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ADVANCED REACTOR SAFEGUARDS

Advanced Reactor Deployment: Safeguards and Security Challenges

NAS Study: Laying the Foundation for New and Advanced Nuclear Reactors in the United States

PRESENTED BY

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Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY

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ARS Program Goals

- The Advanced Reactor Safeguards (ARS) program applies laboratory R&D to address near-term challenges advanced reactor vendors face in meeting U.S. domestic Material Control and Accounting (MC&A) and Physical Protection System (PPS) requirements.
- Safeguards and Security by Design is a strong overarching principle behind our program, and we see more integration of the 3S's required as the world moves toward SMRs and microreactors.
- We are focused on near-term deliverables in order to provide guidance/design alternatives to vendors now (when they need it). Several of the projects have FY21 year-end reports.

Background

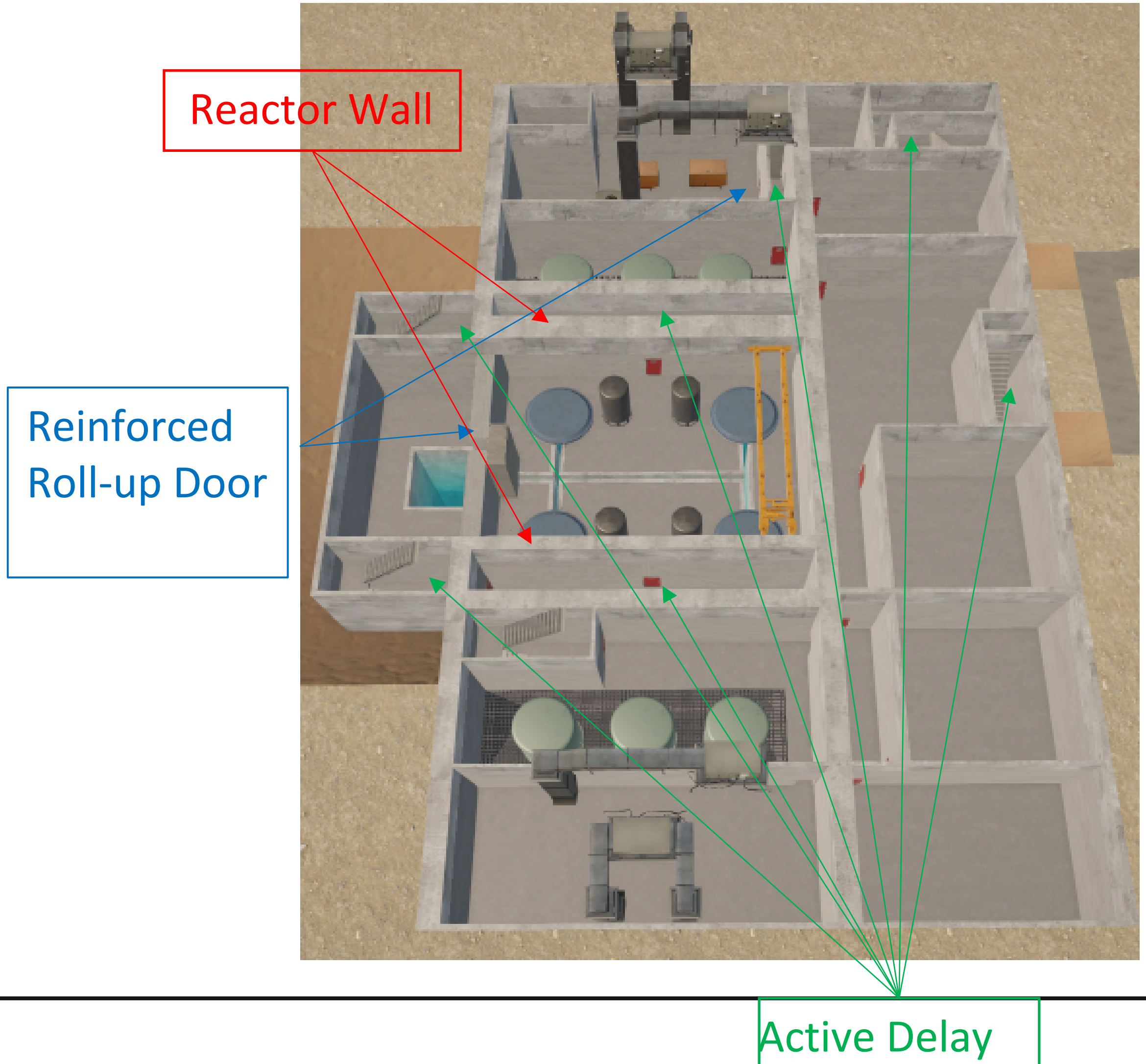
- MC&A and PPS regulations for U.S. nuclear reactors are driven by large light water reactors, and so certain aspects present difficulties to advanced and small reactor designs.
- The Nuclear Regulatory Commission (NRC) is going through rulemaking to create regulations more suited to different reactor designs and smaller footprints.
- The new rulemaking will provide additional options for the PPS design as well as more clarity on MC&A requirements.

