The MPACT 2020 Milestone: Lessons Learned

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MPACT Program Area

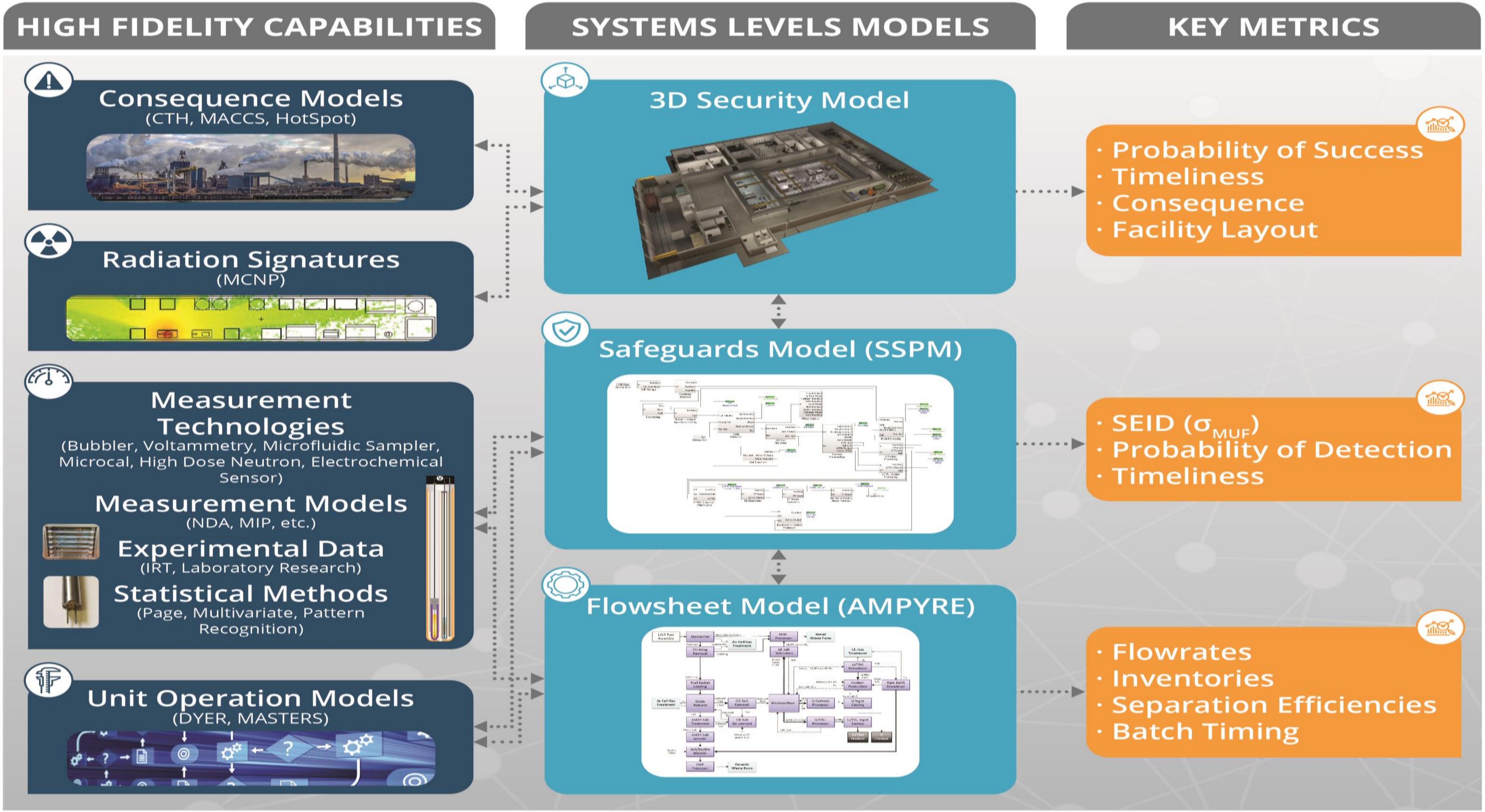
- The Materials Protection Accounting and Control Technologies (MPACT) working group completed a 2020 Milestone to demonstrate **Safeguards and Security by Design (SSBD)** for next generation nuclear facilities.

- The 2020 milestone is encompassed in a **Virtual Facility Distributed Test Bed** that incorporates measurement technologies, data from field testing, and mod/sim tools to demonstrate SSBD.

