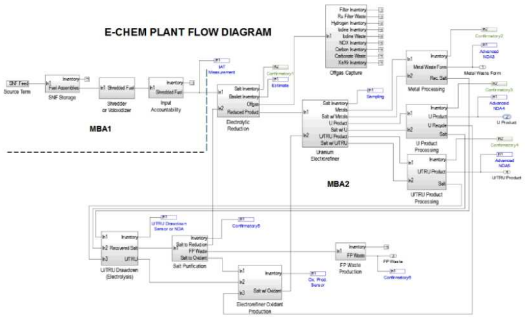
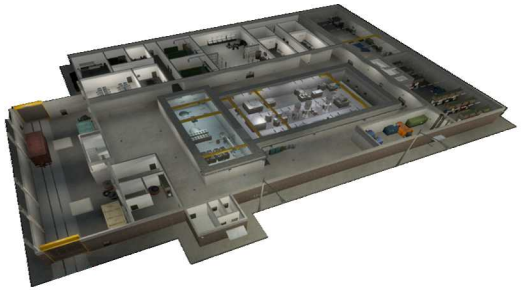
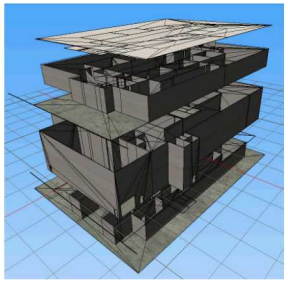
SAND2020-6536C

The Role of Modeling and Simulation in the MPACT 2020 Milestone







PRESENTED BY

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SAND2020-xxxxPE

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Material Protection Accounting and Control Technologies (MPACT) Program Area

- **The MPACT working group, part of DOE NE focuses on R&D related to domestic safeguards and security for nuclear fuel cycle facilities.**
- **The group has been working toward 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 uses an electrochemical processing facility as an example, but the tools can be extended to other fuel cycle facilities.**

Virtual Facility Distributed Test Bed

HIGH FIDELITY CAPABILITIES

Consequence Models
(CTH, MACCS, HotSpot)

Radiation Signatures
(MCNP)

Measurement Technologies
(Bubbler, Voltammetry, Microfluidic Sampler, Microcal, High Dose Neutron, Electrochemical Sensor)

Measurement Models
(NDA, MIP, etc.)

Experimental Data
(IRT, Laboratory Research)

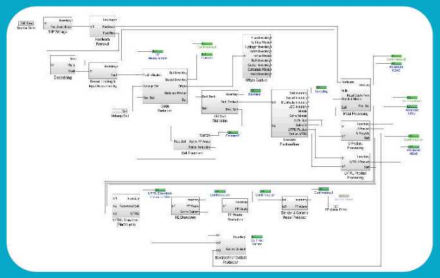
Statistical Methods
(Page, Multivariate, Pattern Recognition)

Unit Operation Models
(DYER, MASTERS)

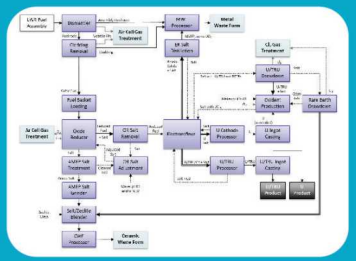
SYSTEMS LEVELS MODELS

3D Security Model

Safeguards Model (SSPM)



Flowsheet Model (AMPYRE)



