ARPA-E CURIE Workshop: Safeguards by Design for Reprocessing Facilities

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Reprocessing Safeguards

1. Ideas for Where to Focus
2. Safeguards by Design
3. General International Safeguards Components for Reprocessing Facilities
4. DOE/NE Domestic Safeguards by Design Milestone 2020

Reprocessing Safeguards: Where Can We Help?

- Focus on tools that can support domestic or international safeguards applications.
- Domestic nuclear safeguards, regulated by the NRC, is aimed at "**ensuring that special nuclear material within the United States is not stolen or otherwise diverted from civilian facilities… and does not pose an unreasonable risk owing to radiological sabotage**."
  - Focused on non-state actors, theft and sabotage
- International nuclear safeguards, developed and implemented by the IAEA, is to "**to deter the spread of nuclear weapons by the early detection of the misuse of nuclear material or technology."**
  - Focused on state-sponsored diversion and misuse
- So, what can we do to support the safe and secure utilization of current nuclear energy technologies and help prepare for advanced nuclear energy fuel cycle technologies???

Nuclear Material Accountancy and Process Monitoring

- Both domestic and international nuclear safeguards utilize nuclear material accountancy (NMA) and process monitoring (PM) as components to accomplish objectives.
- Develop and demonstrate NMA and PM tools and technologies that may support the NRC and IAEA in the implementation of their respective responsibilities
  - Improved efficiency and accuracy where needed
  - New NMA and PM tools to address gaps or new fuel cycle technologies
- Engage and utilize the NRC and NNSA through appropriate support infrastructure to enable evaluation (and if appropriate) implementation and acceptance of these tools for routine use.
  - E.g. In the case of IAEA technical support, coordination with DOE/NNSA Office of International Nuclear Safeguards. In the case of domestic safeguards, coordination with the NRC.

NMA and PM Objectives for Reprocessing Facility

- There are no commercial U.S. domestic reprocessing facilities. The NRC has worked on developing reprocessing/recycling regulatory framework, but it is incomplete. Therefore, it is important to engage with the NRC before making any specific assumptions about NMA/PM deployment.

- The IAEA has developed and implemented several safeguards approaches for commercial and research reprocessing facilities.

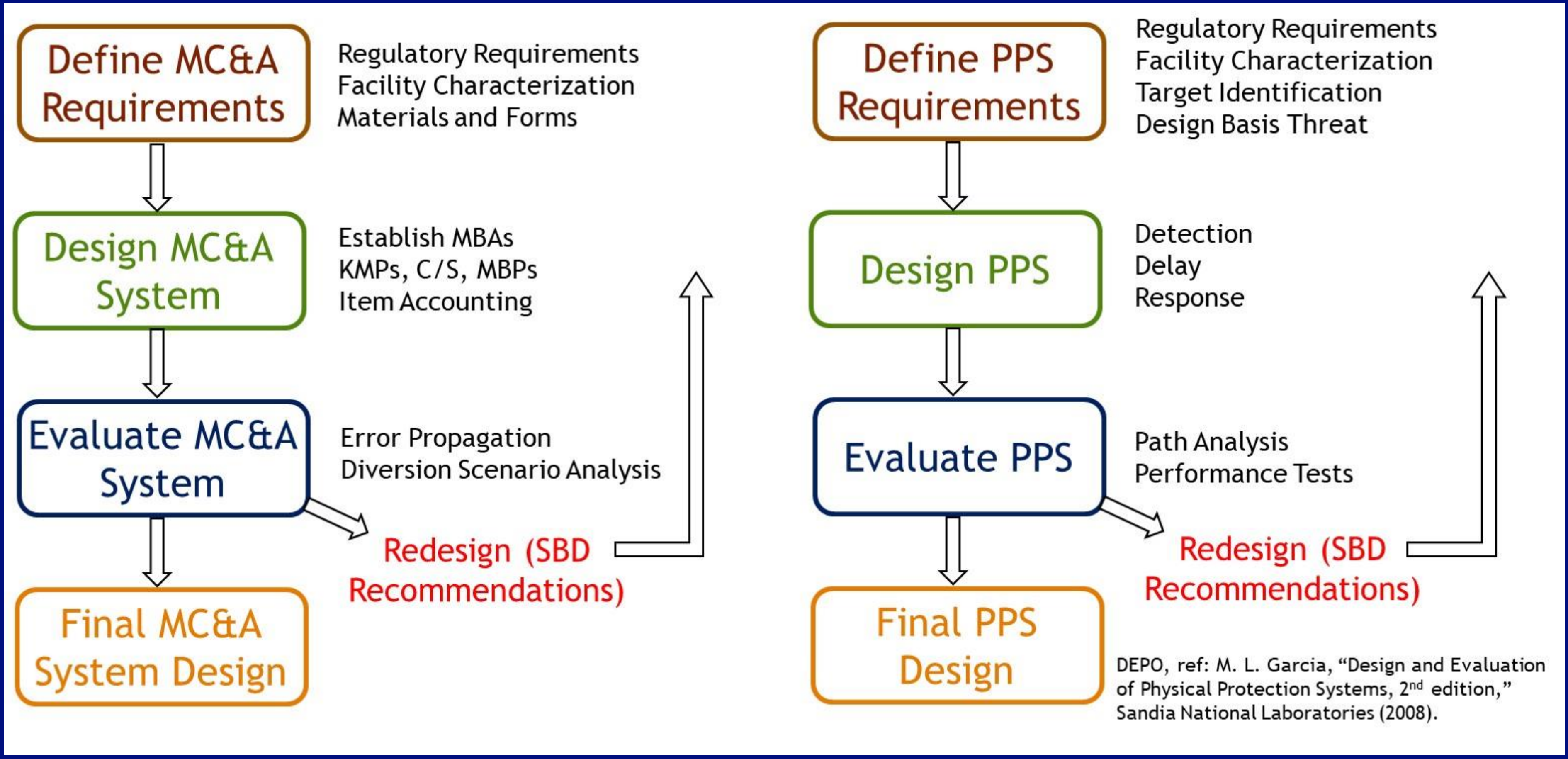
- For NMA/PM development purposes, it is most useful to look at the IAEA safeguards approaches, measurement objectives, and timeliness goals

