Fully-Integrated Safeguards and Security for Reprocessing Plant Monitoring

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MPACT Working Group Meeting
September 14-15, 2011 • Gaithersburg, MD

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Relevance and Significance

- **The goal of this work is to design and analyze future reprocessing plant monitoring systems that significantly improve the timeliness of detection of plant anomalies. Improved timeliness reduces the risks of nuclear proliferation and terrorism. The Separations and Safeguards Performance Model (SSPM) has been used to evaluate:**

  - **Potential improvements in material accountability through new measurement technologies.**

  - **The integration of safeguards and security systems for more effective and efficient monitoring systems.**

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Integration Philosophy

- **Reprocessing plants contain a wealth of information including materials accountancy, process monitoring, administrative procedures, and physical security data.**

- **Integration into one overall plant monitoring system can allow more timely detection of anomalies that put the facility in a heightened state of alert—this alert state makes detection of material diversion more probable and more timely.**

  - **Anomalies in actinide accountancy balances, process monitoring balances, or administrative checks/procedures trigger a heightened state of alert.**

  - **The heightened state increases the probability of detecting material movement through physical security elements.**

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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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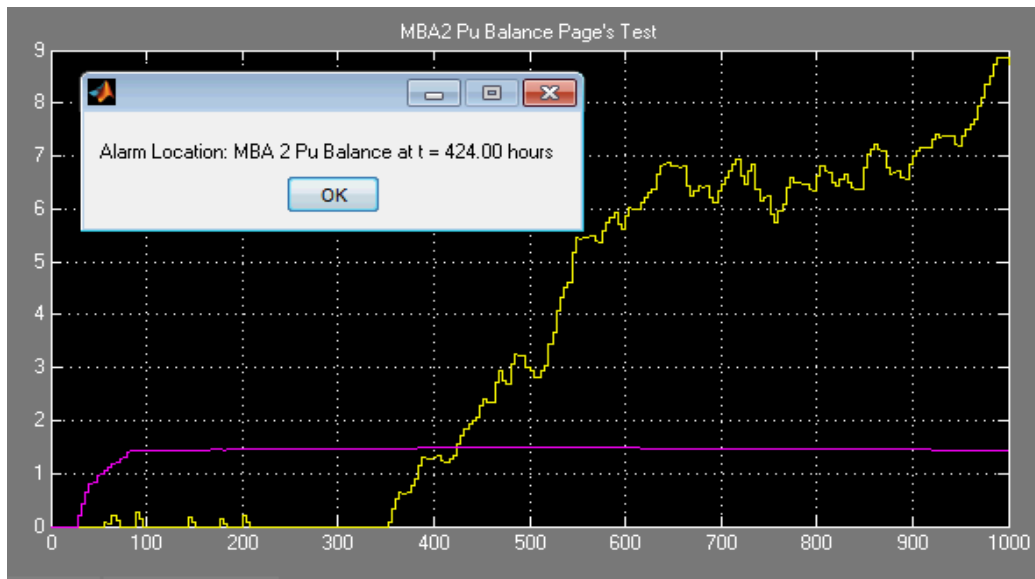
Process Monitoring Balances

- **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.**
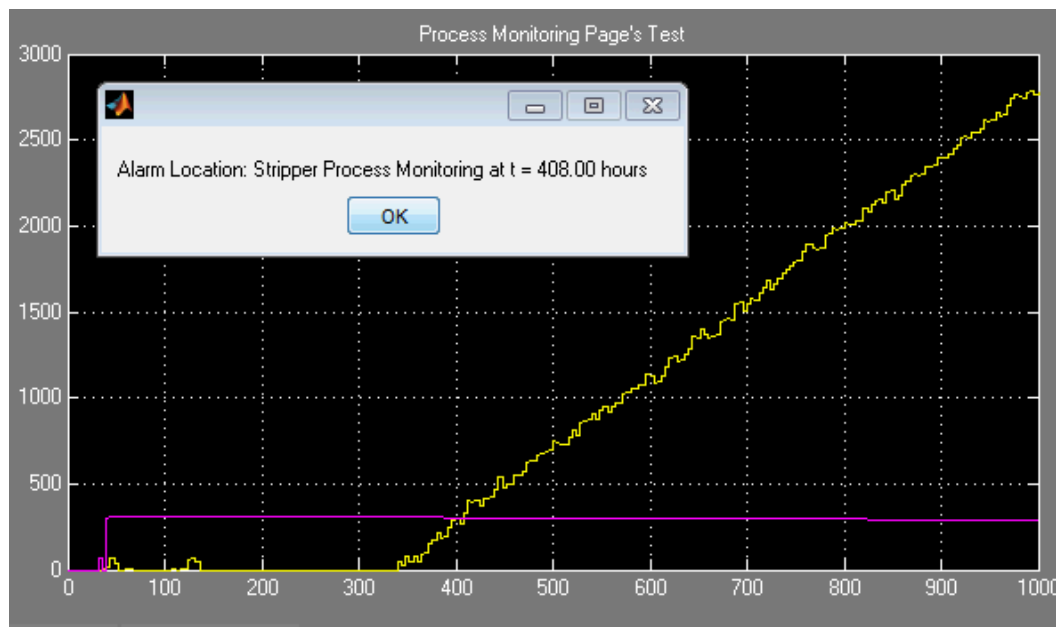
Administrative Procedures

- **Administrative procedures are similar to operator tasks in nuclear power plants, checking for anomalous conditions.**

