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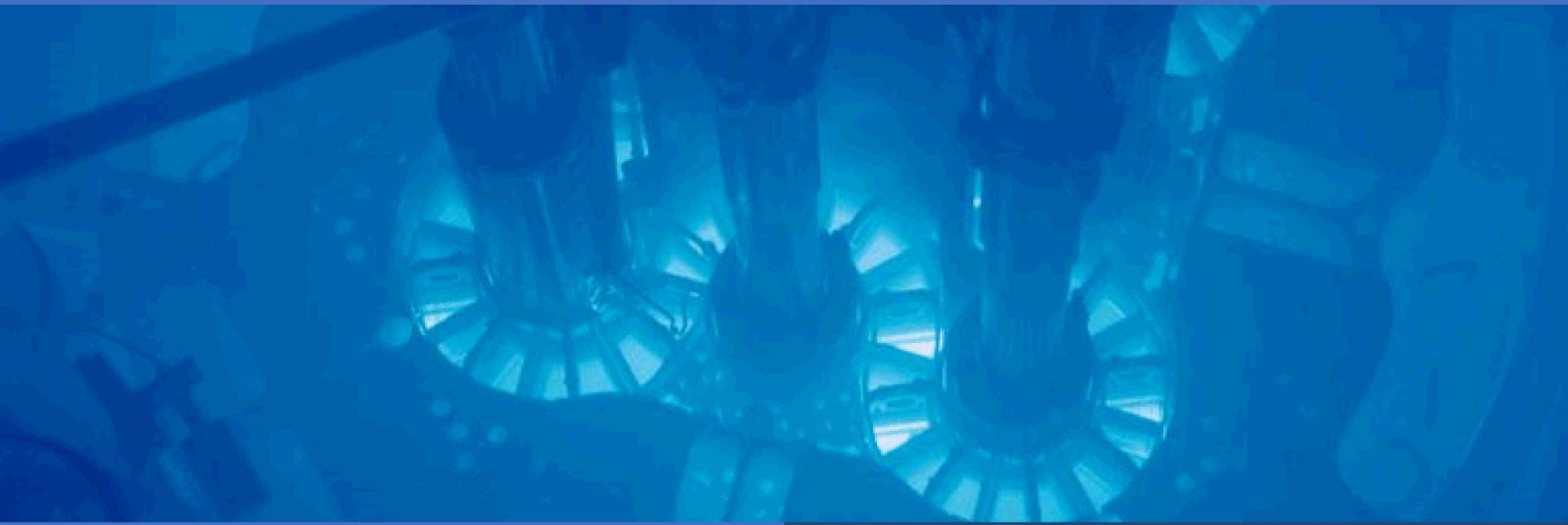

ADVANCED REACTOR SAFEGUARDS

Fall Working Group Meeting

October 5-6, 2020

NTD: Ben Cipiti

Federal Program Manager: Won Yoon

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Agenda

Monday, October 5th

10:00 AM	Welcome and Meeting Goals (Ben Cipiti)
10:15 AM	DOE NE Remarks (Won Yoon and Suibel Schuppner)
10:30 AM	Program Overview (Ben Cipiti)
10:45 AM	Security by Design VA for Advanced Reactors (Jordan Parks)
11:00 AM	Fused Radar and Video Analytics (JR Russell)
11:15 AM	Interplay between Safety and Security using PRA (T.Jay Harrison)
11:30 AM	Treatment of Uncertainty, Risk Informed Licensing Approach (Curtis Smith)
11:45 AM	Unique Sabotage Targets for Advanced Reactors (Vince Mousseau)
12:00 PM	--Break--
12:15 PM	(Security Discussion)
12:45 PM	MC&A for Pebble Beds (Philip Gibbs)
1:00 PM	Pebble Accountancy for Pebble Bed Reactors (Claudio Gariazzo)
1:15 PM	Machine Learning for Video Surveillance of Pebble Beds (Yonggang Cui)
1:30 PM	(Pebble Bed MC&A Discussion)
2:00 PM	End