International Safeguards By Design (SBD)*

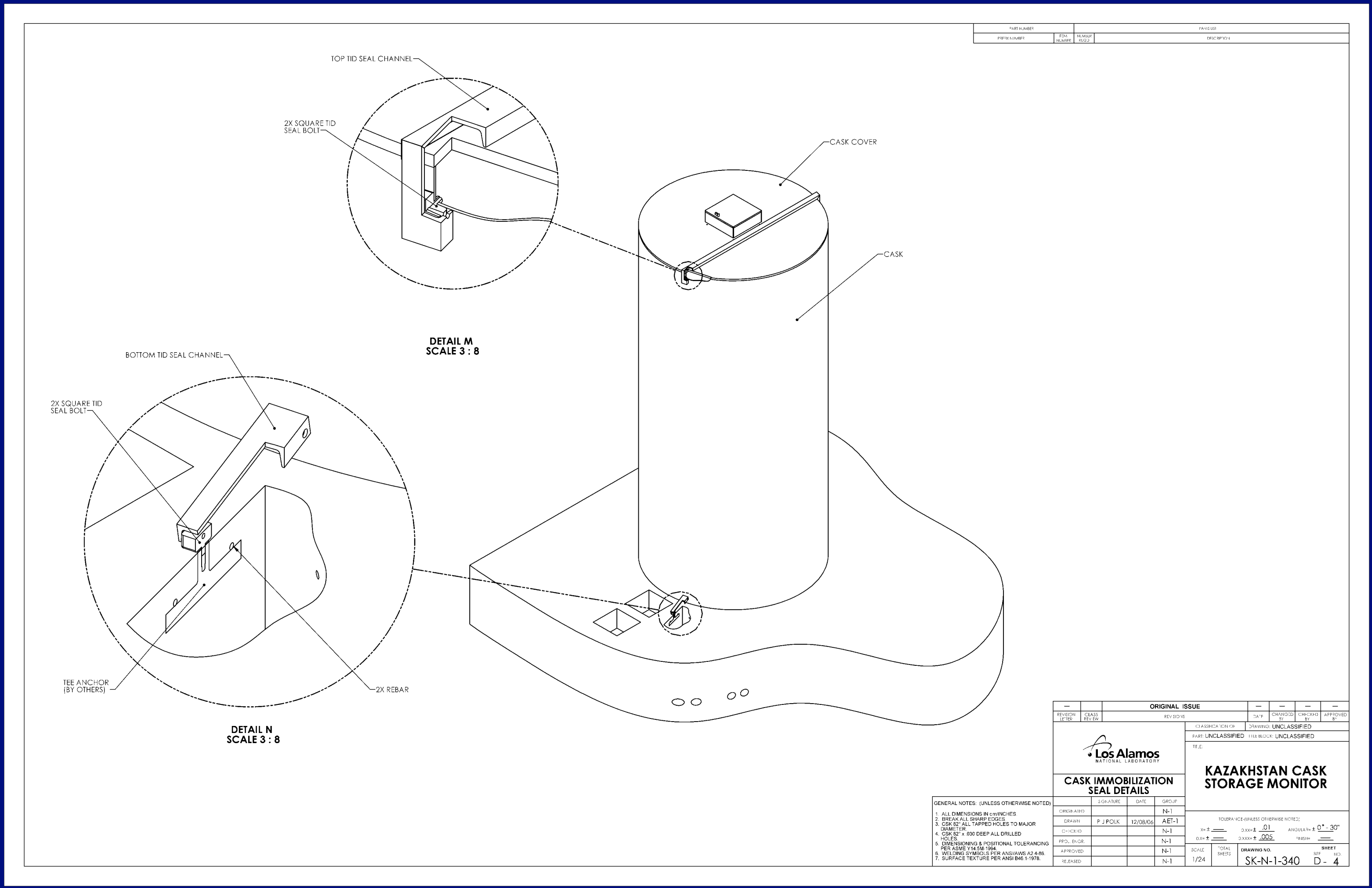
- SBD is defined by the IAEA as “an approach whereby international safeguards requirements and objectives are fully integrated into the design process of a nuclear facility, from initial planning through design, construction, operation, and decommissioning.”
- SBD benefits include:
  - Minimizing risk associated with project scope, schedule, budget, and licensing
  - Reducing the costs of safeguards implementation to the operator and the IAEA
  - Decreasing costs for State regulators
  - Improving safeguards assurances to the international community and the general public
- Critical to identify stakeholders early in the SBD process and incorporate reviews/feedback with all parties. Stakeholders include, but not limited to:
  - Facility owners & operator
  - Facility designer
  - IAEA
  - Safeguards regulatory authority
  - Equipment suppliers
  - Scientific & technical services

