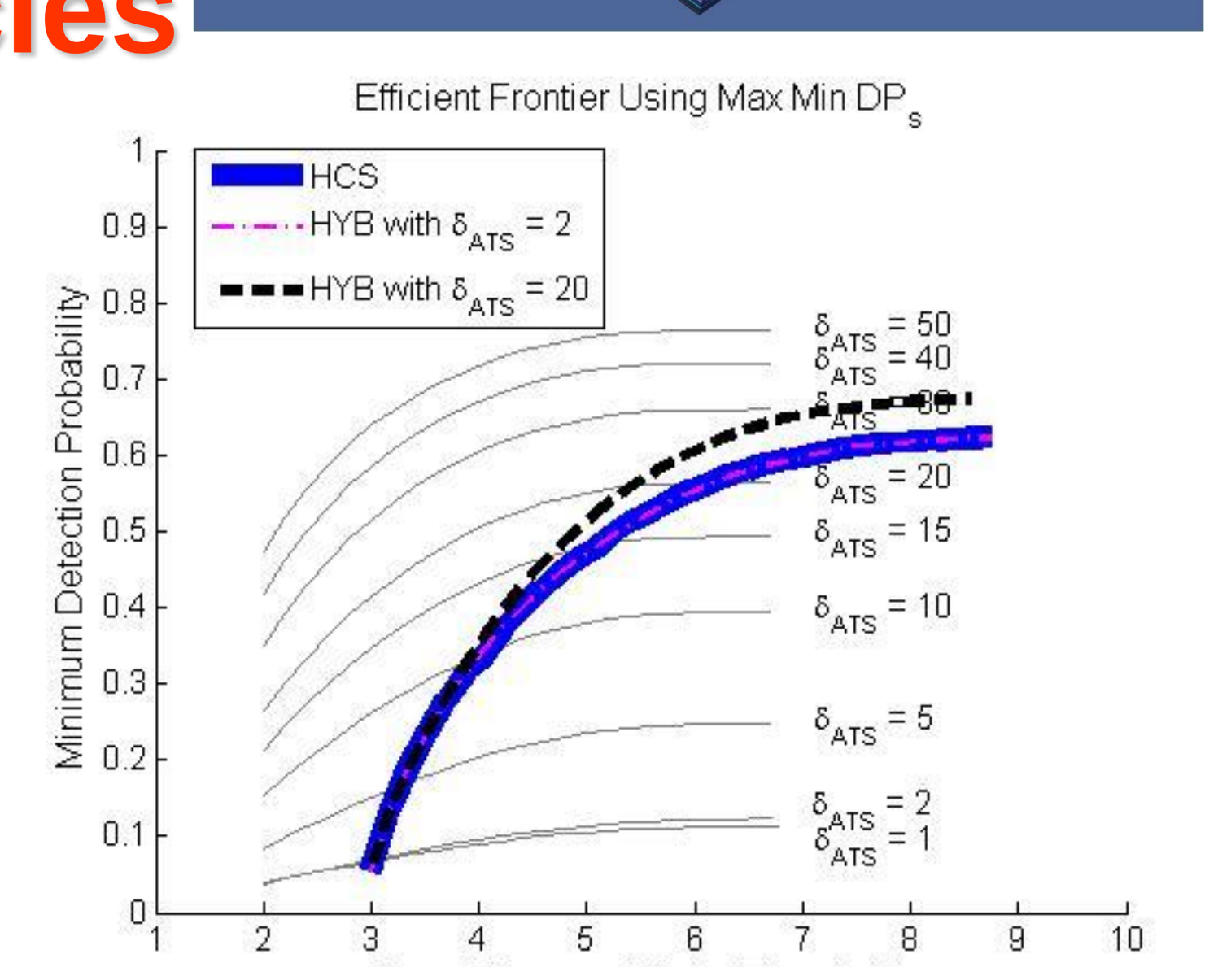
- Hardness: a measure of how hard it is for a given passive detector to detect HEU inside that particular container; the area of overlap between the two pdfs
- MCNP code mimics the working of a given type of passive detector
  - takes the z-value matrix associated with a given container type as its input
  - outputs the average photon counts per unit time for a given container type.



