

ADVANCED REACTOR SAFEGUARDS

# MC&A Recommendations for Liquid-Fueled MSR

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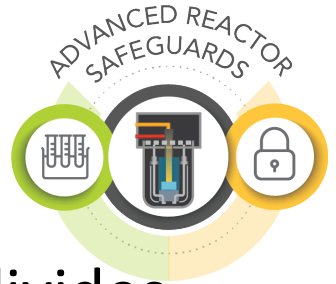
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# Introduction

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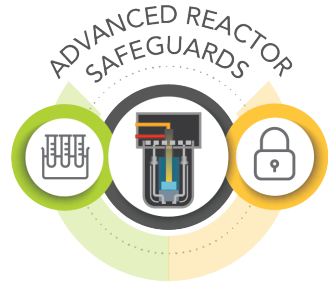


Bottom Line Up Front: We recommend a general MC&A approach that divides the MSR facility into three MBAs, with item accounting on the front- and back-ends and diversion monitoring while the SNM is in difficult to access areas.

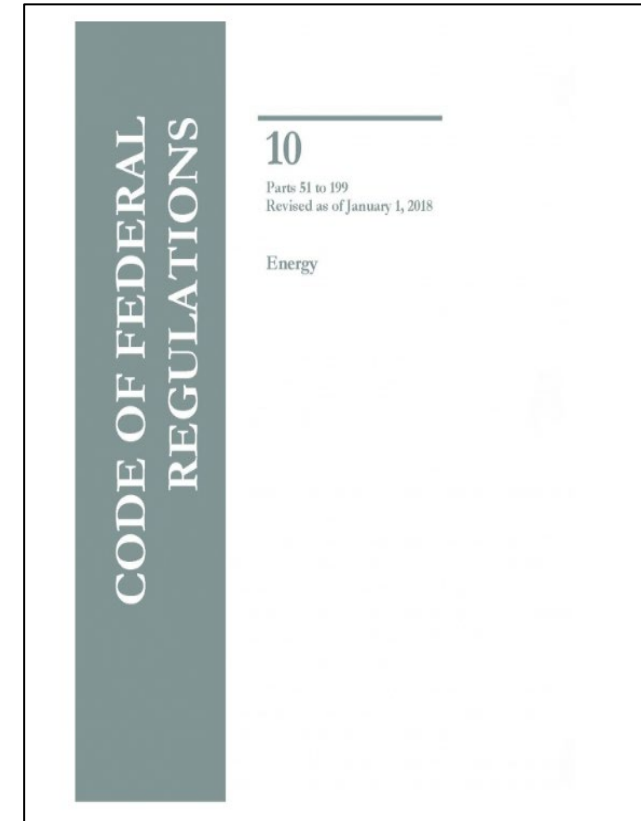
Definition: MC&A is a system of material control measures and material accounting measures to prevent, deter, and detect theft or loss of SNM (U enriched in  $^{235}\text{U}$ , Pu,  $^{233}\text{U}$ ).

- Outline
  - NRC Licensing Context for MSRs
  - Our Recommended Approach for MC&A of MSRs
  - Performance Based Regulation and Diversion Path Analysis
  - Conceptual Implementation of MC&A

