ADVANCED REACTOR SAFEGUARDS

ARS Program Overview & FY23 Planning

PRESENTED BY

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ARS Spring Meeting, May 3-4, 2022

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Advanced Reactor Safeguards Program Goals

- The Advanced Reactor Safeguards (ARS) program focuses on addressing near-term challenges advanced reactor vendors face in meeting U.S. domestic Physical Protection System (PPS) and Material Control and Accounting (MC&A) requirements.
- The program will continue to support work across reactor classes to help as many vendors as possible.
- But, we will increasingly be supporting work with individual designs as the R&D matures (all vendor projects will need to generate a more generic report as one of the milestones).

Working Group Meeting Goals

- Present progress on technical work.
- Discuss collaboration within the program.
- Discuss external collaboration with vendors, stakeholders, and related program areas in DOE NE and NNSA.
- Plan work for FY23 and next five years.

Stakeholders and Interfaces

- The U.S. AR vendors continue to be our key stakeholder, but we need to continue to stay aligned with NRC.
- We have strong partnerships with NEI, EPRI, and NNSA to help develop coordinated approaches to Safeguards and Security by Design.
- Other key NE program areas that require coordination include: **Gas Cooled Reactors, Fast Reactors, Molten Salt Reactors, Microreactor Technologies, Nuclear Cyber Security, Advanced Reactor Regulatory Development, Advanced Sensors and Instrumentation, Nuclear Reactor Innovation Center, Material Protection Accounting and Control Technologies, HALEU Program, Spent Fuel and Waste Sciences Technologies.**

FY22-23 Thrust Areas

Physical Protection Systems

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

Pebble Bed Reactor MC&A

- Evaluate regulatory approach
- Determine driving requirements
- Evaluate new monitoring technologies

Microreactor PPS and MC&A

- Develop a licensing framework
- Develop approaches appropriate to the very small scale
- Evaluate new monitoring technologies

Liquid Fueled MC&A

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

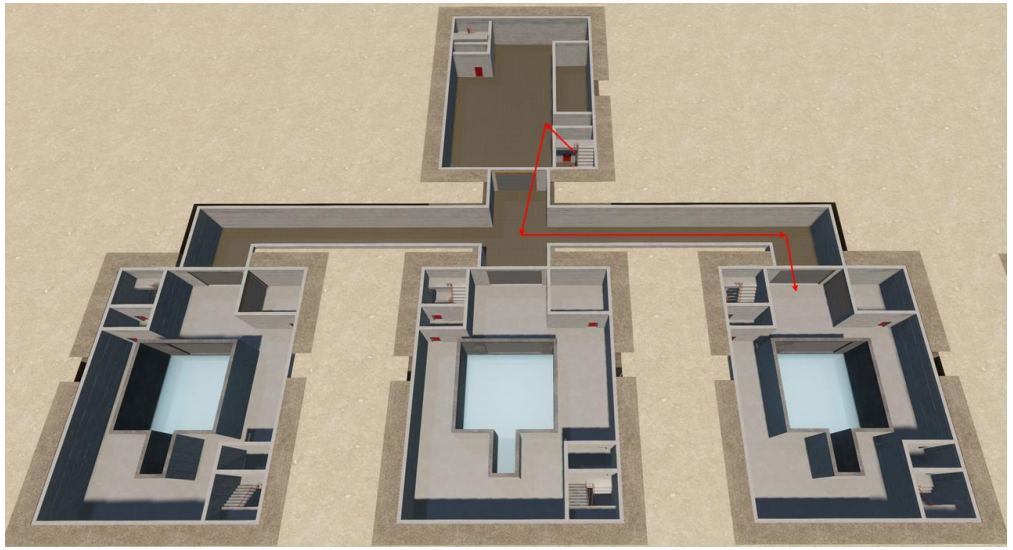
International Considerations

- Consider international safeguards requirements
- Interface with NNSA programs
- Support the Gen-IV PR&PP working group

