SAND2024-08738C

ADVANCED REACTOR SAFEGUARDS & SECURITY

Advanced Reactor Safeguards and Security: Solving U.S. Domestic Challenges

INMM Annual Meeting

PRESENTED BY

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July 21-25, 2024

SAND2024-08738C

ARSS Program Goal and Objectives

The ARSS program is addressing near term challenges that advanced reactor vendors face in meeting material control and accounting (MC&A), physical protection system (PPS), and cybersecurity requirements for reactors built in the U.S.

Material Control & Accounting

Systems Level

- PBR MC&A Approach
- MSR MC&A Approach
- Vendor Engagements
- International Coordination

Technology Level

- Measurement Technologies
- Process Monitoring
- Statistical Evaluations

Physical Protection Systems

Systems Level

- SMR PPS Design Approach
- Microreactor PPS Design Approach
- Vendor Engagements

Technology Level

- Advanced Intrusion Detection
- Advanced Delay Technologies
- Advanced Response Tech/Tactics

Cybersecurity

Systems Level

- Cyber-Informed Engineering
- Defensive Cyber Architecture
- Vendor Engagements

Technology Level

- Secure Elements/Tokens
- Supply Chain
- Control System Component Testing

← Interface with Safety →

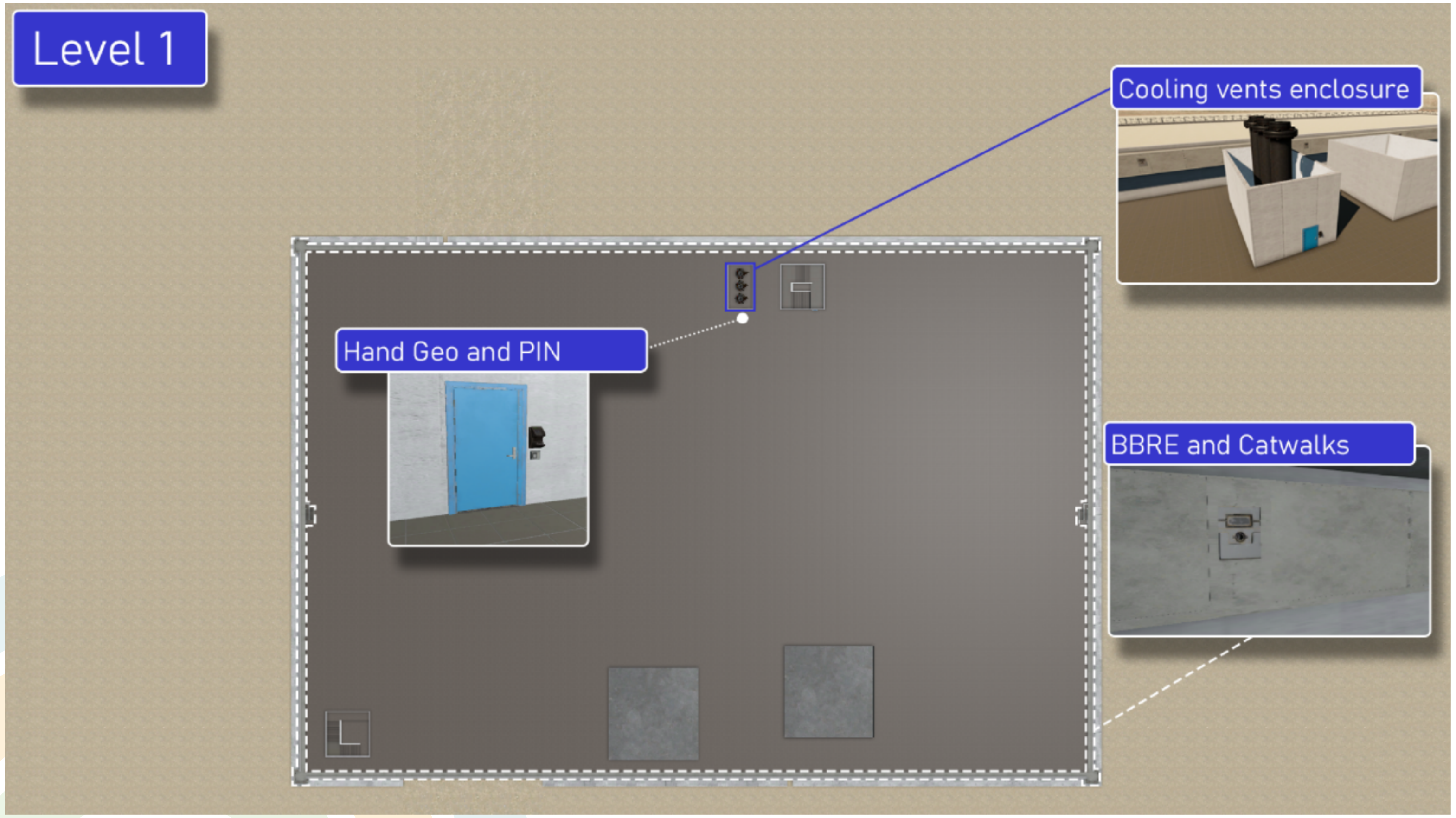
3SBD vs. 2S Interfaces

