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Lessons Learned from Exploring Safety, Security, and Safeguards Interfaces in Advanced and Small Modular Reactors

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Topical Issues in Nuclear Installation Safety: Strengthening Safety of Evolutionary and Innovative Reactor Designs

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Roadmap

Introduction & Background

Safety-Security-Safeguards (3S) Examples in Advanced & Small Modular Reactors

An Approach to 3S Risk Reduction

Conclusions, Insights & Implications

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

- *Increased overlap* between safety -security-safeguards from such advanced/small modular reactor characteristics as:
  - Increased deployment flexibility
  - Novel fuel types (including physical attributes)
  - New fuel flows & handling systems
  - Increased automation in operations
  - Smaller onsite staffing

OR

Today's State of the art:

3S Alignment

Today's State of the art:

3S Interaction

(3S) Examples: Advanced & Small Modular Reactors

Example 1:
Security-Safety Interfaces in SMRs

- *Challenge*: smaller economic margin vs. same DBT
- *Individual 'S' Considerations*:
  - Increased reliance on off-site response
  - Increased efficiency for onsite solutions
  - Implementing advanced technologies
- *Interactions-based Solution(s)*:
  - Additional protection for "less-critical"
  - Decay heat removal can mitigate sabotage

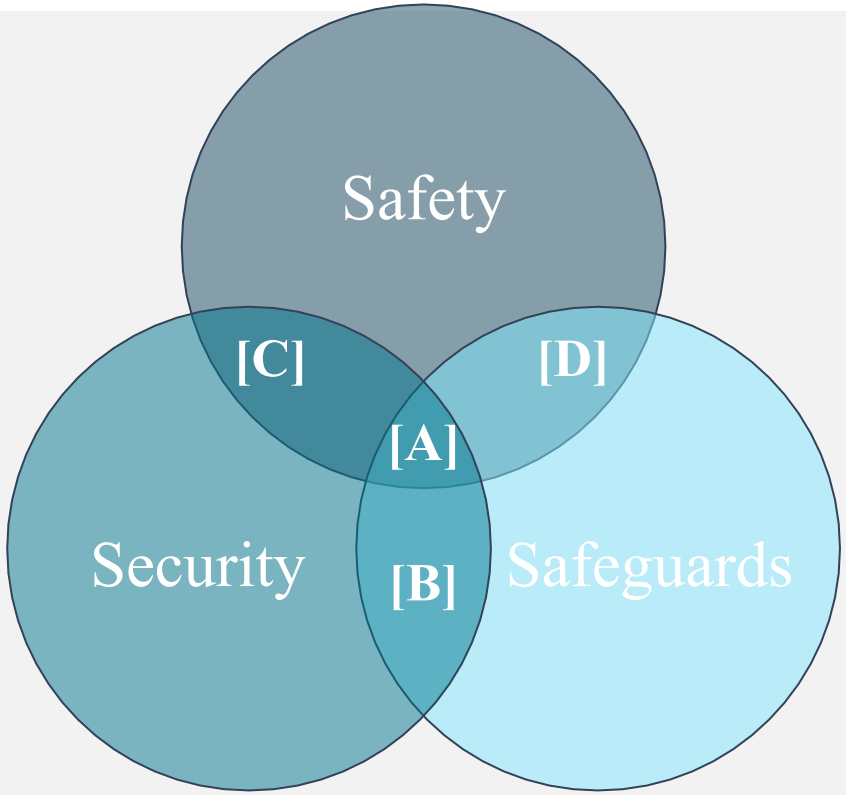
Example 2:
3S Implications from New Fuel Forms

- *Challenge*: shift 3S approaches from item to bulk/mass materials
- *Individual 'S' Considerations*:
  - Safeguards refocus on C&S (vs. NMA)
  - Increased uncertainty in safety calculations
  - More security challenge via insider threat
- *Interactions-based Solution(s)*:
  - Advanced technical & procedural measures
  - Balance relative "S" risk per material form

Example 3:
Impacts on Risk Management

- *Challenge*: how to handle new risk dynamics (vs. traditional elements of NPP risk)
- *Individual 'S' Considerations*:
  - Established PRA approaches → Safety
  - Established VAI approaches → Security
  - Passive techno
- *Interactions-bas*
  - Incorporate pa
  - Overlapping "b

An Approach to 3S Risk Reduction



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

An Approach to 3S Risk Reduction

- 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

An Approach to 3S Risk Reduction

A/SMR Example	Safety	Security	Safeguards	[3S Interaction Type] Systems Engineering Design Goal
1	Capturing increased role of "less-critical" facility components as potential targets for malicious actions	Co-locating "critical" facility components to reduce security system footprint	(Similar challenges can be expected when considering fewer resources to support safeguards obligations)	[Conflict] Identify & reconcile → Security designs can incorporate facility/reactor physics
2	Verifying the burnup of each pebble/ concentration of liquid fuel during rotation for efficiency	Accounting for/locating each pebble or amount of liquid fuel to prevent potential use as RDD	Confirming location of pebbles/liquid fuel to prevent diversion	[Leverage points] Identify & exploit → Selected measurement solutions for process monitoring can support actinide accounting &/or asset tracking
2	Implementing traditional PSA-approaches can neglect important elements of A/SMR operational risk	Conducting traditional VAI techniques propagate/compound these missing elements of operational risk	(Similar challenges might be expected when acquisition pathway analysis borrows from traditional adversary path analysis)	[Gaps] Identify & approach include pa conducte d

Conclusions, Insights & Implications

- New A/SMRs characteristics → *Need for taking advantage of 3S interactions*
  - Risks may *not be* independent
  - Systems theory concepts → framework for addressing interdependencies
- A/SMR risk mitigation can be driven by addressing *interactions*
  - Exploring interactions can help reduce uncertainty in A/SMR risks
  - Additional benefits from *explicitly designing* for *interdependencies*
- Additional investigation → "3S-informed" policy & technology solutions to support A/SMR development & deployment

QUESTIONS???