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Fully-Integrated Safeguards and Security for Reprocessing Plant Monitoring

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Outline

- Separations and Safeguards Performance Model (SSPM)
- Systems integration
  - Physical protection systems
  - MC&A administrative procedures
- Results
- Conclusions/Future work

Purpose

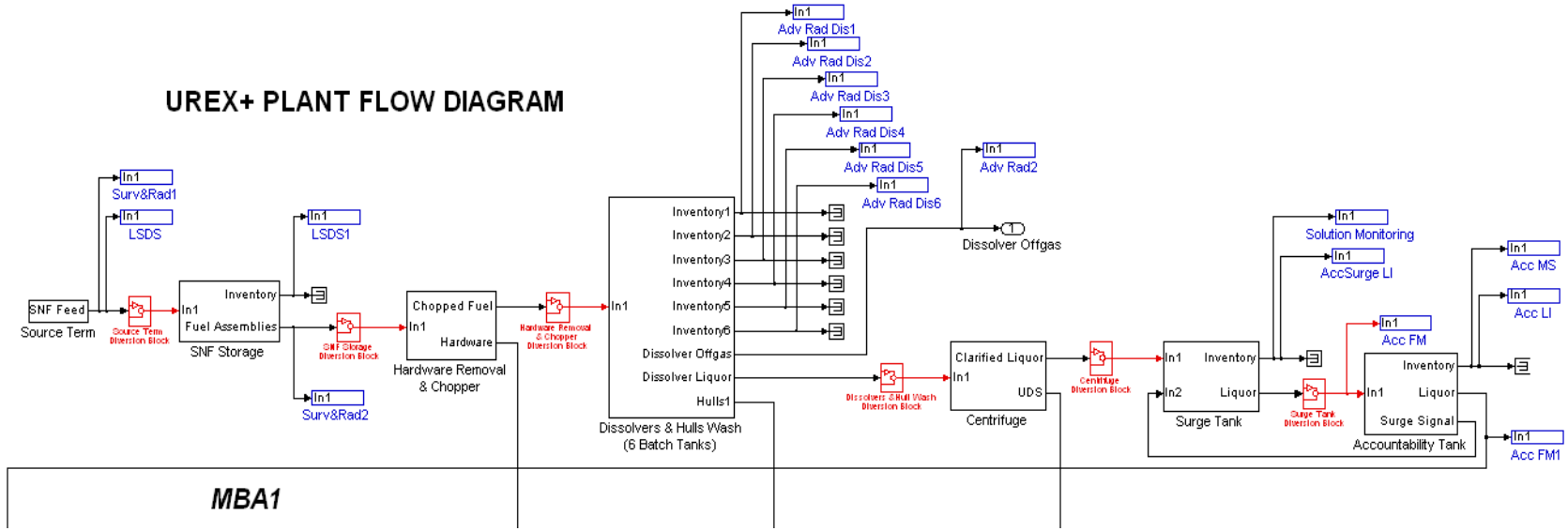
- Safeguarding reprocessing facilities is challenging due to the large quantities of bulk material

- The Separations and Safeguards Performance Model has been developed to design and evaluate advanced safeguarding concepts, including
  - Improved timeliness of detection of material loss
  - Near real-time plant awareness
  - Integrated safeguards and security systems for more efficient operations

Separations and Safeguards Performance Model

- Simulink model based on a UREX+ plant design
- Tracks material flow through the plant and simulates measurements for the safeguards system
  - Mass tracking of elements 1-99, bulk solid & liquid, heat load & activity
  - Customizable measurement points with user-defined measurement error
  - Alarm conditions, bias correction, and statistical tests
- User-defined diversion scenario analyses
- Process monitoring integrated with traditional Pu accounting techniques