Vendor Engagements

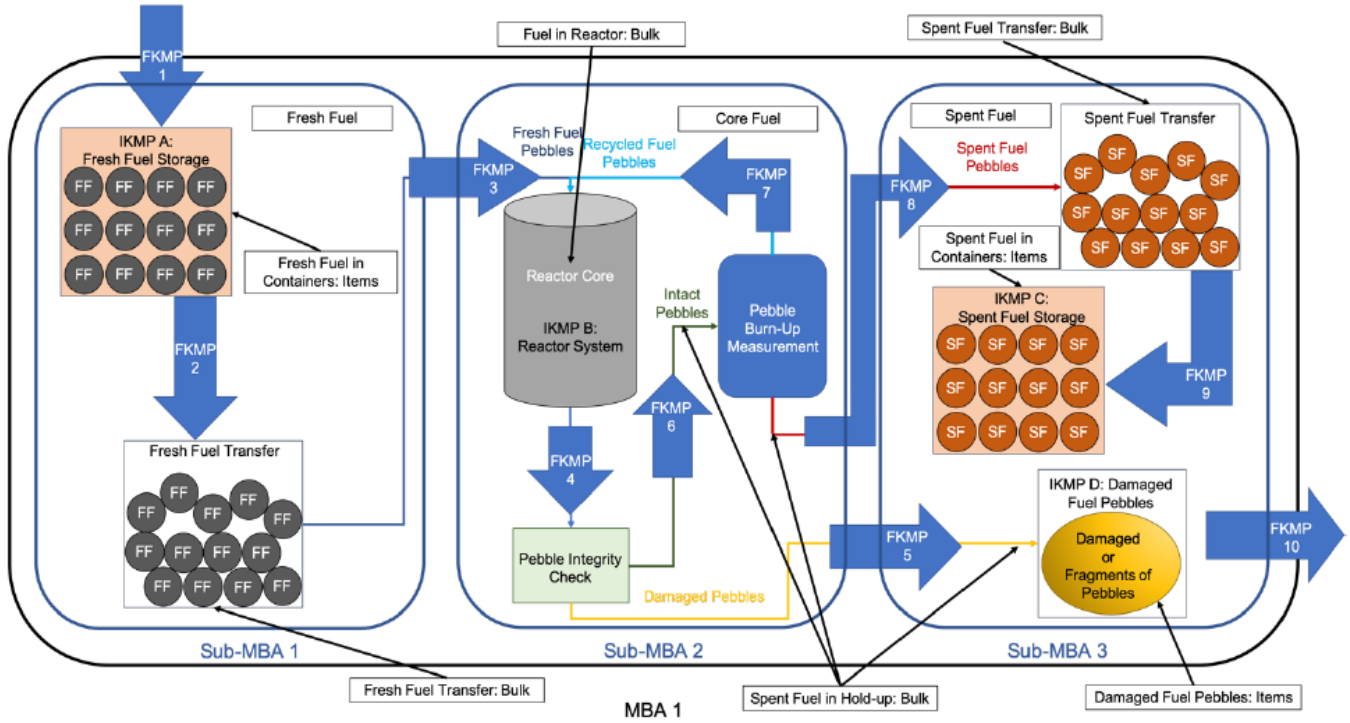
- Design-specific MC&A and PPS challenges.
- NNSA partnerships
- Translate to lessons learned or generic deliverables.

Physical Protection Systems



- We’re evaluating a combination of new technologies and new approaches to reduce upfront and operational costs to improve economics.
- Continuing to evaluate the Deliberate Motion Algorithm and Remote Operated Weapons Systems for next gen PPS.
- Moving away from reliance on off-site responders due to challenges involved, but will plan to provide different options to vendors.
- Exploring interface with safety and scenario timeline analysis.
- Goal is to provide 2-3 PPS options for both microreactors and SMRs along with proof through performance metrics.

Pebble Bed Reactor MC&A



- 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.

- The pebble handling system is likely the most complex area requiring a short cooling area, imaging for pebble integrity, potential batch identification, burnup measurement, and rejection for damaged pebbles and pebbles at the burnup limit.
- Very large numbers of pebbles are required to acquire a goal quantity, so accounting is mainly on the canister level.

