

Methodology and Tool for the Physical Security Analysis of Micro and Advanced Reactors

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Methodology and Tool for the Physical Security Analysis of Micro and Advanced Reactors

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United States Department of Energy National Nuclear Security Administration International Nuclear Security Methodology and Tool for the Physical Security Analysis of Micro and Advanced Reactors

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Overview

- Develop a dynamic methodology to evaluate physical security
 - Allow dynamic scenarios with timing uncertainties
- Leverage existing work for light-water reactors (LWRs) using Event Modeling Risk Assessment using Linked Diagrams (EMRALD) tool
 - Include preventive safety procedures and analysis
 - Allow rapid scenario assessments using templates
- Relevance to INS: enables stakeholders to design and/or analyze A/SMR security risks using ModSim by considering safety and security features





Methodology







EMRALD Libraries



Barriers

- Fences
- Sticky Foam
- Concrete Walls
- Security Doors
- Active Delay Systems
- Etc.



Properties

- Delay Time
- Equipment Requirements
- Detection Probability
- Etc.
- Specific reactor design features
 - Above / below grade
 - Flood reactor area
- Passive safety systems
- Etc.

Diagrams Barrier ADS-Long ADS-Medium ADS-Short BarbedWire Concrete30cm Concrete60cm Door10cmMetalSheeting HighSecurityPadlock PTR 10cmWoodDoor PTR 30cmReinforcedConcreteWall PTR Fence PTR Gate PTR MetalDoor PTR Turnstile PTR Window PTR WoodenDoor PTR WoodGlassDoor WeldedWireFabricFence Attacks Sensor Exterior Infrared Fence TautWire Interior Infrared PTR ActiveIR PTR AreaPatrol PTR BMS PTR CCTV PTR LimitedRoad PTR MetalDetector RovingPatrol SeismicBuriedCable Area AreaLarge AreaMedium

AreaSmall





4

A/C Output

From RG 5.81 Rev 1:

- Achievable target set elements are those that are within the capabilities of a DBT adversary to compromise, destroy, or render nonfunctional, independent of response strategy.
- Achievable target set elements are determined by the capabilities of the DBT adversary.
- The definition and development of target sets do not consider the success of the security organization.

We also use a SBT / RAPT to define a timeframe of achievability.









Disclaimer:

International Nuclear Security

Reducing Risk of Nuclear Terrorism

Facility drawing, targets, and scenario are hypothetical, and do not represent any actual nuclear power plant.











Results



Histogram of time





A/C Plot Safety measures 0.8 Security 0.6 measures nievability 0.4 łch 0.2 0 10 15 0 8 Radiologicar consequence (Rem)



Conclusion

- Proposed a security-safety (2S) methodology to assess A/SMR security risks
- Added new capabilities to EMRALD to support rapid estimation of A/SMR security risks
- Continue work into FY24 to run scenarios on example SFR and HTGR models, tweak and/or add templates, & gain insights
- Work will benefit A/SMR vendors during the design iteration phase



Research Team

- INL: Robby Christian, Steve Prescott, Christopher Chwasz, Shawn Germain, Vaibhav Yadav
- ANL: Dave Grabaskas, Matthew Bucknor
- X-Energy (non-funded SME)