Agenda

Tuesday, October 6th

10:00 AM	PICS NE Overview and Training (Wendy Jue)
10:15 AM	STI – OSTI (Steve Pellegrino)
10:30 AM	MC&A Approach for MSRs (Mike Dion)
10:45 AM	MSR Safeguards Modeling (Nathan Shoman)
11:00 AM	Experimental Validation of NDA for MSR Safeguards (Mark Croce)
11:15 AM	On-Line Monitoring for MSR Safeguards (Amanda Lines)
11:30 AM	Flow Enhanced Sensors for MSRs (Nathan Hoyt)
11:45 AM	(MSR MC&A Discussion)
12:00 PM	--Break--
12:15 PM	Framework for Microreactor Safeguards and Security (Andrew Breshears)
12:30 PM	Radiography of Microreactor Sealed Cores (Robbie Weinmann-Smith)
12:45 PM	Safeguards Challenges for HALEU (Warren Stern)
1:00 PM	(Microreactor & HALEU Discussion)
1:15 PM	Leveraging IAEA Safeguards for Advanced Reactors (Chris Orton)
1:30 PM	Gen-IV PR&PP (Lap Cheng)
1:45 PM	(International Interfaces Discussion)
2:00 PM	Closeout

Meeting Goals

- Our plan is to limit this meeting to PI's and team members to focus more on future planning and collaboration.
- All of our projects should be increasingly collaborating with other work packages as we get into FY21 and FY22. We have discussion time planned after each grouping of presentations for this purpose.
- For our next meeting, we plan to reach out to other stakeholders more, including NRC, NEI, Vendors, other programs in NE-5 and NE-4, NNSA, and Universities.
- We also need to coordinate our interactions with stakeholders.

Program Overview

Five-Year Program Objectives

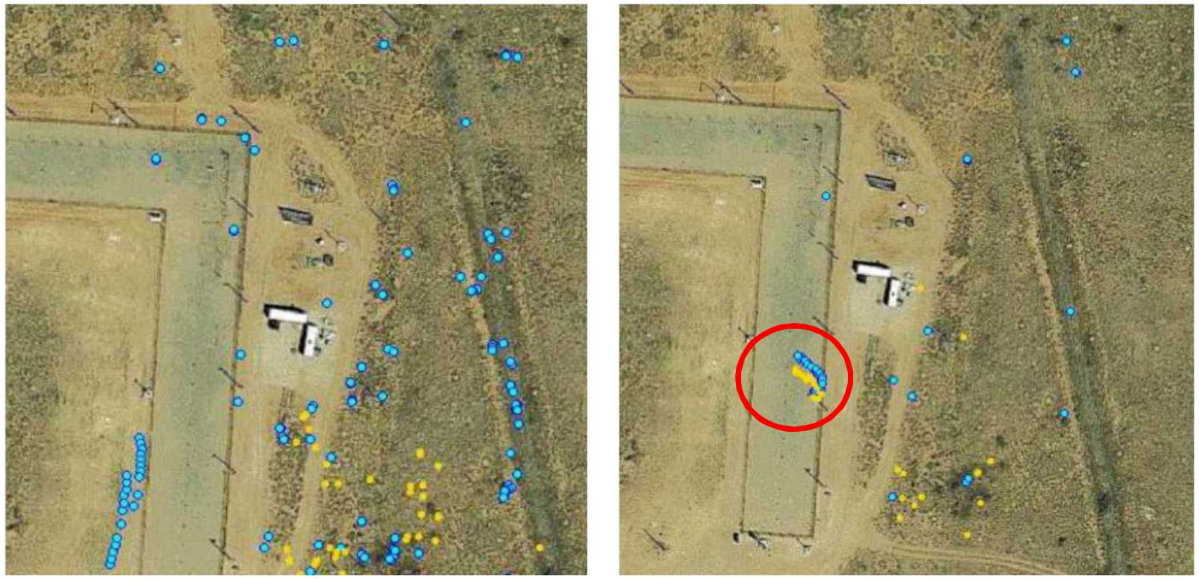
- Provide physical protection system design alternatives that significantly reduce cost or need for on-site responders that all advanced reactors designers can utilize.
  - Demonstrate advanced detection systems that replace the high costs of a PIDAS.
  - Examine unique sabotage targets and tie into security analysis.
  - Provide approaches to vendors to take credit for enhanced safety systems and tie security work into the risk-informed regulatory approach.
- Provide recommendations to vendors (which will also help inform NRC) on MC&A approaches for advanced reactors (emphasis on MSR, PBR, Micro).
  - Provide new measurement technologies for accountancy and monitoring of advanced reactors.
  - Examine regulatory issues with the use of HALEU in addressing the above issues.