* International Safeguards in Nuclear Facility Design and Construction; NP-T-2.8

Safeguards and Security System Design Process



SBD Real World Example: Maintaining COK & Reverification



SBD Real World Example: Maintaining COK

Safeguards Inclusions

Seals for Maintaining COK

SBD Real World Example: Reverification

Cask Concrete Section for
Neutron Measurements

Safeguards Reverification Detector

SBD Real World Example: Who was Involved

- Who was involved:

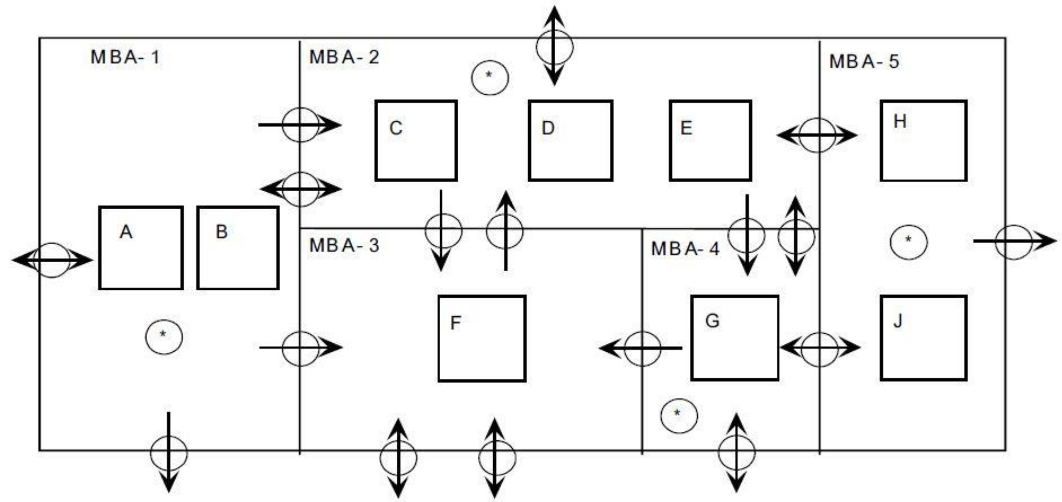
- Cask designer
- Cask manufacturers
- Cask licensing authority
- IAEA – Operations
- IAEA – Concepts and Approaches
- IAEA – Technical services
- In–country regulator
- In-country physical protection authority
- Facility operator
- Multiple U.S. organizations & technical experts

General International Safeguards Components for Reprocessing Facilities

- Focus on IAEA safeguards components as we have examples to draw on (TRP, Rokkasho)
- Focus on technical infrastructure supporting reprocessing safeguards approaches, but not the safeguards approaches themselves
- Some of the key NMA/PM areas for international safeguards on a reprocessing facility:
  - Establishing input accountancy
    - NMA as the spent fuel goes through change in form (assuming current reactor technology like a PWR)
  - Nuclear material accountancy throughout processing
    - Remote operations
    - High dose rates
    - Maintaining COK on samples
  - Final product NMA
  - Holdup NMA
  - Waste NMA

