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A Systems-Theoretic Framing for an Integrated Nuclear Safety, Safeguards, & Security (3S) Approach

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Roadmap

Introduction & Background

3S-Informed Systems Theory Concepts

3S-Informed Evaluation: Representative Case Studies

Conclusions

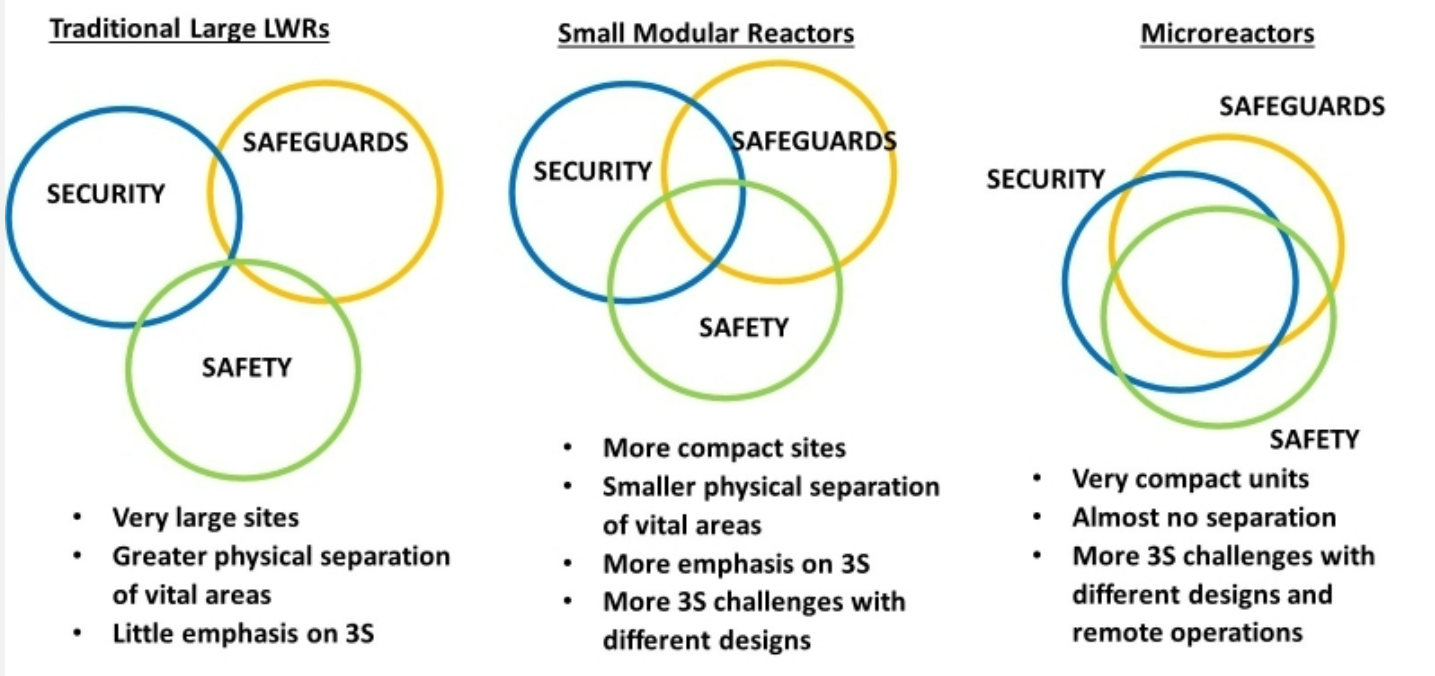
Introduction & Background

Safeguards, security, and safety are commonly seen as *separate areas* in nuclear governance. While there are technical and legal reasons to justify this, they *also co-exist and are mutually reinforcing*. Each has a *synergetic effect on the other*, and authorities should carve out avenues for collaboration to contribute to the effectiveness of the nuclear order. For instance, *near real-time nuclear material accountancy and monitoring systems* provide valuable information about the location and status of nuclear material. This in turn is useful for *nuclear security* measures. Similarly, such information enhances *nuclear safety* by contributing as input to critical controls and locations of nuclear materials.