High Level Milestones

FY21

- Design, analyze, and prove a PPS design alternatives that significantly reduces or eliminates the need for on-site responders using a generic SMR design. **(M2, August 2021)**
- Demonstrate advanced detection systems to eliminate the PIDAS at future nuclear plants.
- Provide an MC&A approach for PBRs and MSRs.
- Provide a regulatory approach framework for microreactors based on design choices.

Deliberate Motion Algorithm can eliminate the large number of nuisance alarms (left) but alarms when deliberate motion is observed (right)



High Level Milestones

FY22

- Examine how vendors can take advantage of new rulemaking to take credit for improved safety systems and tie into PPS analysis. **(M2)**
- Examine regulatory gaps related to the use of HALEU and incorporate into the program's MC&A and PPS work.
- Perform NDA measurements on molten salts and potentially pebbles to benchmark NDA performance for MC&A.

Microcalorimeter (right) and spent fuel samples (below)

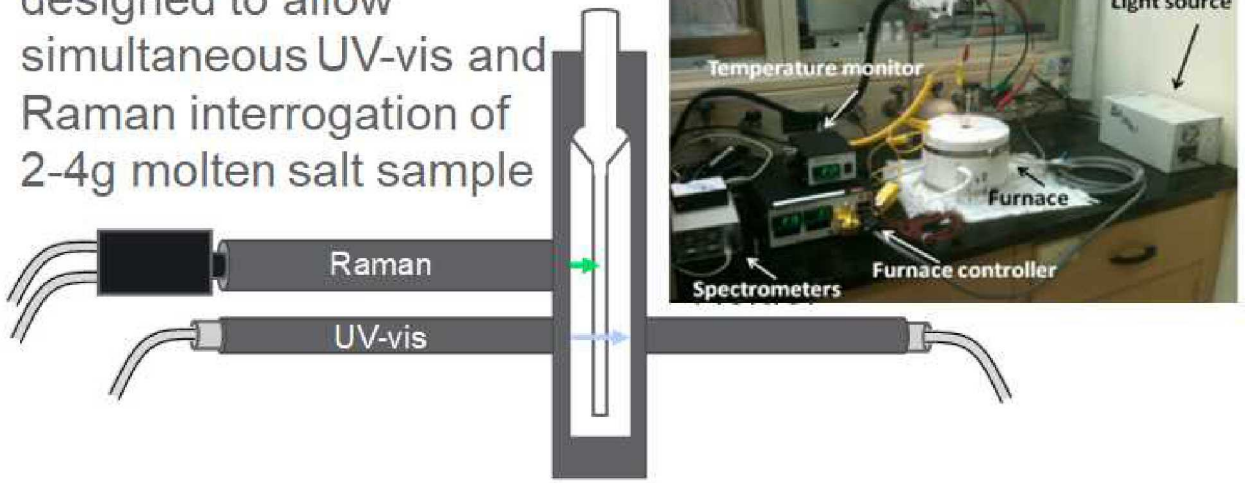
High Level Milestones

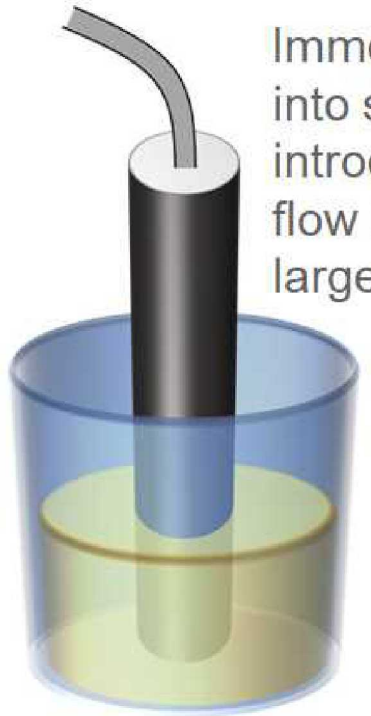
FY23

- Demonstrate new measurement technologies for accountancy for PBRs and MSRs on real material/systems. **(M2)**
- Provide a complete listing of unique sabotage targets that advanced reactors need to take into consideration. **(M2)**