General International Safeguards Components for Reprocessing Facilities

- RRP is a large facility; 800 MTU/yr
- RRP MBA structure and KMPs are relatively straightforward.
- Many technical systems support this structure
- Important to engage both regulator (NRC/IAEA) as well as facility designer/builder/operator in order to adequately define MBAs, IKMPs, and FKMPs in a manner that reflects the processing flow.
- International safeguards – DIQ and DIV process is critical



MBA-1: Spent fuel receipt and storage area, Head-end area
MBA-2: Main process area (including U conversion and laboratories)
MBA-3: Waste treatment and storage area
MBA-4: MOX conversion area
MBA-5: Product storage area

IKMP A: Spent fuel receipt and Storage area
IKMP B: Head-End area
IKMP C: Nuclear material in main process area
IKMP D: Nuclear material in the analytical laboratory
* : Nuclear Loss
IKMP E: Nuclear material in the U conversion area
IKMP F: Nuclear material in the waste treatment and storage area
IKMP G: Nuclear material in the MOX conversion area
IKMP H: UO3 product material in the storage area
IKMP J: MOX product material in the storage area

Development of the safeguards approach for the Rokkasho Reprocessing Plant; S.Johnson et al IAEA-SM-367/8/01

RRP – Lessons Learned

- RRP safeguards was the evolution of material balance procedures & inspections from a U.S. reprocessing facility, and IAEA experience in Germany and Japan.
- RRP safeguards development was a massive SBD effort involving Japan, IAEA, and the U.S.
- SBD process enabled process flow/controls to support safeguards activities.
- Even with SBD engagement, issues arose during construction and early operations that required coordination among stakeholders
- “But clearly the most relevant lesson learned from both RPP and all previous efforts by IAEA to deploy international safeguards is that the involvement and dialog between all interested parties must start from the earliest stages of the project” *

* Lessons Learned in International Safeguards – Implementation of Safeguards at the Rokkasho Reprocessing Plant: S. Johnson & M. Ehinger ORNL/TM-2010/23

MPACT Milestone 2020 (Lead by Ben Cipiti – SNL)

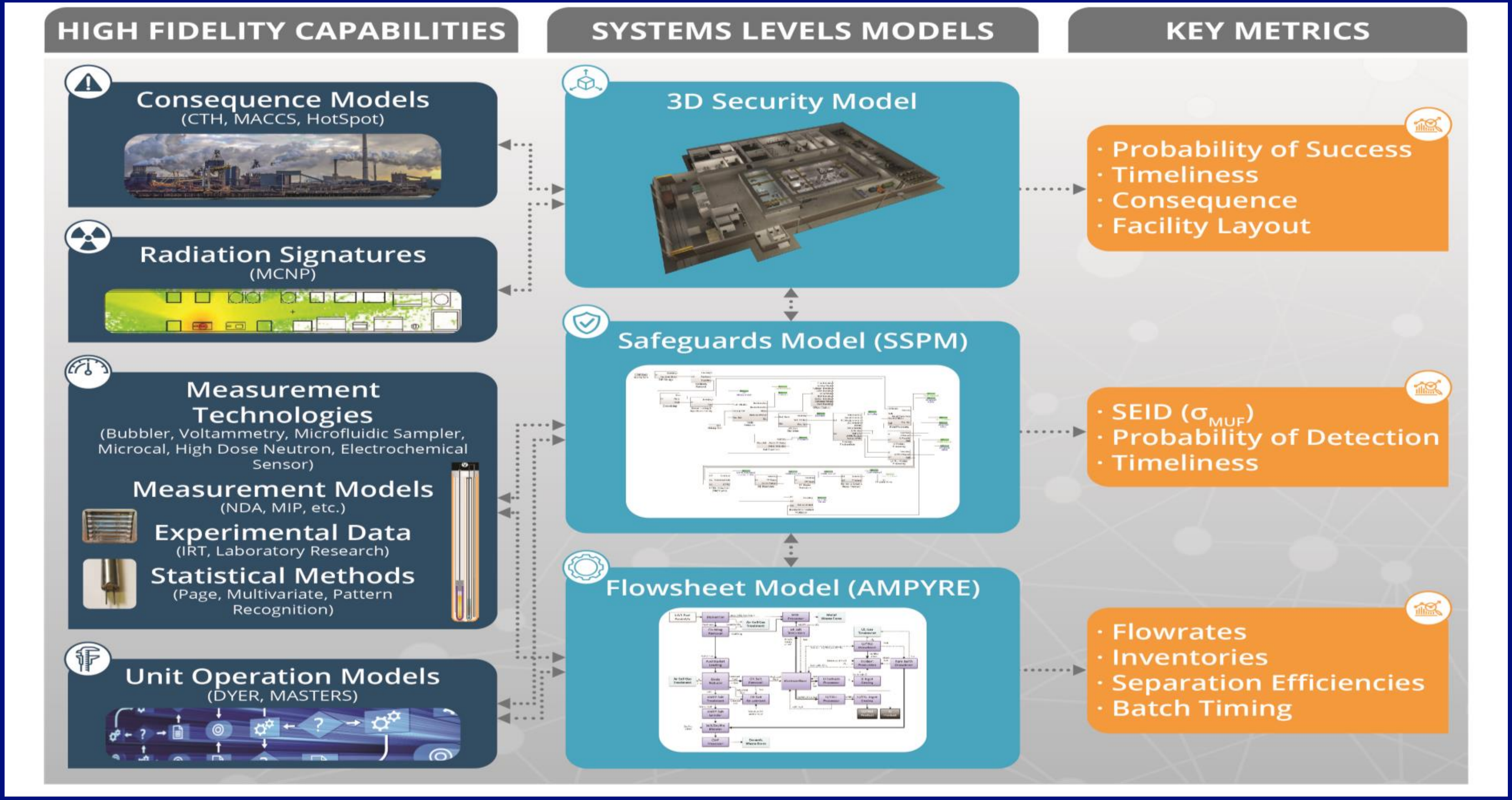
- The Materials Protection Accounting and Control Technologies (MPACT) working group completed a 2020 Milestone to demonstrate **Safeguards and Security by Design (SSBD)** for next generation nuclear facilities.
- The 2020 milestone was encompassed in a **Virtual Facility Distributed Test Bed** that incorporates measurement technologies, data from field testing, and mod/sim tools to demonstrate SSBD.
- The milestone used an **electrochemical processing facility** as an example, but the tools can be extended to other fuel cycle facilities. The results were published in a special issue of JNMM (Spring of 2021).
- The effort concluded with preliminary material control and accountancy and physical protection system designs, and also several SSBD recommendations.