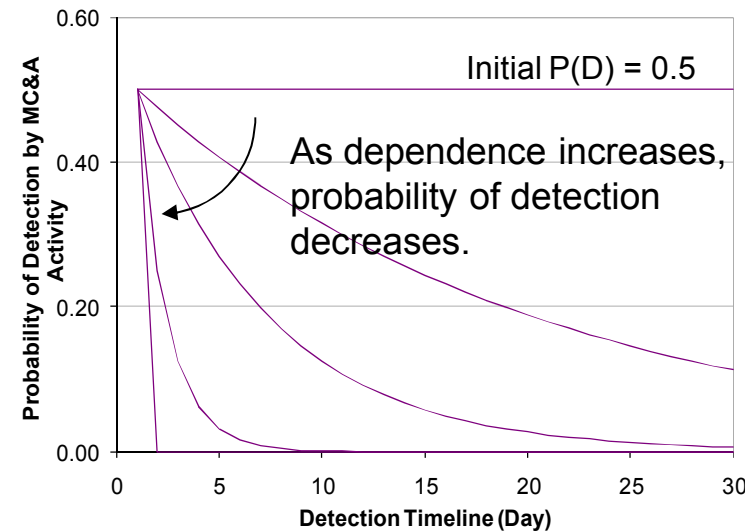- **Human reliability analysis (HRA) models estimate human error probability (HEP) for operator actions**

MC&A Activity	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 for Columns 2 and 3: A.D. Swain III and H. E. Guttmann, "Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plants," SAND80-0200, Sandia National Laboratories, 1983, Albuquerque NM.
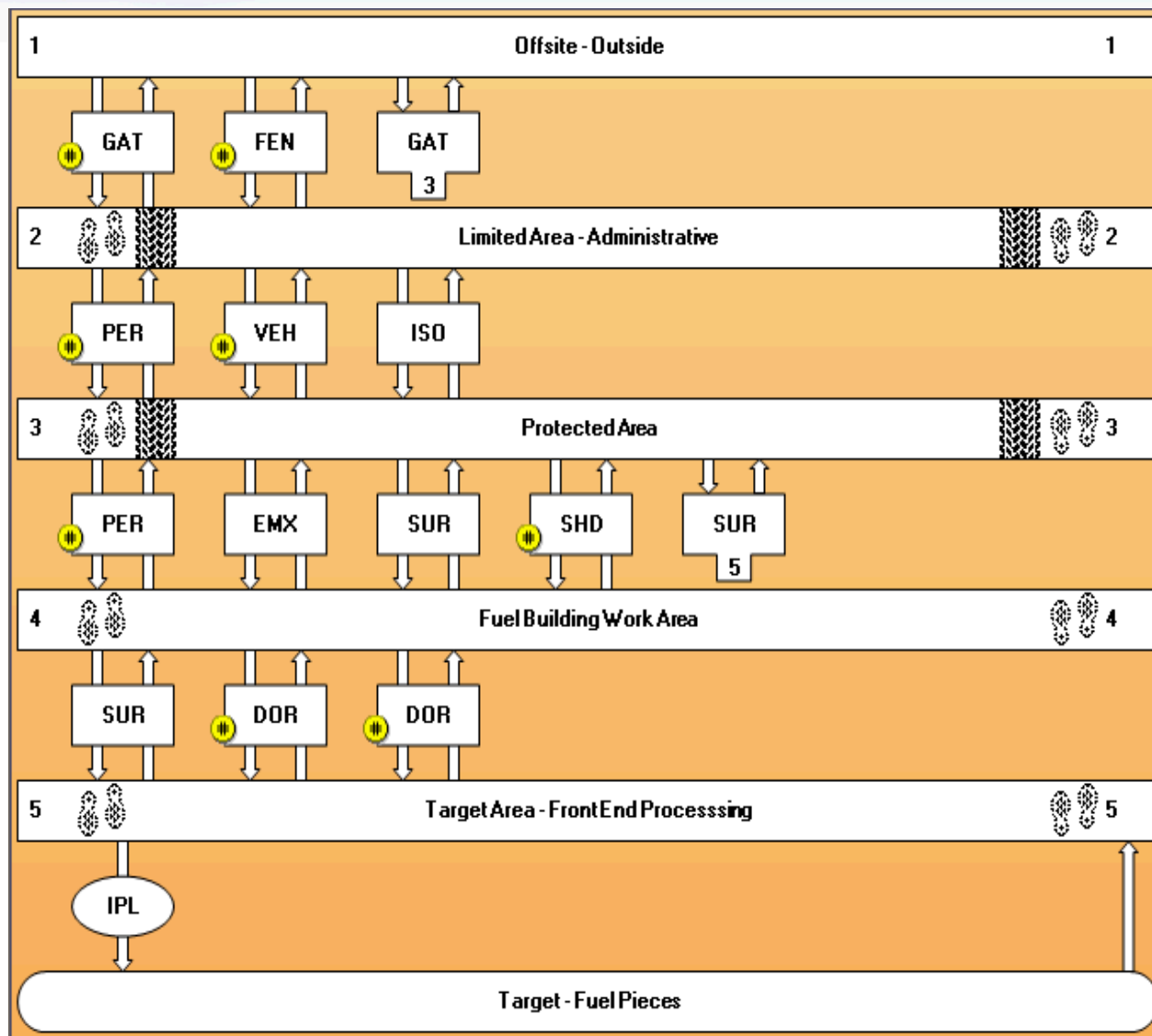
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- **Failure to recognize an anomaly at a check leads to a higher chance of failing again on the next check.**

- **Probability of success decreases with successive observations, depending on the dependency.**