KEY METRICS

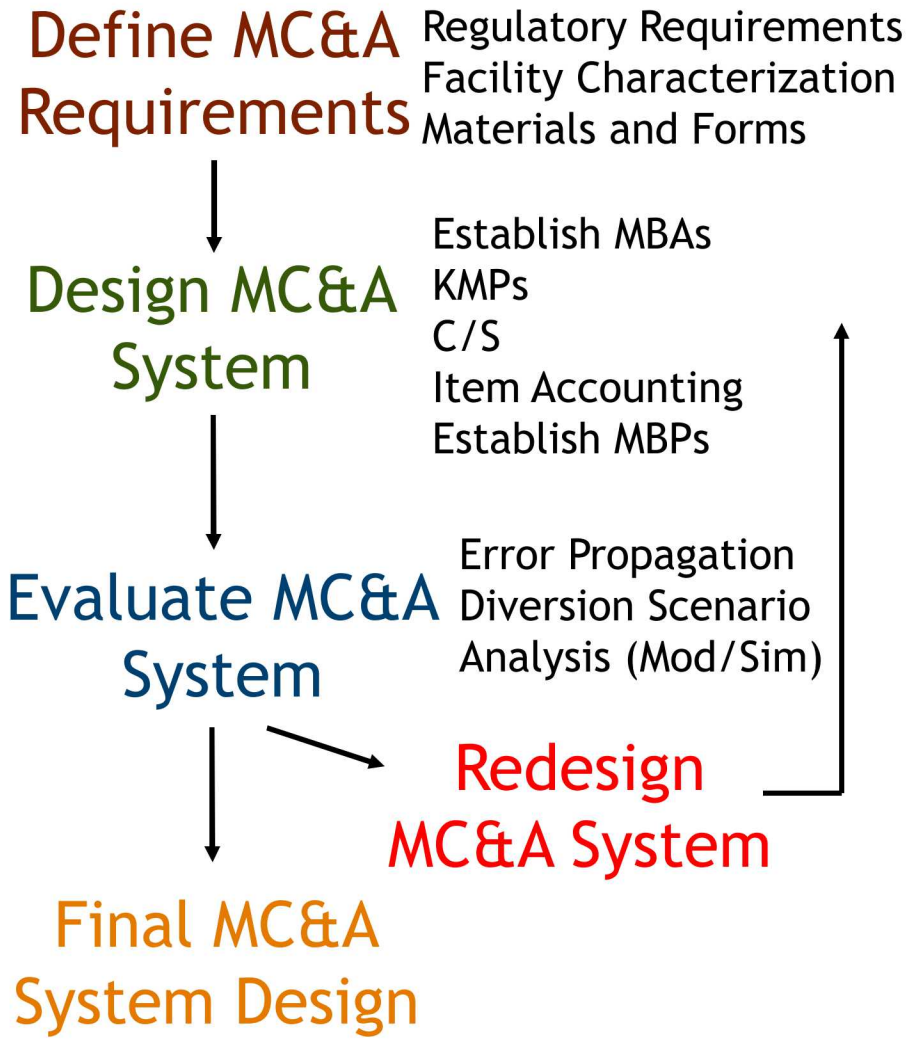
- Probability of Success
- Timeliness
- Consequence
- Facility Layout

- SEID (σ_{MUF})
- Probability of Detection
- Timeliness

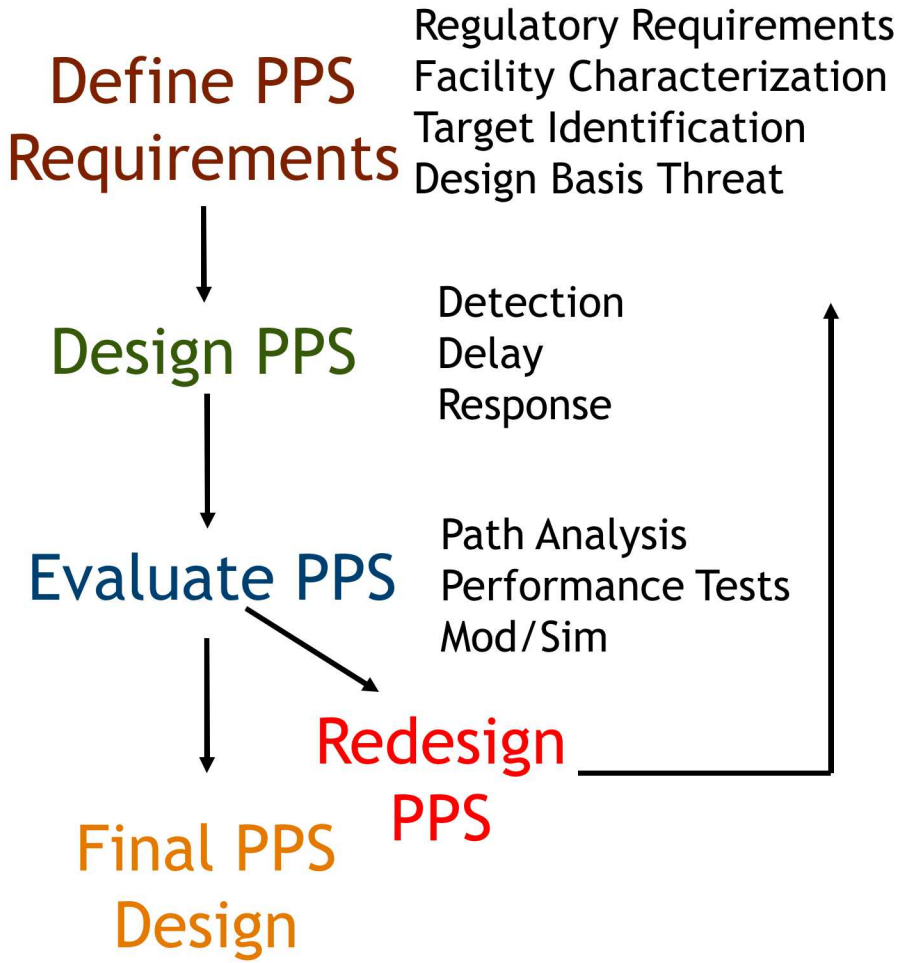
- Flowrates
- Inventories
- Separation Efficiencies
- Batch Timing