Journal Papers

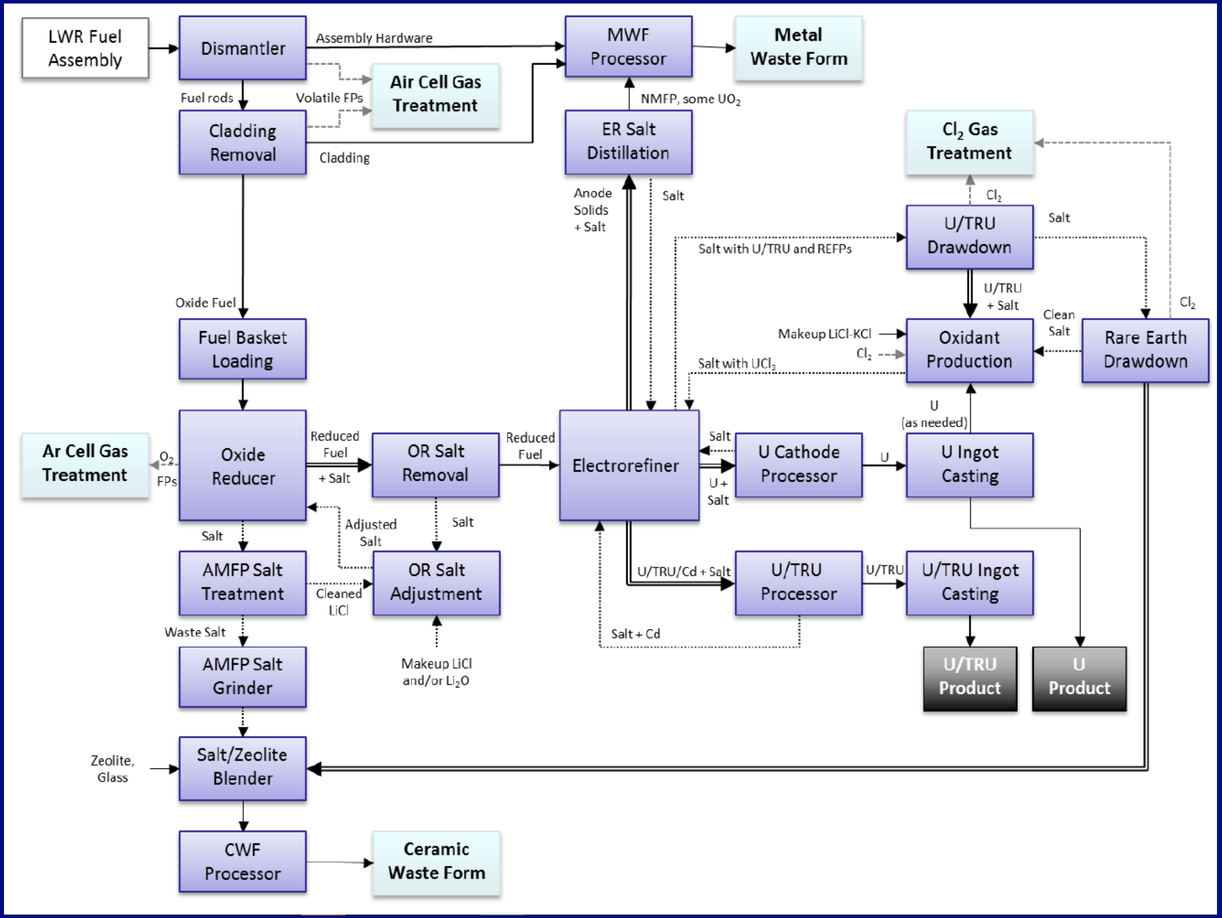
- 9 papers published in a special issue of the Journal of Nuclear Material Management (Spring 2021)
  - Papers include contributions from 4 National Laboratories (ANL, INL, LANL, SNL) and 6 universities under coordinated Nuclear Energy University Program (NEUP) activities (Oregon State University, Virginia Polytechnic University, University of Tennessee, Ohio State University, University of Utah, University of Colorado)

