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A New Look at Transportation Security: A Complex Risk Mitigation Framework for the Security of International Spent Nuclear Fuel Transportation

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Outline

- Introduction
- Case Study
- Complex Risk Approaches
- Analysis & Discussion
- Conclusions

Introduction

- Motivation
  - Expected significant increase in spent nuclear fuel (SNF) to be transported globally
    - Growing international interest in nuclear energy programs
    - Growing popularity of 'fuel take back' agreements
    - SNF reclamation projects

- New sources of complexity into traditional nuclear materials transportation operations (including, but not limited to):
  - an increasing number of SNF cask transfers between transportation modes (e.g., road to rail to water);
  - an increasing number of geopolitical or maritime borders crossed by SNF casks
  - the higher potential for interactions with safeguards and safety
  - the higher potential for inconsistent security along approved SNF transit routes
  - the increased salience of geopolitical issues on potential threats to SNF in transit

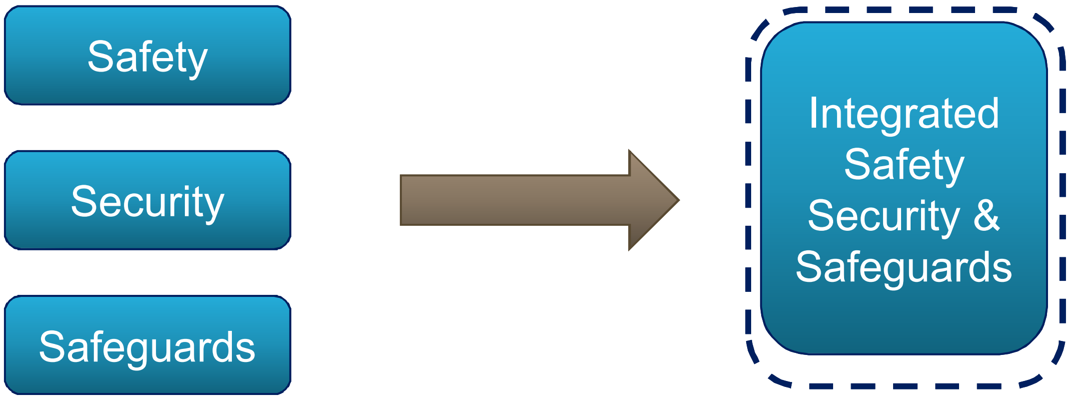
Introduction

- Individually, these complexities challenge traditional approaches to SNF transportation security approaches, which emphasize
  - Technical cask design
  - Acceptable dose rates
  - Defense-in-depth
  - Probabilistic hazard estimates

- Together, they represent a significant increase in risk complexity that suggests the need for new security analysis approaches

Introduction

- In response, evaluate a **complex risk** management framework built on the interdependence of **security**, **safety** & **safeguards**, which



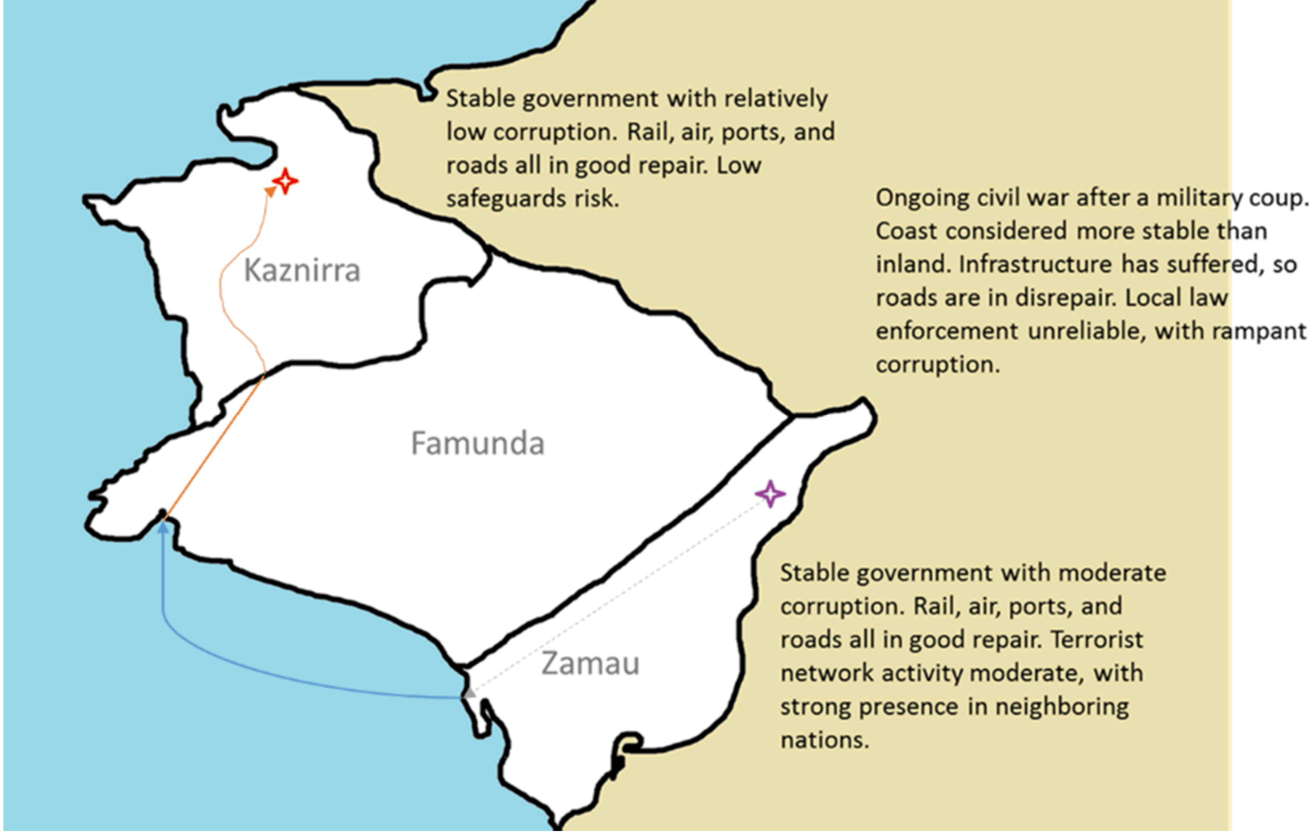
  - Considers security as a key characteristic of complex risk to SNF transportation
  - Provides higher fidelity analysis of real-world hazards
  - Identifies solutions more aligned with complex realities