SSPM Front End



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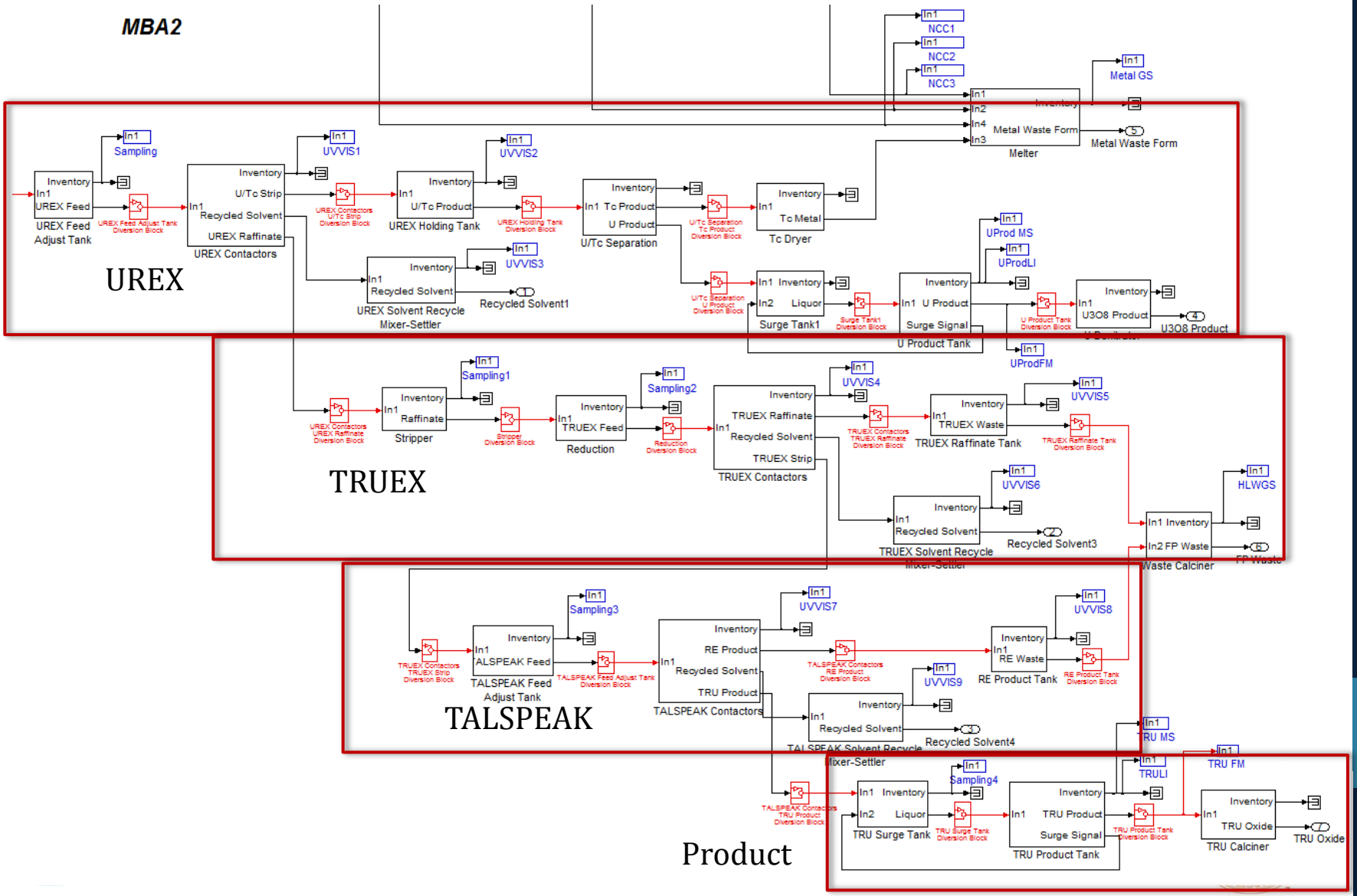
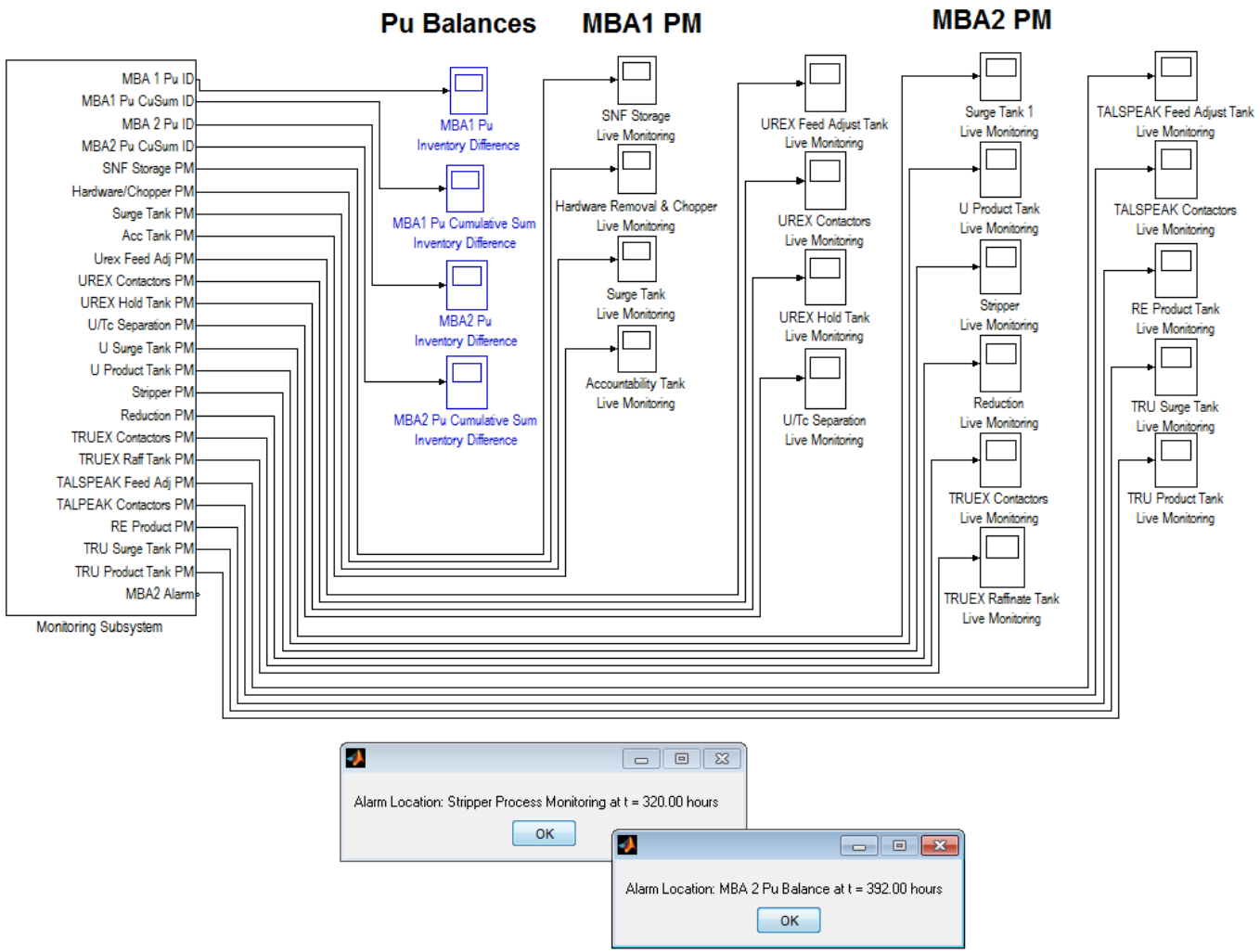
SSPM Separations