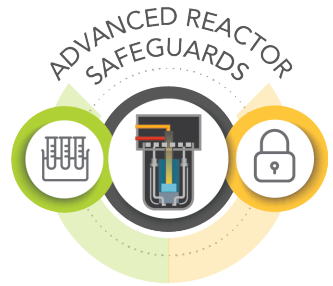
# NRC Licensing for Conventional LWRs



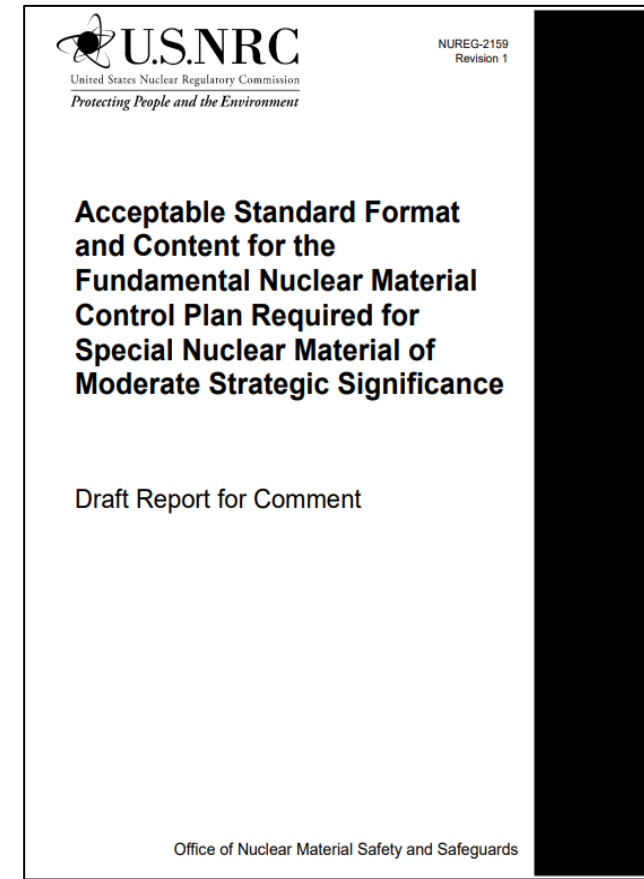
- License applicants for conventional LWRs do not submit a Fundamental Nuclear Material Control (FNMC) plan
  - Exclusion in 10 CFR part 74 for *Utilization Facilities* licensed under 10 CFR part 50.
- LWR assemblies are large, heavy, items with incapacitating dose rates (post-irradiation)
  - Many theft scenarios are not highly credible
- Fresh fuel assemblies are inventoried, loaded into the reactor, and sealed for years, then offloaded to a pool.
  - Used fuel assemblies are inventoried (counted).
  - Once offloaded, SNM is “put on the books” using quantities using computational models.



# NRC Licensing Context for MSRs

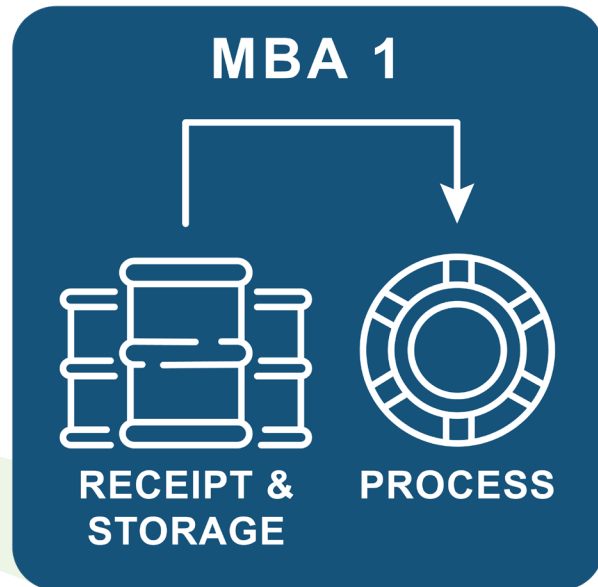


- Fuel fabrication and enrichment facilities **do** submit FNMC plans
  - Bulk facilities with SNM in powder or gaseous form.
  - No transmutation, depletion, and only limited losses due to decay
- MSRs are bulk facilities and will very likely need to develop, submit, and implement FNMC plans
  - No current plans for NRC to develop a modified approach for MSRs
  - No current FNMC template for MSRs