Online Spectroscopy for MSRs

Small scale setup designed to allow simultaneous UV-vis and Raman interrogation of 2-4g molten salt sample





Immersion probe that dips into salt (i.e. can be introduced through port on flow loop) for characterizing larger scale salt systems

FY21 Lab Splits at $5M Planning Level & FY20 Carryover

	ANL	BNL	INL	LANL	ORNL	PNNL	SNL	Total
FY20 Carryover	$340K	$175K	$140K	$100K	$275K	$75K	$545K	**$1650**
FY21 Planning	$700K	$445K	$235K	$525K	$575K	$260K	$975K	**$3715**

- Note that increases in funding will focus on restoring original year 2 budget requests for all projects (as opposed to adding new work packages).

FY21 Integrated Priority List summary

	FY20	FY21
Project Management	$ 200K	$ 200K
Competitive projects	$ 183K	$ 1180K
Other Contributions	$ 657K	$ 105K
Direct funded research	$ 3960K	$ 3515K
MC&A for MSRs (5 projects)	*$ 1255*	*$ 1250K*
MC&A for Pebble Beds (3 projects)	*$ 700*	*$ 625K*
MC&A for Microreactors & HALEU (3 projects)	*$ 520*	*$ 445K*
PPS Reduction of Cost (2 projects)	*$ 850*	*$ 550K*
PPS Interplay Between Safety and Security (3 projects)	*$ 575*	*$ 485K*
Gen-IV and IAEA Safeguards Interface (2 projects)	*$ 60*	*$ 160K*
Total	**$ 5000K**	**$ 5000K**

Current NEUP Projects

- Two NEUP projects were transferred from MPACT to ARS oversight.
- Development of an MC&A Toolbox for Liquid-Fueled MSRs with Online Reprocessing
  - Steve Skutnik, University of Tennessee-Knoxville, Started FY18
  - Develop reactor libraries in ORIGEN and a series of self-contained process component modules for MSR systems. Develop MC&A recommendations based on physical signatures. Developed SERPENT models for MSRE, LFTR, MCFR and a dynamic model of MSRE.
- Modeling and Uncertainty Analysis of MSR Nuclear Material Accounting Methods for Nuclear Safeguards
  - William Walters, Penn State University, Started FY19
  - Model and analyze limits of detection for diversion of SNM. Quantify changes in reactor performance due to material loss. Analyze detection methods and effect of modeling uncertainty on confidence levels for detection. Scale and SERPENT models have been developed and verified for MSRD.

Challenge:

Reduce Physical Security Costs

Develop PPS Approaches that Meet Regulatory Requirements
Significantly Reduce Cost to the Operator
Provide Methods to Take Advantage of Enhanced Safety Features
Consider Unique Sabotage Threats

FY21 Work Packages: PPS Activities

Project Objectives and Scope

Security by Design VA for Advanced Reactors (SNL, Parks, $300K)

Building on the PPS modeling from FY20 (including both path and neutralization analysis), evaluate enhanced security features, emerging technologies, and facility designs that can provide enough delay during an attack to allow the plant to rely on offsite local law enforcement resources. This work will provide industry design alternatives to reduce security costs for advanced reactors. **August 2021** ***M2 Milestone: Report describing design alternatives, analysis results, and fit into the regulatory structure.***

Fused Radar and Video Analytics (SNL, Russell, $250K)

The FY20 project will be finalized at the beginning of FY21. The initial goal of this activity is to successfully demonstrate the spatial and temporal data fusion of radar and infrared imagers with video analytics, addressing detection issues at the Palo Verde Generation Station (PVGS). The onsite pilot demonstration will show that the fused sensor system will significantly reduce false positive alarms from weather, foliage, and wildlife as well as provide reliable detection of threats specified by PVGS, under real-world conditions. This pilot demonstration will verify that the Deliberate Motion Analytics (DMA) sensor data fusion capabilities can be deployed at advanced nuclear power facilities. Additional work in FY21 will transition to application against the drone threat (land and air).