Integrated Monitoring System



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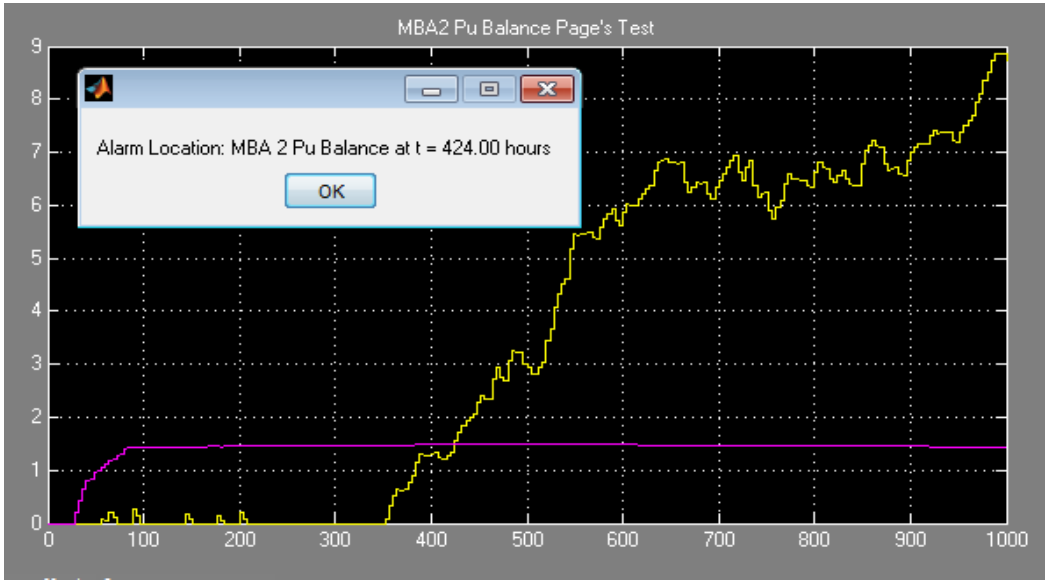
Materials Accountancy Balances

- Actinides are balanced across MBAs
  - Existing plants do not provide timely detection due to high uncertainties for inventory estimates—material loss may be seen many months later at a flushout
  - New measurement technology may allow future plants to achieve NRTA with low uncertainty—providing timely data



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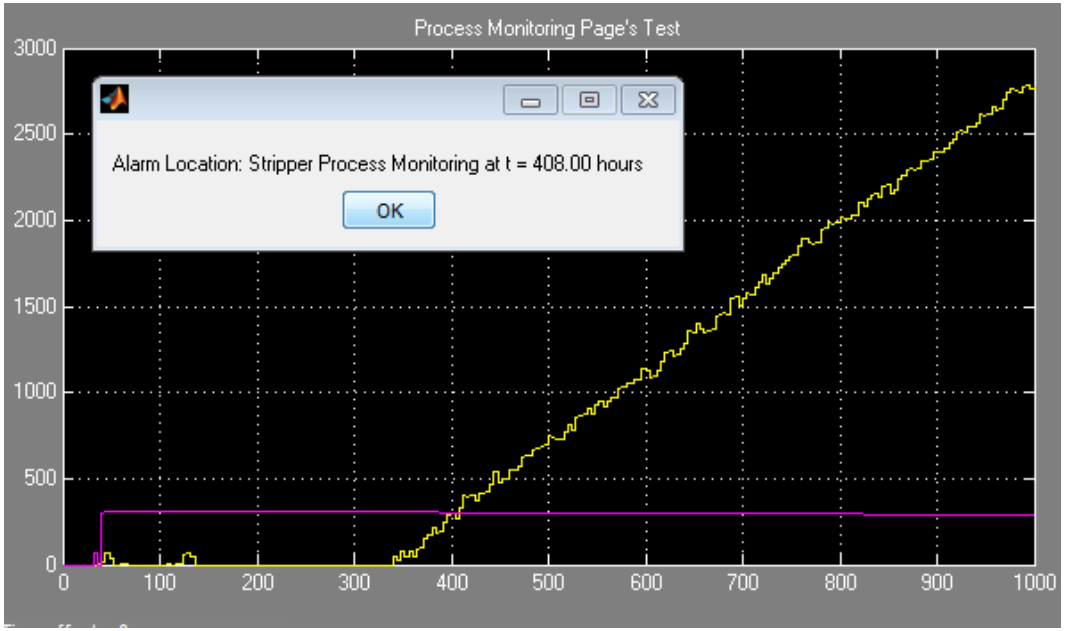
Process Monitoring Balances

- Process monitoring data can be used for bulk material balances across individual tanks/vessels.
  - Existing plants do not take full advantage of this data
  - PM data provides timely data for detecting bulk material loss