System Design Process (Regulatory Requirements Follow a Graded Approach)

MC&A System Design Process:

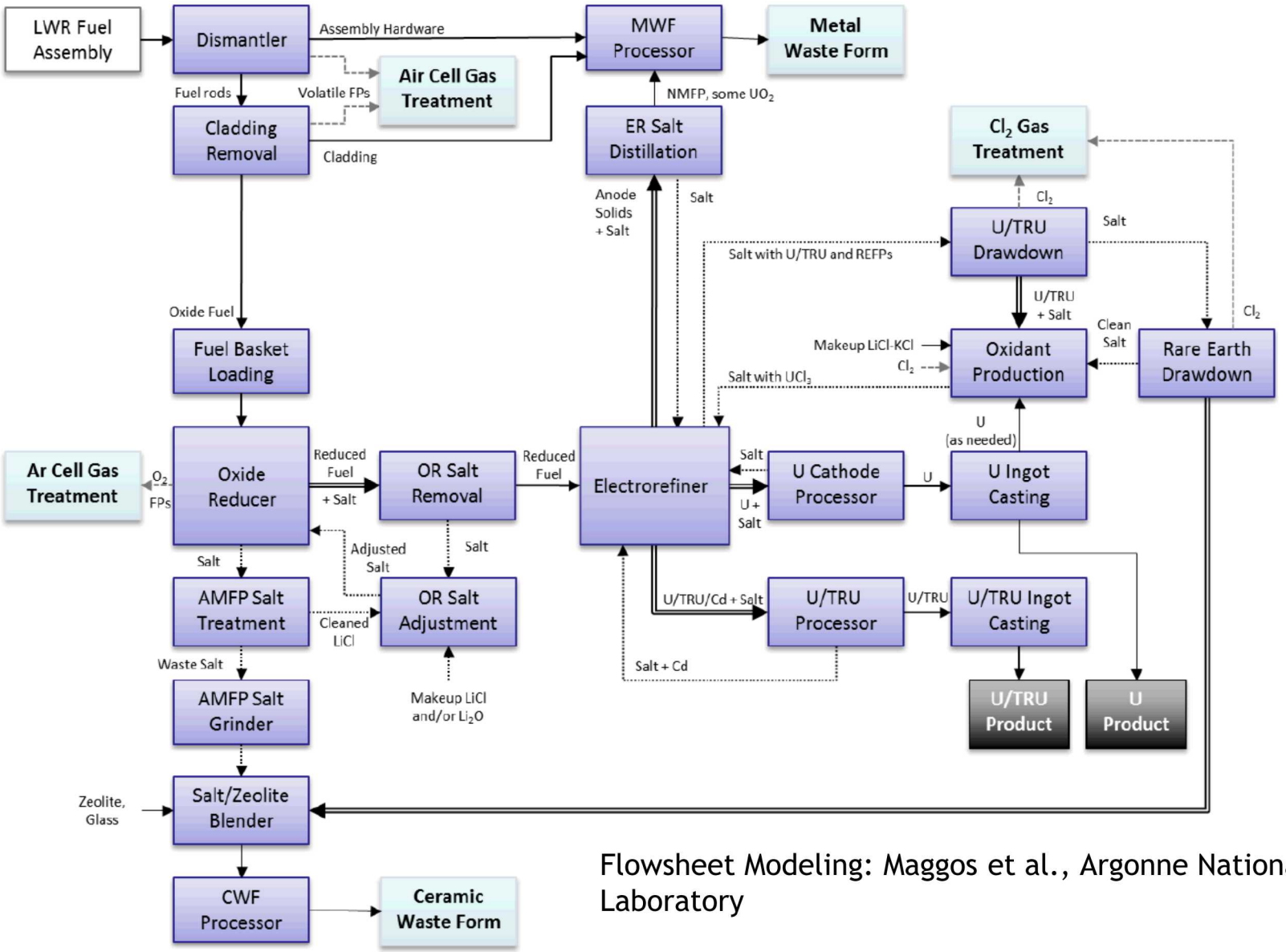


PPS System Design Process:



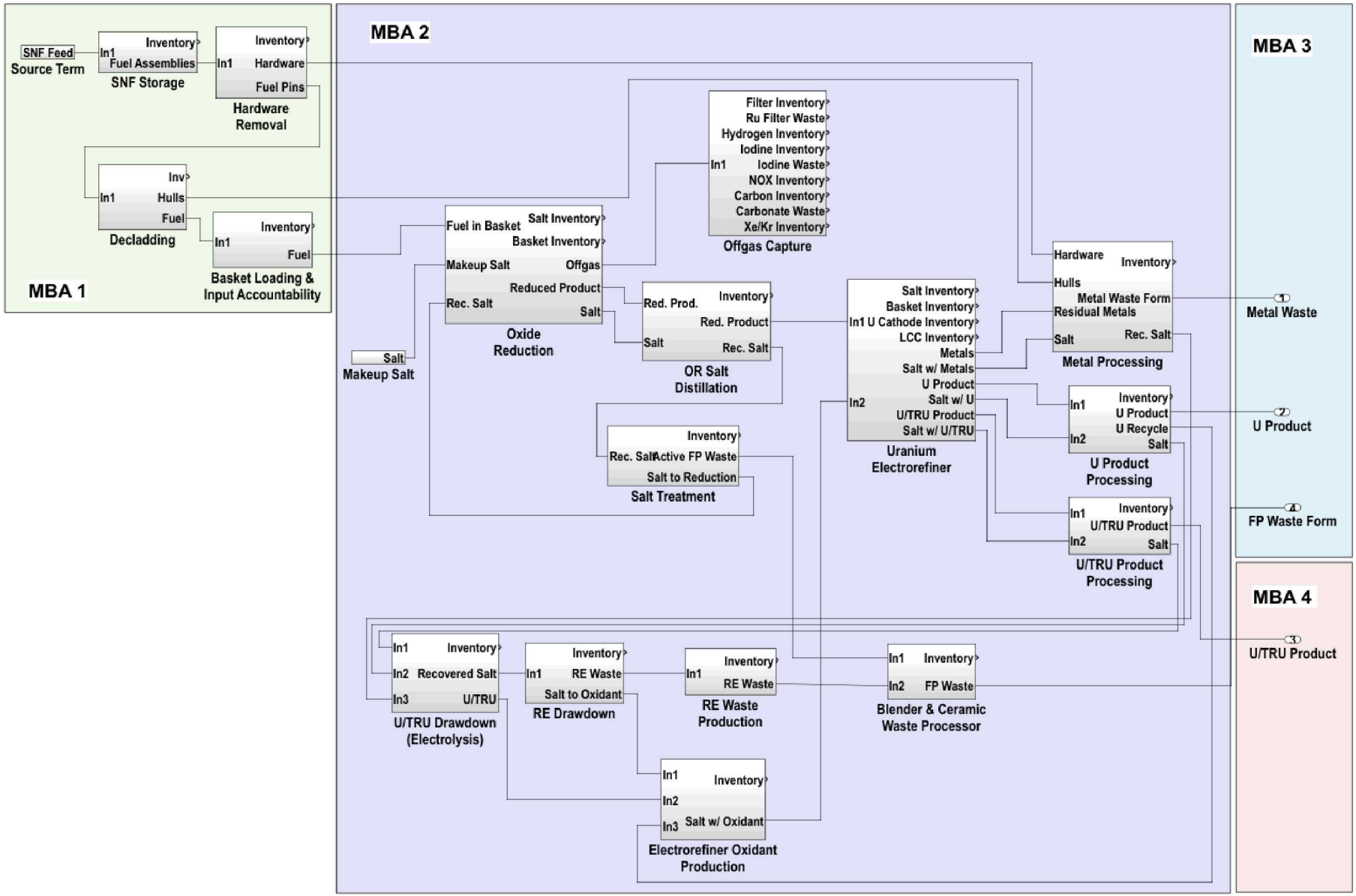
DEPO, ref: M. L. Garcia, "Design and Evaluation of Physical Protection Systems, 2nd edition," Sandia National Laboratories (2008).

