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ADVANCED REACTOR SAFEGUARDS

Advanced Reactor Deployment: U.S. Safeguards and Security Challenges

INMM & ESARDA Joint Virtual Annual Meeting

PRESENTED BY

Ben Cipiti

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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 was established in the U.S. in 2020 as part of appropriations for the Advanced Reactor Demonstration Program (ARDP) within the Office of Nuclear Energy in the Department of Energy.
- The 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 for U.S. construction.
- Funded work examines regulatory approaches, optimization of MC&A and PPS costs, and development of new technology where needed.

Safeguards and Security by Design

- SSBD 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 will produce final reports at the end of FY21.
- The ARS program focuses on results that will be applicable to multiple vendors:
  - PPS work may apply more generally to all vendors, but we are evaluating different design options for SMRs versus Microreactors.
  - MC&A work will apply to general reactor classes.

ARS Program Areas

Physical Protection Systems

- Reduce number of on-site responders
- Reduce upfront costs
- Evaluate enhanced safety systems
- Evaluate unique sabotage targets

HALEU Regulatory Gaps

- Implications to MC&A and the PPS
- Evaluate cross-over into the fuel cycle

Pebble Bed Reactor MC&A

- Evaluate regulatory gaps and issues
- Determine driving requirements
- Evaluate new monitoring technologies

Microreactor PPS and MC&A

- Develop a licensing framework based on gaps and issues
- Develop approaches appropriate to the very small scale
- Evaluate new monitoring technologies

Liquid Fueled MC&A

- Evaluate regulatory gaps and issues
- Develop baseline accountancy approaches
- Evaluate new measurement and monitoring technologies

International Considerations

- Consider international safeguards requirements
- Support the Gen-IV PR&PP working group

Background

- MC&A and PPS regulations for nuclear reactors built in the U.S. are driven by large light water reactors, and so certain aspects present difficulties to advanced and small reactor designs.
- The Nuclear Regulatory Commission is currently 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.

Develop 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.

Examine HALEU Regulatory Impacts

- Many vendors are planning to use HALEU, but its use can have regulatory implications. The implications are generally small for MC&A and could have more impact on PPS.
- A past, cancelled NRC rulemaking considered dilution, and some vendors may be able to take credit for dilution in their licensing approach.

Category I - Strategic SNM (SSNM)

5 kgs or more of U-235 (contained in uranium enriched to 20 percent or more in the U-235 isotope)

Category II - SNM of moderate strategic significance

Less than 5kgs but greater than or equal to 1kg of uranium-235 (contained in uranium enriched to 20 percent or more in the U-235 isotope); or

10kg or more of uranium-235 (contained in uranium enriched to 10 percent or more but less than 20 percent in the U-235 isotope)

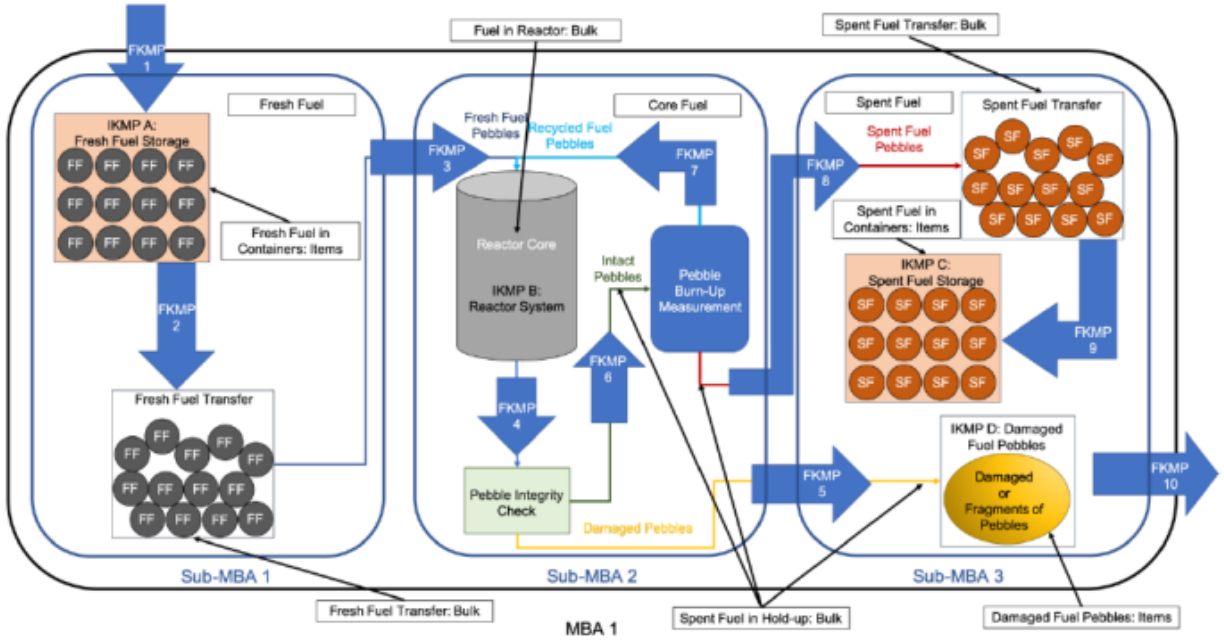
Category III - SNM of low strategic significance

Less than 1kg but more than 15 grams of uranium-235 (contained in uranium enriched to 20 percent or more in the U-235 isotope)