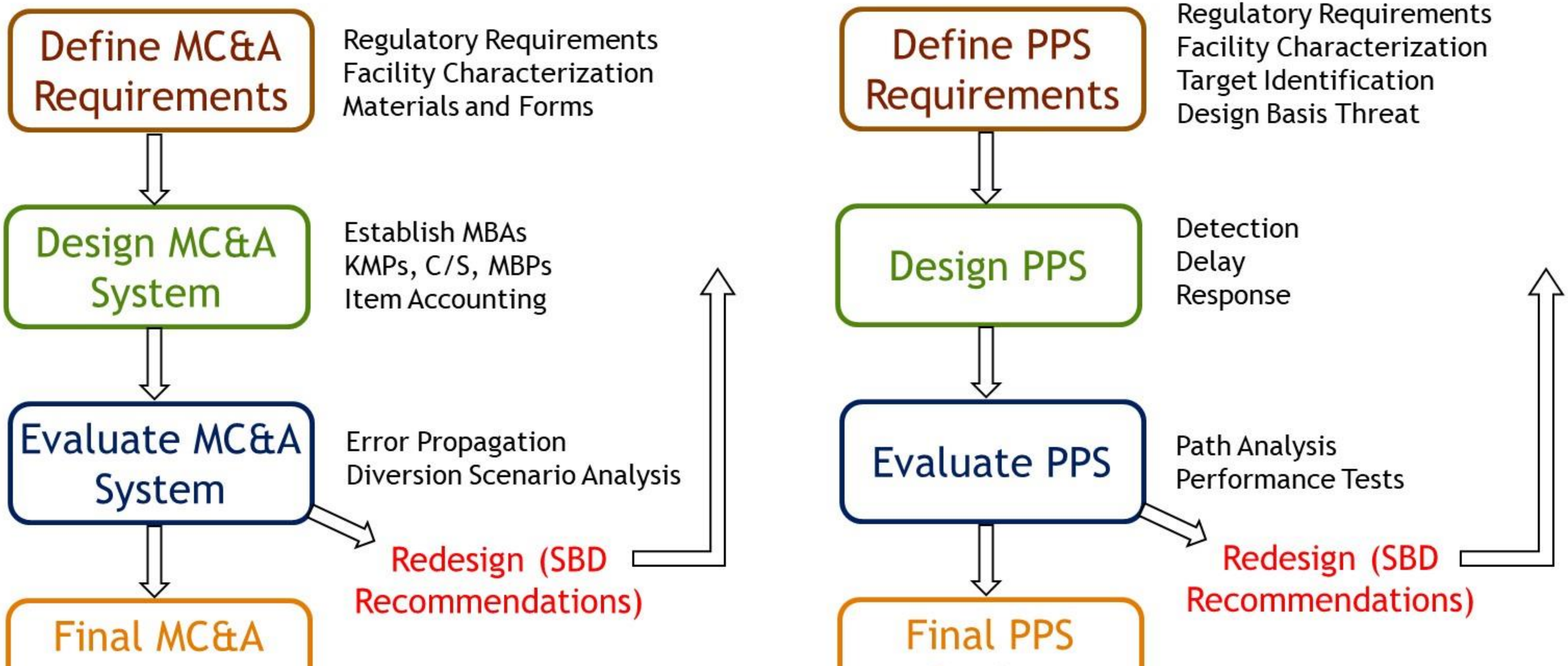
- The milestone used an **electrochemical processing facility** as an example, but the tools can be extended to other fuel cycle facilities. The results will be published in a special issue of JNMM (Spring of 2021).

- The effort concluded with preliminary material control and accountancy and physical protection system designs, and also several SSBD recommendations.