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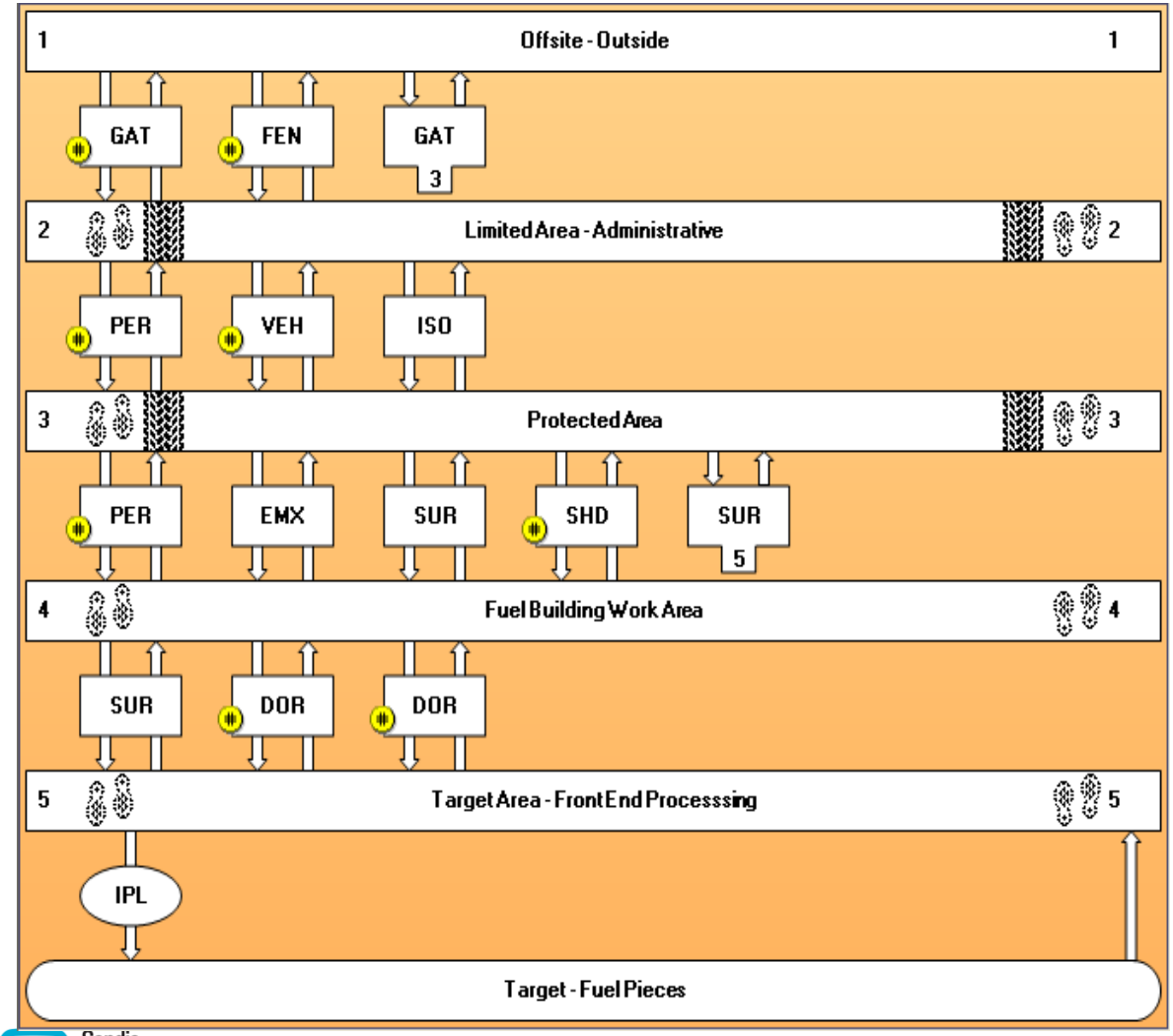
ATLAS Software

- Software tool developed at Sandia to assess physical protection system effectiveness
- Physical protection layers and elements are modeled with default or user-specified performance data
- User specifies threat
  - Cannot explicitly model insider threat
- Software uses Critical Detection Point methodology to identify 10 most vulnerable pathways and probability of PPS success

Integration of Physical Protection Systems: MBA1



ATLAS Model – Adversary Sequence Diagram

Physical Areas

Protection Layers
Path Elements

Target Location

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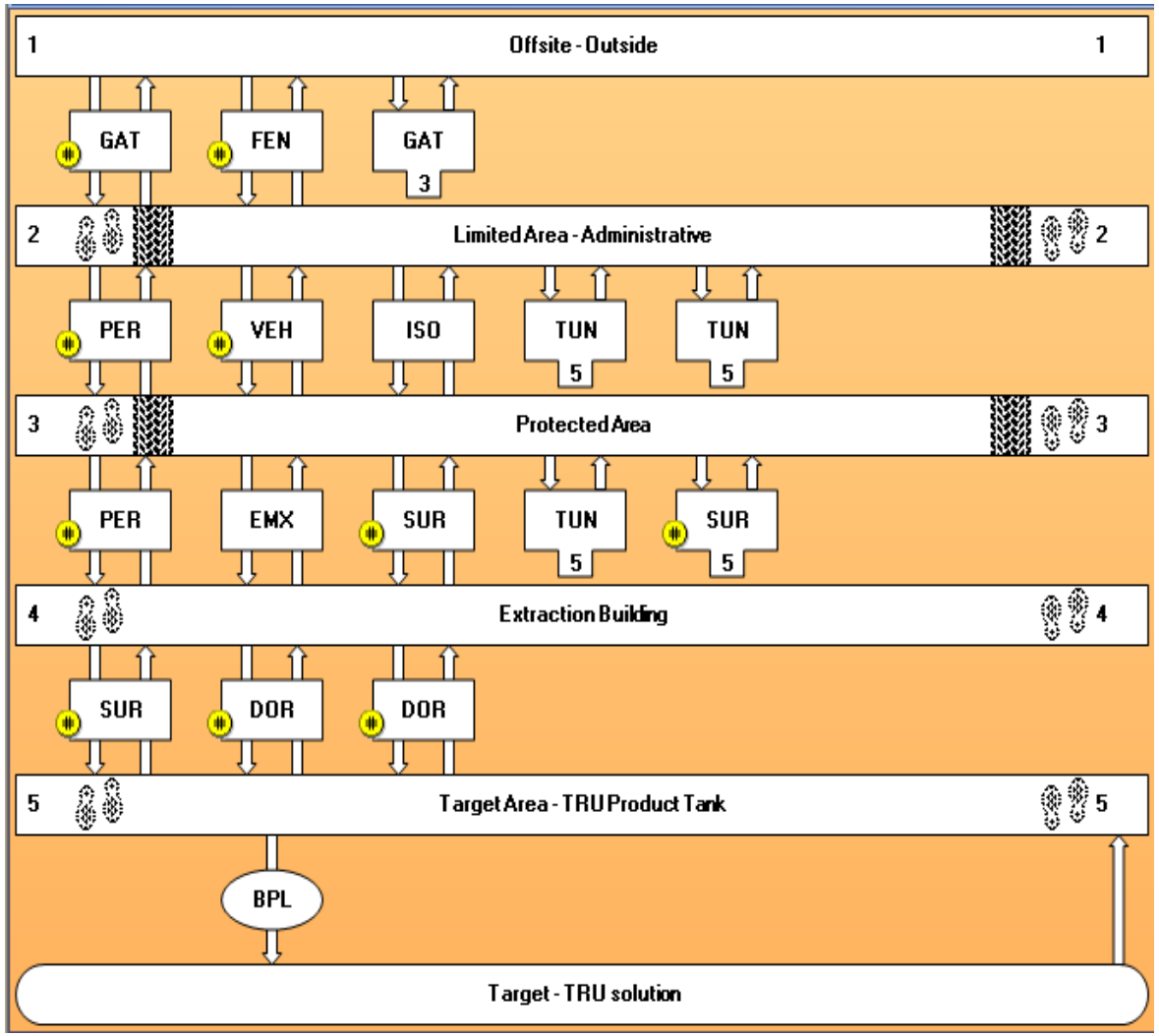
Integration of Physical Protection Systems: MBA2



