SAND2011-4354C

Separations and Safeguards Performance Model

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

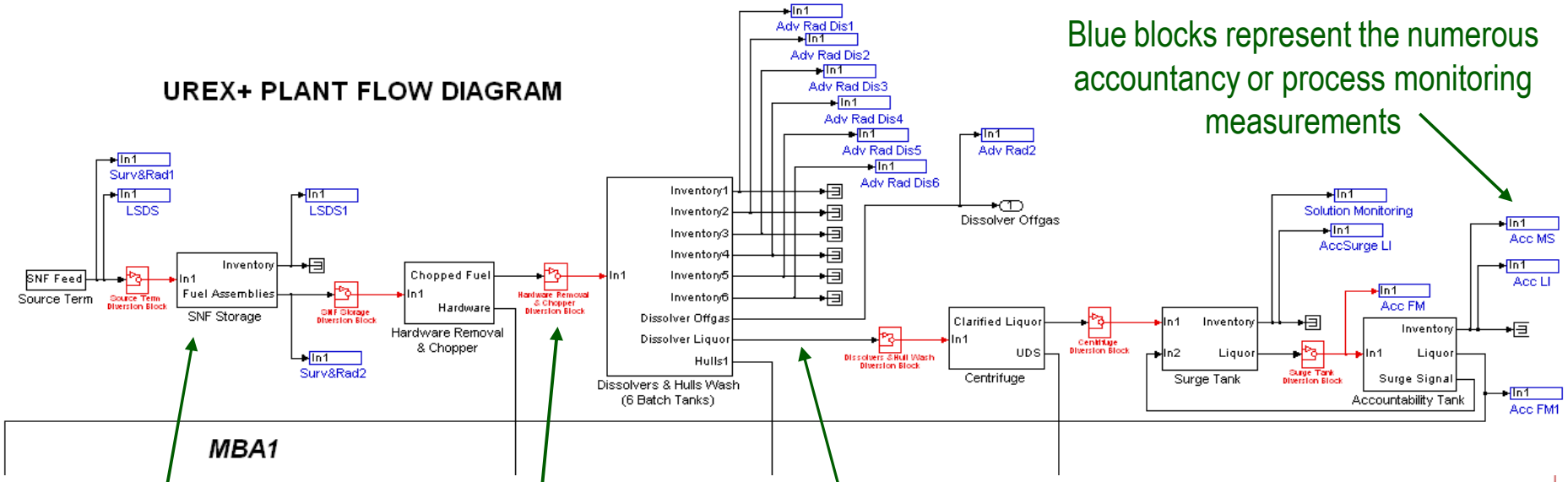
Research Objective

- **Future reprocessing facilities face challenging economic goals and increasing safeguards and security requirements. Systems modeling provides a way to test new plant monitoring strategies and related technology that can be worked in early in the design process.**
- **The Separations and Safeguards Performance Model (SSPM) is a virtual platform for designing and testing advanced plant monitoring systems under various diversion scenarios.**
- **The goals of this modeling work include:**
  - Testing the effect of adding in new measurement instrumentation
  - Using diversion scenarios analysis to identify gaps in current systems
  - Integrating process monitoring, materials accountancy, and physical protection in a more efficient and effective system
  - Evaluating the cost-effectiveness of advanced monitoring strategies

SSPM Features

- **The SSPM is a Matlab Simulink model of a reprocessing plant that tracks elemental and bulk material flows through the various unit operations—capabilities include:**
  - Spent fuel source term library
  - Mass, heat load, and radioactivity tracking
  - Chemical separations modeling through integration with SEPHIS and AMUSE codes (still work in progress)
  - Customized measurement blocks
  - Automated calculation of inventory differences and error propagation in real-time
  - User-defined diversion scenario analyses
  - Statistical test to set alarm conditions
  - Physical protection system models (still work in progress)