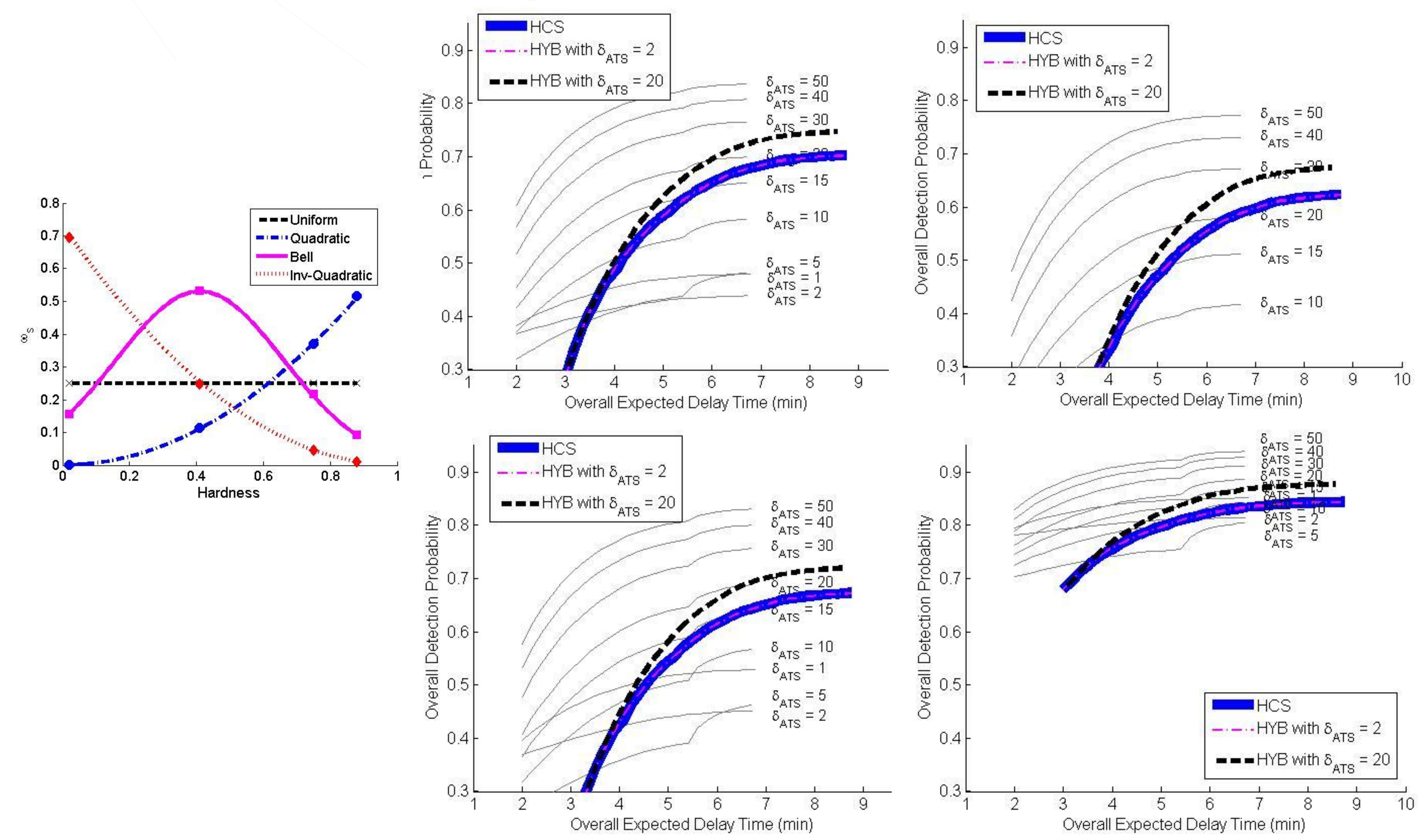


Analysis of the Inspection Policies

- In an HEU container, one kg HEU (30% of U-238 and 70% of U-235) with one cm lead shielding is placed in the center of highest z-value area of the container.
- Efficient frontiers: the trade-off between detection probability (DP) and expected delay time (DT).