GAT – Vehicle or Rail Gate
FEN – Fence
PER – Personnel Portal
VEH – Vehicle Gate
ISO – Isolation Zone
TUN – Pipe Tunnel
EMX – Emergency Exit
SUR – Wall or Ceiling
DOR – Transfer Door
SHD – Shipping/Receiving
BPL – Bulk Processing Line

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Administrative Procedures – Checking Operations

- Approach is based on integrated path analysis methods for insider theft of nuclear materials
  - ✧ The paper James presented two weeks ago
- Administrative procedures are similar to operator tasks in nuclear power plants checking for anomalous conditions
- Human reliability analysis (HRA) models estimate human error probability (HEP) for operator actions

Administrative Procedure	Nuclear Power Plant Checking Operation	BHEP
Plan of the Day	Checking routine tasks using written materials	0.10
Material Transfer	Checking by reader/checker of the task performer in a two-man team, or checking by a second checker, routine task	0.50
Product Storage	Checking by reader/checker of the task performer in a two-man team, or checking by a second checker, routine task	0.50
Daily Administrative Check	Checking routine tasks using written materials	0.10
Physical Inventory	Checking that involves active participation, such as special measurements	0.01
Inventory Audit	Checking that involves active participation, such as special measurements	0.01

Reference: A.D. Swain III and H. E. Guttmann, "Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plants."

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Administrative Procedures – Dependency

- Failure to recognize an anomaly at a check leads to a higher chance of failing again on the next check
- Probability of success decreases with successive observations, depending on the dependency
  - Dependency can be thought of as surrogate for manpower
- Probability of detection is the complement of the associated human error probability

Level of Dependence	***a***	**Failure Equation**
Complete Dependence (CD)	0	$P(F_M \mid F_{M-1} \mid CD) = 1.0$
High Dependence (HD)	1	$P(F_M \mid F_{M-1} \mid HD) = \frac{1+P_{M-1}}{2}$
Moderate Dependence (MD)	6	$P(F_M \mid F_{M-1} \mid MD) = \frac{1+6P_{M-1}}{7}$
Low Dependence (LD)	19	$P(F_M \mid F_{M-1} \mid LD) = \frac{1+19P_{M-1}}{20}$
Zero Dependence (ZD)	∞	$P(F_M \mid F_{M-1} \mid ZD) = P_{M-1}$