Virtual Facility Distributed Test Bed

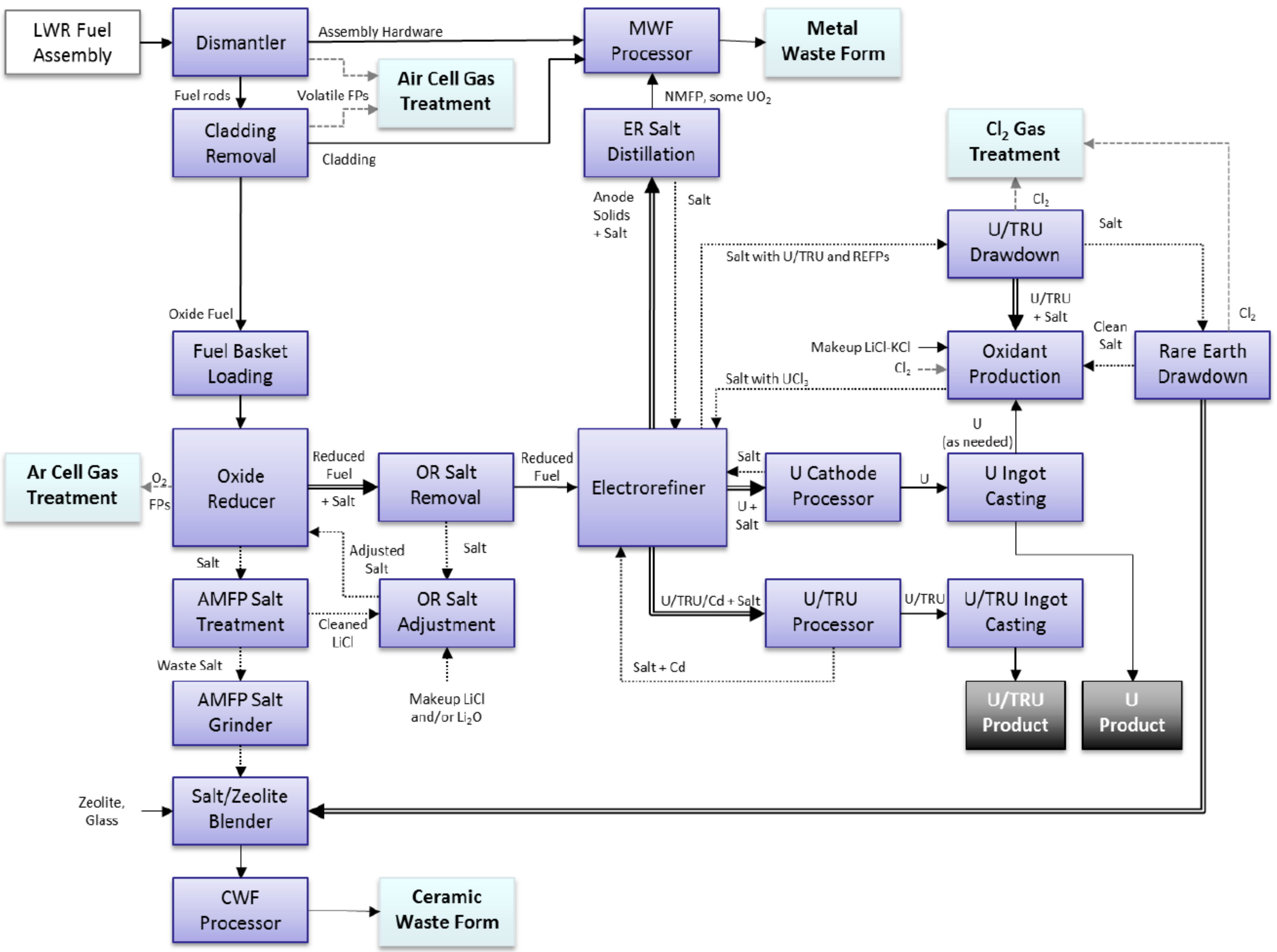


Safeguards and Security System Design Process



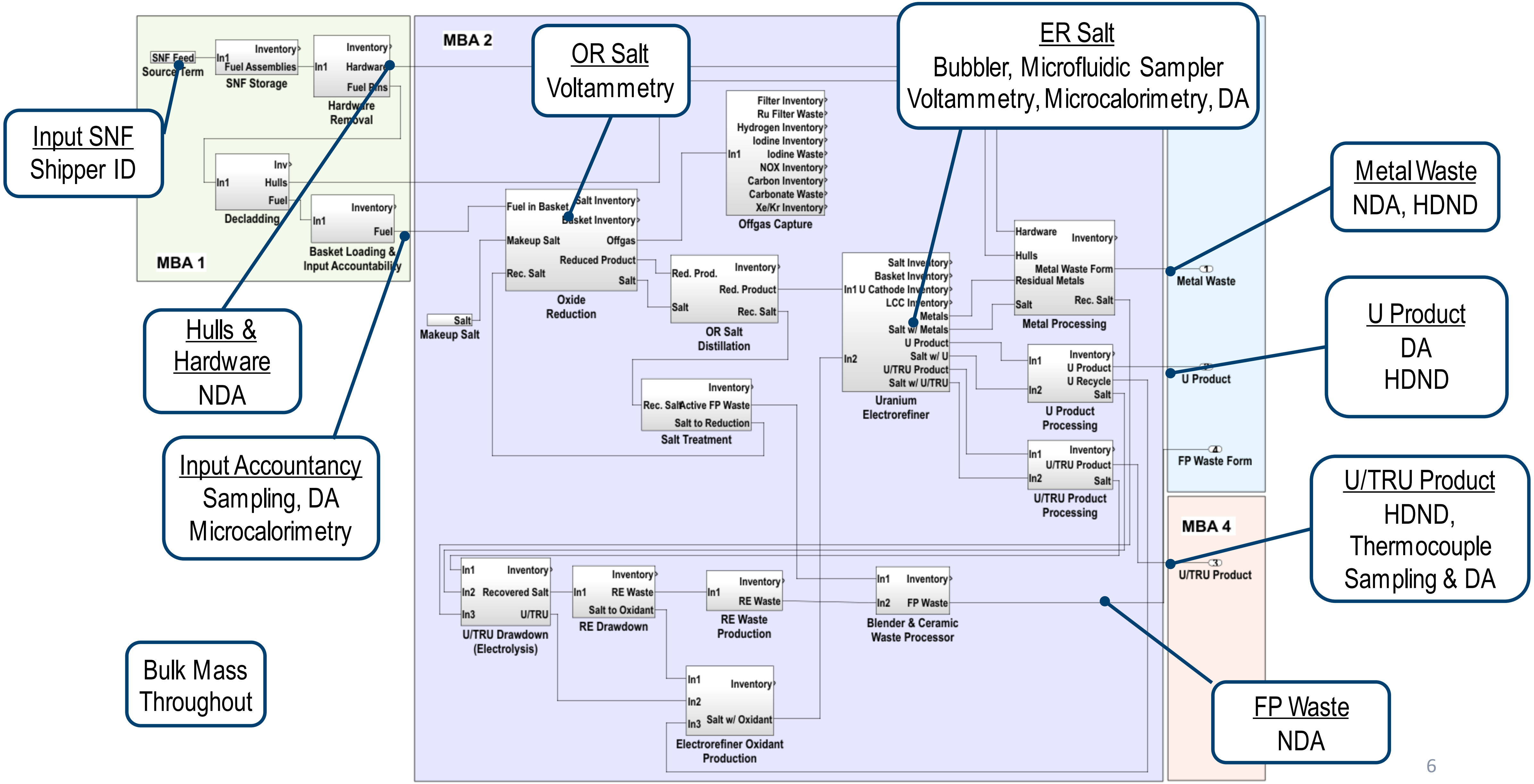
DEPO, ref: M. L. Garcia, "Design and Evaluation of Physical Protection Systems, 2nd edition," Sandia National Laboratories (2008).