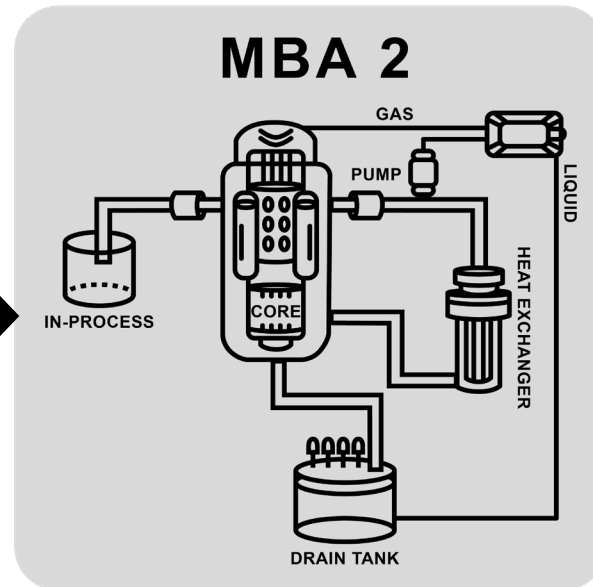




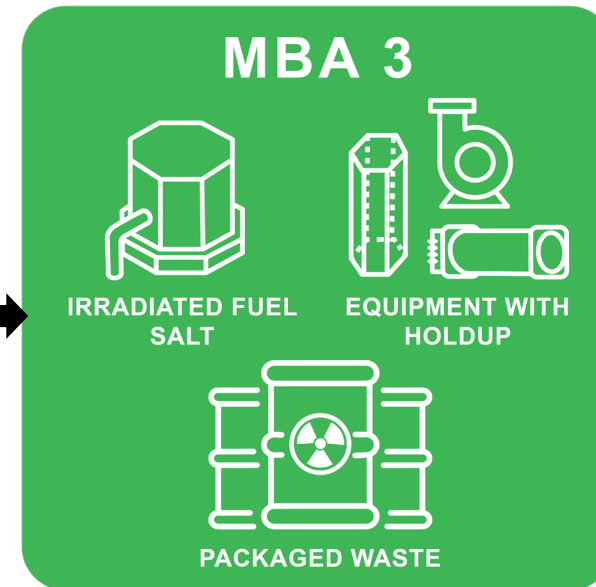
# Recommended MC&A Approach



Periodic inventories performed, IDs and SEIDs calculated  
(follows Part 74 requirements)



Monitoring performed in specific locations to detect diversion



Periodic inventories performed, IDs and SEIDs calculated  
(follows Part 74 requirements)

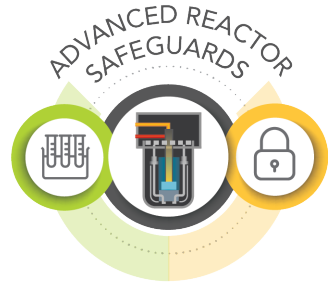
# Comprehensive Process Monitoring Would Be Difficult



- Alternative Approach: treat a liquid-fueled MSR like any other bulk facility and apply 10 CFR Part 74 requirements
  - MSRs aren't the same as fuel fab or enrichment facilities;
    - SNM in process is **highly radioactive** material and not accessible
  - **Inconsistent** with NRC's approach for other reactors
  - Likely **not attainable** with current technologies
    - Thought experiment – consider all parameters necessary to monitor
    - Uncertainties (measurement precision, nuclear data,...) and biases (sensor drift, hold-up,...)
    - If expected and measured don't agree for inventory, NRC notified of "loss or theft"
  - Full process monitoring would be **expensive** to implement, even if possible
  - High level of resources devoted to MC&A is **not necessary** to prevent or detect diversion

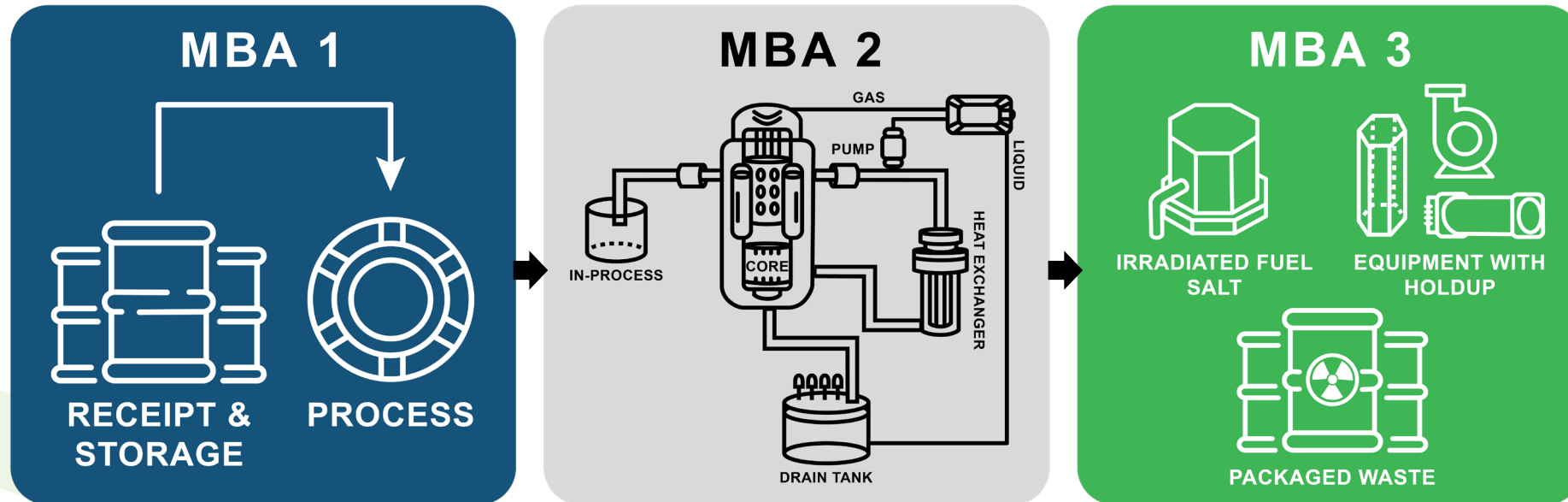
# Measuring Inputs & Outputs Are Not Enough