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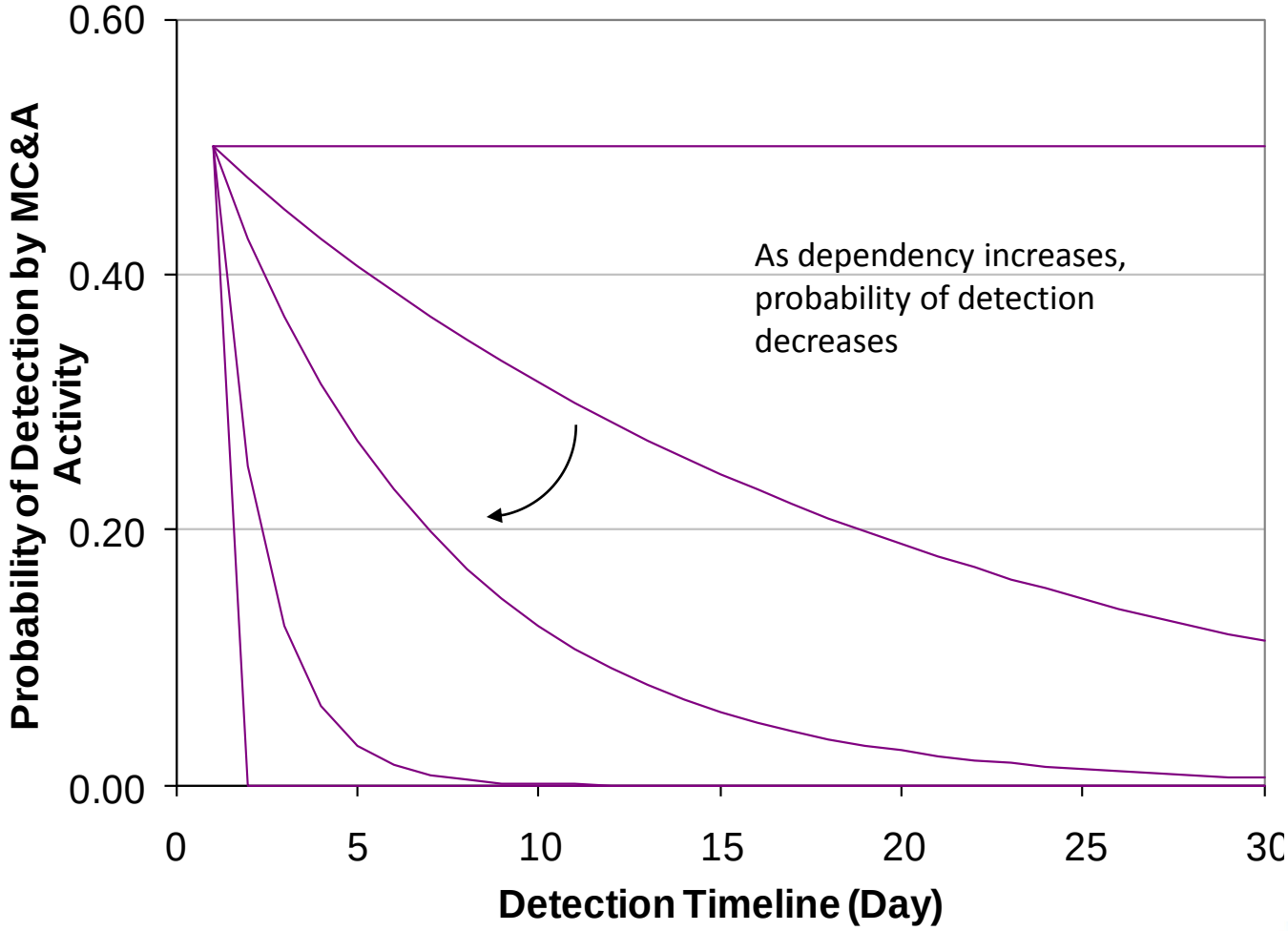
Administrative Procedures-Dependency



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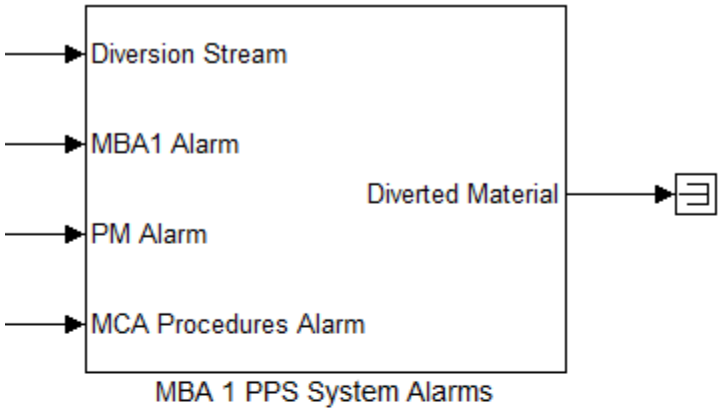
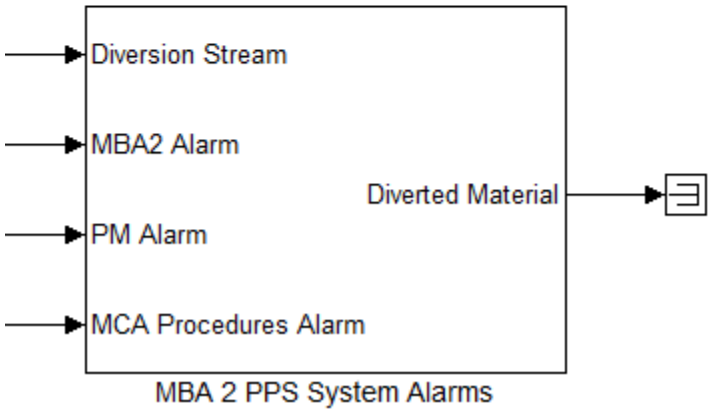
Integration of Systems in the SSPM





- The ATLAS models were used to build the PPS Systems in the SSPM
- The Pu balance, PM balance, and MCA procedures subsystems may generate alarms during material loss
- Any alarm will trigger an alert state in the PPS elements
- The alert state will usually modify (increase) the detection probabilities of the PPS elements

