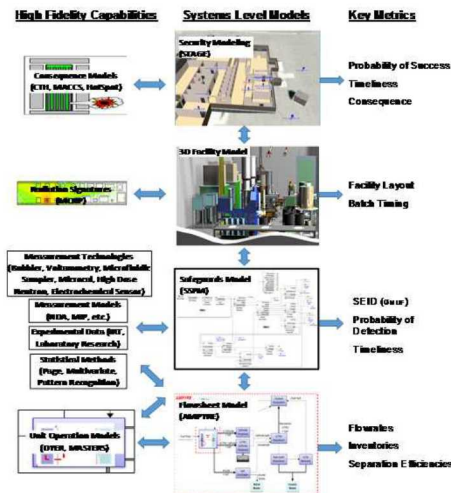
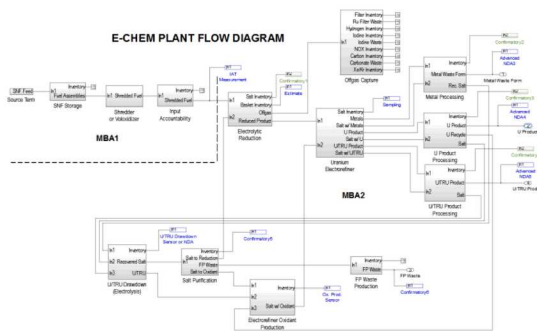


# Modeling and Simulation to Support the Virtual Facility Distributed Test Bed



PRESENTED BY

Ben Cipiti



- **The Materials Protection, Accounting, and Controls Technology (MPACT) program is developing a Virtual Facility Distributed Test Bed for safeguards and security design for future nuclear fuel cycle facilities.**

The goal of the Virtual Test Bed is to bring together experimental and modeling capabilities across the laboratory complex to provide a one-stop-shop for advanced safeguards and security by design.

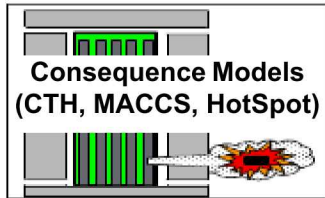
- **Modeling and simulation plays a key role in the Virtual Test Bed.**
- **This presentation provides an overview of the Virtual Test Bed with a focus on two of the systems-level models that are utilized.**

## Virtual Facility Distributed Test Bed

- **Recognizing that experimental safeguards facilities are too costly (and in many cases unneeded), a Virtual Test Bed allows safeguards and security design and analysis to be done more efficiently.**
- **The laboratory (and university) complex has many experimental test beds and testing capabilities that can be used for safeguards and security related fields.**
- **MPACT has a 2020 milestone to demonstrate the Virtual Test Bed for electrochemical reprocessing facilities.**
- **The milestone focuses on how the various capabilities work together, and provides a model for addressing safeguards and security needs in the future.**

# Virtual Facility Distributed Test Bed

## High Fidelity Capabilities

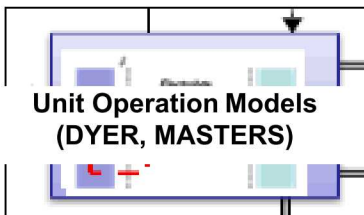


Measurement Technologies  
(Bubbler, Voltammetry, Microfluidic  
Sampler, Microcal, High Dose  
Neutron, Electrochemical Sensor)

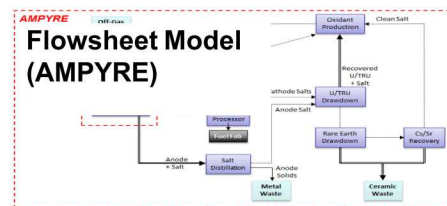
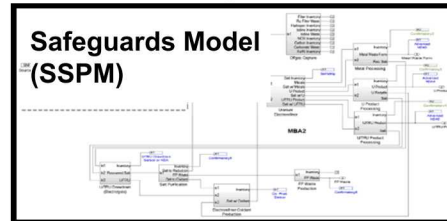
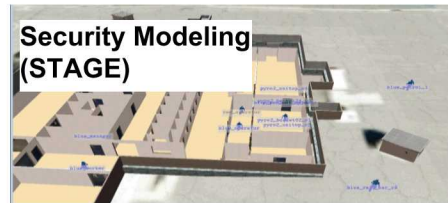
Measurement Models  
(NDA, MIP, etc.)