MBA1: Front End



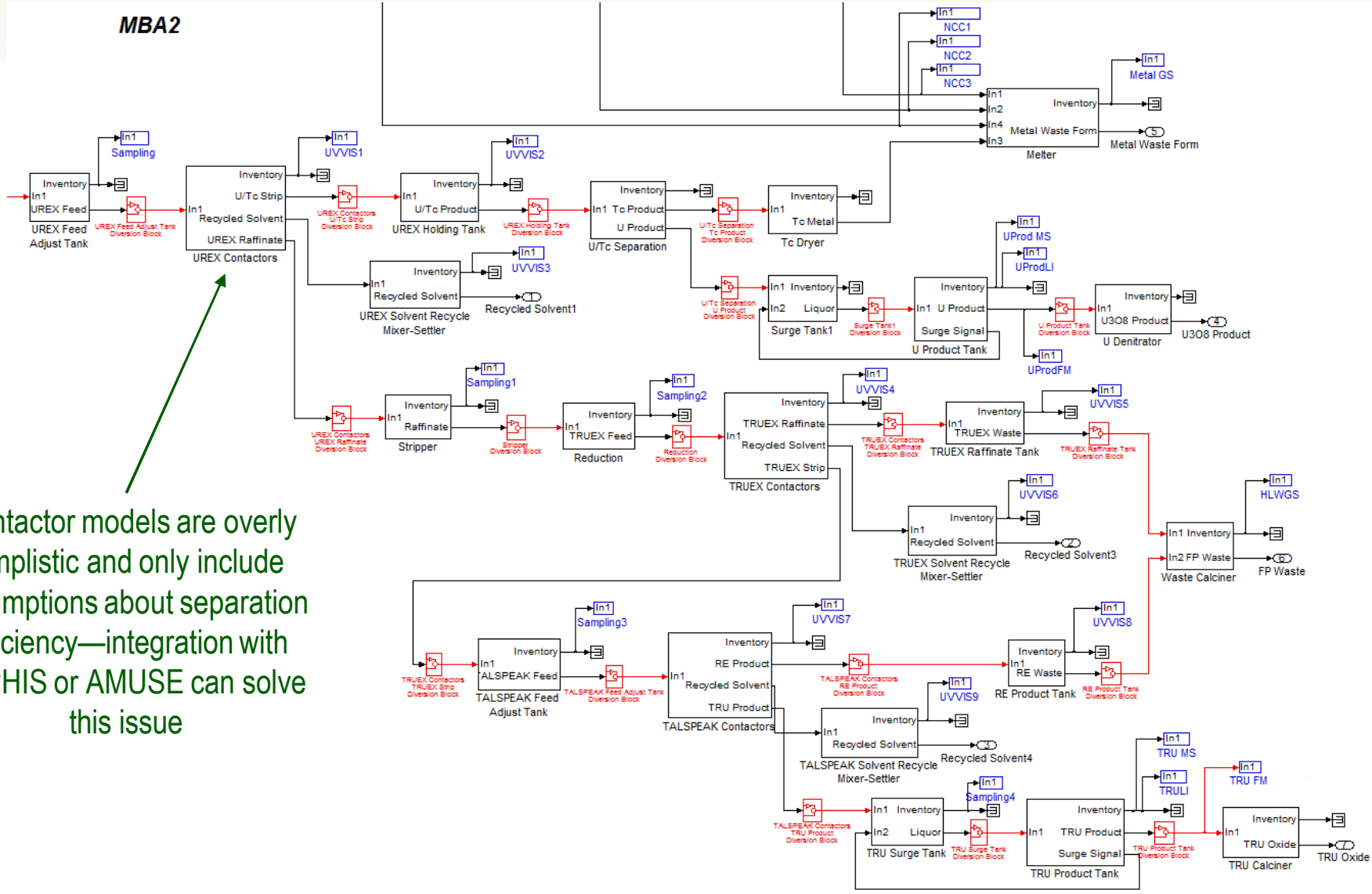
Blue blocks represent the numerous accountancy or process monitoring measurements