- The concept of safety, security, and safeguards by design (3SBD) is excellent in theory.
- The reality is that in many cases the 2S interfaces are more important in the design process. Case studies will be presented to discuss:
  - Physical Security – Safety Interface
  - Cyber – Physical – Safety Interface
  - Safeguards – Security Interface
  - Safeguards – Safety Interface

Physical Security – Safety Interface

- Need for emergency exits versus access control (tension)
  - Limiting building access points would be preferred for security, but minimum numbers of exits are a safety requirement.
- Underground siting versus above ground siting (tension)
  - Below grade siting for a small reactor can reduce dose to responders located inside the building.
- Protection of plant safety systems (alignment)
  - Heat rejection to the ultimate heat sink should be protected an ideally located on the roof without easy access.
- Protection of unique sabotage targets (alignment)
  - Sodium coolants (example) are typically contained within hardened walls both for safety and to provide delay against sabotage events.

Protection of Decay Heat Removal Systems



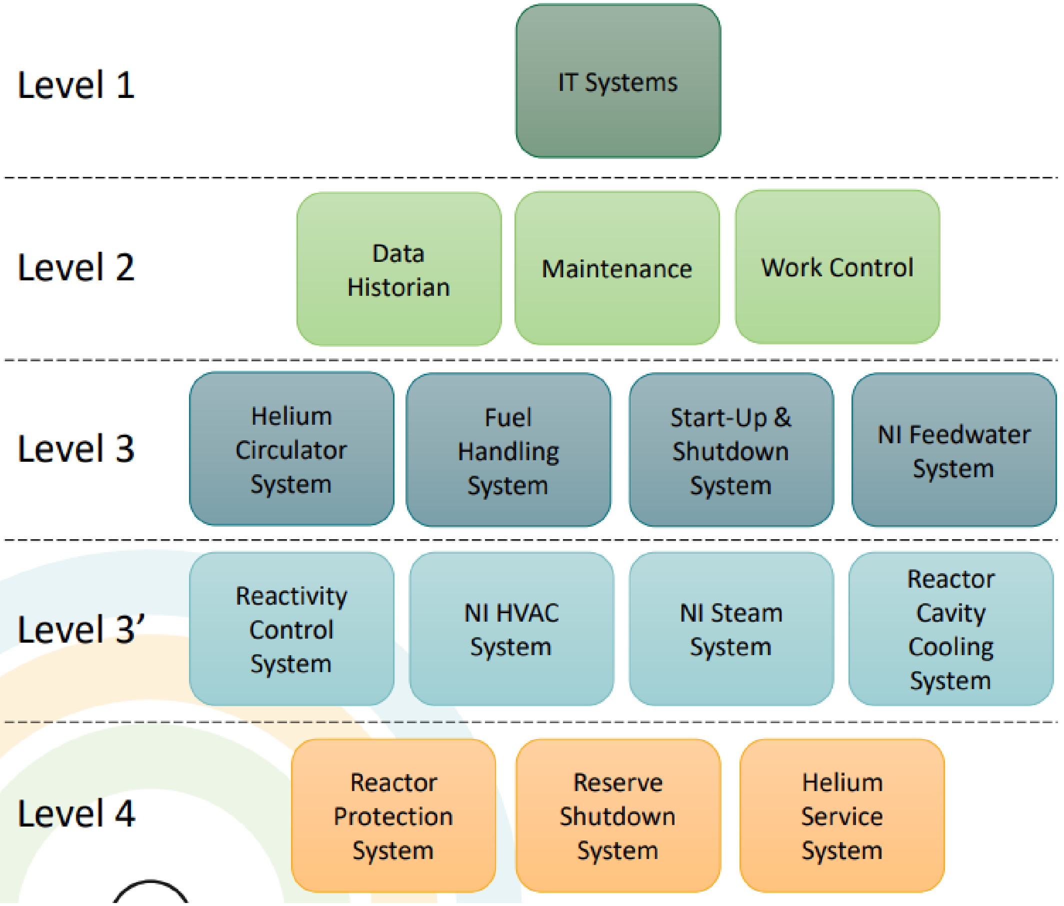
- Cooling vents/heat rejection should be located on the building roof to make access difficult.
- Enclosures or additional delay barriers reduce ease of attack.