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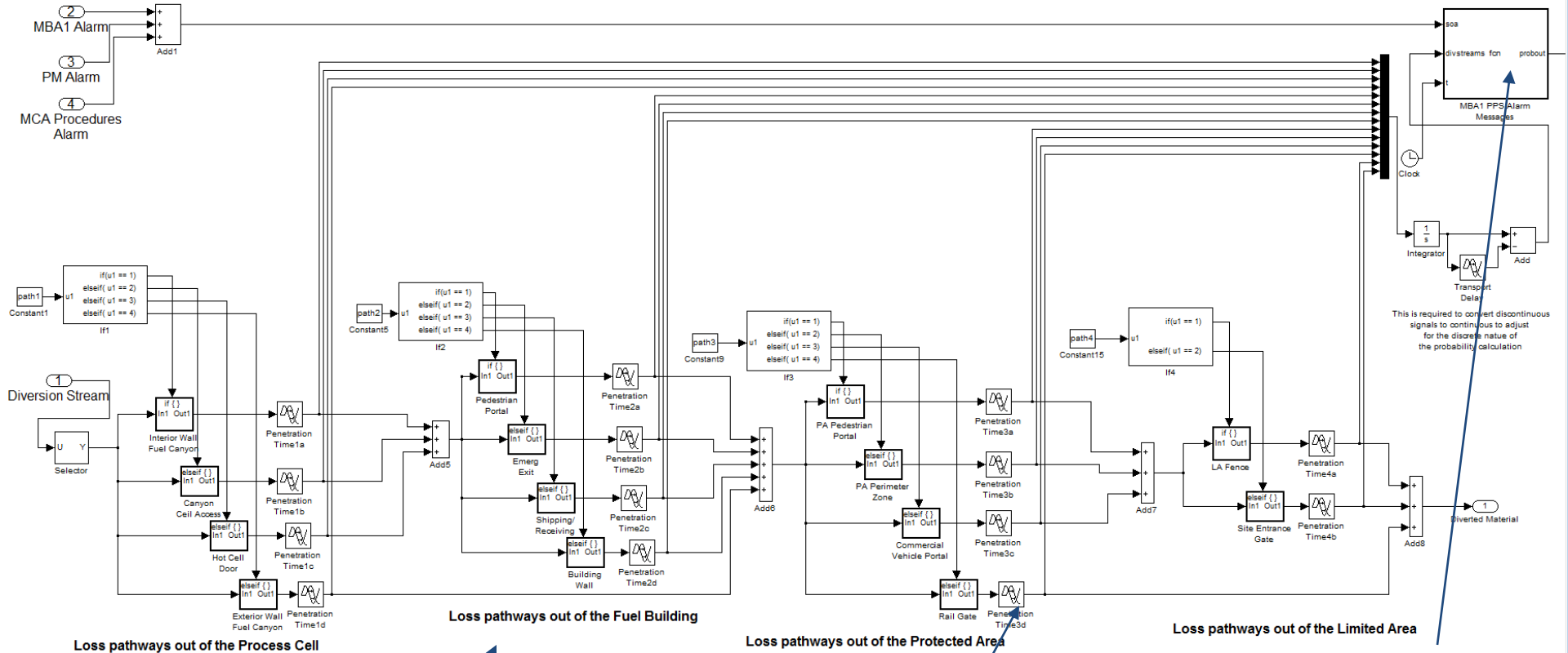
PPS Architecture



The particular loss pathway is chosen by the user

Delay blocks simulate the time to get through the barrier

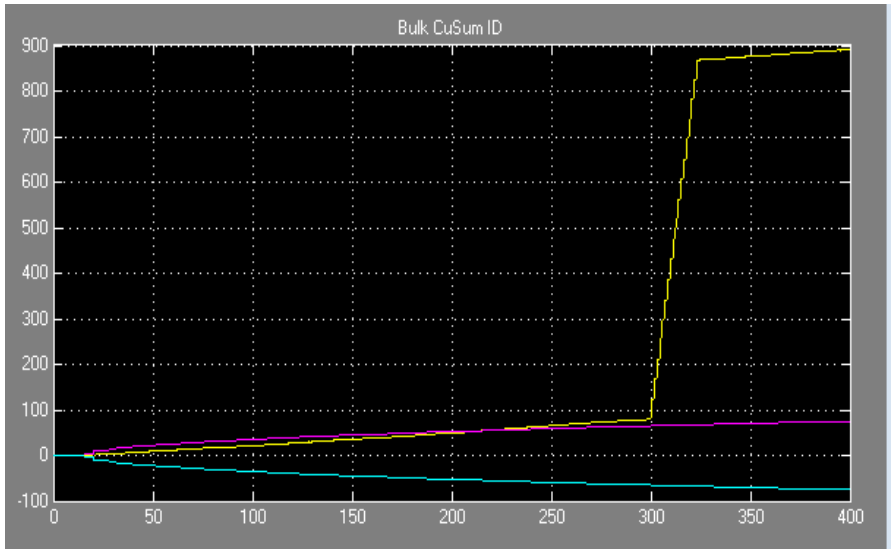
Detection probabilities are set here based on the alert level of the facility

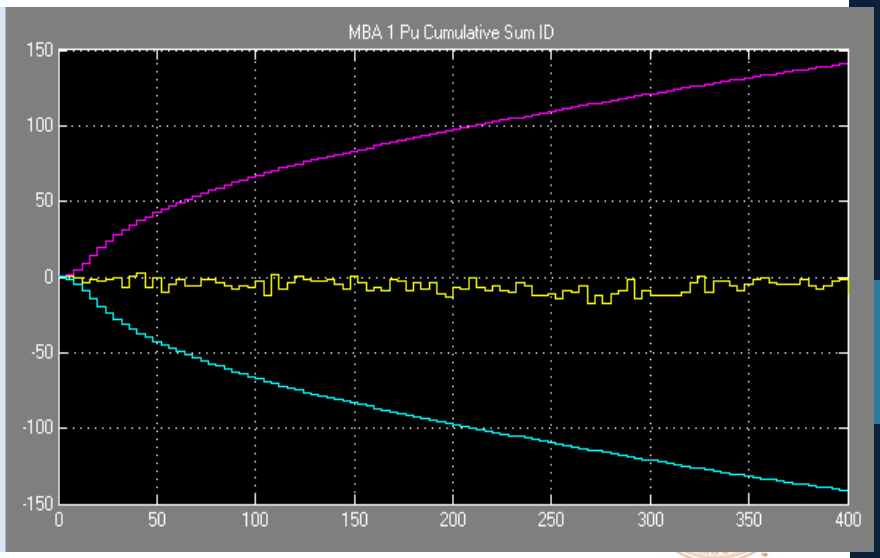
Integration of MC&A Administrative Procedures into SSPM