FY21 Work Packages: PPS Activities

Project Objectives and Scope

Unique Sabotage Targets for Advanced Reactors (SNL, Mousseau, $200K)

Examine any potential vulnerabilities to passive safety systems and unique coolants/target sets for advanced reactors. Initial models will continue to be developed to determine order of magnitude estimates of the energy addition or energy removal that would damage the reactor. Coordinated with the following projects at INL and ORNL.

Treatment of Uncertainty, Risk-Informed Licensing Approach (INL, Smith, $185K)

Methods will continue to be developed to address the security-design uncertainty. The outcome of this research and development will be a cross-cutting approach to assist advanced reactor designers to understand and manage uncertainty as concepts move into risk-informed licensing.

Interplay between Safety and Security using PRA (ORNL, Harrison, $100K)

PRA-based methods will continue to be adapted for security analysis for advanced reactors to establish security-by-design principles. The outcome of this work will provide a framework and methodology for security analysts to leverage decades of development and experience in PRA methods used for safety analyses, and evaluate the interplay between safety and security.

Challenge:

MC&A Requirements for Liquid Fueled Reactors

Provide R&D to Inform Regulatory Efforts
Develop Baseline MC&A Approaches
Develop Measurement Technologies to Meet the Need
Provide Analysis to Prove the Approaches

FY21 Work Packages: MSR MC&A Activities

Project Objectives and Scope

MC&A Approach for Molten Salt Reactors (ORNL, Dion, $300K)

Develop an MC&A approach for MSRs through engagement with the NRC, a signature and modeling study to identify measurement locations, and an infrastructure assessment. Work is in collaboration with the two WPs below. The results of this research will support the MSR vendor community through their design licensing plans.

Molten Salt Reactor Safeguards Modeling (SNL, Shoman, $75K)

Both traditional and non-traditional materials accountancy approaches will be examined for MSRs using modeling and simulation. The mod/sim tools allow for testing of system response to material loss and provide uncertainty goals for measurement technologies.

Experimental Validation of NDA for MSR Safeguards (LANL, Croce, $375K)

This project will develop a comprehensive set of validated nondestructive measurement capabilities needed for safeguards models. Using traditional and advanced NDA technologies, measurement performance will be evaluated for samples and environments representative of an operating MSR.

FY21 Activities: MSR MC&A Activities (cont.)

Project Objectives and Scope

On-Line Monitoring for Molten Salt Reactor Safeguards (PNNL, Lines, $200K)

PNNL is assessing the use of optical spectroscopy based on-line monitoring for the real-time and in situ analysis of molten salts. PNNL will focus on building a laboratory setup for testing. Initial work will focus primarily on chloride salts with uranium being the primary target analyte. Approaches will be extended to other target analytes and salt compositions in future years.

Flow Enhanced Sensors for MSRs (ANL, Hoyt, $300K)

The goal of this work is to develop a flow-enhanced electrochemical sensor for information on the redox state, salt composition, and local flow rates in MSRs. Argonne's sensor development work will take place in a modular flow testing platform that will permit the simultaneous installation of a variety of complementary safeguards-relevant sensor technologies. Upon completion of the project, the technology is expected to be deployed within molten salt loops.

Challenge:

MC&A Requirements for Pebble Bed Reactors

Provide R&D to Inform Regulatory Efforts
Further Develop MC&A Approaches
Develop Monitoring Technologies

FY21 Activities – Pebble Bed MC&A Activities

Project Objectives and Scope

MC&A for Pebble Beds (ORNL, Gibbs, $175K)

The FY20 work will complete an MC&A approach for Pebble Bed reactors. The scope for FY21 will examine tying in specific technologies into the approach and working with the two WPs below. Fuel handling systems and C/S will be a significant focus of the approach.

Pebble Accountancy for Pebble Bed Reactors (ANL, Gariazzo, $225K)

Argonne will continue to work with Texas A&M University on experimentally validating a conceptual design for item accounting of fuel pebbles that can be applied to pebble-fueled U.S.-designed reactors. The experiment uses embedded inert ZrO2 microspheres within the outer 5mm-thick graphite layer of uranium-dioxide fuel pebbles for unique accounting measures in a U.S.-designed pebble-fueled reactor.

Machine Learning for Video Surveillance of Pebble Beds (BNL, Stern, $225K)

BNL will continue to examine the use of video surveillance for pebble beds to identify a new safeguards approach. Conventional item accountancy of fuel assemblies is difficult to apply to pebble beds which have hundred of thousands of pebbles. The team will work on development of machine learning methods that can help improve the efficiency and effectiveness of video surveillance.