Experimental Data (IRT,  
Laboratory Research)

Statistical Methods  
(Page, Multivariate,  
Pattern Recognition)



## Systems Level Models



## Key Metrics

Probability of Success  
Timeliness  
Consequence

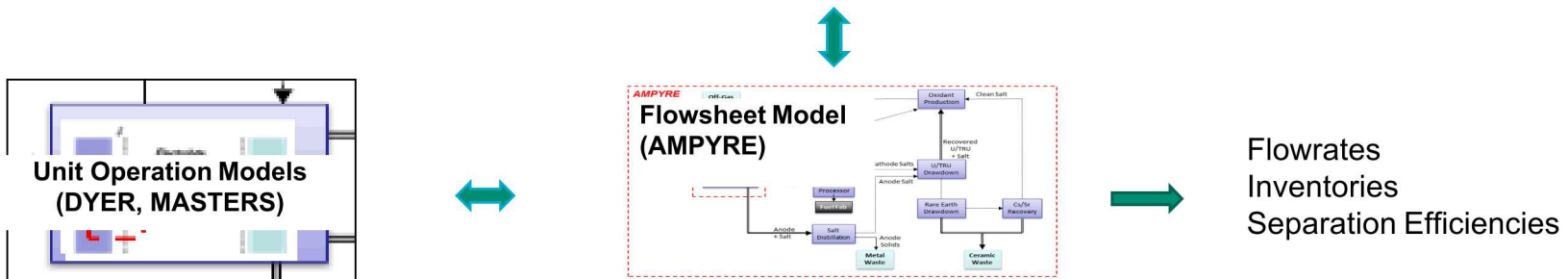
Facility Layout  
Batch Timing

SEID ( $\sigma_{MUF}$ )  
Probability of Detection  
Timeliness

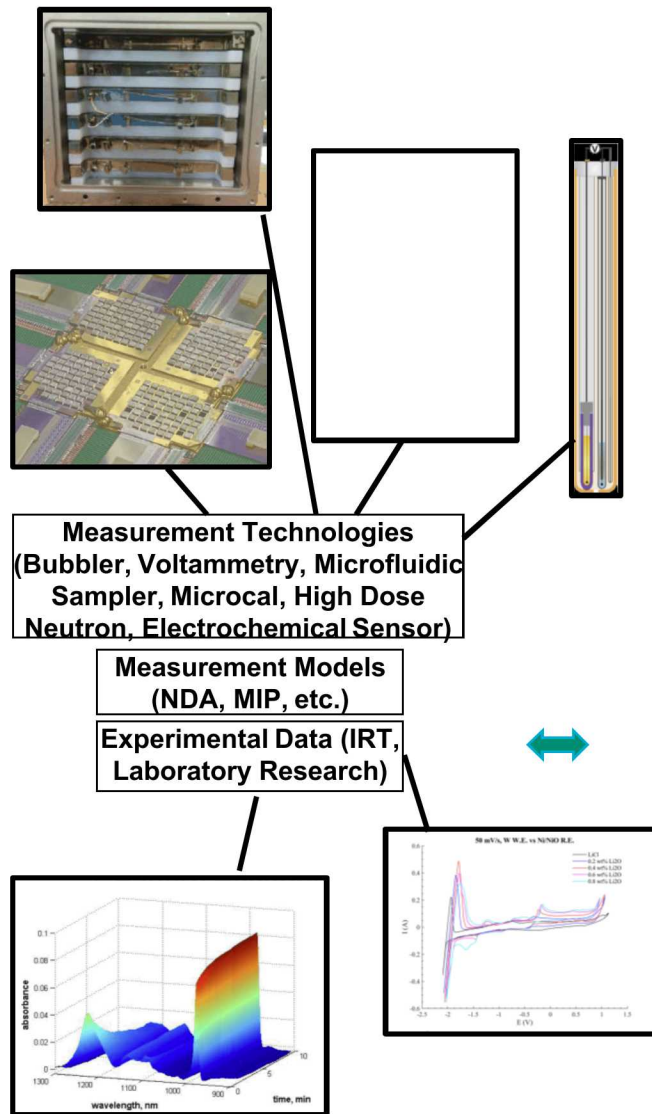
Flowrates  
Inventories  
Separation Efficiencies