Facility Design Starts by Defining the Flowsheet

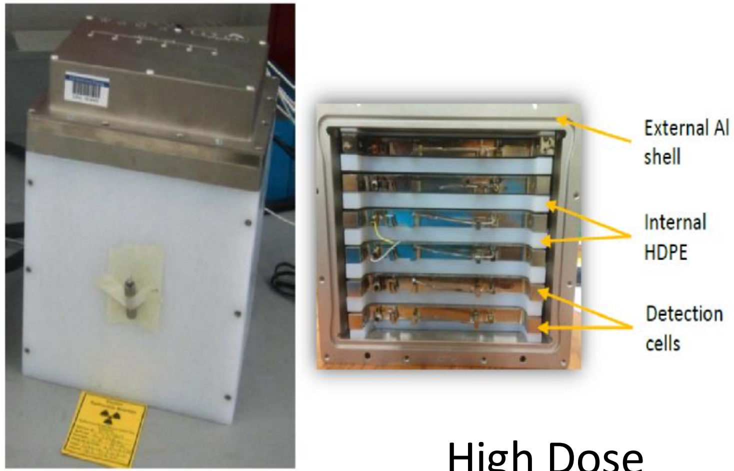


- The flowsheet defines the facility and provides data to inform the other modeling capabilities.
- SSBD recommendations may be used to alter the flowsheet and facility design