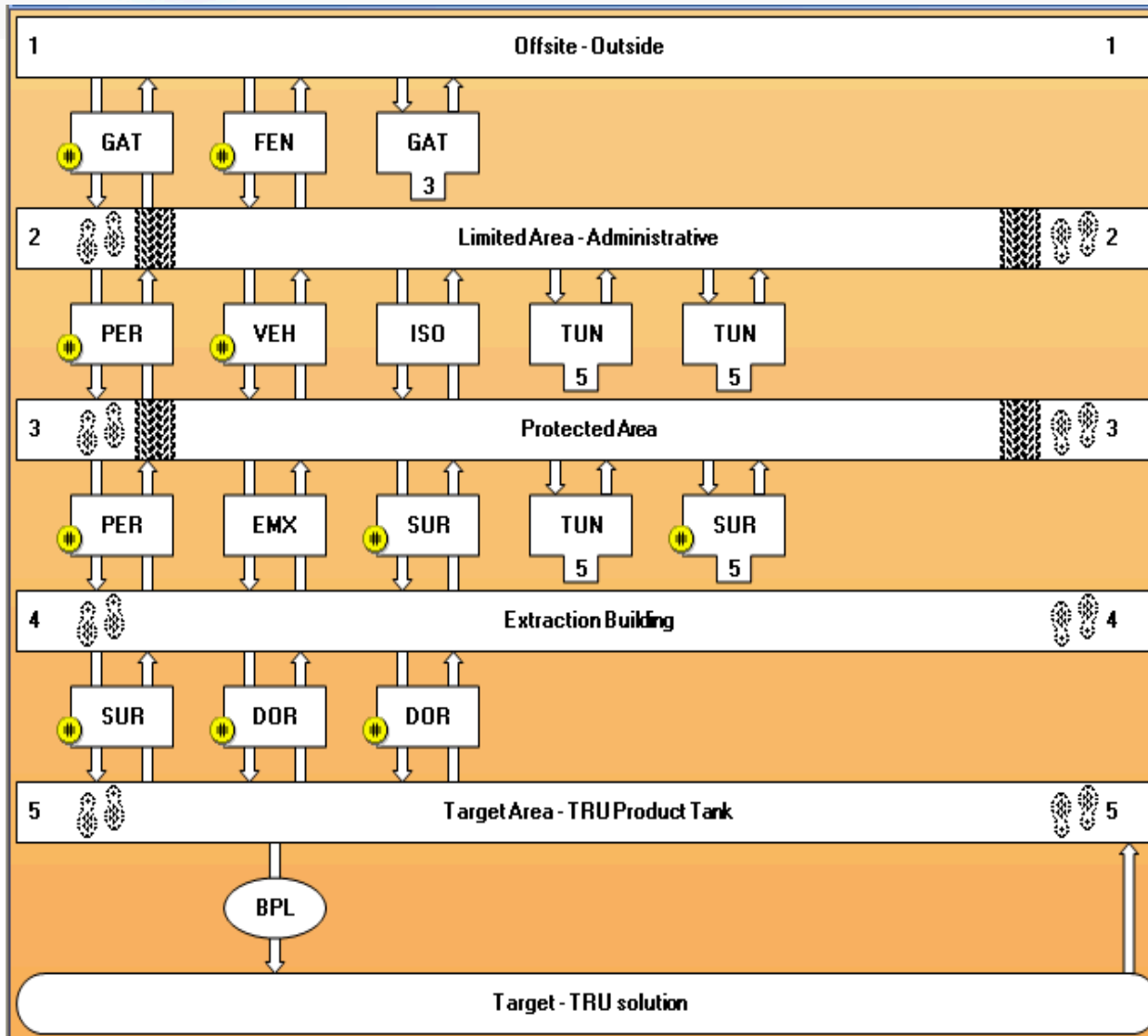- **Probability of detection is the complement of the associated HEP**

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	$P(F_M \mid F_{M-1} \mid HD) = \dfrac{1 + P_{M-1}}{2}$
Moderate Dependence (MD)	6	$P(F_M \mid F_{M-1} \mid MD) = \dfrac{1 + 6P_{M-1}}{7}$
Low Dependence (LD)	19	$P(F_M \mid F_{M-1} \mid LD) = \dfrac{1 + 19P_{M-1}}{20}$
Zero Dependence (ZD)	∞	$P(F_M \mid F_{M-1} \mid ZD) = P_{M-1}$

Initial P(D) = 0.5

As dependence increases, probability of detection decreases.

Probability of Detection by MC&A Activity

Detection Timeline (Day)

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ATLAS Model

Areas

Pathways

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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 - ???

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Integration of Systems in the SSPM

MBA 1 PPS System Alarms

MBA 2 PPS System Alarms
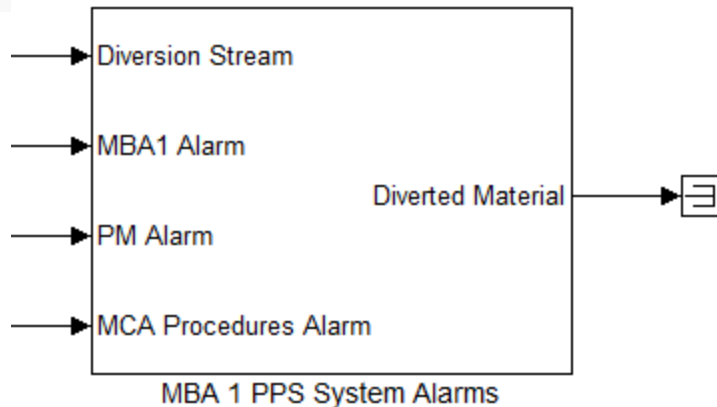
- **The ATLAS models were used to build the PPS Systems in the SSPM**

- **The Pu balance, PM balance, and MCA procedures subsystems may generate alarms during material loss.**

- **Any alarm will trigger a heightened state of alert in the physical protection system (PPS) elements.**