# Progress Toward the 2020 Milestone: Electrochemical Flowsheet

- The baseline flowsheet for a generic electrochemical facility has been mostly developed, but continues to be refined. This feeds into the other modeling capabilities.
- More detailed unit operation models are in development and help inform the flowsheet design.



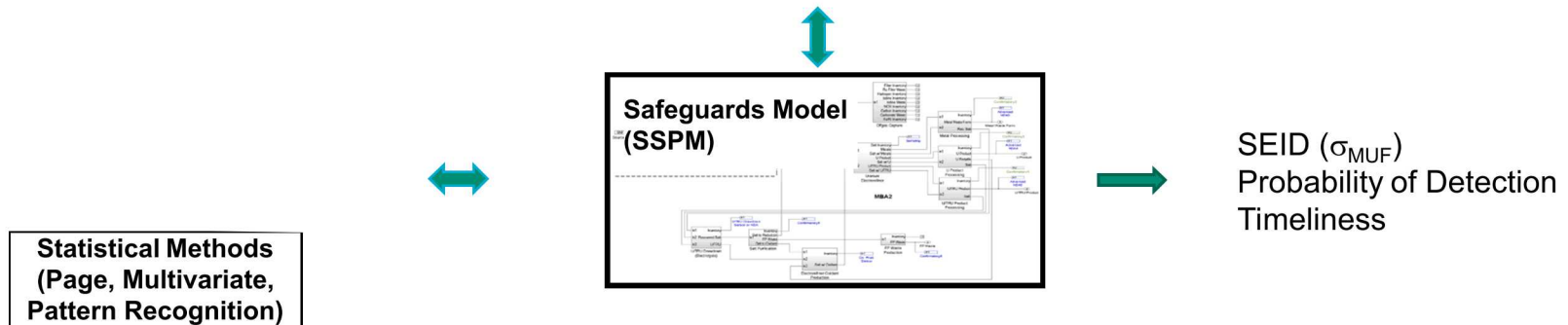
# Progress Toward the 2020 Milestone: Measurement Technologies