- MPACT is applying Milestone 2020 framework to other NE fuel cycle R&D processes to facilitate domestic safeguards and security by design as well as answer questions that may come up in broader fuel cycle analysis.

Virtual Facility Distributed Test Bed



Facility Design Starts by Defining the Flowsheet

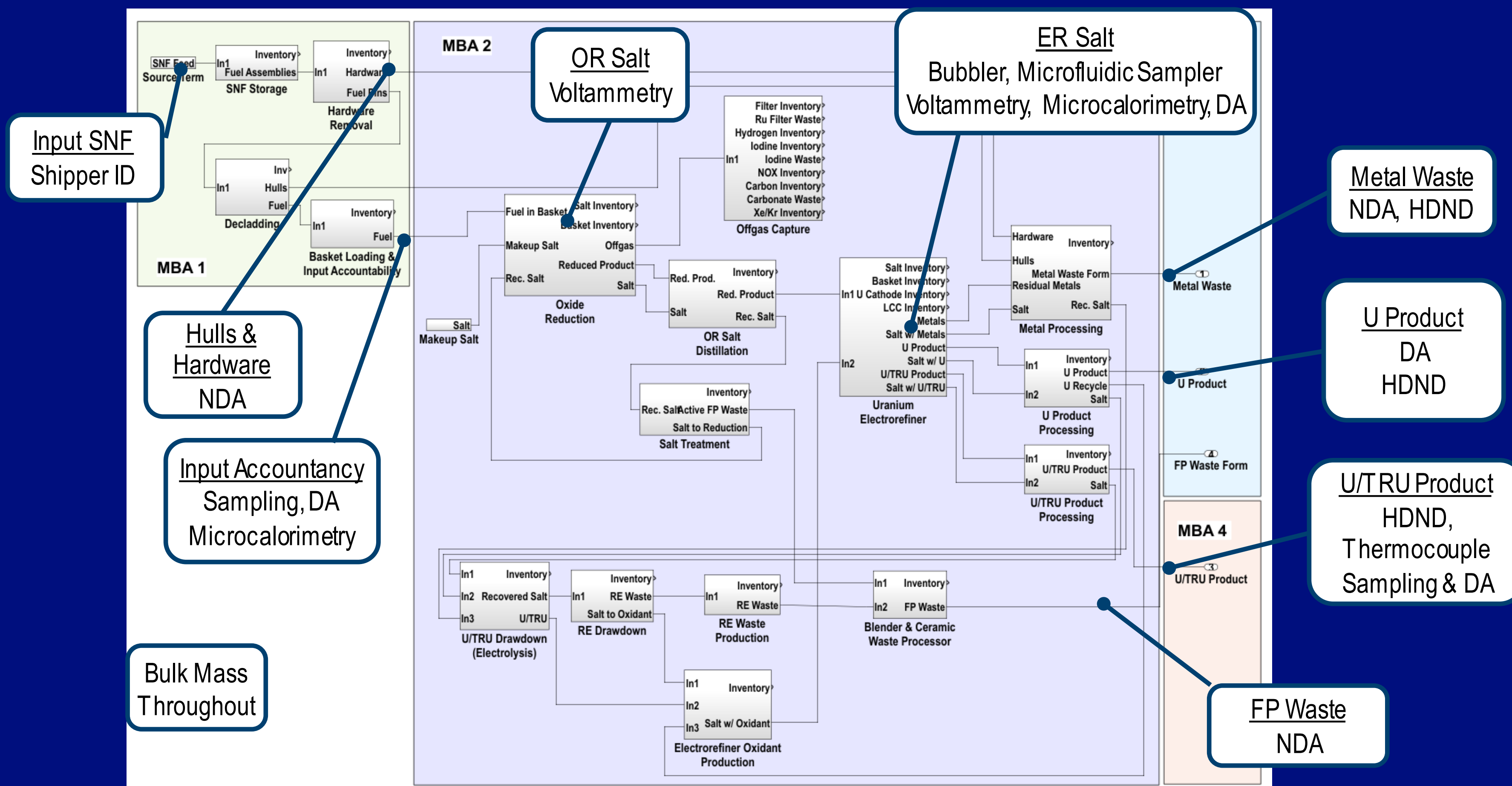


- The flowsheet defines the facility and provides data to inform the other modeling capabilities.
- SSBD recommendations may be used to alter the flowsheet and facility design