Each unit operation is a subsystem that models the process

Red blocks are potential diversion points that can be turned on by the user

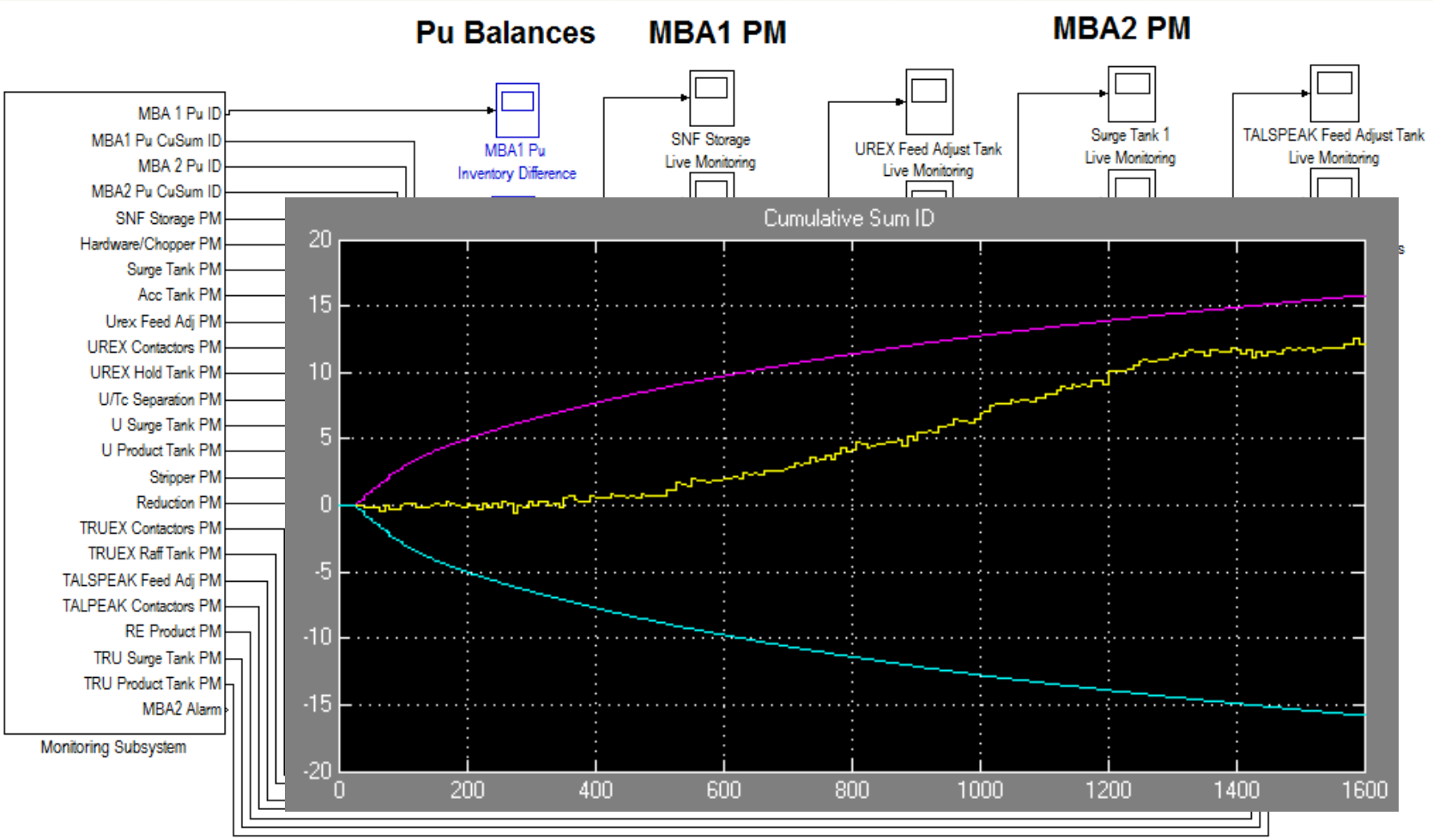
Each signal is an array that contains the mass flow rate of each element as well as bulk liquid and solid flow rate—arrays are expandable