Introduction

- This framework is demonstrated on a **hypothetical case study** (see next slides) & 2 novel analytical approaches:
  - Dynamic probabilistic risk assessment (DPRA)
    - Uses dynamic event trees to provide systematic & automated assessment of possible scenarios arising from both aleatory & epistemic uncertainties in complex systems
    - DPRA evaluates security as an individual characteristic of complex risk influenced by (and influencing) safety & safeguards of SNF during international transportation
  - System theoretic process analysis (STPA)
    - Uses socio-technical system models to provide a rigorous, structured mechanism for linking specific design details to supporting overall system objectives
    - STPA evaluates security as the ability to control technical & social component interactions to mitigate migration of the system to a state of higher risk

Case Study

- The SNF generated in Zamau
  - 50 GWd/tU fuel rods
  - removed from a pressurized water reactor
  - in wet storage for up to 50 years
- SNF will be transported in an IAEA-compliant, type B cask



- SNF to travel from a storage site in Zamau (Site A) to the disposal site in Kazmirra (Site B), according to:
  - SNF cask loaded from the storage site in Zamau onto a rail car for transporation to the Port of Zamau where it is loaded onto a barge;
  - SNF cask travels via international waters to the Port of Famunda in the southwest corner of the country and loaded onto a truck; and,
  - SNF cask travels by road through western Famunda, across the border and across interior Kaznirra to Site B
- Hypothetical route selected amidst a set of security-related factors, including
  - the desire to avoid the greater political instability and terrorist activity of interior Famunda and along Kaznirran borders
  - the various types of inspections along the route that demonstrate the additional complexities introduced by inconsistent regulations
  - the potential for lapses of security along international routes

Complex Risk Approaches

Key Attribute	DPRA	STPA
Risk characterization	Stochastic description of likelihood of undesired events	Level of control to prevent system migration into a state of higher risk
Type of Uncertainty	Aleatory, Epistemic	Coordination, Heuristics, Biases
Type of Complexity	Combinatorial, Dynamic	Dynamic, Interactive
Influence on Security	Probabilistic description(s) of security component reliability along path(s) framed in complex risk uncertainty	Technical (reliability), organizational & (threat) environmental interdependence & feedback
‘Direction’ of Analysis	Bottom-up	Top-down

Analysis & Discussion

- **<u>DPRA</u>**: dynamically captures ***uncertainty*** & ***interdependence*** for realistic description of the security environment at the Famunda/Kaznirra border
  - (Uncertainty) Unknown time for Kaznirran approvals can result in confusion over security responsibility while the SNF is at the border
    - Could result in uncoordinated (at best) or delayed (at worst) response to an adversary attack
  - (Interdependence) Relationship between the extended Kaznirran process for confirming safeguards credibility influences to the adequate response to an attack on the SNF while at the border
    - Potential solutions include increased clarity in security responsibilities & enhanced communications between the two security forces

- DPRA expanded both the problem & solution space beyond traditional approaches

Analysis & Discussion

- **STPA**: describes security as ***maintaining control*** over system behavior against a realistic set of plausible influences working to degrade security effectiveness at the Famunda/Kaznirra border
  - Interaction within the system
    - Emphasizing credible safeguards while the cask is in Famunda may redirect resources or attention away from ensuring security protocols
    - Emphasizing safety in SNF transport might cause the Famundan security force to travel more slowly—which may increase the time spent in a hostile area
  - Coordination & Feedback within the system
    - Identify the important—and non-stochastic—role(s) humans play in preventing degraded security effectiveness
    - The ability of Kaznirran security forces to adjust their security posture after identifying insufficient security reporting from the Famundan security forces

- STPA, also, expands both the problem & solution space beyond traditional approaches

Conclusions

Attributes	Traditional Characterization (e.g., security in isolation)	Complex Risk Characterization
Risk Definition	Probabilistic ability to protect along path(s) against anticipated adversary capabilities	Emerges from potential system migration toward states of higher risk
Risk Reduction	From improved component reliability & defense-in-depth	Realized as part of complex risk management trade-space
Risk Measure	System effectiveness (e.g., combinatorial reliability of security components)	State description including nuclear material loss, area contamination & socioeconomic harms
Solution Space	Limited to increasing security component reliability or reducing adversaries capabilities	Expanded to technical, organizational or geopolitical influences & safety/safeguards leverage points
Relationship to Safety & Safeguards	None, treated as an independent risk	Parallel characteristic, treated as interdependent component of complex risk

Questions?