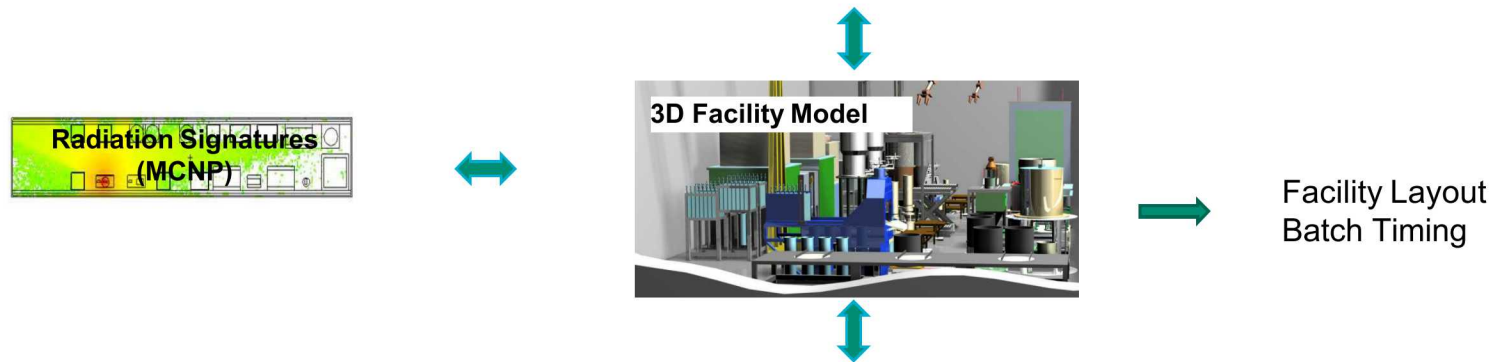
- Measurement technologies have been a key focus of the MPACT program for the past decade, and includes the vast majority of the experimental work.
- Performance of measurement technologies (uncertainties) on relevant solutions/materials are passed to the systems level models.
- Detailed measurement models have also been developed and are integrated in or utilized by the systems level models.

# Progress Toward the 2020 Milestone: Safeguards Modeling

- The safeguards model is built from the baseline flowsheet, and measurement uncertainties from the technology development is a key input.
- Much past work was spent developing statistical methods that have been worked into the model. Current work is examining newer process monitoring and machine learning approaches (includes NEUP collaborations).



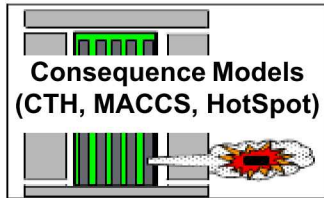
# Progress Toward the 2020 Milestone: 3D Facility Modeling



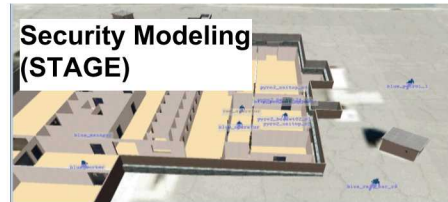
- In the past, less work has been done on 3D facility modeling, but this is useful for facility layout and batching timing.
- Research on radiation signatures mapping allows for some unique safeguards by design work: for example, how to design gamma detectors into the facility and suggesting design changes to make those measurements feasible.