Thrust Area 1: Developing a Robust and Cost-Appropriate PPS

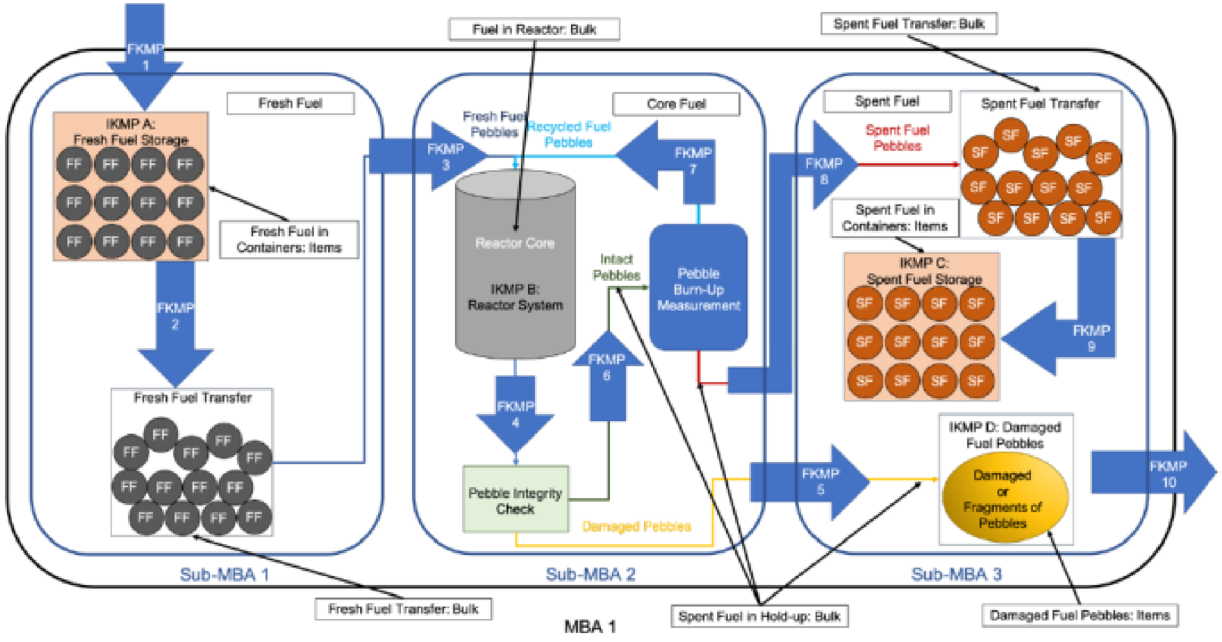
- Large numbers of on-site responders may not be appropriate for smaller and safer reactor designs.
- New rulemaking may allow the vendors to take credit for enhanced safety and smaller source terms to reduce the PPS footprint.
- Path analysis and force-on-force adversary modeling is being used to evaluate enhanced delay and increased reliance on local law enforcement, with different options for SMRs and microreactors.
- New detection, delay, and response technologies are being evaluated to help optimize costs.