MBA2: Separations



Contactor models are overly simplistic and only include assumptions about separation efficiency—integration with SEPHIS or AMUSE can solve this issue

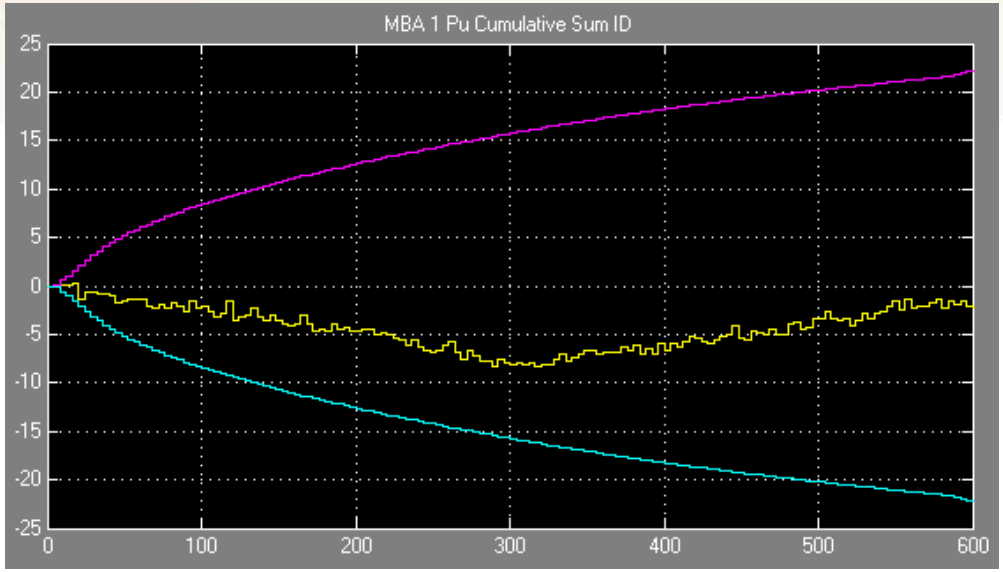
Monitoring System

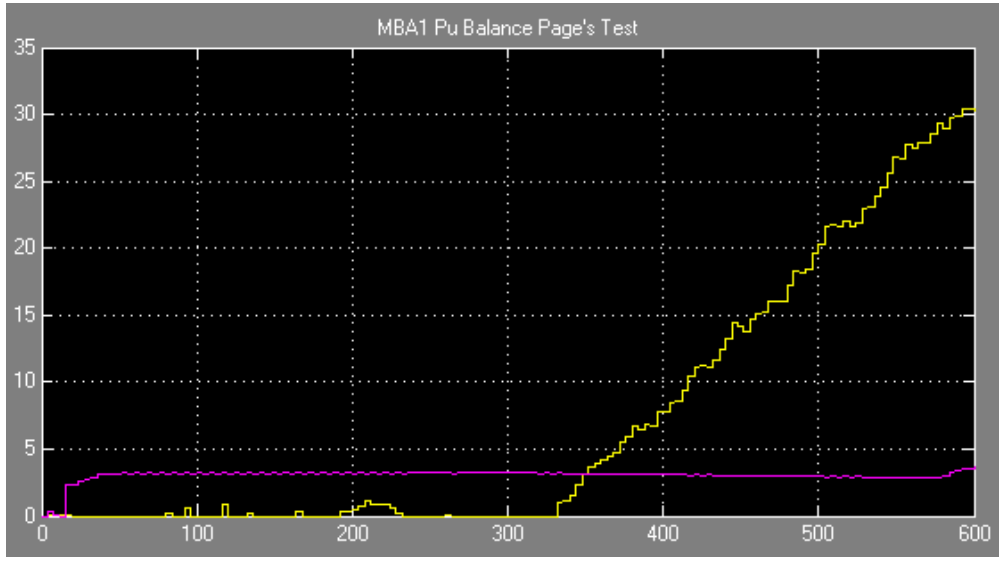


Page's Test for Alarm Conditions

- **Page's Test is a well-accepted statistical test used for setting alarm conditions for material diversion.**
  - However, existing plants may perform an inventory balance every 10 days, so only 36 balances per year. The move toward more frequent balances leads to lengthy computational times.
  - Page's Test is optimized for a particular instrumentation setup, which is of limited use for modeling when the setup changes.