- **The heightened state will usually modify (increase) the detection probabilities of the PPS elements.**
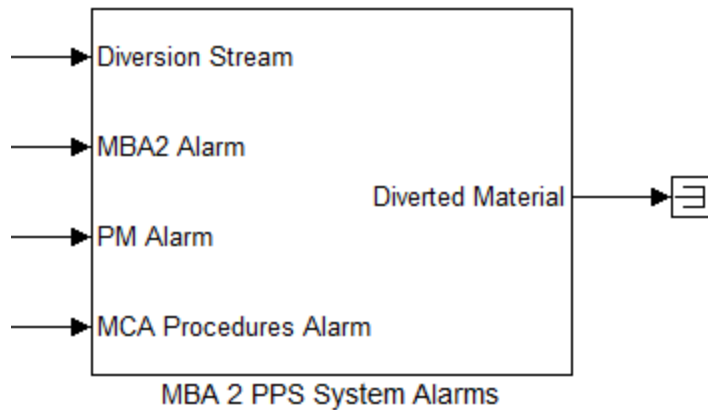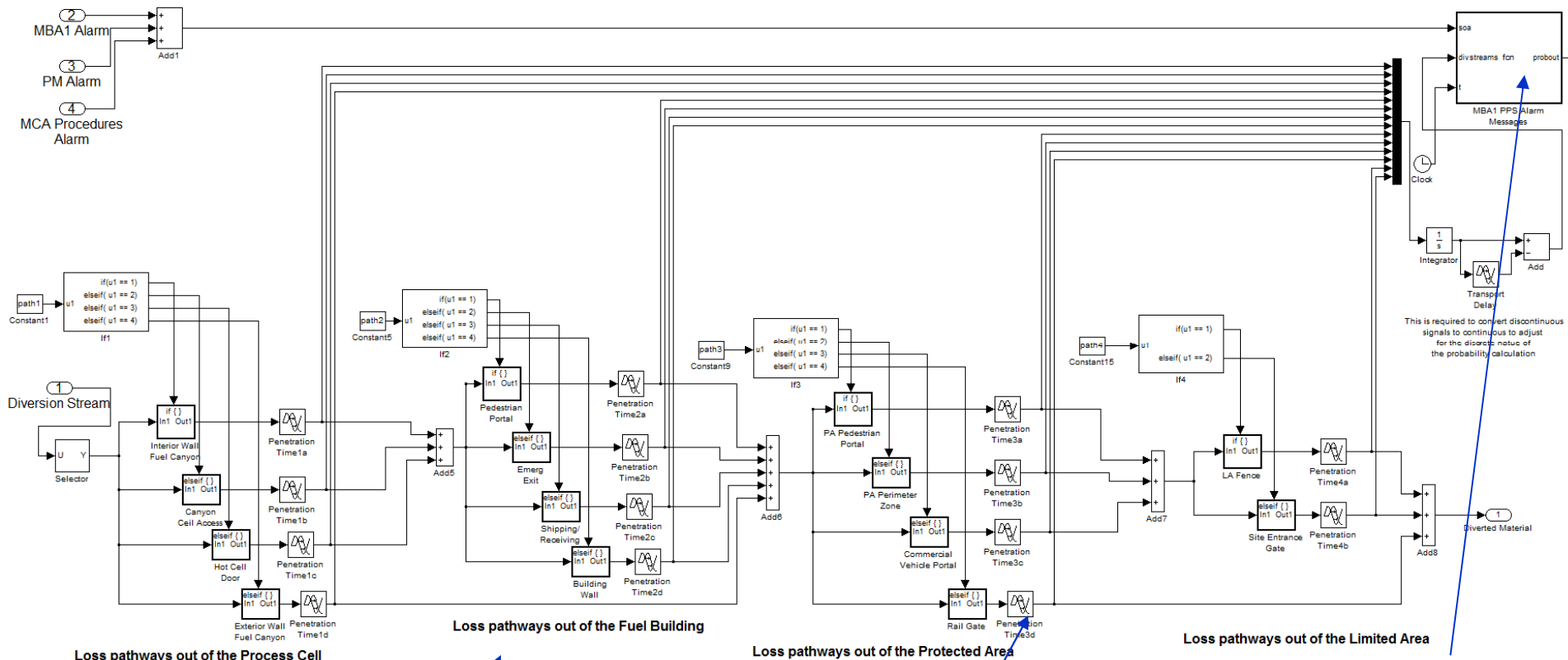
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PPS Architecture

Loss pathways out of the Process Cell

Loss pathways out of the Fuel Building

Loss pathways out of the Protected Area

Loss pathways out of the Limited Area

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

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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

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Diversion Analysis with Integrated Security and Safeguards

- **Identify targets**

- **Identify potential insiders**
  - Characterize level of access, authority and knowledge

- **Review and characterize MC&A procedures**
  - Type of procedure
  - Dependency