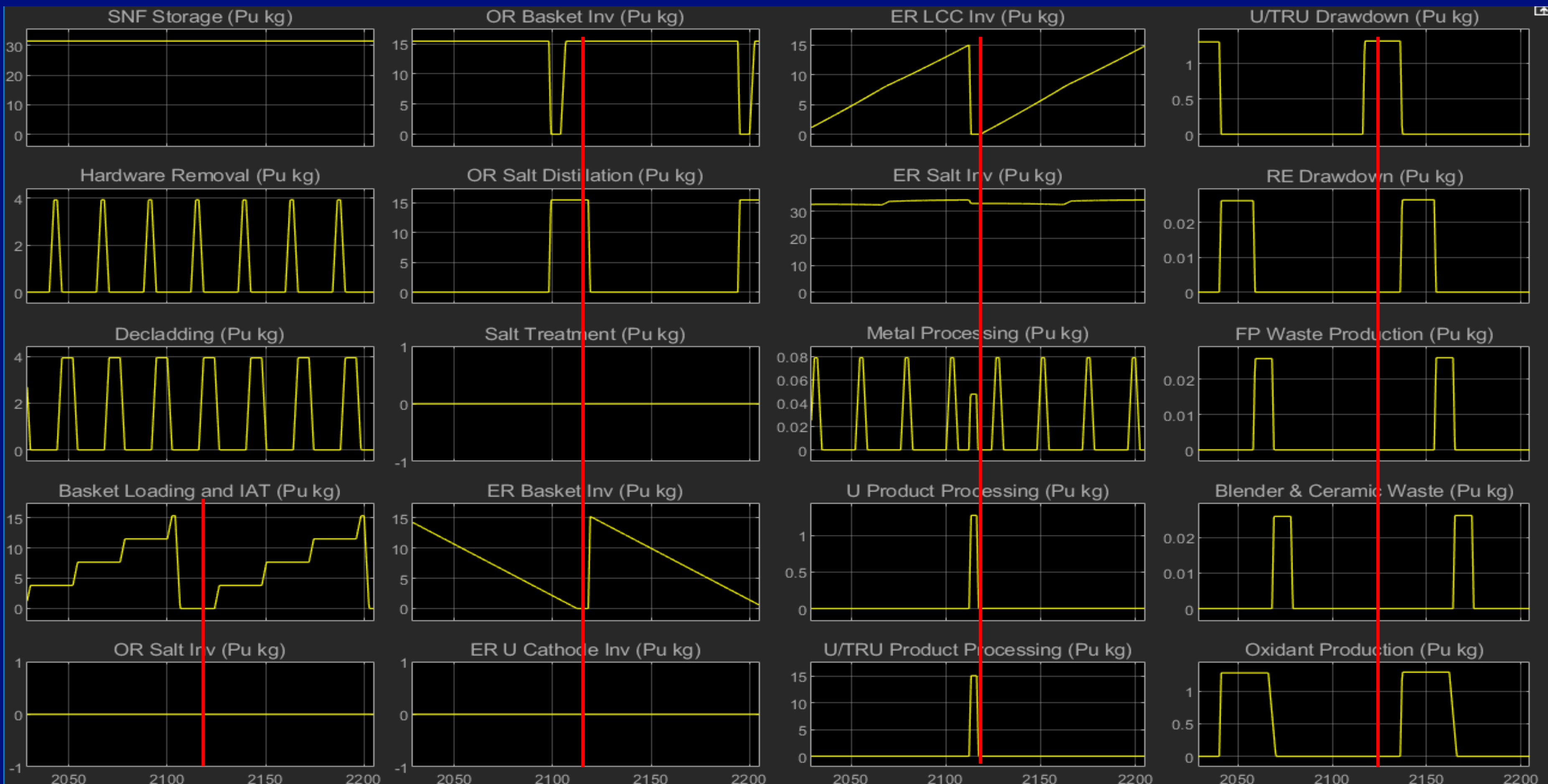
Key Safeguards NMA/PM Areas

- **Plant Flushouts** – Some plant designs are not suited to a yearly plant flushout, so will require reliance on inventory measurements.
- **Input Accountability** – Since fuel is not dissolved before processing, how to provide low uncertainty measurements.
- **Obtaining Representative Salt Samples** – Process salts have inhomogeneities that makes sampling difficult.
- **Accountability of Metallic Products** – Metallic products present different measurement forms.
- **Holdup** – Both process and residual holdup must be identified in any bulk handling facility