Develop the MC&A Approach

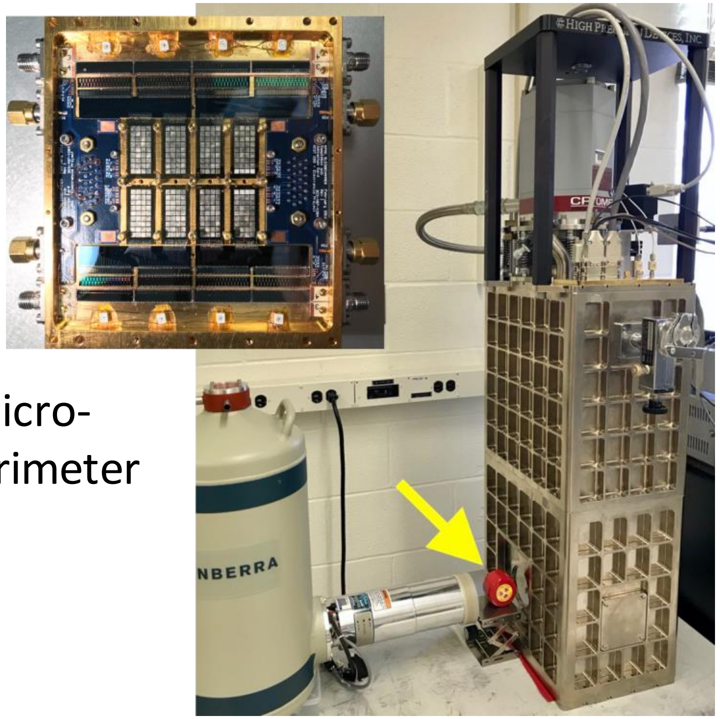


Measurement Technologies to Support MC&A



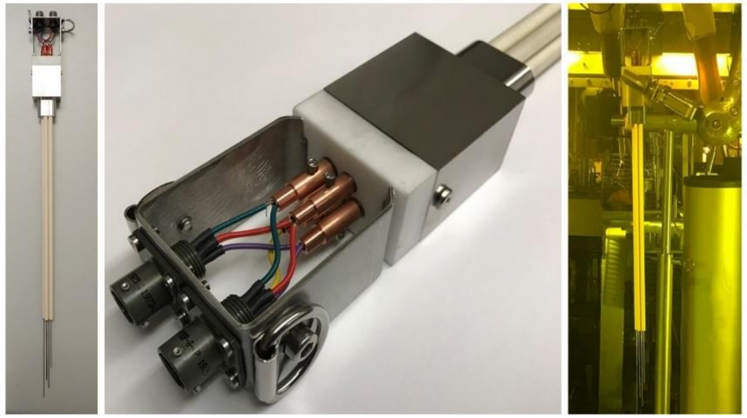
High Dose Neutron Detector

Triple Bubbler

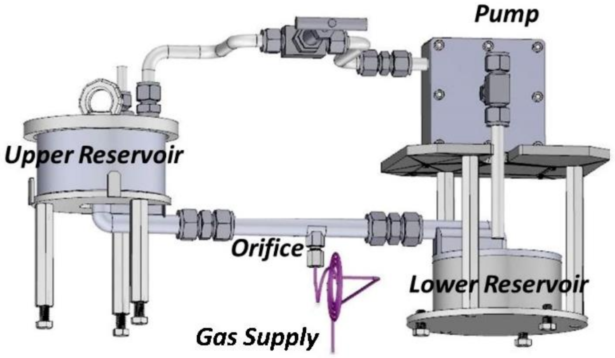