- **Perform/review PPS path analysis**

- **Incorporate PPS and MC&A elements and data into system modeling**
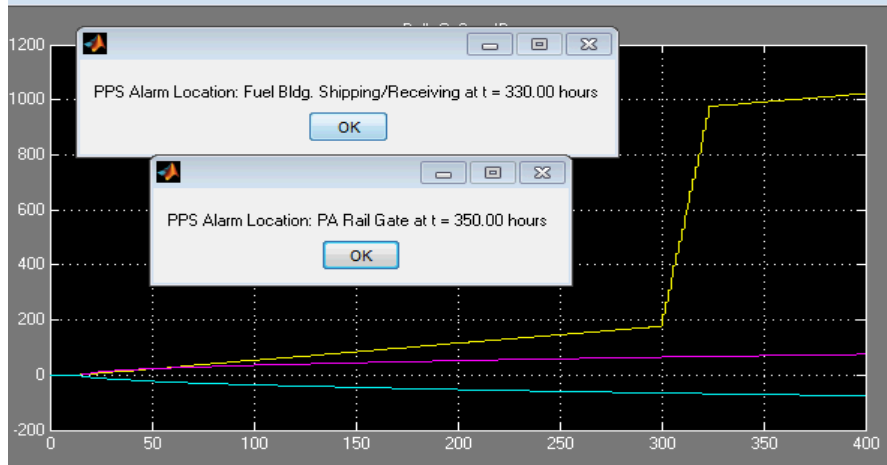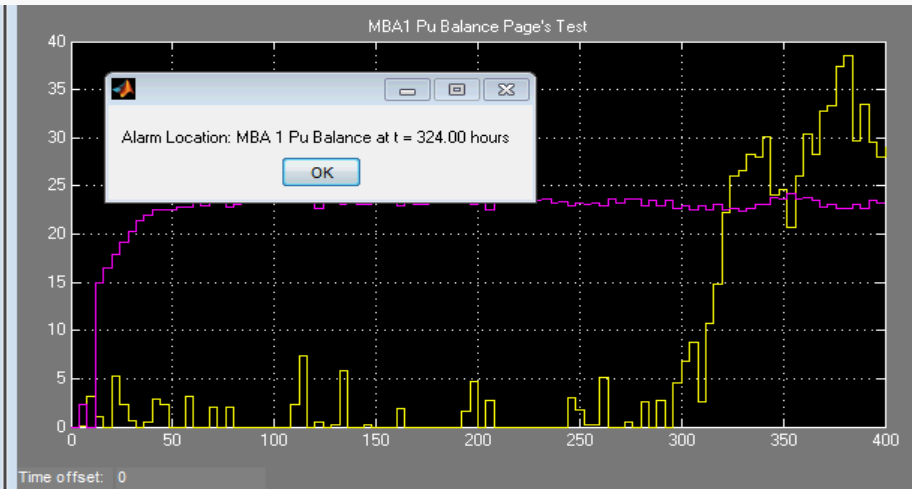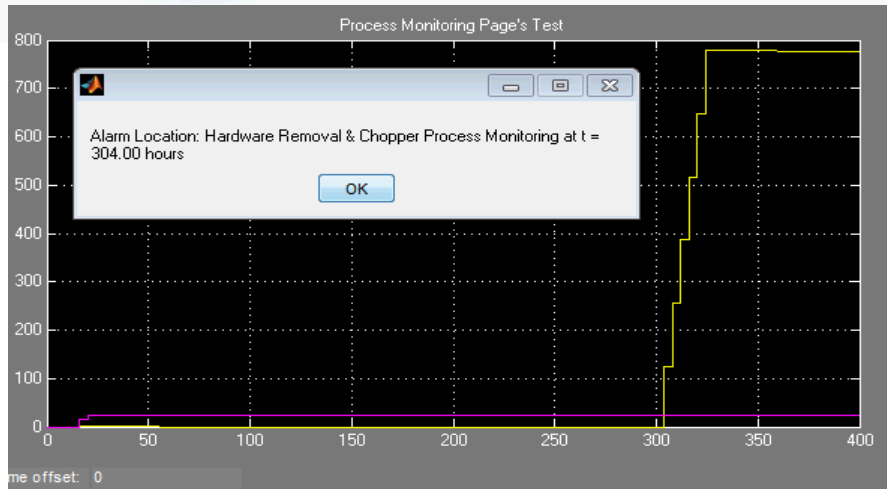
- **Run diversion scenarios**