Cyber – Physical – Safety Interface

- The interface with safety is a key aspect of cybersecurity by design.
- A probabilistic risk analysis (PRA) is a starting point for Tiered Cybersecurity Analysis (TCA).
  - Tier 1: Eliminate cyber attack pathways which do not lead to unacceptable consequence
  - Tier 2: Identify where denial of access should be designed into the system – Defensive Cybersecurity Architecture (DCSA)
  - Tier 3: Identify where active controls (denial of task) need to be in place.
- As part of the design process, cyber-physical attacks must be considered
  - These attacks fall on a continuum with solely cyber attacks on one end and solely physical attacks on the other end. An adversary may use a physical breach to then gain access to digital systems or they may use a cyber attack to make breaching the plant easier.

Defensive Cybersecurity Architecture

- The DCSA identifies all digital systems and determines the level of cybersecurity controls that must be in place for each.
- Technologies that may be used for cybersecurity protection are defined for each level as well as how communication between levels is controlled.
- The DCSA will also include physical protection systems and those used for material control and accounting.

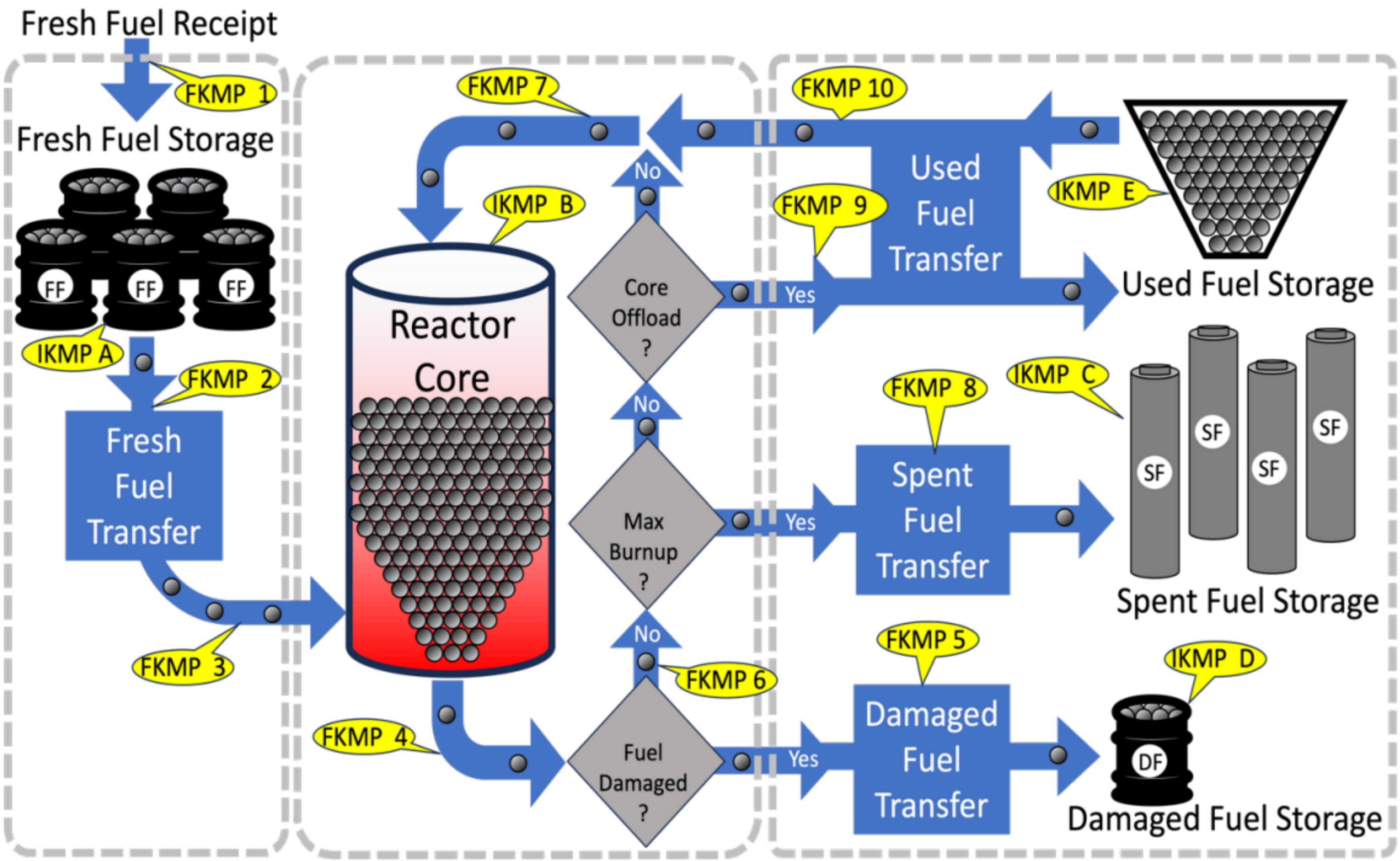


Safeguards – Security Interface

- The “control” aspect of Material Control and Accounting (MC&A) has always been a natural interface between domestic safeguards and security.
  - Existing and future reactors all utilize aspects of physical protection as part of controlling nuclear material.
- Advanced reactors with more unique fuel (pebble beds and molten salt) will benefit from a more combined MC&A-security design approach.
  - Pebble bed reactors have various drivers for pebble accounting
  - Molten salt reactors may utilize containment and control of diversion paths as part of their MC&A approach.

Pebble Bed Reactors: How Well Do We Need to Account for Pebbles?

- From a domestic MC&A and international safeguards perspective, we only need to account for pebbles at the canister level (very dilute).
- From a process control standpoint, every spent pebble needs a burnup measurement (and this can be used to inform MC&A).
- From a physical security perspective we don't want to lose a spent pebble due to the threat of an RDD device.