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- Alternative Option: Only look at material transferred between MBAs (inputs & outputs)
  - SNM in MSR is not in large, heavy countable items
  - Fuel is not stationary and sealed in one location
  - Sampling ports, etc. are possible pathways for material diversion
  - Timely detection of material loss or theft unlikely
  - Would not achieve the purpose of MC&A

# Recommended MC&A Approach

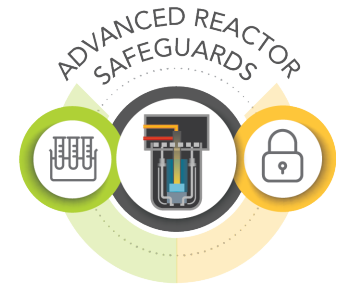


Periodic inventories performed, IDs and SEIDs calculated (follows Part 74 requirements)

Monitoring performed in specific locations to detect diversion

Periodic inventories performed, IDs and SEIDs calculated (follows Part 74 requirements)





# Performance-Based Regulation

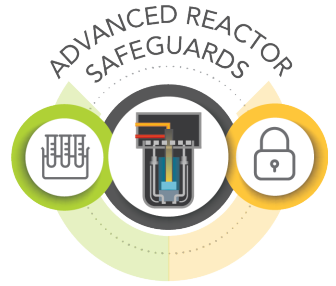
“A regulatory approach that focuses on desired, measurable outcomes, rather than prescriptive processes, techniques, or procedures. Performance-based regulation leads to defined results without specific direction regarding how those results are to be obtained. At the NRC, performance-based regulatory actions focus on identifying performance measures that ensure an adequate safety margin and offer incentives for licensees to improve safety without formal regulatory intervention by the agency.”



Already in use by the NRC

Proposed by ORNL

# Diversion Path Analysis



## Purpose

- Identify potential pathways SNM might be diverted in each process stream by assessing:
  - Approximate quantities of SNM that could be diverted
  - Technical difficulty
  - Indicators of diversion

## Methodology

- Held 3 separate 4-hour brainstorming workshops (in a classified environment)
- ORNL team included SMEs in nuclear engineering, mechanical engineering, chemistry, and safeguards; all familiar with MSRs

## Outcomes

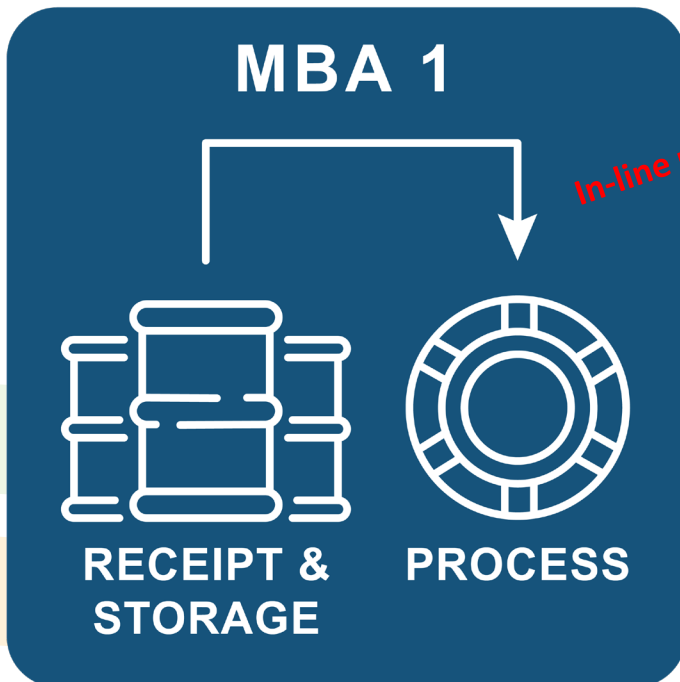
- List of MC&A technical objectives that need to be achieved by MC&A plan
  - E.g., Detect diversion of SNM in containers of fresh fuel salt in storage (or salt components like  $UCl_3$ ), Quantify SNM in used filters from the off-gas system