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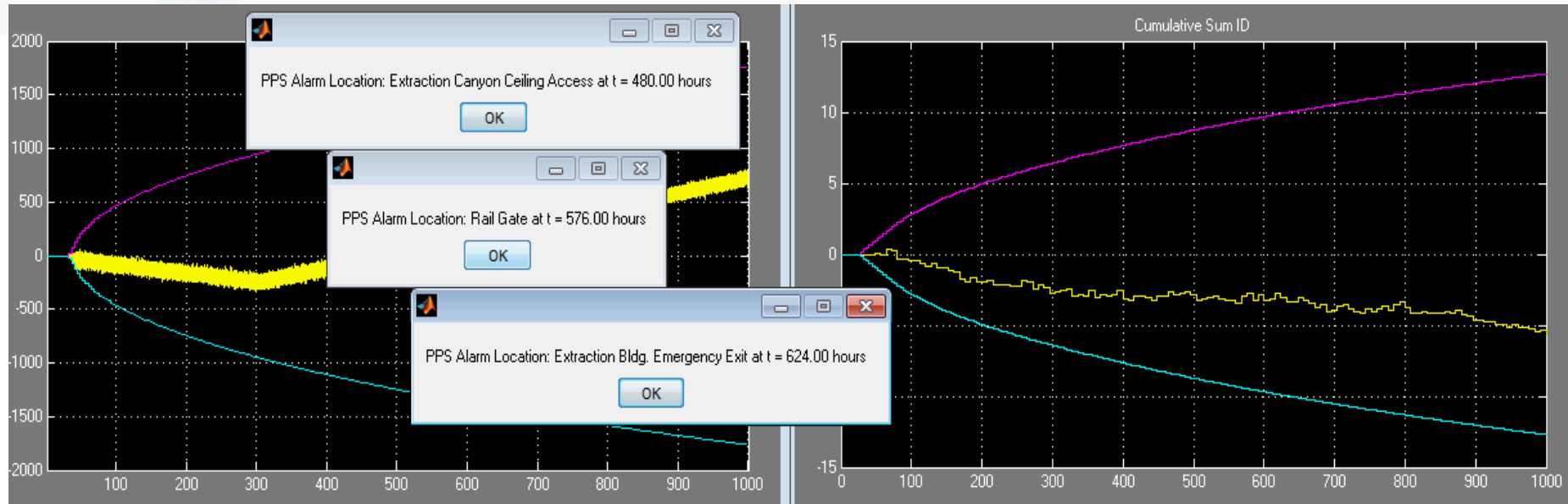# Abrupt Diversion from MBA1 without Integrated Systems
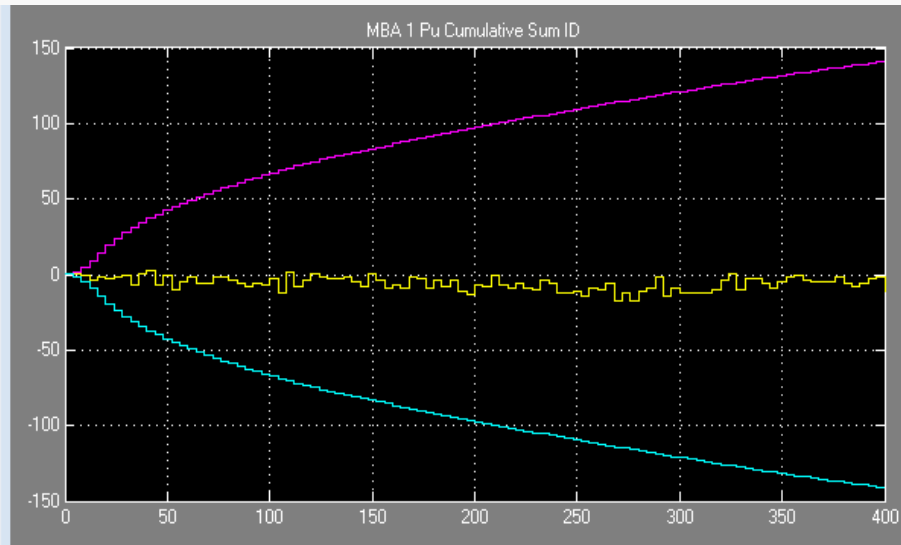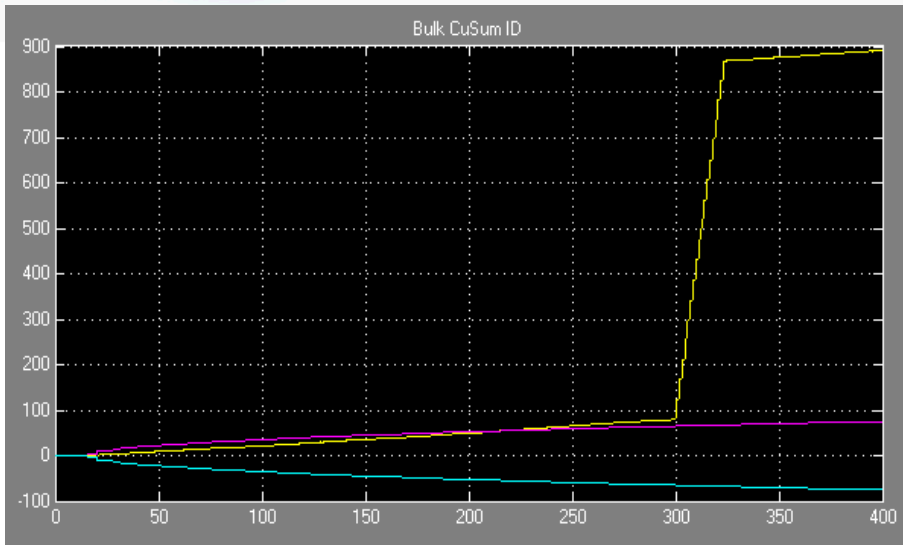
- **24 hour diversion, starting at hour 300, total of 8 kg Pu removed from MBA1.**

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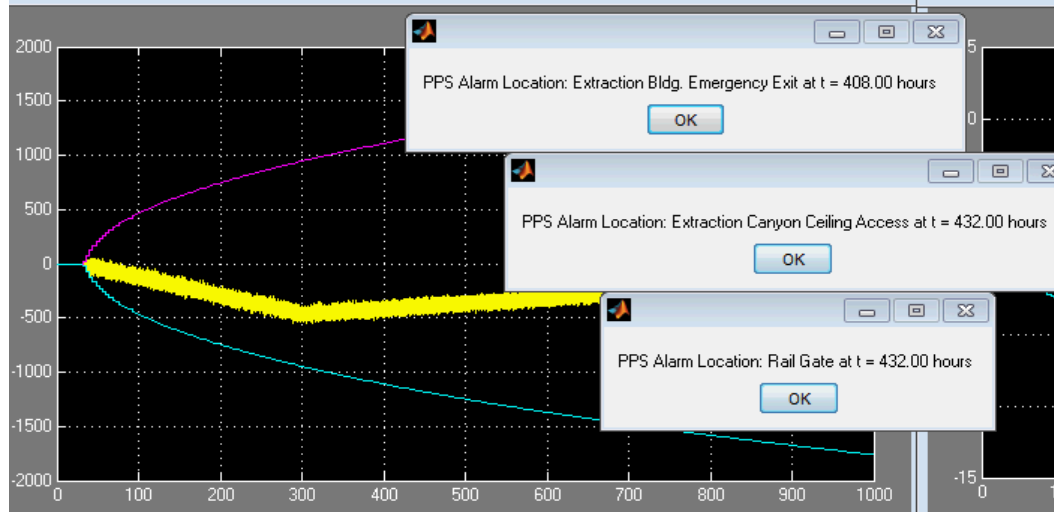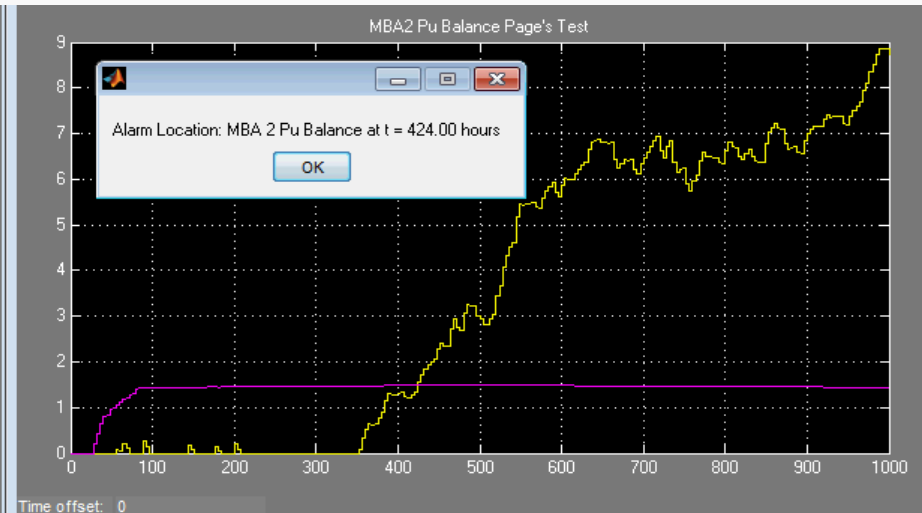
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- **Same diversion scenario as previous**
- **PM Alarm triggers heightened state of alert, and detection probabilities arbitrarily assumed to increase: 50% for hot cell door, 50% at shipping/receiving, 50% at the rail gate.**
- *Two PPS alarms were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