Less than 10kgs but more than 1kg of uranium-235 (contained in uranium enriched to 10 percent or more but less than 20 percent in the U-235 isotope); or

10 kgs or more of uranium-235 (contained in uranium enriched above natural but less than 10 percent in the U-235 isotope)

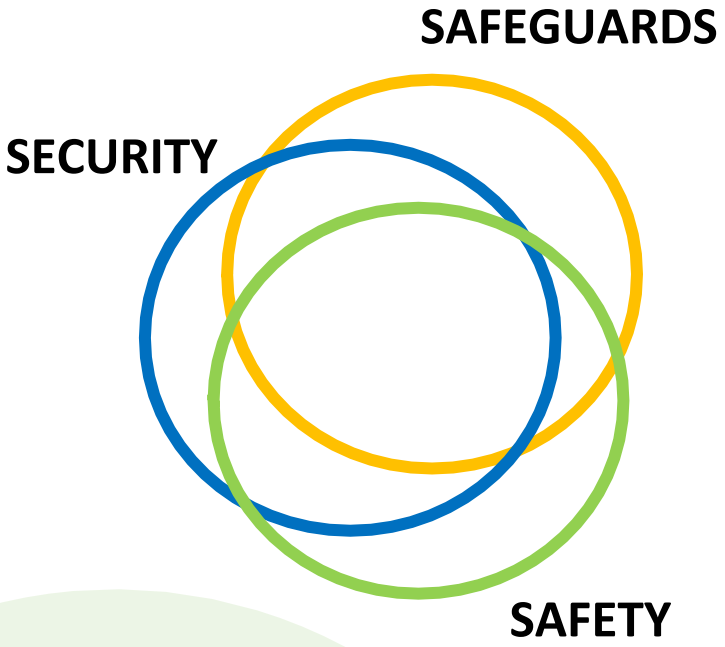
Develop MC&A Approaches for PBRs



- The MC&A approach for pebble bed reactors is based around 3 sub-MBAs: 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.

- Examining machine learning approaches to improve burnup measurements since they’re important for reactor economics.
- Examining embedded microspheres for rapid batch identification.

Determine MC&A and PPS Requirements for Microreactors

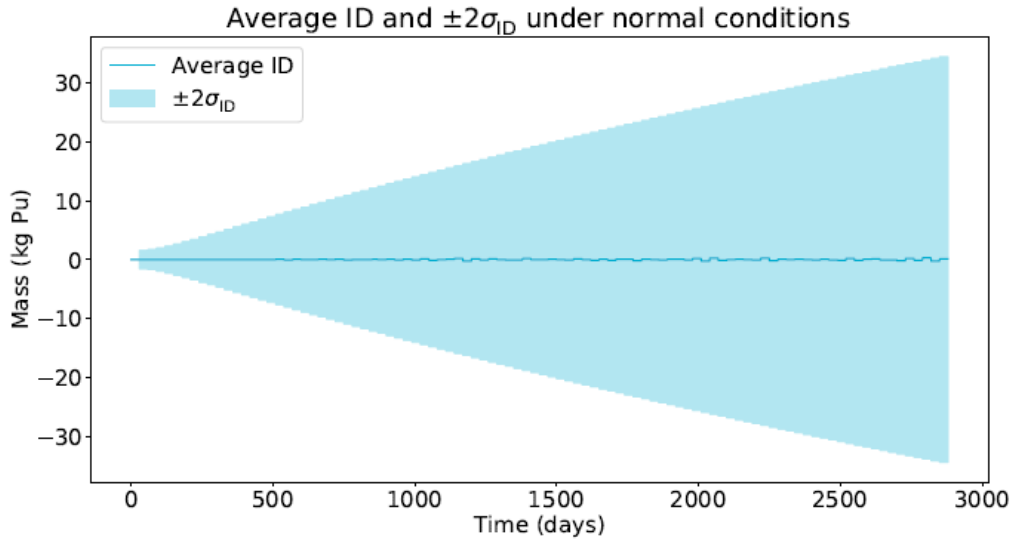


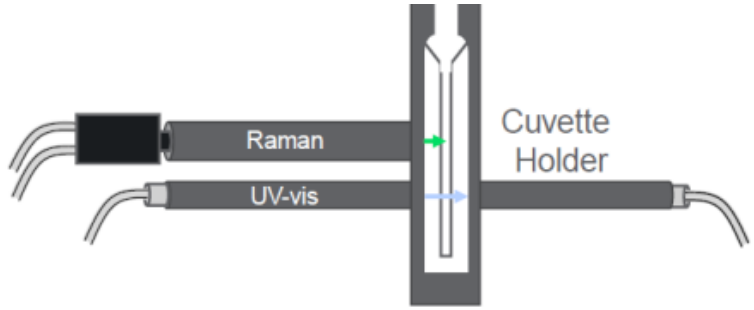
- Microreactors face challenges in meeting regulatory requirements in cost-effective ways.
- Current work is creating a two-step framework for safeguards and security to guide requirements as a function of design choices.
- Microreactors are likely to see more integration of the 3S's since there's almost no separation in functions and due to increased reliance on remote operations.

- NDA measurements are being evaluated for verification of small, sealed cores and whether that may be needed through the life cycle.

Develop MC&A Approaches for Molten Salt Reactors

- An MC&A approach for liquid-fueled MSRs is being developed based on a process monitoring approach. More work is needed to understand inventories and radiation levels with time.
- 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.





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)
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.