Micro-calorimeter

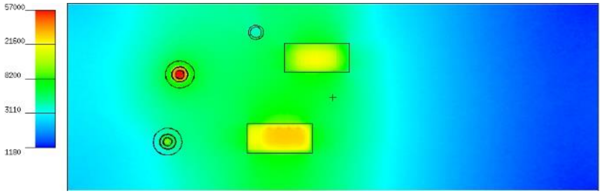
Voltammetry Sensor



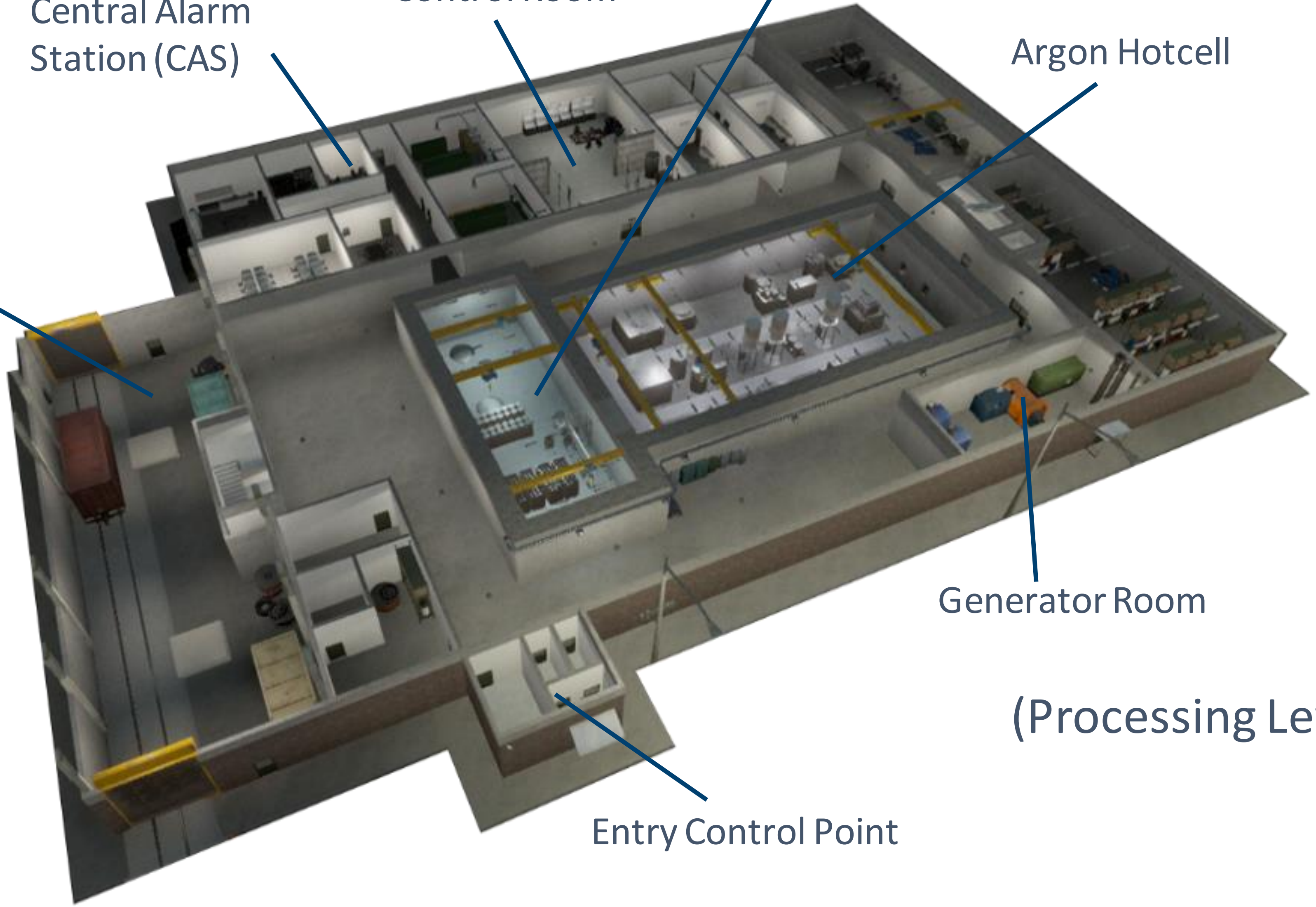
Sample Extractor



Hot Cell Flux Mapping



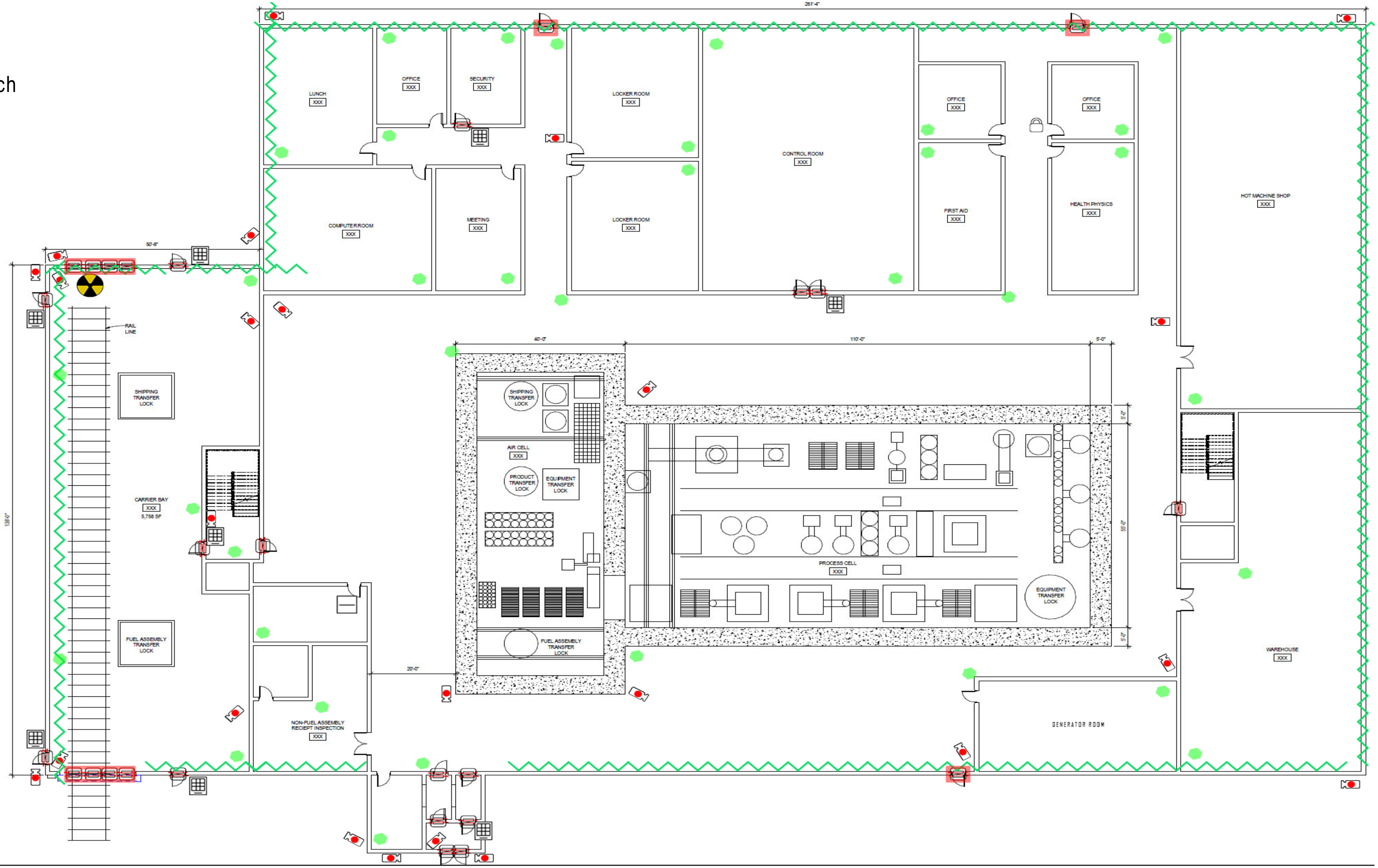
Develop the PPS Approach



(Processing Level)

