No Access, No Data, No Problem: Toward Autonomous Robotic Inspections of Nuclear Facilities

Eric Lepowsky[1], Robert J. Goldston[1,2], Alexander Glaser[1]
1. Princeton University, 2. Princeton Plasma Physics Laboratory
PI: Alexander Glaser, Contact: {lepowsky, rjg, alx}@princeton.edu
Consortium for Monitoring, Technology, and Verification (MTV)

Introduction and Motivation

Nuclear safeguards and arms control traditionally require intrusive on-site inspections to perform verification tasks

Localizing a radioactive source is imperative for identifying anomalies when no significant neutron emitters are expected or declared to be present:
- Searching for withdrawal stations in the cascade hall of a gas-centrifuge enrichment plant
- Confirming the absence of undeclared warheads in a storage facility

Autonomous mobile robots, if designed properly, may be **more effective and efficient** and **less intrusive** than their human counterparts

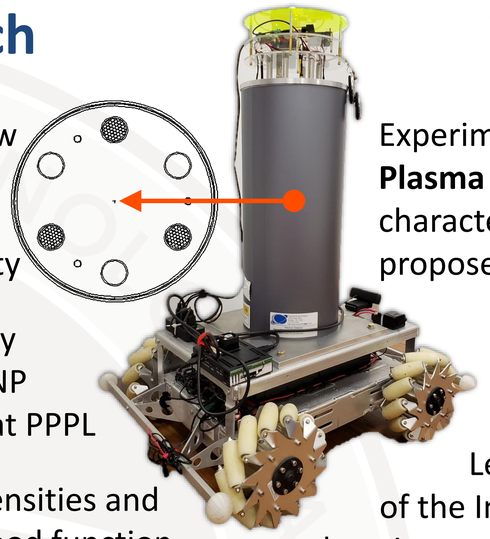
Mission Relevance

Safeguards | Developing and implementing new safeguards concepts, approaches, and technologies; ways to detect and monitor the nuclear fuel cycle

Arms Control | Developing and maintaining the technical means to monitor whether the terms of a nuclear arms control treaty or other international agreement are fulfilled

Technical Approach

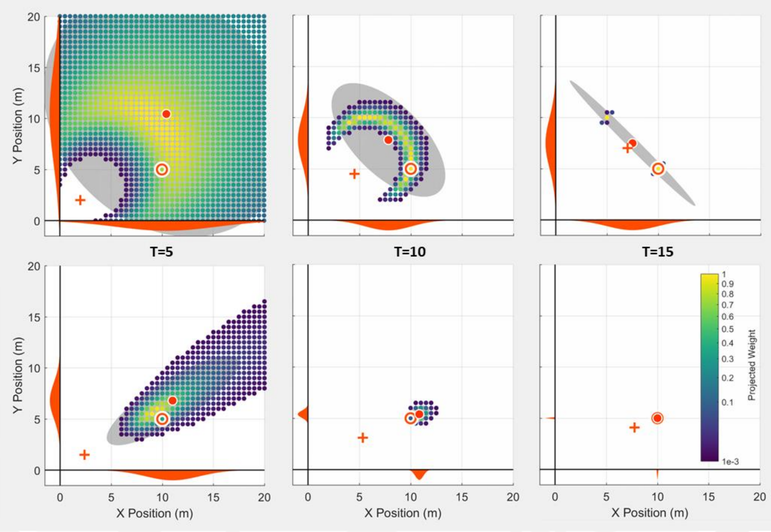
Inspector Bot | Three boron-coated straw detectors azimuthally distributed within a cylinder of high-density polyethylene provides directional and energy sensitivity



Calibration| Detection system extensively characterized with Cf-252 source by MCNP modeling benchmarked to experiments at PPPL

Particle Filter | Hypothesized source intensities and locations weighted by cumulative likelihood function

Results



Snapshots of the particle filter for localizing an unknown source in a 400 m² search area with negligible background. Hypotheses (5e5+) uniformly distributed in space and intensity. At each iteration, the robot (orange crosshair) takes a new set of measurements and moves one meter toward the estimated source (orange solid dot), compared to the true source (orange ring). 95% confidence ellipse of the particle filter estimate (gray ellipse). **Directional information improves convergence (below) compared to gross counts alone (above).**

MTV Impact

Experimental campaign(s) at **Princeton Plasma Physics Laboratory** (PPPL) to characterize and eventually test the proposed Inspector Bot design

Conclusion

Leveraging the directional sensitivity of the Inspector Bot correctly estimates the location and intensity of a source with fewer measurements, as compared to particle filtering based only on gross counts

Development and characterization of a detection system for autonomously performing verification inspections in support of NNSA mission-relevant safeguards and arms control

Next Steps

- Effect of **background noise** and **walls/obstacles** on the source localization capabilities
- Uncertainty-informed **motion planning**
- Investigate employing the **spectral sensitivity** of the detection system

This work was funded in-part by the Consortium for Monitoring, Technology, and Verification under Department of Energy National Nuclear Security Administration award number DE-NA0003920

National Nuclear Security Administration