Microreactor PPS and MC&A

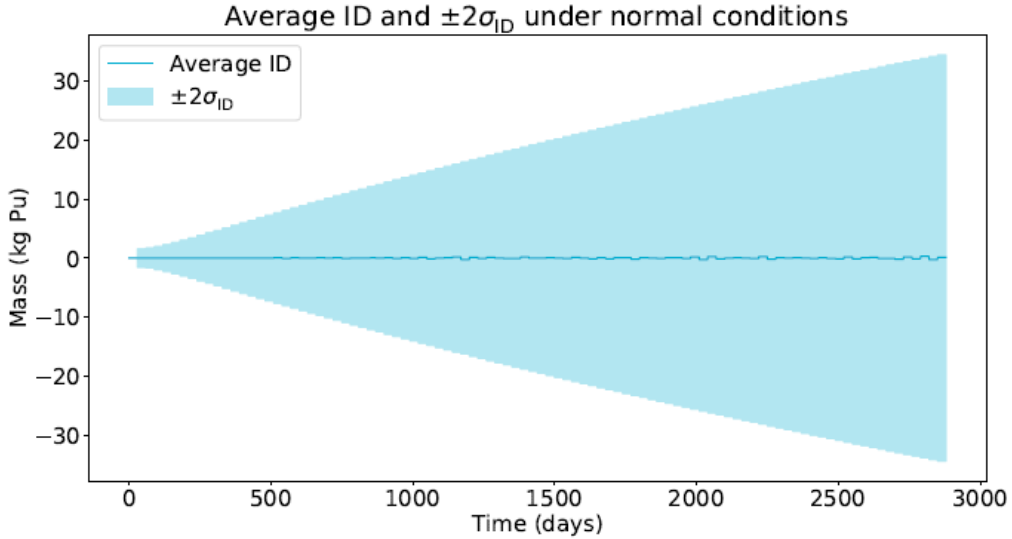
- We are working to develop a domestic licensing framework for microreactors as a function of design options.
- MC&A is relatively straight-forward for microreactors since most designs either use solid fuel assemblies or sealed cores that will be tracked as a unit.

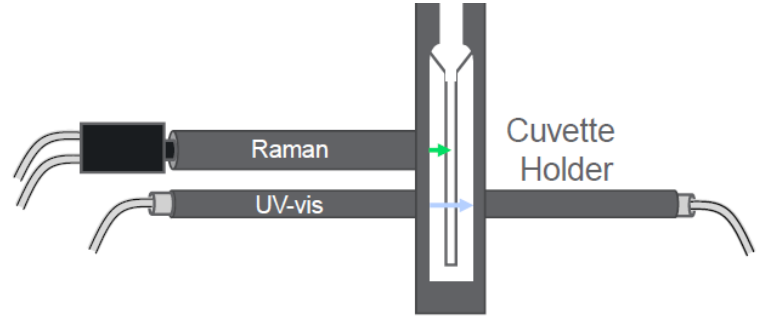
	Licensing	Physical Security	MC&A
Power Reactors	10 CFR 50, "Two step" *NUREG 0800 (LWR)* *R.G. 1.1-1.239*	10 CFR 73, 50.34 *RG 5.59, 5.69, 5.70, 5.76, etc*	10 CFR 74, 50.34 *Partially exempt from Part 74 requirements.* *RG 5.29, 5.51*
Power Reactors	10 CFR 52, Combined License *NUREG 0800 (LWR)* *NUREG 1789 (Construction)* *R.G. 1.1-1.239*	10 CFR 73 *RG 5.59, 5.69, 5.70, 5.76, etc*	10 CFR 74, 52.46 *Part 52 is not **explicitly** exempt from Part 74 requirements.* *RG 5.29, 5.51*
Non-Power	10 CFR 50.21, Class 104 License *NUREG 1537* *R.G. 2.1-2.6*	10 CFR 73.60, 50.34 (c) *Additional clarifications in Part 73.6 and 73.23*	10 CFR 74, 50.34 *Partially exempt from Part 74 requirements.*

- Physical protection is more challenging since microreactors in particular need to develop efficient PPS's with limited on-site presence.
- Future work will integrate more with the cyber program since autonomous operation and possibly remote monitoring present cyber challenges.