Thrust Area 1: Developing a Robust and Cost-Appropriate PPS

- Enhanced safety systems may provide new opportunities, but the vendors do still need to examine sabotage—this is an area where the national laboratories can help.
- We are working to understand sabotage scenarios better for the wide range of reactor designs, determine which are credible and fall within the design basis threat, and then determine progression timelines.
- Reduced on site security presence and more reliance on off-site response requires understanding the progression timelines

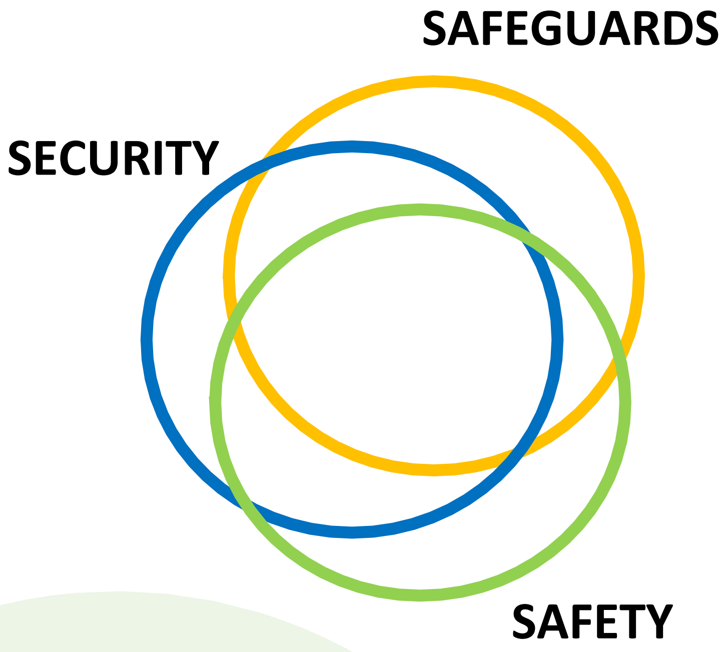


Thrust Area 2: Develop MC&A Approaches for Pebble Bed Reactors



- The MC&A approach for pebble bed reactors is based around 3 item control areas: fresh pebble storage, the reactor and pebble handling system, and spent pebble storage.
- Current work is determining the driving requirements for MC&A versus process control versus protection of rad materials.
- Pebble burnup measurements are important for reactor economics—the program has examined machine learning approaches to improve burnup measurements.
- Examining embedded microspheres within the pebbles for rapid batch identification (helps optimize the pebble handling system).

Thrust Area 3: Determine MC&A and PPS Requirements for Microreactors



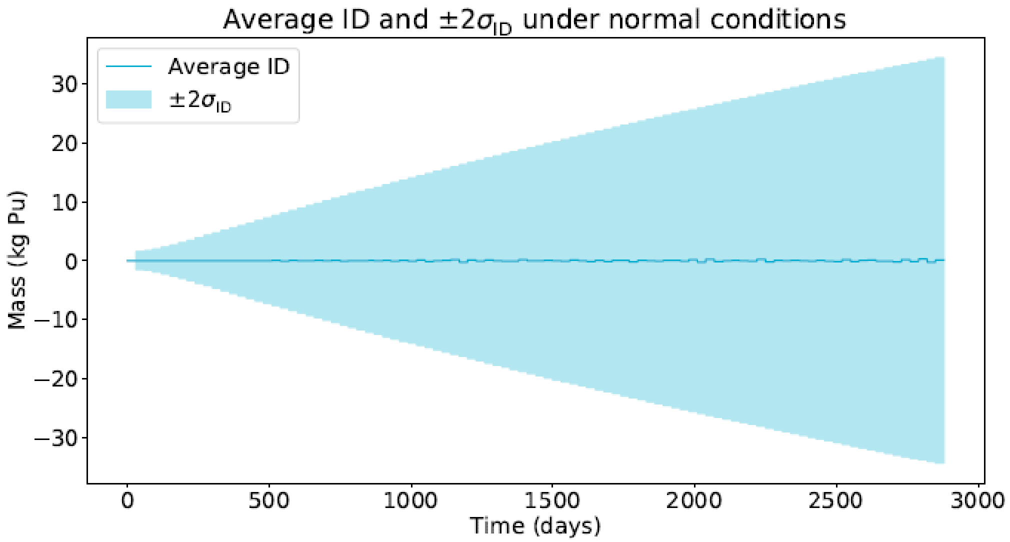
- Microreactors especially face challenges in meeting regulatory requirements in cost-effective ways—PPS approaches may require more out-of-the-box thinking.
- Current work is creating a two-step framework for safeguards and security to guide requirements as a function of design choices.
- Microreactors are likely to see more integration of the 3S's since there's almost no separation in functions and due to increased reliance on remote operations.
- Microreactor vendors are also interested in remote operations, so we see cybersecurity as having increasing priority.