- Administrative procedures provide additional detection opportunities against the insider threat
- Daily Administrative Check used for demonstration
  - Plant administrator reviews data from variety of sources to check for anomalies
  - Occurs every 24 hours
  - Moderate dependency
  - Initial probability of detection depends on time since diversion began and amount of material being diverted
  - HRA positive dependence relationship used to degrade daily detection probability

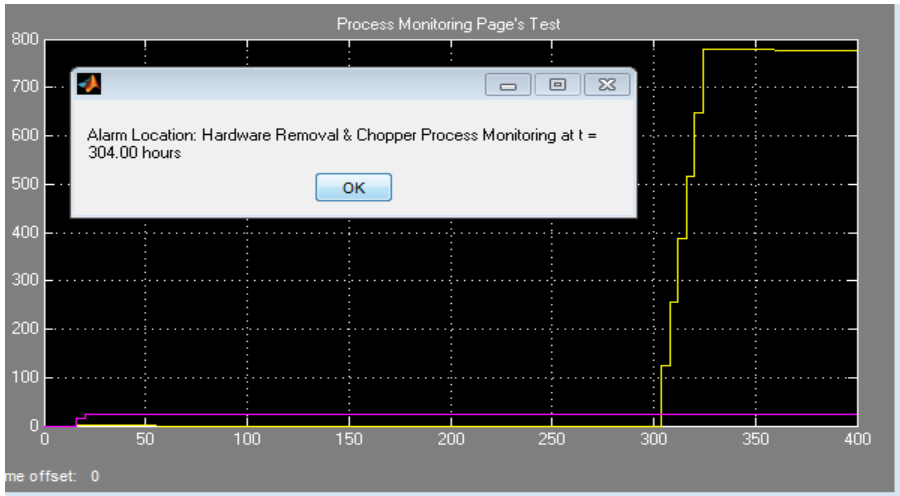
Abrupt Diversion from MBA1 without Integrated Systems

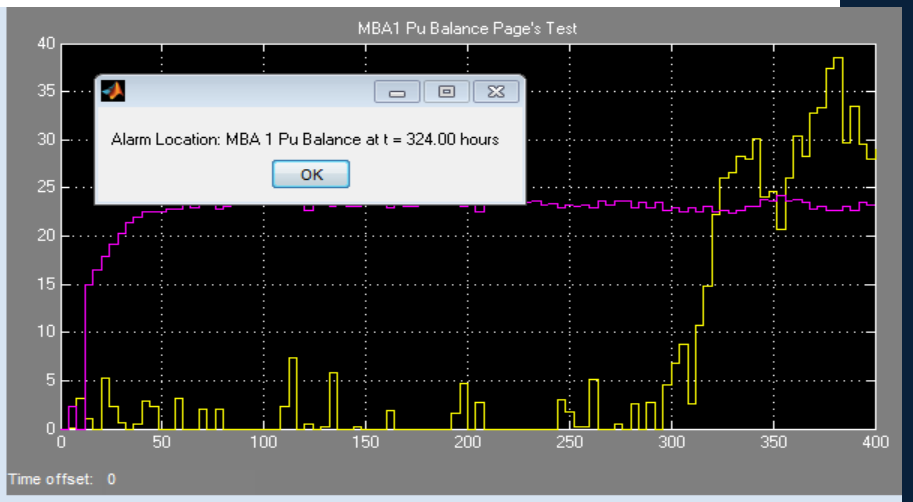
- 24 hour diversion, starting at hour 300, total of 8 kg Pu removed from MBA1
- Assumed material was removed in 2 trips (2 opportunities to detect material movement)
- Pathway: hot cell door, shipping/receiving, and then through the rail gate
- Detection probabilities arbitrarily assumed: 25% for hot cell door, 10% at shipping/receiving, 10% at the rail gate
- *No PPS alarms were indicated during this diversion*

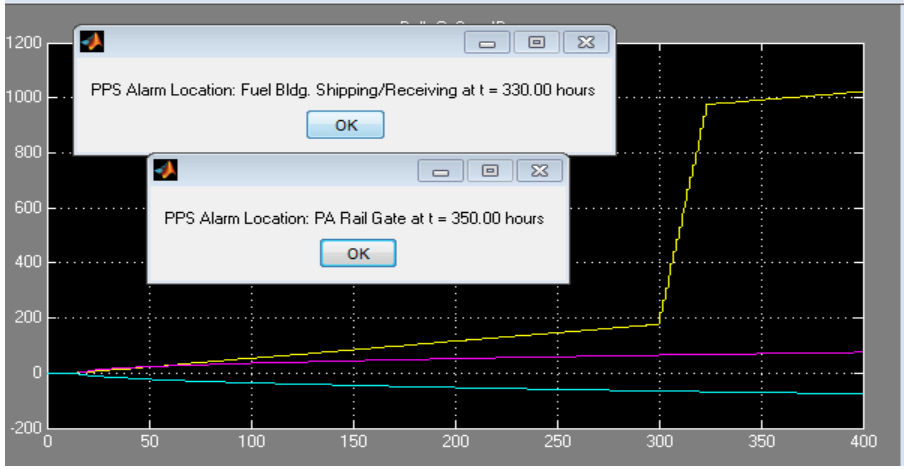




Abrupt Diversion from MBA1 with Integrated Systems







- Same diversion scenario as previous
- PM Alarm triggers alert state, and detection probabilities arbitrarily assumed to increase: 50% for hot cell door, 50% at shipping/receiving, 50% at the rail gate
- *Two PPS alarms were indicated during this diversion*

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Conclusions and Future Work

- Demonstrated value of plant systems integration
  - Improved the probability of detecting an abrupt diversion
  - Improved the timeliness of detecting a protracted diversion
- The use of process monitoring data for near real-time accountancy could be advantageous to operator and safeguarder
- Future work will focus on adapting the model for an electrochemical plant