Appendix Slides

These slides are just for backup







SFR Preventive Actions

Sources of Radioactivity						
Core	Primary Sodium Purification System	Cover Gas Purification System	Fuel Washing Station	Fuel Storage Facility	Intermediate Sodium Loop	
 Power runback (or Hot Standby) 	 Closure of isolation valves Shutdown of system 	 Closure of isolation valves Shutdown of system 	 Cessation of any fuel washing activities 	 Cessation of any fuel movement activities 	(<u>see</u> core)	
 Reactor Shutdown Containment Isolation Transition to passive heat removal system (shutdown of BOP) 	 Cell HVAC isolation Cold trap cooling switched to emergency power 	 Cell HVAC isolation Decay bed cooling switched to emergency <u>power</u> 	• Washing station HVAC isolation	 Facility HVAC isolation Spent fuel pool cooling power switched to emergency power (or passive cooling) 	 Shutdown of intermediate sodium pumps 	
 Remote control room activation Emergency response implementation⁴ 	 Emergency response implementation⁴ 	 Emergency response implementation⁴ 	 Activate emergency mercury flood <u>system</u> Emergency response implementation⁴ 	 Emergency response implementation⁴ 	 Activate intermediate sodium loop <u>drain</u> Emergency response implementation⁴ 	
	Core • Power runback (or Hot Standby) • Reactor Shutdown • Containment Isolation • Transition to passive heat removal system (shutdown of BOP) • Remote control room activation • Emergency response implementation ⁴	CorePrimary Sodium Purification System• Power runback (or Hot Standby)• Closure of isolation valves • Shutdown of system• Reactor Shutdown • Containment Isolation• Cell HVAC isolation • Cold trap cooling switched to emergency power• Transition to passive heat removal system (shutdown of BOP)• Emergency response implementation4	CorePrimary Sodium Purification SystemCover Gas Purification System• Power runback (or Hot Standby)• Closure of isolation valves• Closure of isolation valves• Closure of isolation valves• Reactor Shutdown • Containment Isolation• Cell HVAC isolation • Cell HVAC isolation • Cold trap cooling switched to emergency power• Cell HVAC isolation • Decay bed cooling switched to emergency power• Remote control room activation• Emergency response implementation4• Emergency response implementation4	Sources of RadioactivityCorePrimary Sodium Purification SystemCover Gas Purification System• Power runback (or Hot Standby)• Closure of isolation valves • Shutdown of system• Closure of isolation valves • Shutdown of system• Cessation of any fuel washing activities• Reactor Shutdown • Containment Isolation • Cold trap cooling switched to • Emergency power• Cell HVAC isolation • Decay bed cooling switched to emergency power• Washing station HVAC isolation • Decay bed cooling switched to emergency power• Remote control room activation• Emergency response implementation4• Emergency response implementation4• Emergency response implementation4	Sources of RadioactivityCorePrimary Sodium Purification SystemCover Gas Purification SystemFuel Washing StationFuel Storage Facility• Power runback (or Hot Standby)• Closure of isolation valves• Closure of isolation valves• Closure of isolation valves• Cessation of any fuel washing activities• Cessation of any fuel washing activities• Cessation of any fuel washing activities• Cessation of any fuel movement activities• Reactor Shutdown • Containment Isolation• Cell HVAC isolation • Cold trap cooling switched to emergency power• Cell HVAC isolation • Decay bed cooling switched to emergency power• Washing station HVAC isolation • Washing station HVAC isolation• Facility HVAC isolation • Spent fuel pool cooling power switched to emergency power• Remote control room activation• Emergency response implementation4• Emergency response implementation4• Activate emergency mercury flood system • Emergency response implementation4• Emergency response implementation4	

¹ Assumption that detection has certain level of confidence (*i.e.*, multi-sensors, etc.).

² Confirmation of site intrusion.

³ If sabotage is related to the designated radionuclide source.

⁴ As described in the plant's emergency plan. Includes protective actions and other emergency response measures for workers and public.





Case Study Results

Attack Outcome		Reactor State	Probability	Radiological Consequence (Rem)
Attack fails due to timely interruption		Reactor full power	88.3%	0
Attack successful	Sabotage completed after preventive actions	Reactor is shut down, and nearby population is evacuated	7.2 %	2E-2
	Sabotage completed before preventive actions	Reactor is shut down	3.6 %	2.07
	Sabotage completed before detection was confirmed	Reactor hot standby	0.9%	7.1
	Sabotage goes undetected	Reactor full power	0 %	17.83





Histogram up to 2 Hours



Time (hours)





Scenario Flow Diagram