- **Confirmatory Measurements in the Hot Cell** – Difficult measurement conditions with the high dose environment.
- **Process Monitoring Information** – Pyroprocessing has unique additional information that can be part of the safeguards approach.

Develop the MC&A Approach

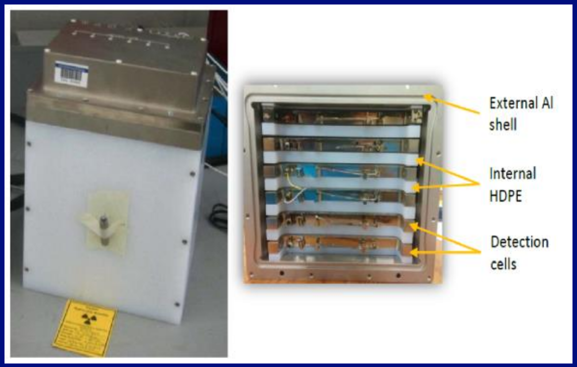


Proper Material Balance Timing



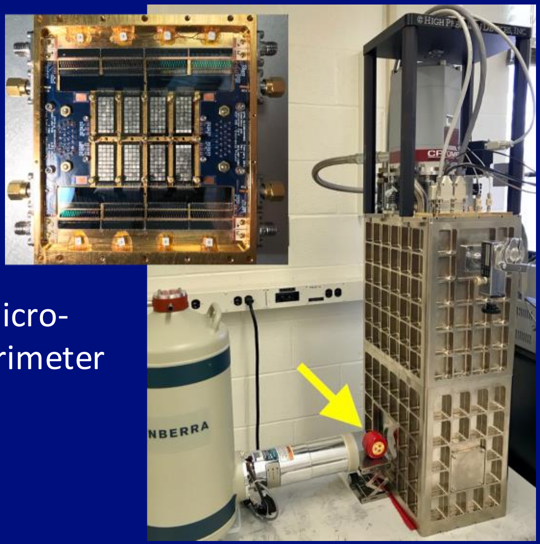
Los Alamos
NATIONAL LABORATORY

Measurement Technologies to Support MC&A



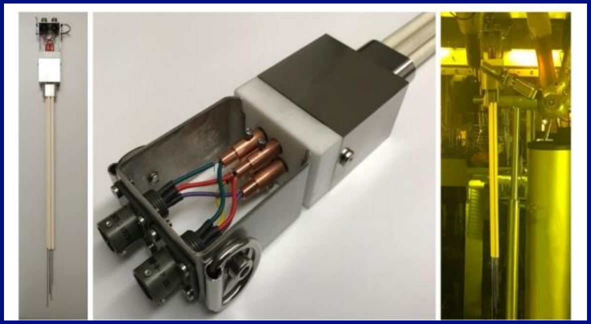
High Dose Neutron Detector

Triple Bubbler

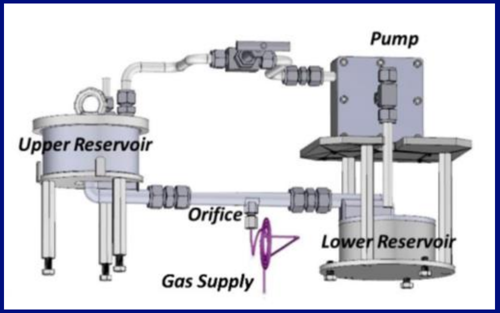


Micro-calorimeter

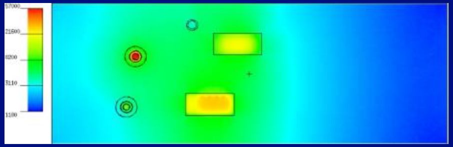
Voltammetry Sensor



Sample Extractor



Hot Cell Flux Mapping



Advanced Integration