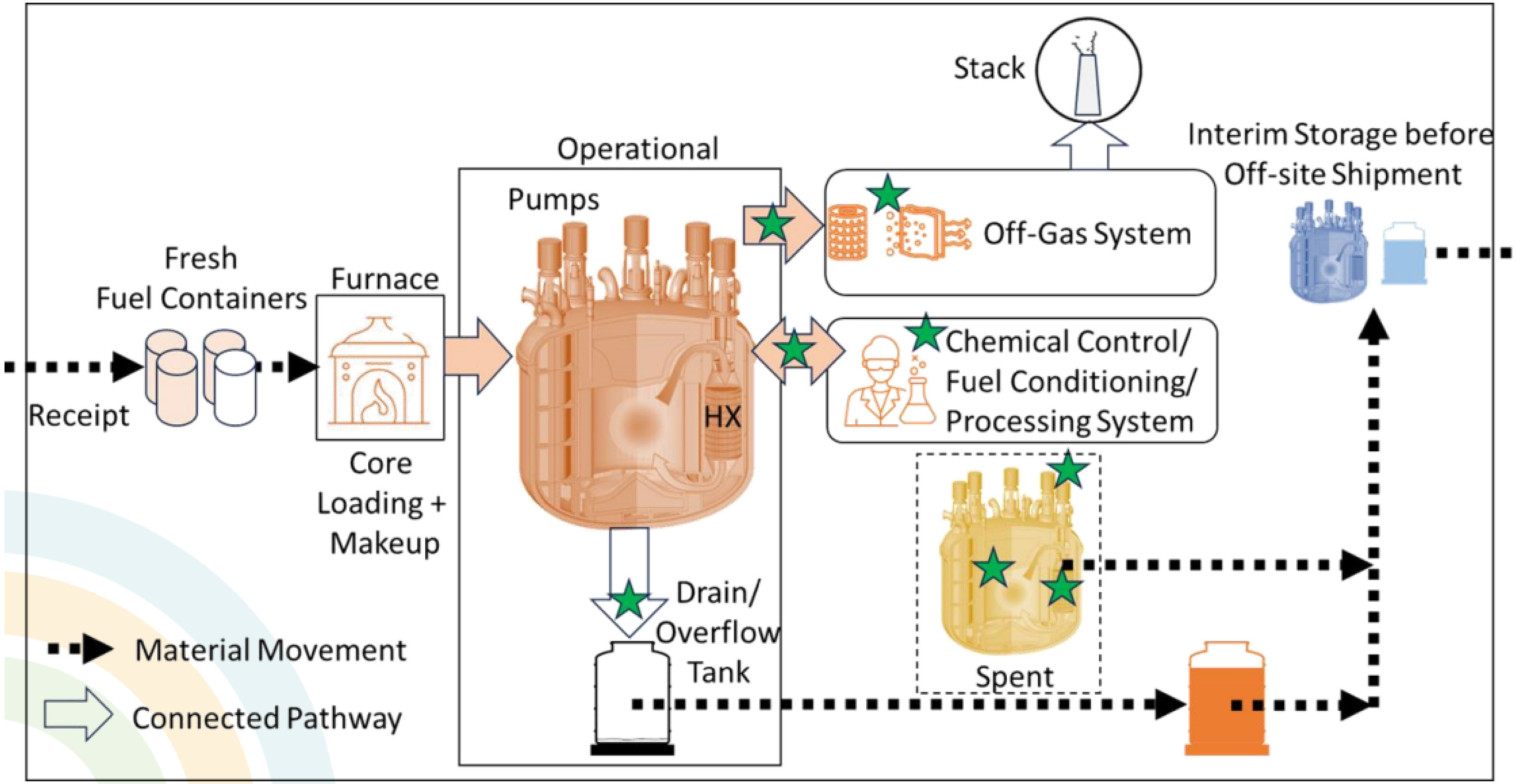


Safeguards – Safety Interface

- Measurements of nuclear material or samples versus dose to workers.
  - Potential measurements of material like pebbles or molten salts need to consider dose to workers/technicians.
- Access to material for inspections (more of an impact on international safeguards).
  - Balance between providing access to nuclear material for inspections and safety of the inspector.
- Holdup and criticality control
  - New reactor designs will have different places where nuclear material may accumulate, which affects MC&A balances and criticality control.

MC&A for Liquid Fueled Molten Salt Reactors

- Current work in the ARSS program is identifying potential holdup locations in a liquid fueled MSR.
- Related work is also looking at more use of containment instead of a material balance across the reactor due to challenges with material accountancy of MSRs.



Conclusion

- New reactors can take full advantage of a 3SBD approach to develop cost-effective yet robust plant protection and monitoring systems.
- In reality, the 2S interfaces are a more useful starting point, but full 3S approaches are evolving.
- The ARSS program plans to develop a series of reports in the 3-5 year time frame on integrated 3S design recommendations for each class of advanced reactor.

Program Contacts

UUR Reports are posted to the program website:

https://energy.sandia.gov/arss

CUI Reports can be shared with vendors, NEI, and NRC provided certain conditions are met to protect the information.

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