# Progress Toward the 2020 Milestone: Security Modeling

## High Fidelity Capabilities



## Systems Level Models



## Key Metrics

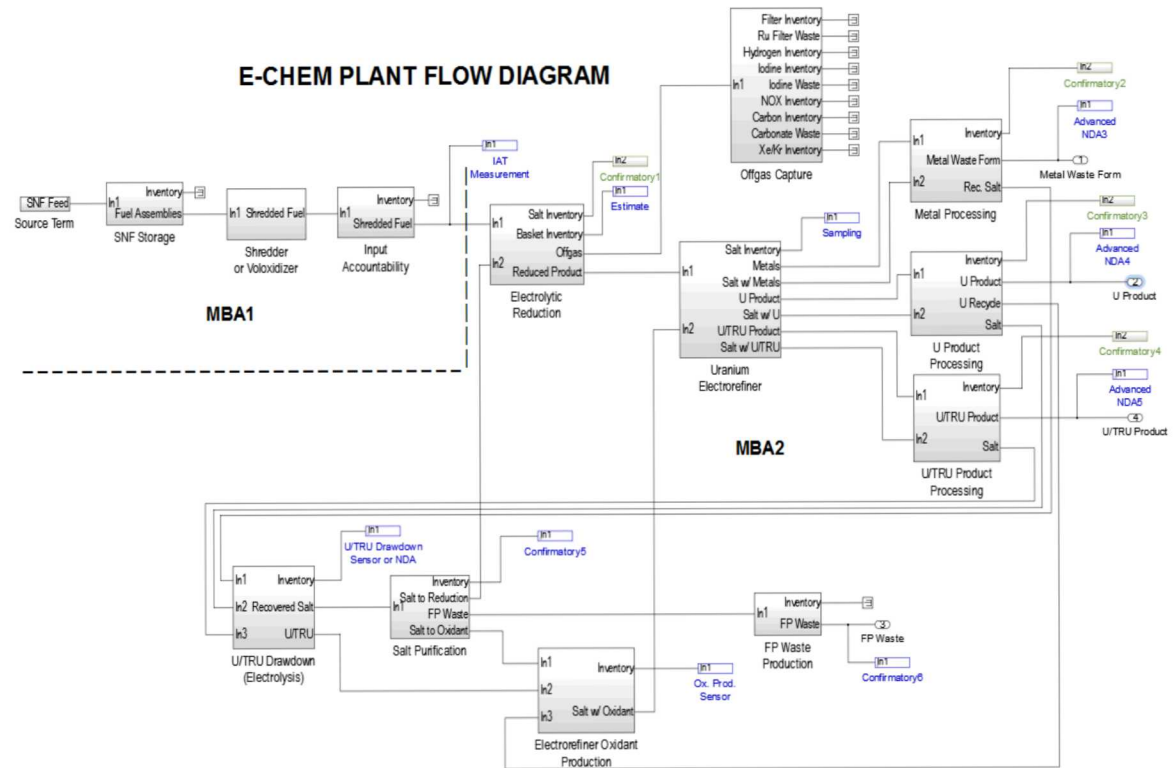
Probability of Success  
Timeliness  
Consequence

- The flowsheet, safeguards model, and 3D facility models are used to develop a 3D security model. These models include the full building and site layout and are used to model adversary attack and design the physical protection systems.
- Key metrics include probability of adversary success, timeliness, and consequence.
- Consequence models are used to determine the effect of specific attacks on different targets (spent fuel, molten salts, etc.)

# Separation and Safeguards Performance Model

The SSPM is a transient mass tracking and safeguards model based in Matlab Simulink.