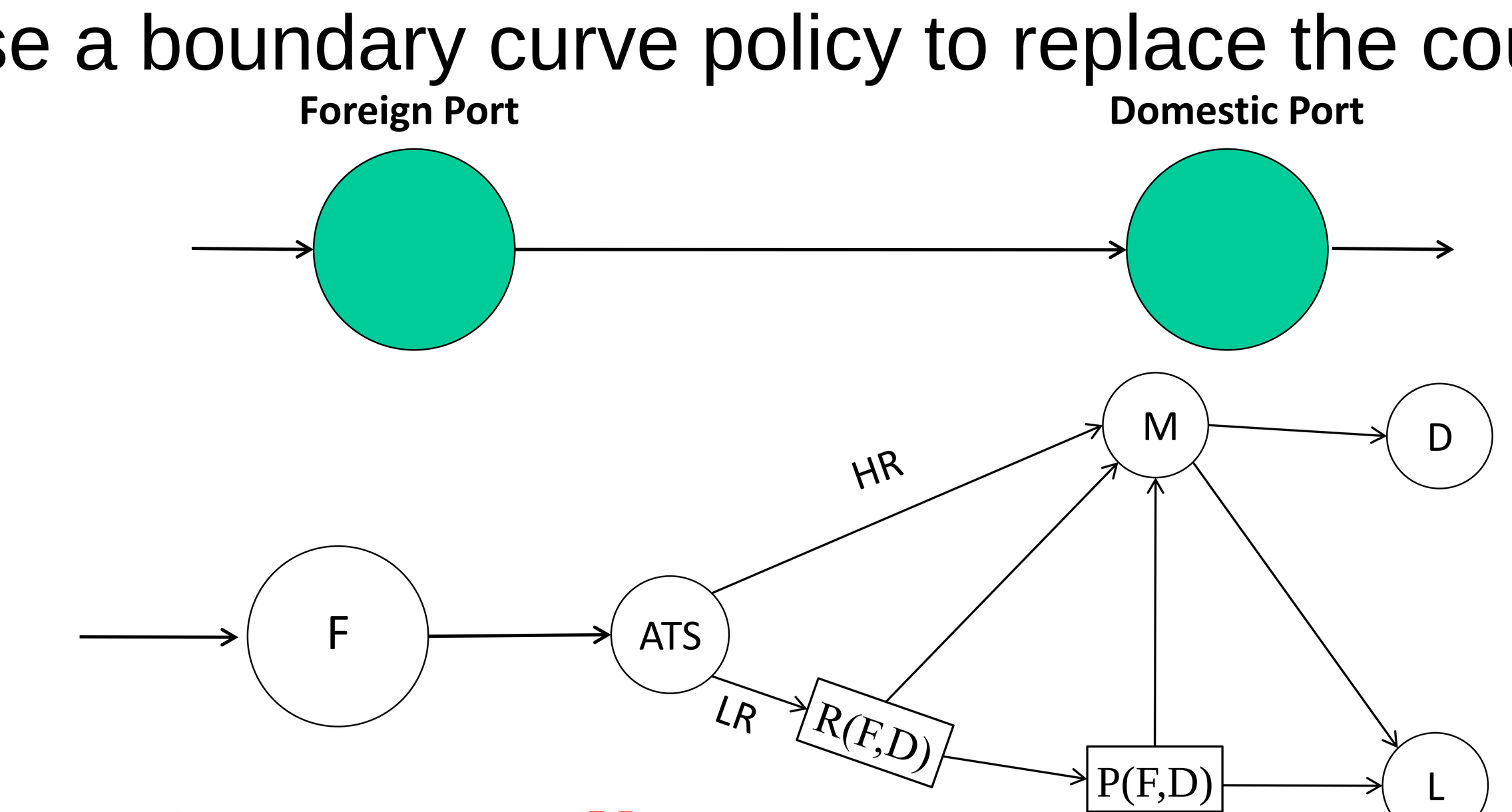


Impact of Adversary Behavior



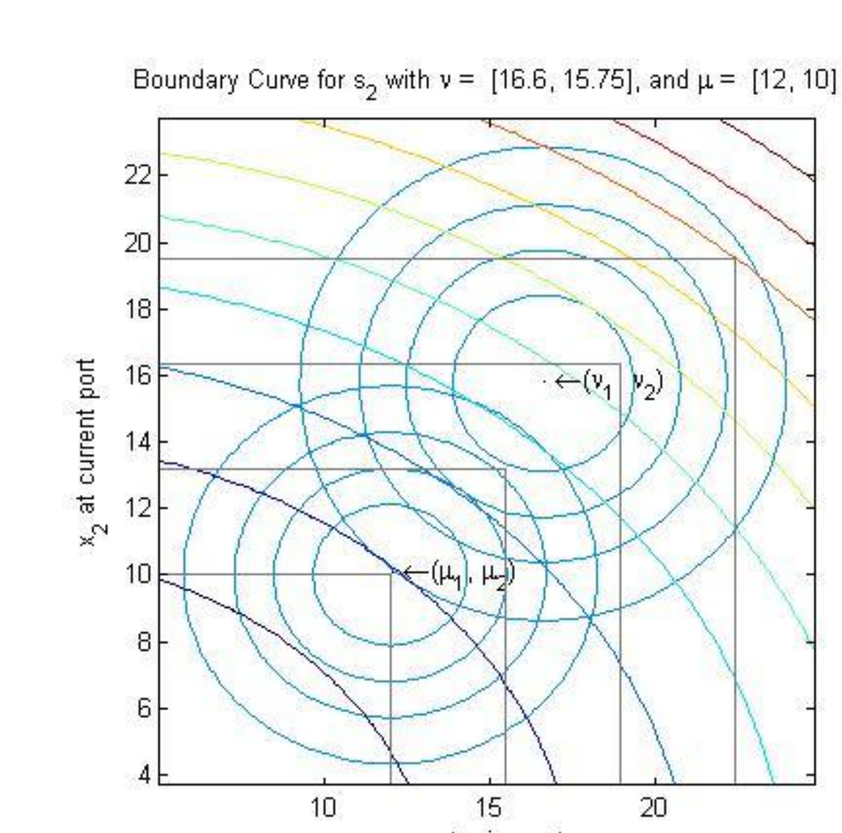
Novel Inspection System Using Prior Information

- Incorporate prior information into the current inspection system
- Propose a boundary curve policy to replace the count threshold policy