Challenge:

MC&A and PPS Challenges for Microreactors and the use of HALEU

Evaluate Regulatory Gaps/Issues for Microreactors
Develop Approaches Appropriate to the Scale
Evaluate MC&A Technologies
Evaluate Regulatory Gaps/Issues for the use of HALEU

FY21 Activities – Microreactor & HALEU Approaches

Project Objectives and Scope

Framework for Microreactor Safeguards and Security (ANL, Breshears, $175K)

This project will develop a framework that identifies MC&A and PPS requirements for microreactors as a function of size, design, fuel, fuel form, etc. The goal of this work is to help micro-reactor vendors produce quantifiable evidence to the NRC that the unique safeguards advantages and/or challenges for these reactors can be factored into the safety and security licensing procedure.

Radiography of Microreactor Sealed Cores (LANL, Weinmann, $150K)

Technologies to nondestructively image the core of a microreactor are being examined for safeguards purposes in a rapid non-invasive external measurement. It will lay the foundation for high TRL development of the technology into a fieldable product. The project will investigate the variety of technologies currently under development to down-select for the most promising for further development.

Safeguards Challenges for HALEU (BNL, Stern, $120K)

This project will review and assess the US regulatory framework for physical protection and material control and accounting for the use of HALEU in advanced reactors. The review will include an evaluation of regulatory resources.

Challenge:

International Interfaces

Gen-IV PR&PP Working Group Support
Interface with International Programs
Taking International Deployment into Account

FY21 Activities – Gen-IV & IAEA Interface

Project Objectives and Scope

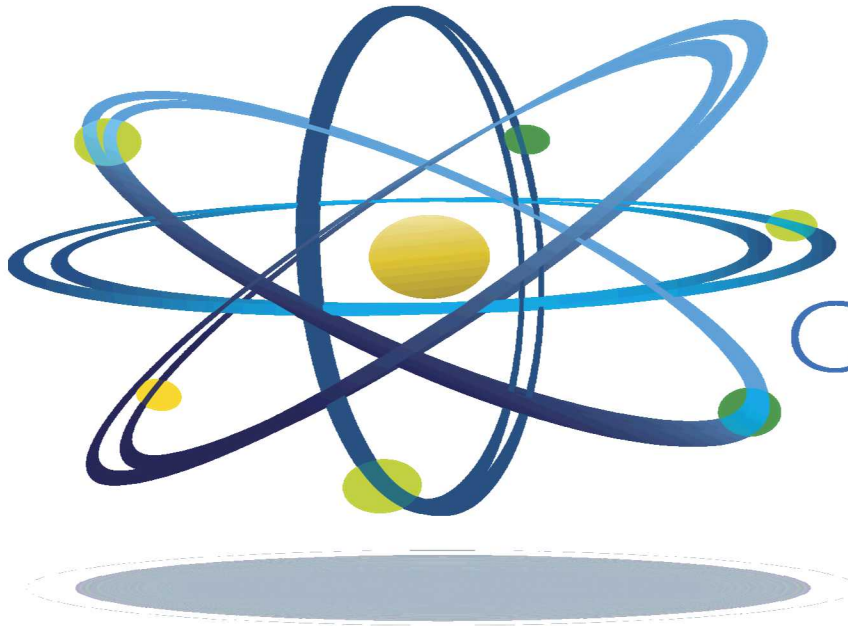
Gen-IV PR&PP Support (BNL, Cheng, $100K)

Provide support for Lap Cheng, a co-chair of the Gen-IV Proliferation Resistance and Physical Protection working group. The groups current efforts to update the six advanced reactor system white papers is strongly aligned with the ARS mission. White papers should be finalized in Spring-Summer of 2021.

Leveraging IAEA Safeguards for Advanced Reactors (PNNL, Orton, $60K)

This project serves as an interface between DOE NE and NNSA programs. Areas of commonalities between international and domestic safeguards requirements and practices will be reported with the goal of informing design choices for advanced reactors to facilitate compliance with both regulatory systems thereby reducing export barriers and the potential need for costly redesigns.

Questions?



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