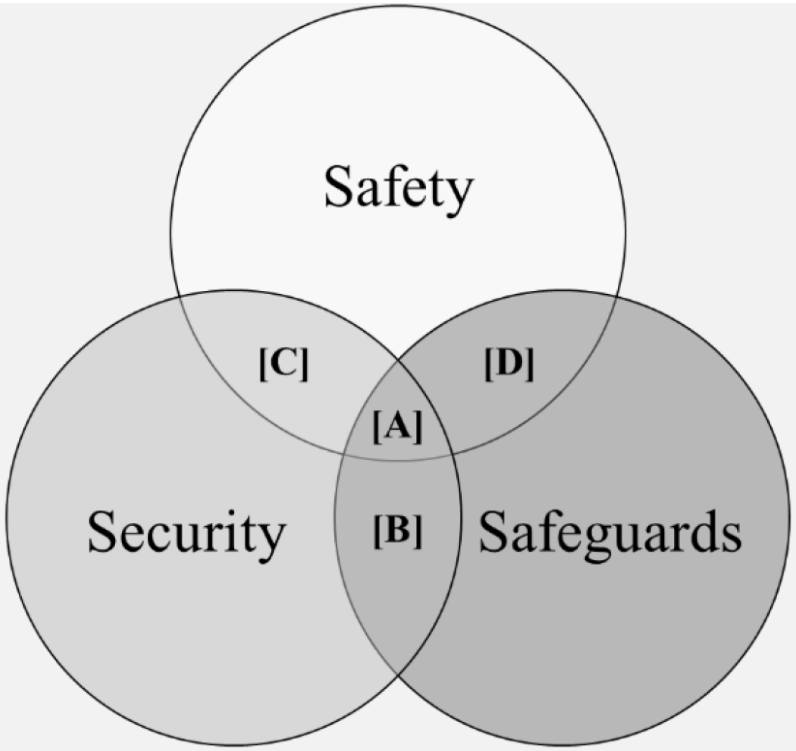
Former Deputy Director-General for Safeguards at the International Atomic Energy Agency Olli Heinonen

Introduction & Background

- Advanced/Small Modular Reactors → 3S approaches
  - Smaller operational footprints
  - Smaller staff sizes
  - Fewer resources
  - Tighter economic margins
- Current efforts:
  - Global Nuclear Assurance & Security (GNAS) studies [Sandia]
  - Advanced Reactor Demonstration Program (ARDP) [US/DOE]
  - Various Defense Nuclear Nonproliferation efforts [NNSA]



3S-Informed Systems Theory Concepts



3S Interaction	Representative Example [Location on Venn Diagram]
Interdependency	Coordination of 3S responsibilities during emergency operations [A]
Conflict	Intrusive access control could impede evidence of peaceful uses (*increase safeguards risk*) [B]
Gap	Passive safety systems could be new targets for malicious acts (*increase security risk*) [C]
Leverage Point	Safeguards inspections could reveal a reactor vessel integrity issues (*reduce safety risk*) [D]

- System theory principles → hierarchy, emergence, interdependence
- Complex systems concepts → socio-technical, multidomain interactions

3S-Informed Systems Theory Concepts

- Interactions *may* be desired, but *need* to be identified/understood
- Interactions *can be* categorized based on relational dynamics
- 3S interactions → facility design parameters to reduce risk

3S Interaction	Systems Engineering Design Goal
Interdependency	Identify & (possibly) decouple
Conflict	Identify, eliminate, and/or reconcile
Gap	Identify, eliminate, and/or reconcile
Leverage Point	Identify & exploit

3S-Informed Evaluation: Case Study I

- U.S. Domestic Licensing for Advanced Reactors
  - Strong regulatory process/history for LWRs
  - A/SMRs ≠≠ LWRs (e.g., footprint, timescales, multi-stakeholder dynamics)
- Challenge: A/SMRs need to meet security goal in cost effective manner
- Response: US/NRC undergoing rulemaking on AR licensing
  - Emphasizes a "risk-informed" approach = safety → security
  - Example of identifying leverage points to gain system efficiencies
- US/DOE-ARDP supporting additional R&D in this area

3S-Informed Evaluation: Case Study II

- International SMR Security-by-Design
  - Increased global interest in SMRs, particularly as economic option
  - Inherent safety ≠≠ inherent security
- Challenge: Develop/deploy SMR “security-by-design” ≈≈ “safety-by-design”
- Response: Evaluating impact of moving security/safety earlier in design
  - Leverage points → physical separation (safety) increases adversary time (security)
  - Coordination between safety/security ensures accurate target ID
- Various NA20 customers supporting additional R&D in this area

Conclusions

- A/SMRs introduce new challenges → *new 3S opportunities*
- A/SMR benefits exist from *explicitly designing* for *interdependencies*
- A/SMR risk mitigation can be driven by addressing *interactions*
  - Risks may *not be* independent
  - Systems theory concepts → framework for addressing interdependencies
  - Exploring interactions can help reduce uncertainty in A/SMR risks
- Additional investigation → "3S-informed" policy & technology solutions A/SMRs


QUESTIONS???