Facility Design Starts with the Flowsheet



Flowsheet Modeling: Maggos et al., Argonne National Laboratory

Material Balance Area Structure



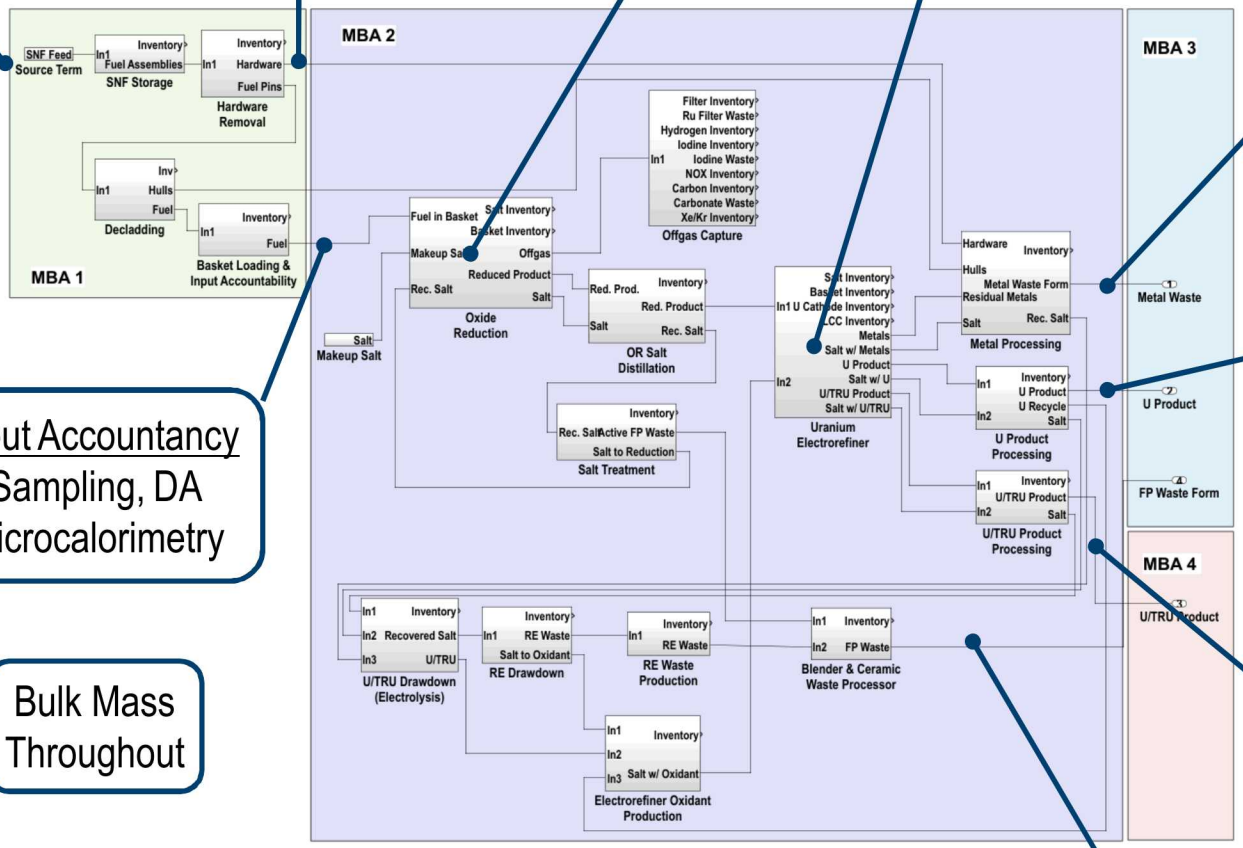
Focusing on Finalizing the MC&A Approach