# Conceptual Implementation of MC&A

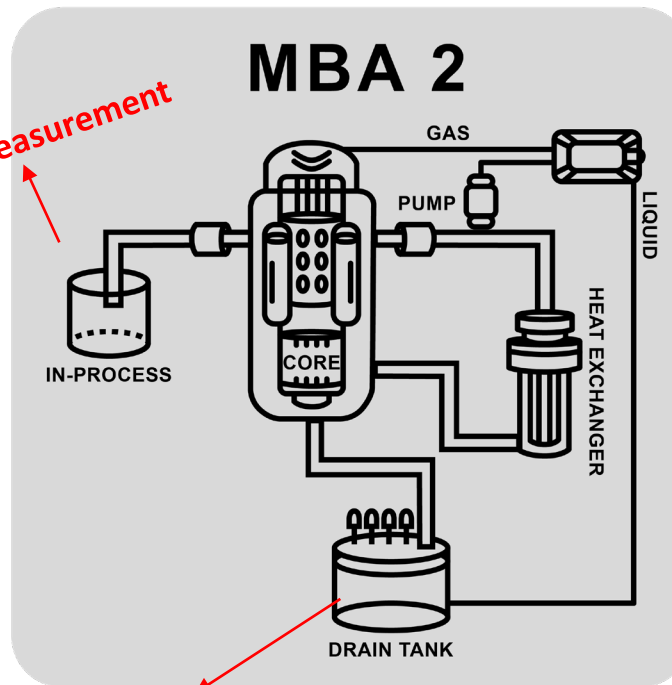


- Gross net weight of containers and transfer tanks
- Gamma spectroscopy on outside of containers
- Verifying TIDs on containers

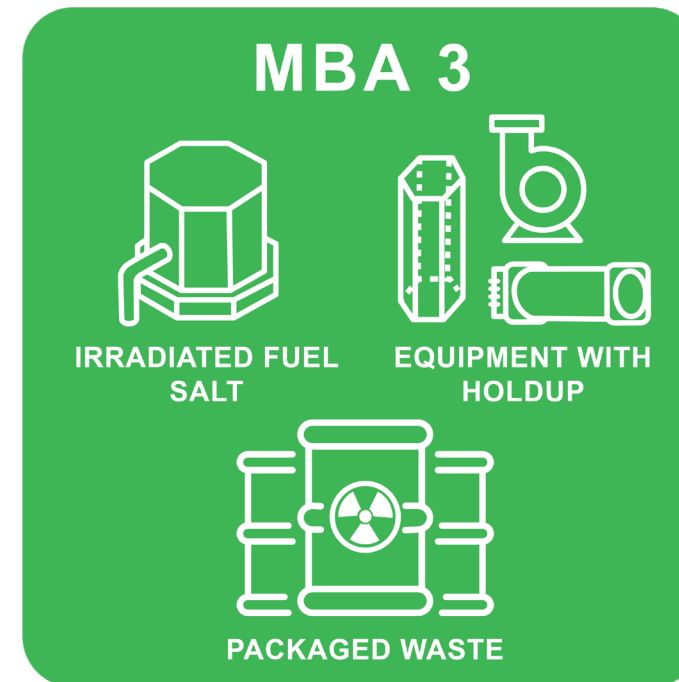
- Gross net weight of any containers and tanks
- NDA measurements on outside of containers
- NDA measurements to quantify residual material
- TID verification on containers



- Gross net weight of containers upon receipt
- Verification of serial numbers, TIDs



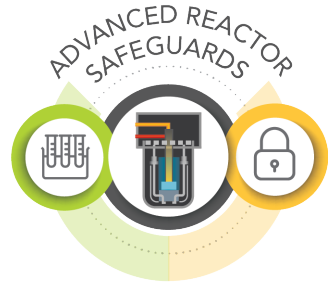
- Gross net weight of tank
- Sample line with mass spec. analysis or in-tank measurements



- Gross net weight of containers prior to shipment
- Verification of serial numbers, TIDs

# Additional Technical Assessments

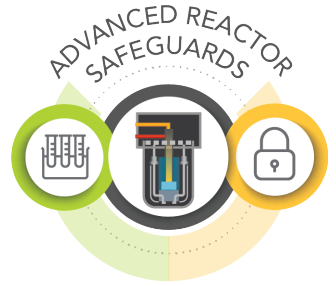
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- Practical recommendations for adding makeup salt
  - Pros/cons of storing makeup salt outside or inside containment
- Assessment of safeguards-relevant open-source MSR designs
  - Thermal vs fast
  - U/Pu vs Th/<sup>233</sup>U fuel cycle
  - TRU vs LEU vs HALEU

# Conclusions and Future Work

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- We recommend a general MC&A approach that divides the MSR facility into three MBAs, with item accounting on the front- and back-ends and diversion monitoring while the SNM is in process.
  - Satisfies the goals of MC&A without process monitoring and ensures diversion pathways are analyzed and monitored
  - Consistent with conventional LWR and bulk facility MC&A
- Future work will include methods to:
  - Quantify hold-up in used equipment
  - Practical containment and surveillance
  - Quantifying SNM in fresh fuel in pipes and tanks