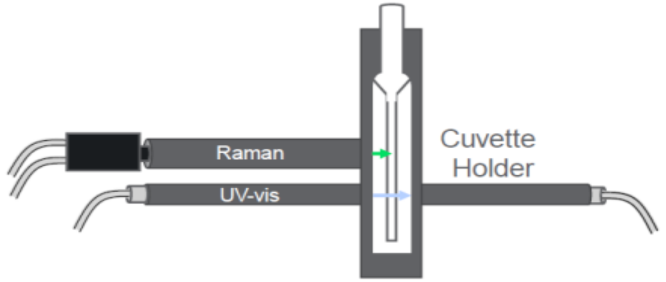
Thrust Area 4: Develop MC&A Approaches for Molten Salt Reactors

- An process monitoring approach is being examined for liquid-fueled MSRs. More work is needed to understand inventories and radiation levels.

- Preliminary work has shown high error for actinide measurements due to buildup of actinides in the salt over time.

- Two on-line measurement technologies are being examined for actinide measurements: spectroscopy and voltametric measurements Both can provide additional information about salt chemistry that may be of interest to the operator.





Thrust Area 5: Leverage International Interfaces

- The ARS program is coordinating with related NNSA programs that support international safeguards and security.
- Vendors should consider international safeguards requirements when designing the MC&A system.
- ARS supports the two U.S. members of the Generation-IV Proliferation Resistance and Physical Protection working group, which is currently examining PR&PP considerations for the six classes of advanced reactors.

GIF System	System Options	Design Tracks Considered
GFR	Reference Concept	2400MWt GFR ALLEGRO as a GFR demonstrator
LFR	Large System	600 MWe (ELFR, EU)
	Intermediate System	300 MWe (BREST-OD-300, RF)
	Small Transportable	20 MWe (SSTAR, US)
MSR	Liquid-Fueled with Integrated Salt Processing	MSFR (EU), MOSART, (RF)
	Solid Fueled with Salt Coolant	Mk1 PB-FHR (US)
	Liquid-Fueled without Integrated Salt Processing	IMSR (Canada)

GIF Syste		
SCW		
SFR	Small Modular	AFR-100 (US)
VHTR	Prismatic Fuel Block	Modular HTR, Framatome (ANTARES)
		SC-HTGR, Framatome (US)
		GT-MHR General Atomics (US)
		GT-MHR OKBM (RF)
		GTHTR300C, JAEA (Japan)
		NHDD,KAERI (RoK)
	Pebble Bed	Xe-100, X-Energy (US)
		HTR-PM (China)

ARS Program Next Steps

- Many of the current projects are producing reports at the end of this FY that we hope will be useful to the vendors.
- Over the next year, we plan to circulate those reports to vendors and NRC to gather feedback and inform future work.
- ARS is driven by the needs of the advanced reactor vendors and plans to continue to work with vendors to identify challenges or gaps that national laboratory, university, or small business research can fill.