Input SNF
Shipper ID

Hulls & Hardware
NDA

OR Salt
Voltammetry

ER Salt
Bubbler, Microfluidic Sampler
Voltammetry, Microcalorimetry, DA



Input Accountancy
Sampling, DA
Microcalorimetry

Metal Waste
NDA, HDND

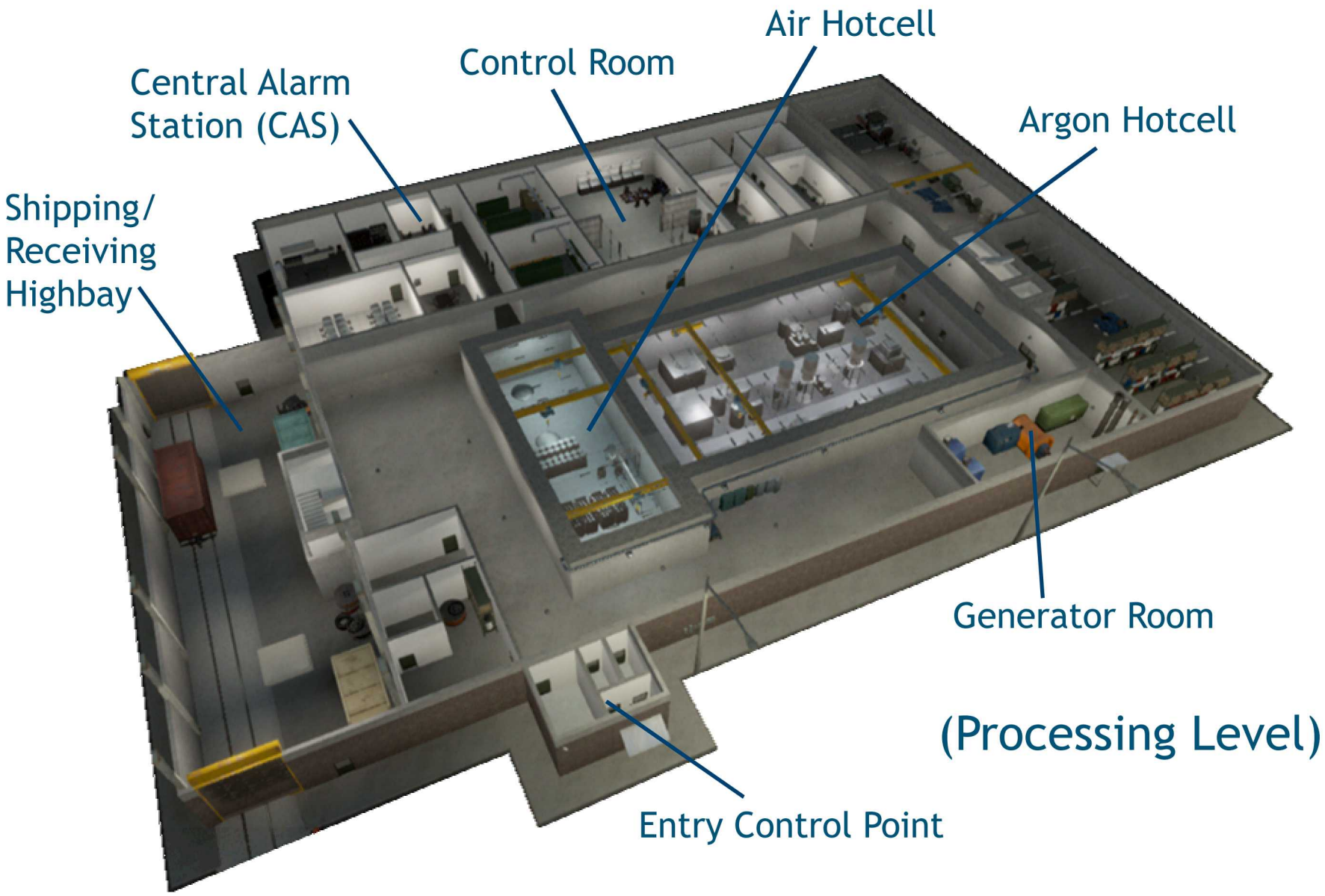
U Product
DA
HDND

U/TRU Product
HDND,
Thermocouple
Sampling & DA

Bulk Mass
Throughout

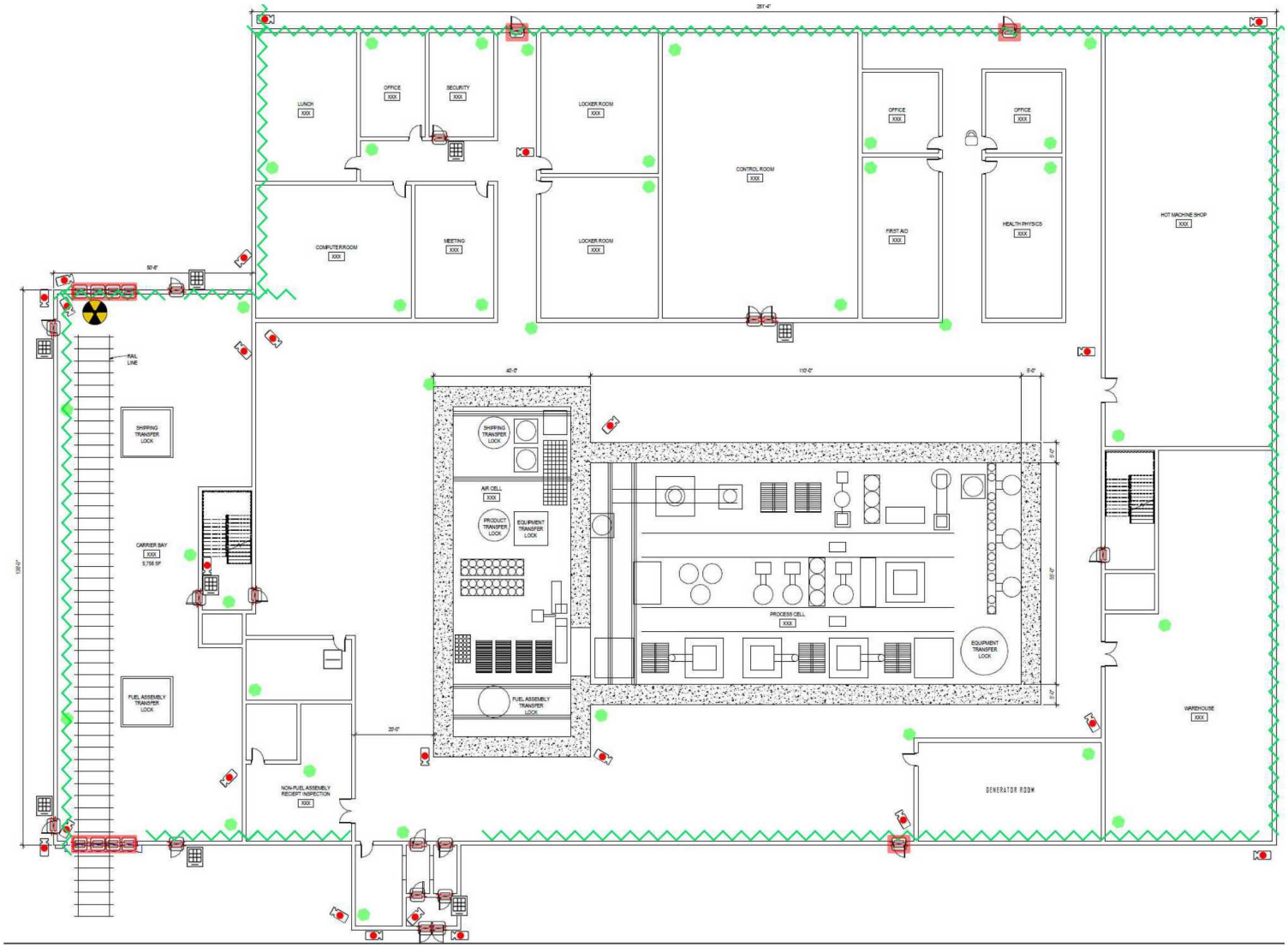
FP Waste
NDA

Facility Model was Created in Blender



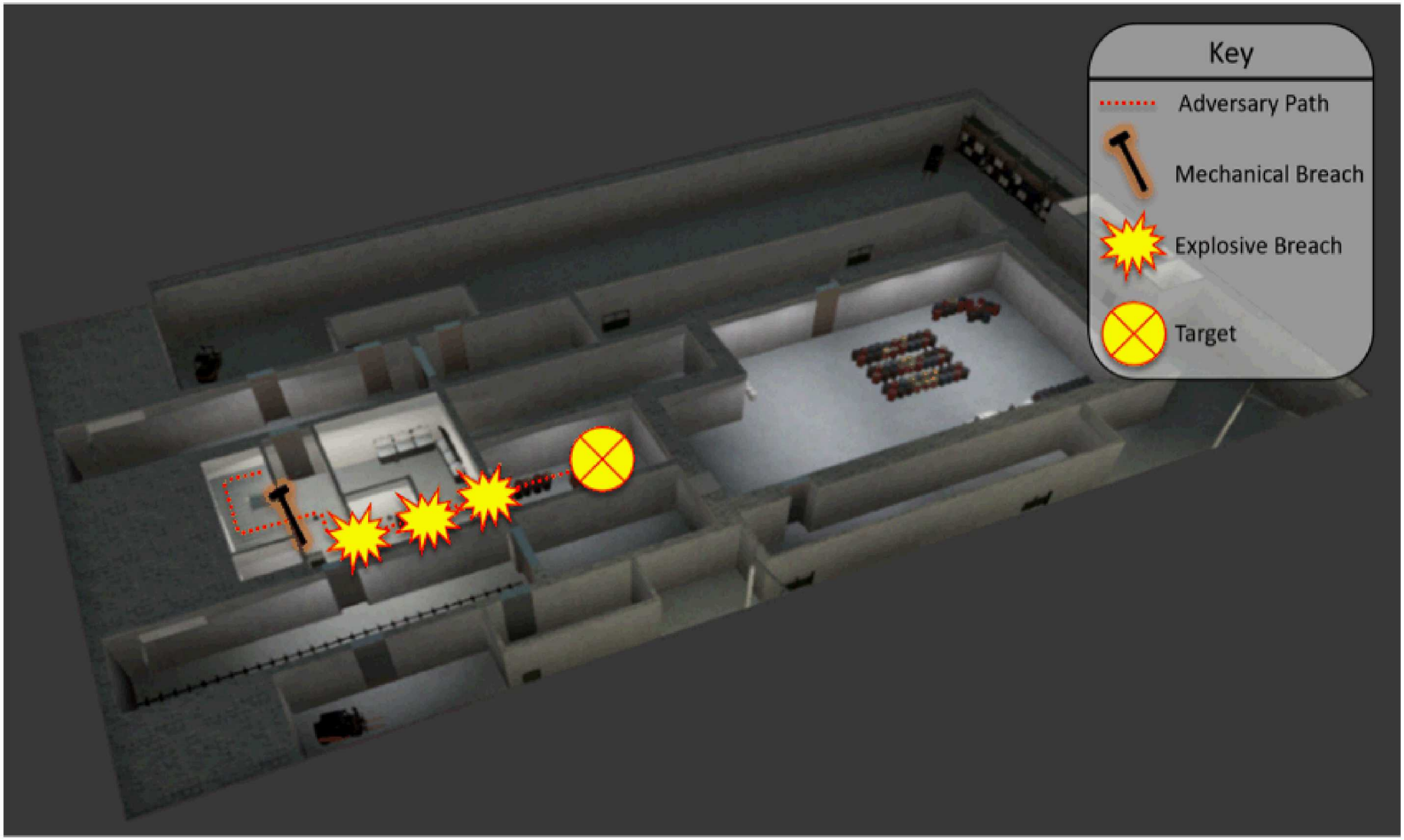
Example PPS Layout

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



Adversary Attack Scenario (Process Level)

Adversary Attack Scenario (Basement Level)



Diversion Scenario Results Placeholder

Diversion Type	Measurement Uncertainty				
	All 1%	All 3%	All 5%	(IAT/ER/OUT) 1%/3%/1%	(IAT/ER/OUT) 3%/1%/3%
Abrupt	100	34	15	67	97
Protracted 1	90	25	6	23	67