Example PPS Layout

- Balanced Mag. Switch
- Dual Tech Sensors
- Active Infrared
- Cameras
- Card Swipe
- Card Swipe Keypad
- Seismic Sensors
- Rad Sensor



Safeguards Performance Modeling Results

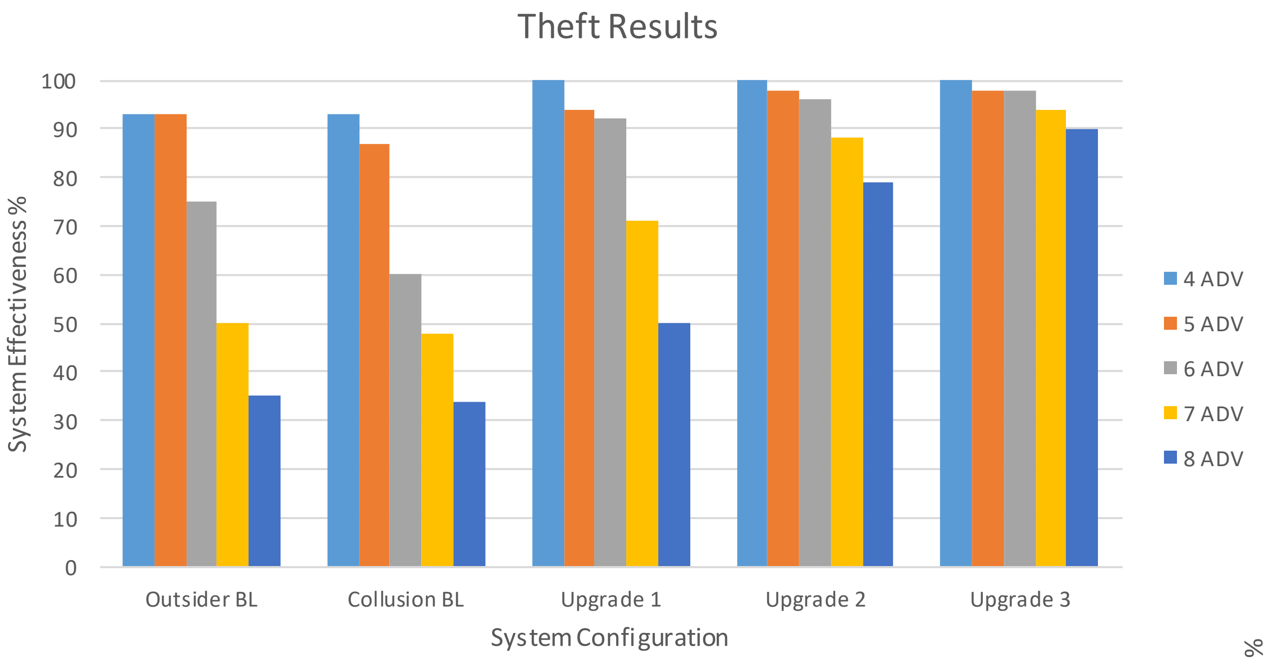
Safeguards Modeling Results Based on IAEA Detection Goal (8 kg Pu in one Month):

Loss Scenario	**Detection Probabilities and SEID as a Function of Measurement Uncertainty (RSD)**		
	All 1%	All 3%	All 5%
Abrupt Loss	100%	99%	63%
Protracted Loss 1	100%	93%	31%
Protracted Loss 2	100%	66%	13%
SEID (kg Pu)	1.9	5.5	9.1

Safeguards Modeling Results Based on NRC Detection Goal (2 kg Pu in 7 Days):