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Protracted Diversion from MBA2 without Integrated Systems

- **1600 hour diversion, starting at hour 300, total of 8 kg Pu removed from MBA2.**

- **Assumed material was removed in daily trips (many opportunities to detect material movement)**

- **Pathway: hot cell ceiling access, emergency exit, rail car exit.**

- **Detection probabilities arbitrarily assumed: 5% for the ceiling access, 10% for the emergency exit, and 5% for the rail car exit.**

- *All three PPS alarms were indicated during this diversion due to multiple detection opportunities.*

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Protracted Diversion from MBA2 with Integrated Systems
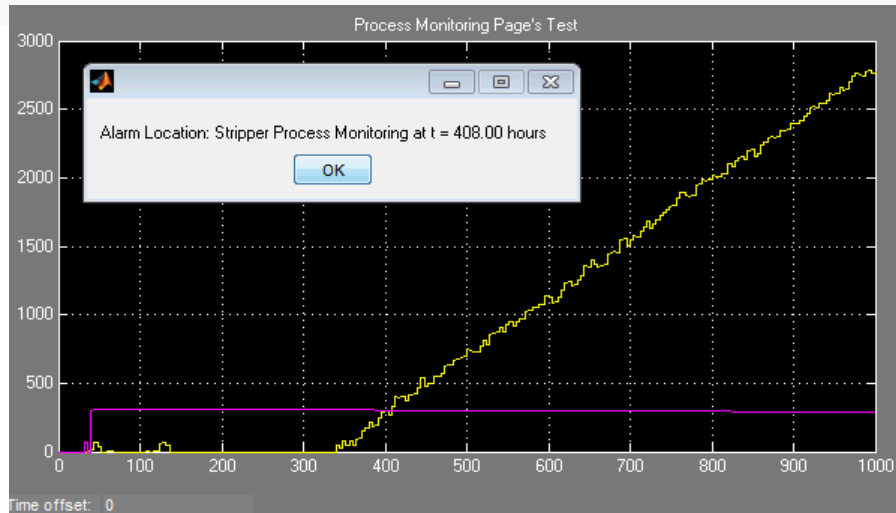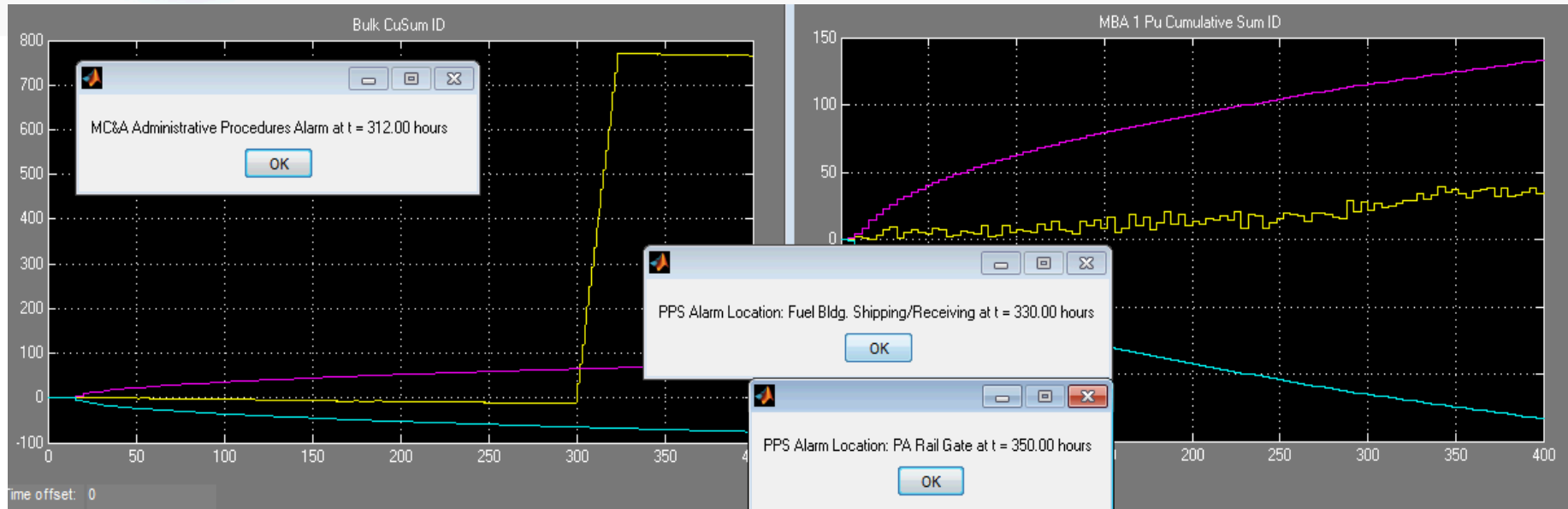

- **Same diversion scenario as previous**

- **PM Alarm triggers heightened state of alert, and all detection probabilities arbitrarily assumed to increase to 50%.**