Protracted 2	52	14	7	8	30

- This table shows the detection probability for various types of diversion (of Pu) as a function of measurement uncertainty on the three key measurement points.
- We plan to maintain this type of parametric analysis but also add two additional columns for best case options based on experimental results.
- Note this assumes a material balance period of one month.

Screibe3D © Simulation Results – 4 Adversaries

Name	Results
Number Of Runs	100
Blue Wins	93
Red Wins	7
Probability of Neutralization (P_N)	93%
Prevent Material Out of Building	7
Average Time (mm:ss)	(15:50)
Average Engagements	20
Average KIA Engagements	7
Blue Force Count	14
Average Blue KIA	2.98
Average Blue KIA in Win	2.75
Red Force Count	4
Average Red KIA	3.76
Average Red KIA in Win	0.57

JNMM Special Issue

- Overview Paper, "The MPACT 2020 Milestone: Safeguards and Security by Design of Future Nuclear Fuel Cycle Facilities"
- Flowsheet and Facility Design Paper
- "Safeguards and Security Modeling for Advanced Nuclear Facility Design"
- Advanced Integration of Echem Safeguards Measurements
- Echem Safeguards Measurement Technology Development at ANL
- Echem Safeguards Measurement Technology Development at INL
- Echem Safeguards Measurement Technology Development at LANL
- University Research to Support Echem Safeguards

Summary

- The Virtual Facility Distributed Test Bed utilizes modeling and experimental work at test beds across the laboratory and university complex to solve safeguards and security challenges for nuclear fuel cycle facilities.
- The JNMM special issue will focus on SSBD for electrochemical reprocessing facilities, but the concepts can be extended to other fuel cycle facilities.