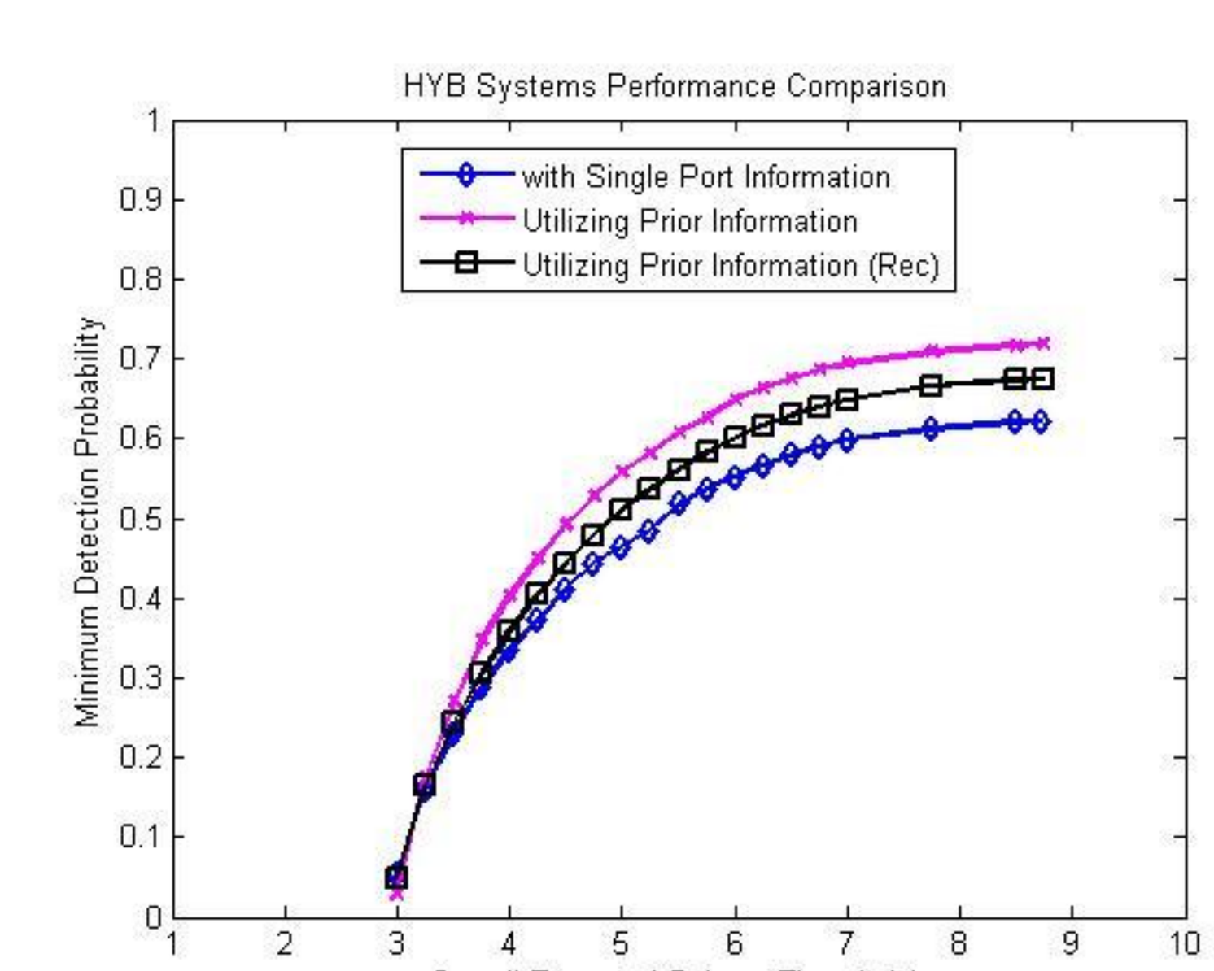
Boundary Curve Policy

- Let r be the natural logarithm of the density ratio of HEU containers and non-HEU containers
- Boundary curve = {all (x1, x2) such that the ratio *r* is a constant, $r = t_r$}
  - If above the boundary curve, $r >= t_r$, classified as suspicious container, and sent for further investigation
  - If below the boundary curve, $r < t_r$, labeled as safe container.



System Comparison

- Compare three inspection system:
  - The hybrid system using the current information only;
  - The hybrid system incorporating the prior information and the proposed boundary curve;
  - The hybrid system incorporating the prior information and the rectangle boundary curve.



Conclusion & Discussion

- The HCS and HYB significantly outperform the ATS-based policy.
- Using prior information can significantly increases the detection probability for a given system.
- Problem of infiltration along the route needs to be addressed.

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