- *All three PPS alarms were indicated sooner during this diversion.*

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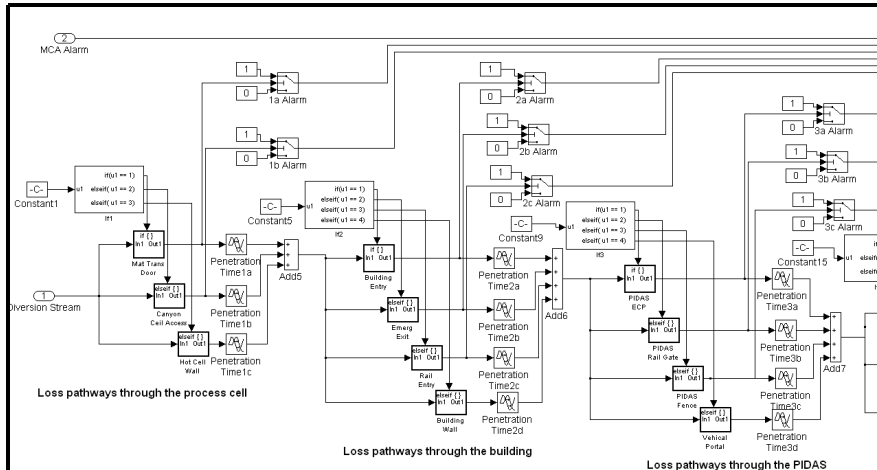# Abrupt Diversion from MBA1 using Administrative Procedures

- **Same abrupt diversion as shown previously.**

- **The Daily Administrative Check signaled an alarm 12 hours after the diversion, leading to a heightened state of alert.**

- *Two PPS alarms were indicated during this diversion.*

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Protracted Diversion from MBA2 using Administrative Procedures
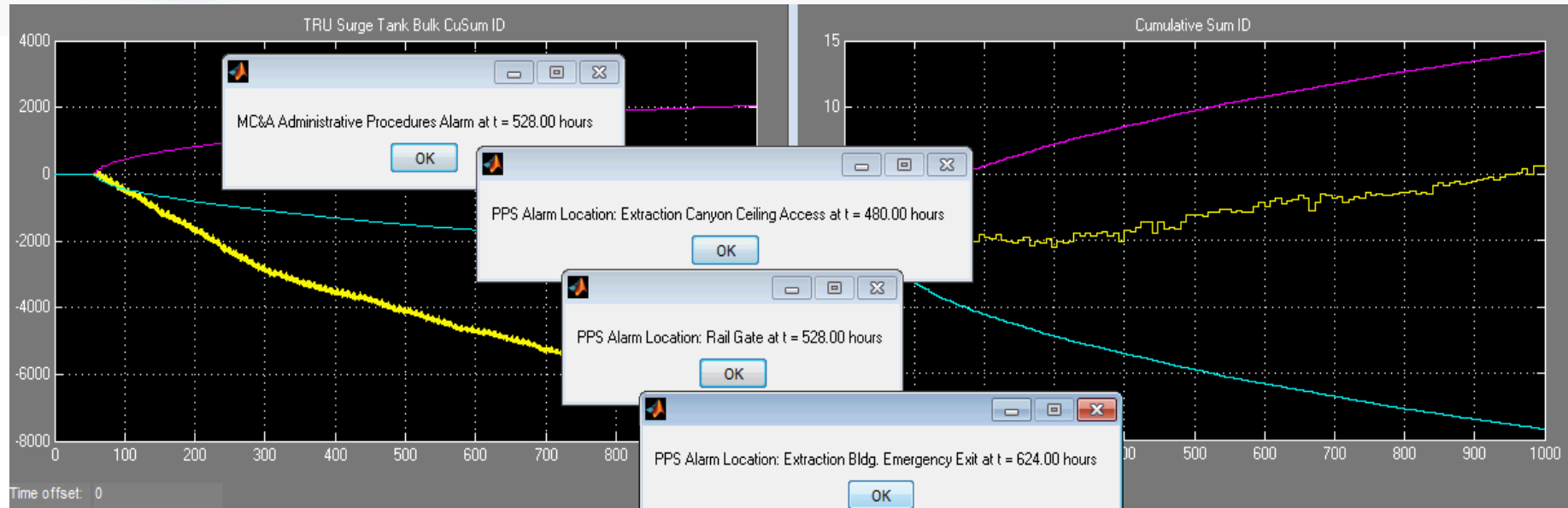
- **Same protracted diversion as shown previously.**

- **The Daily Administrative Check signaled an alarm 228 hours after the diversion, leading to a heightened state of alert.**

- *Three PPS alarms were indicated during this diversion.*

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Loss pathways through the process cell

Loss pathways through the building

Loss pathways through the PIDAS

POCs:
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Statement of the MPACT Need:
Modeling and simulation to evaluate and guide R&D for early detection of theft or diversion of material

Key Outcomes:
Integrated process monitoring and security modules in the Separations and Safeguards Performance Model for analyzing diversion scenarios

Technical Challenges

- **The design architecture is dependent on new measurement instrumentation that allows for NRTA of Pu measurements and PM balances.**

- **Diversion path analysis depends on determining appropriate detection probabilities and appropriate increases in an alert state.**

- **Key challenge is to include a thorough path analysis and determine a way to down-select to the most critical paths**

FY 2011 Accomplishments

- **Architecture for integrating process monitoring and advanced MC&A measurements has been demonstrated.**

- **Diversion scenario analysis was been used to set the goals for new MPACT instrumentation.**

- **Diversion path analysis was expanded to the second MBA, including both an ATLAS and SSPM model analysis. Integration was expanded to include MC&A administrative checks.**

- **Various insider diversion scenarios have been evaluated to demonstrate improved timeliness.**

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