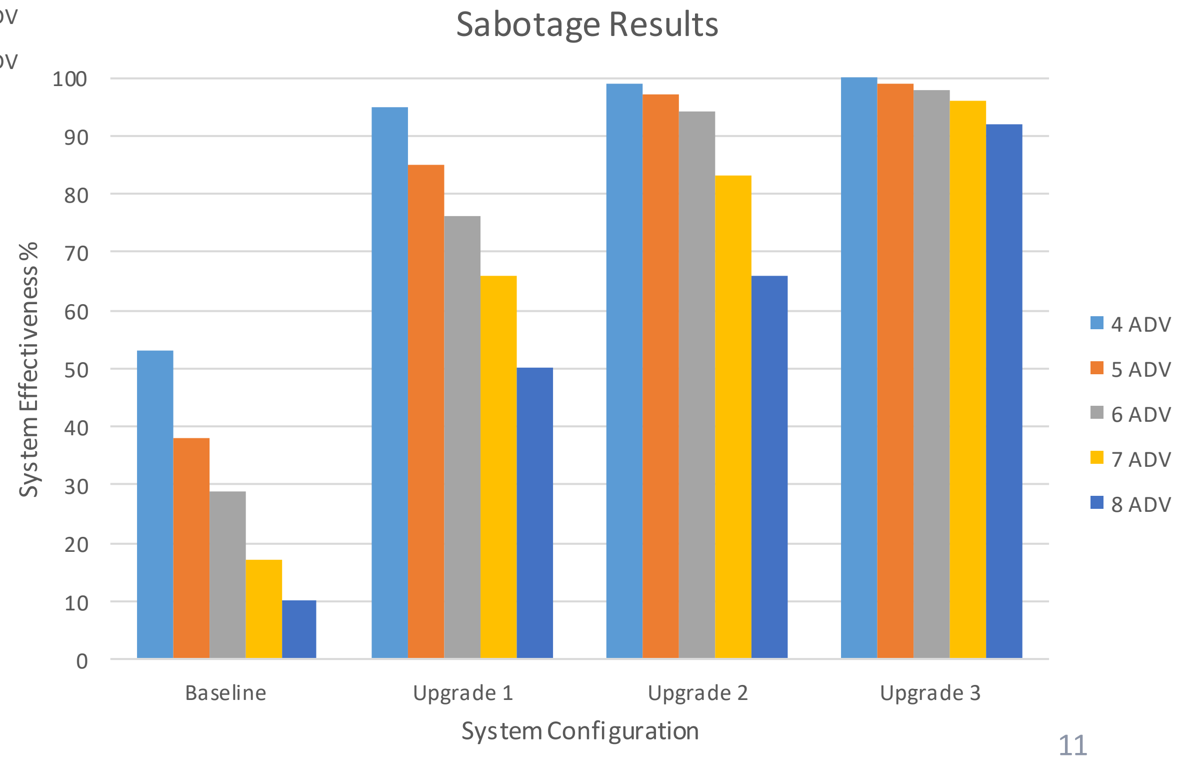
Loss Scenario	**Measurement Uncertainty (RSD)**		
	All 1%	All 3%	All 5%
Abrupt Loss	97%	14%	7%
Protracted Loss	83%	7%	5%
SEID (kg Pu)	1.2	3.0	4.9

Security Performance Modeling Results



Adversary theft scenario results showing the effect of upgrades

Adversary sabotage scenario results showing the effect of upgrades



Key SSBD Recommendations

- Input accountancy continues to be a challenge for pyroprocessing. Recent work has evaluated sampling and homogenization of declad spent fuel, but it requires a lot of effort and destructive analysis. The use of microcalorimetry may help, but reduction of sampling error needs to be demonstrated.
  - The measurement type needs to be compared to a high-precision DA baseline in order to determine measurement uncertainty. Representative standards will be required to determine systematic errors.
- More work is needed on obtaining representative salt samples. Significant advances were made with the Triple Bubbler, ER Voltammetry, and Micro-Droplet Generator, but additional work is required to demonstrate ITV (International Target Value) level of results.
  - Technologies for representative and repeatable salt samples need to be demonstrated.
- The HDND requires more work in actual environments. Experimental work was useful, but limited.

Key SSBD Recommendations (cont.)

- Pyroprocessing plants have unique process monitoring signatures (current, voltage), but significantly more work would be required to determine how to use these signals as part of a safeguards approach.
- Advanced data fusion and machine learning approaches were examined, but a more dedicated effort would be needed to advance this work.
- Waste and confirmatory measurements were not completed; though they don’t have a significant impact on overall model results, these measurements are a part of the overall safeguards approach.
- Process holdup is difficult to estimate or measure, especially when plant designs are still in a conceptual phase. More work is required on this since holdup can be a challenging problem for any bulk handling facility.

Key SSBD Recommendations (cont.)

- There is significantly more potential to incorporate SSBD by calling for facility design changes that make safeguards measurements or security approaches more effective. Examples include customized hot cell shielding to enable confirmatory measurements and taking advantage of thick shield walls as part of the PPS approach.
- PPS work focused on optimized system design with upgrade options. These designs focused on reducing costs (example is the replacement of PIDAS with fused radar and video motion detection). Future work should look at reductions in on-site security staffing since these protection costs and be a large part of operational costs—this can pull from current work on security staff reductions for small modular and advanced reactors.

Discussion

- Advanced reactors may move toward different fuel cycles, but many of the vendors are pushing off fuel cycle facility needs into the future.
  - Pyroprocessing for metal fuels
  - Salt processing facilities for MSRs
- There is still much work required to advance the measurement technologies required to meet a baseline MC&A approach for these facilities.
- PPS strategies are evolving rapidly in order to help optimize the costs of future nuclear facilities.
- This work demonstrates how SSBD can be applied for a new facility, but actual implementation will require iteration on the MC&A system with process developers.

Questions?

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