

AUTONOMOUS MOBILE ROBOTS FOR MANAGED-ACCESS INSPECTIONS

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THE MTV TEAM @ PRINCETON







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THE NEED FOR IMPROVED MONITORING TECHNIQUES AND APPROACHES

The main objective of this project is to identify new technologies and approaches to monitor ongoing fuel-cycle activities (in particular, at gas centrifuge enrichment plants) and to develop a framework for reconstructing the history of fissile-material production programs (including a tool to evaluate the completeness of baseline declarations and to understand inherent uncertainties)



<u>NNSA/DNN & MTV</u>

Preventing nuclear weapons proliferation and reducing the threat of nuclear and radiological terrorism around the world are key U.S national security strategic objectives. The goal for this consortium is to support R&D that improves the "ability to effectively monitor (detect and verify) global fuel cycle activity in any type of environment"

Source: W. Keith Luse, CISAC (top) and IAEA (bottom)





MISSION RELEVANCE





TECHNICAL APPROACH



1. REAL-TIME MONITORING

Our research will support the development a non-invasive UF₆ thermal mass flow monitor, which could play an important role for advanced safeguards in centrifuge enrichment plants; builds on active collaboration with LANL



2. AUTONOMOUS INSPECTION SYSTEMS

collaboration with PPPL

Source: Urenco

Source: Peter Landgren (Princeton)





We will examine the potential role of mobile, directionally and spectrally sensitive neutron detectors ("inspector bots") for safeguards and other monitoring applications; builds on active



3. RECONSTRUCTING THE PAST

We will develop a framework for reconstructing fissile-material production histories that complements nuclear archaeology techniques by examining the role of operating records and simulation tools (including Cyclus)

Source: Rio Tinto



Autonomous Mobile Inspection Systems

"ROBOT INSPECTORS" FOR NUCLEAR SAFEGUARDS AND MONITORING APPLICATIONS

ROBIN: A Way to Collect In-Plant Safeguards Data with Minimal Inspector Access

> Frank F. Dean Sandia National Laboratories Albuguerque, New Mexico 87185

The ROBIN is particularly useful in facilities where security [and] national sovereignty ... require access restrictions.

The ROBIN provides a potential tool that ... allows the inspector to collect data inside a facility without actually entering that facility ... [and] limits the potential disclosure of sensitive technology.

Frank F. Dean, *ROBIN: A Way to Collect In-plant Safeguards Data With Minimal Inspector Access* Sandia National Laboratories, Albuquerque, NM, November 1982





IAEA ROBOTICS CHALLENGE



www.iaea.org/newscenter/news/robotics-challenge-winning-design-helps-speed-up-spent-fuel-verification www.iaea.org/topics/safeguards-in-practice/robotics-challenge-2017



Some of the most common tasks undertaken by IAEA nuclear safeguards inspectors involve making repetitive measurements in locations that can be difficult to access and/ or have elevated radiation levels. This is an area where robotics has the potential to play a useful role.









BORON-COATED STRAW (BCS) DETECTORS

BCS detectors contain 37 star-shaped copper straws coated with a one micrometer thick ¹⁰B enriched boron carbide layer

Thermal neutrons captured in ¹⁰B are converted into secondary particles through the ¹⁰B(n,a) reaction

Source: proportionaltech.myshopify.com









INSPECTOR BOT DETECTOR GEOMETRY (MCNP MODEL)







Results from a First Measurement Campaign (Princeton Plasma Physics Laboratory, September 2019)



INSPECTOR BOT COUNT RATES BARE CALIFORNIUM-252 SOURCE, PPPL, SEPTEMBER 2019







INSPECTOR BOT COUNT RATES MODERATED CALIFORNIUM-252 SOURCE, PPPL, SEPTEMBER 2019







ESTIMATING AVERAGE NEUTRON ENERGY FROM THE FRONT-TO-BACK DETECTOR COUNT RATIOS









ESTIMATING AVERAGE NEUTRON ENERGY FROM THE FRONT-TO-BACK DETECTOR COUNT RATIOS



Front-to-back detector count ratio







INSPECTOR BOT COUNT RATES IN A COMPLEX, CLUTTERED ENVIRONMENT



Detector count rate [cps]



EXPECTED IMPACT



SUPPORTING NEXT-GENERATION SAFEGUARDS

Directionally sensitive neutron (mobile) detectors can provide optimized detection and accounting of undeclared and declared masses of UF_6 through (a,n) reactions

Possible use in cascade areas and in feed and withdrawal areas of gas centrifuge enrichment plants

Source: IAEA







SUPPORTING NON-INTRUSIVE VERIFICATION APPROACHES

Confirming the absence of undeclared treaty accountable items (neutron sources) in sensitive military facilities

Confirming that the neutron field in a storage facility has not changed since the last inspection

Collaborations with research groups at Princeton working on robotics and algorithm development

Source: Peter Landgren



Source: Elle Starkman/PPPL

2º miles



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