Liquid Fueled Reactor MC&A

- An MC&A approach for liquid-fueled MSRs is being developed based on NRC discussions. More work is needed to understand inventories and radiation levels with time.
- Recent 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. NDA Measurements are also being examined.





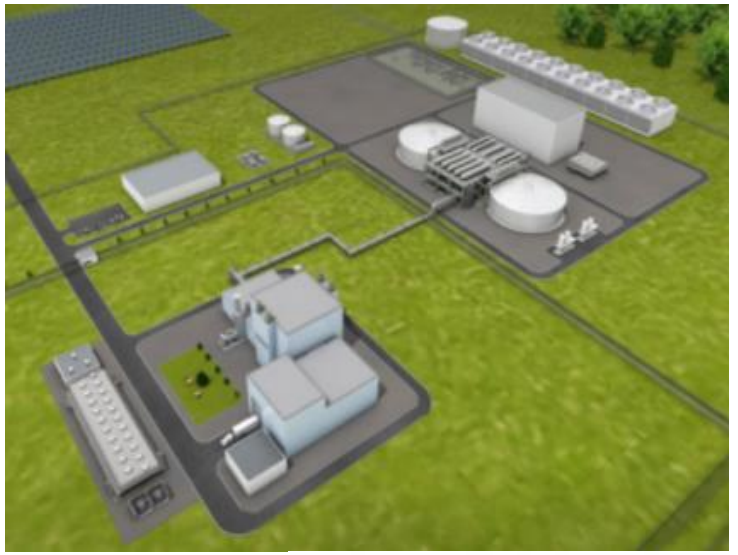
International Considerations

- The ARS program is coordinating with the ARISE program in NA-24 and ARSP program in NA-21 to support U.S. vendors.
- Pushing for common language and deeper understanding of the differences between U.S. domestic and international requirements.
- 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.

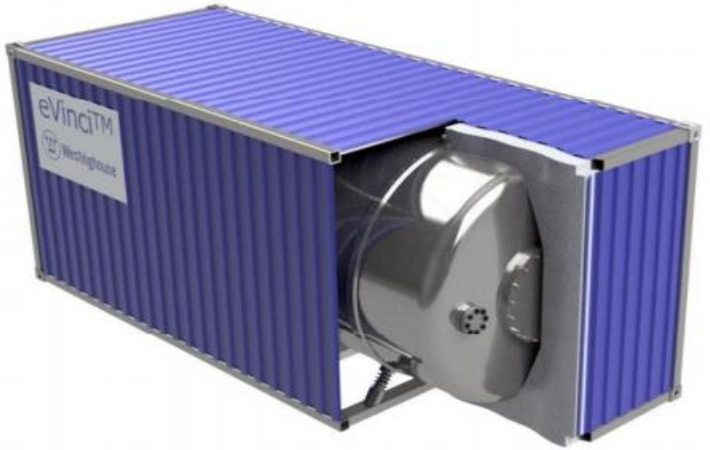
GIF System	System Options	Design Tracks Considered
SCWR	Pressure Vessel	HPLWR (EU) (Thermal)
		Super FR (Japan)
		Super LWR (Japan) (Thermal)
		CSR1000 (China) (Thermal)
		Mixed spectrum (China)
		Fast core (RF)
	Pressure Tube	Canadian SCWR (Canada) (Therm.)
SFR	Loop Configuration	JSFR (Japan)
	Pool Configuration	ESFR (EU), BN-1200 (RF), KALIMER-600 (RoK)
	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)

Vendor Engagements

- We are beginning engagements with Westinghouse eVinci and Terrapower Natrium in collaboration with NNSA.
- Exploring engagements with other vendors.
- We plan to continue to support vendors as needed and encourage them to reach out to PIs or the NTD/Fed with challenges in the MC&A and PPS space.



Terrapower Natrium



Westinghouse eVince

Budget

- Our funding profile is staying flat at the $5M level.
- The work is performance-based, and we expect to rotate through projects as milestone reports are completed.
- We continue to base our work on vendor feedback and prioritize based on the need across vendors.