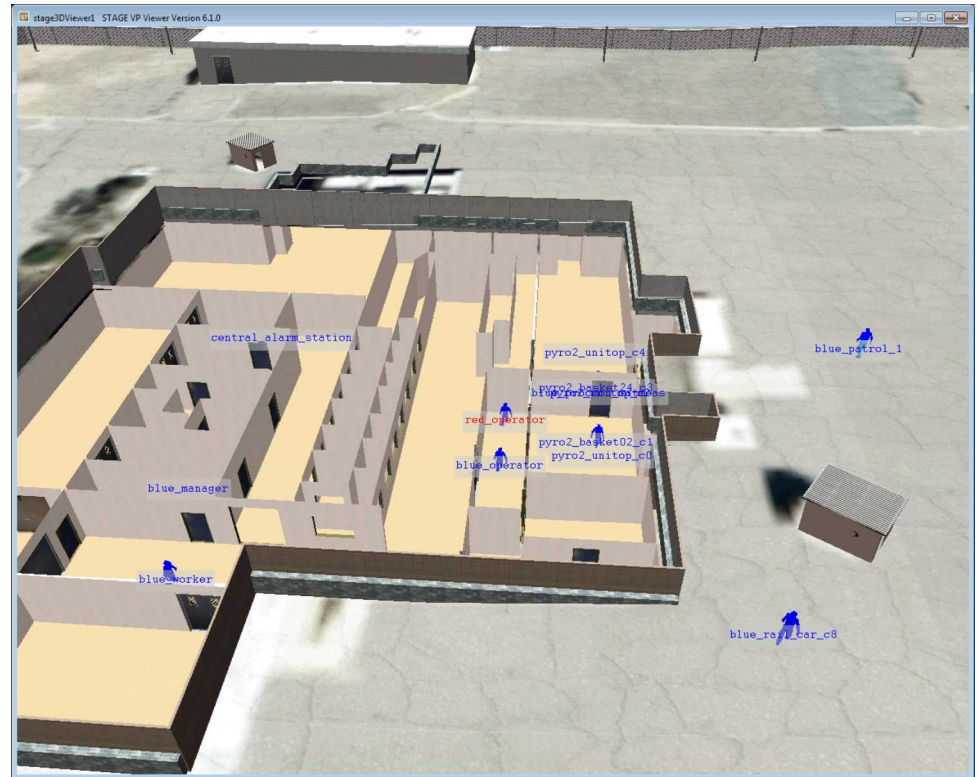
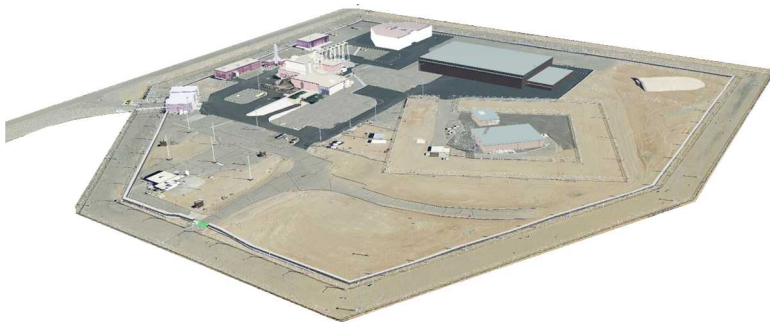
- Spent fuel source term library — integration with SCALE to accommodate most fuel types
- Full elemental and isotopic tracking, and bulk materials
- Customizable measurement points
- Simulation of gamma spectra with GADRAS **NEW**
- Automated calculation of MUF and error propagation in real time.
- Statistical tests for setting alarms
- Diversion scenario analysis
- Integration of process monitoring data





# Scenario Toolkit and Generation Environment

- **STAGE** provides a framework to create end-to-end scalable red team/blue team force-on-force combat simulations:
  - Probability-based combat model
  - Event-based entity missions
  - Performance-based databases
  - Logic-based behavior
  - Ground navigation
  - Scripting support
  - 2D/3D environment
  - Road networks
  - Batch model



# STAGE Modeling Notional Results

	Abrupt Theft 1		
	Baseline	Integration of Pu Balance	Integration of Pu Balance and Bulk Balance
No NMAC Detection	96%	97%	0%
RF Win %	25%	30%	100%
100% of Goal Quantity Removed	79%	79%	0%
Abrupt Theft 2			
No NMAC Detection	62%	0%	0%
RF Win %	45%	92%	100%
100% of Goal Quantity Removed	48%	3%	0%
Abrupt Theft 3			
No NMAC Detection	41%	0%	0%
RF Win %	48%	91%	100%
100% of Goal Quantity Removed	40%	2%	0%
Protracted Theft 1			
No NMAC Detection	15%	0%	0%
RF Win %	57%	80%	100%
100% of Goal Quantity Removed	13%	3%	0%
Protracted Theft 2			
No NMAC Detection	2%	0%	0%
RF Win %	68%	72%	100%
100% of Goal Quantity Removed	4%	3%	0

- **STAGE has been used in the past to evaluate response to insider theft scenarios.**
- **Key metrics include response force win percentage and probability of removing a full goal quantity.**
- **This work has focused on the integration of safeguards and process monitoring data with security to increase response force effectiveness.**

# Conclusions

- **The goal of the MPACT 2020 milestone is to demonstrate safeguards and security by design for a generic electrochemical reprocessing facility.**
- **The Virtual Facility Distributed Test Bed links experimental work with systems level modeling to provide efficient safeguards and security design.**
- **More detailed results will be completed in 2020, and future work will broaden the overall approach to cover other facility types.**