- **In order to make a test that could run in real time, with any instrumentation setup, and with short computational times, the test was modified:**
  - A bias correction was first used in order to correct for systematic errors.
  - Then assuming all of the measurements are independent, a tri-diagonal form of Page's Test was used that could be calculated on the fly.
  - End result is a test that works well in the SSPM.

Page's Test Example



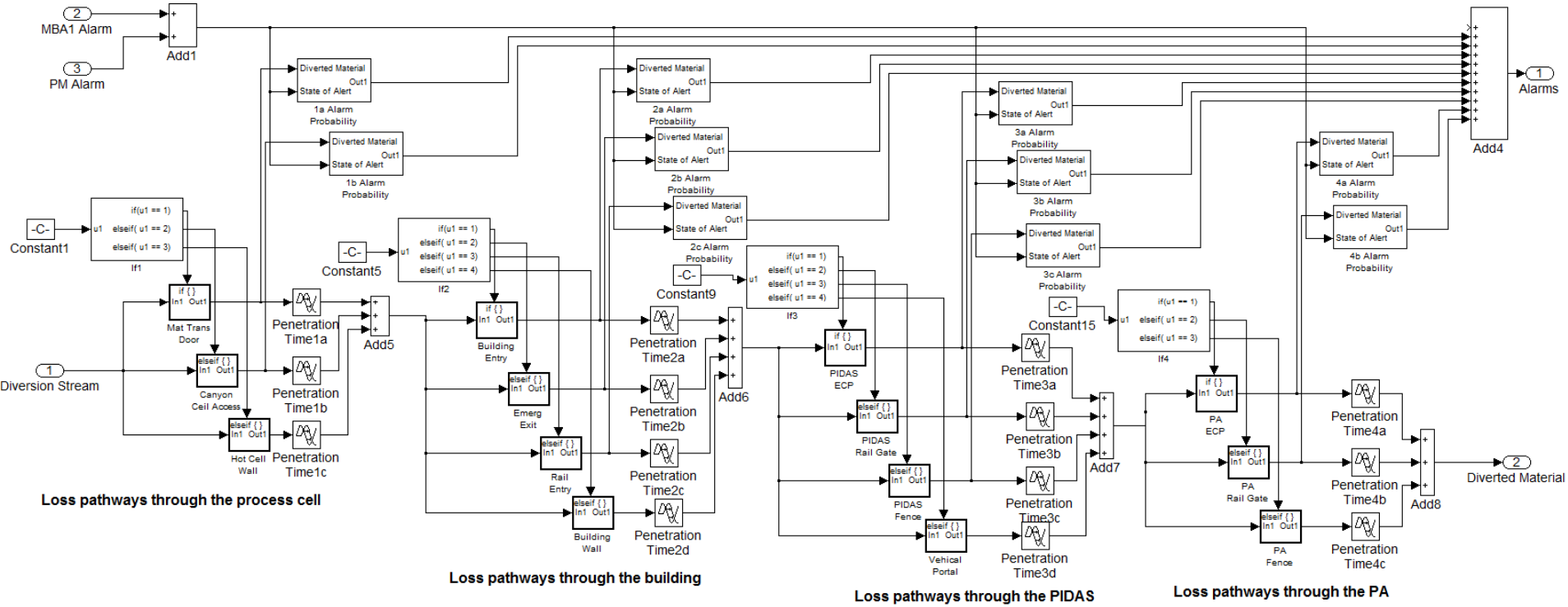


300 hour diversion from Surge Tank before Accountability Tank (MBA1)

MBA1 Pu Cumulative Sum ID

Modified Page's Test

Physical Protection System

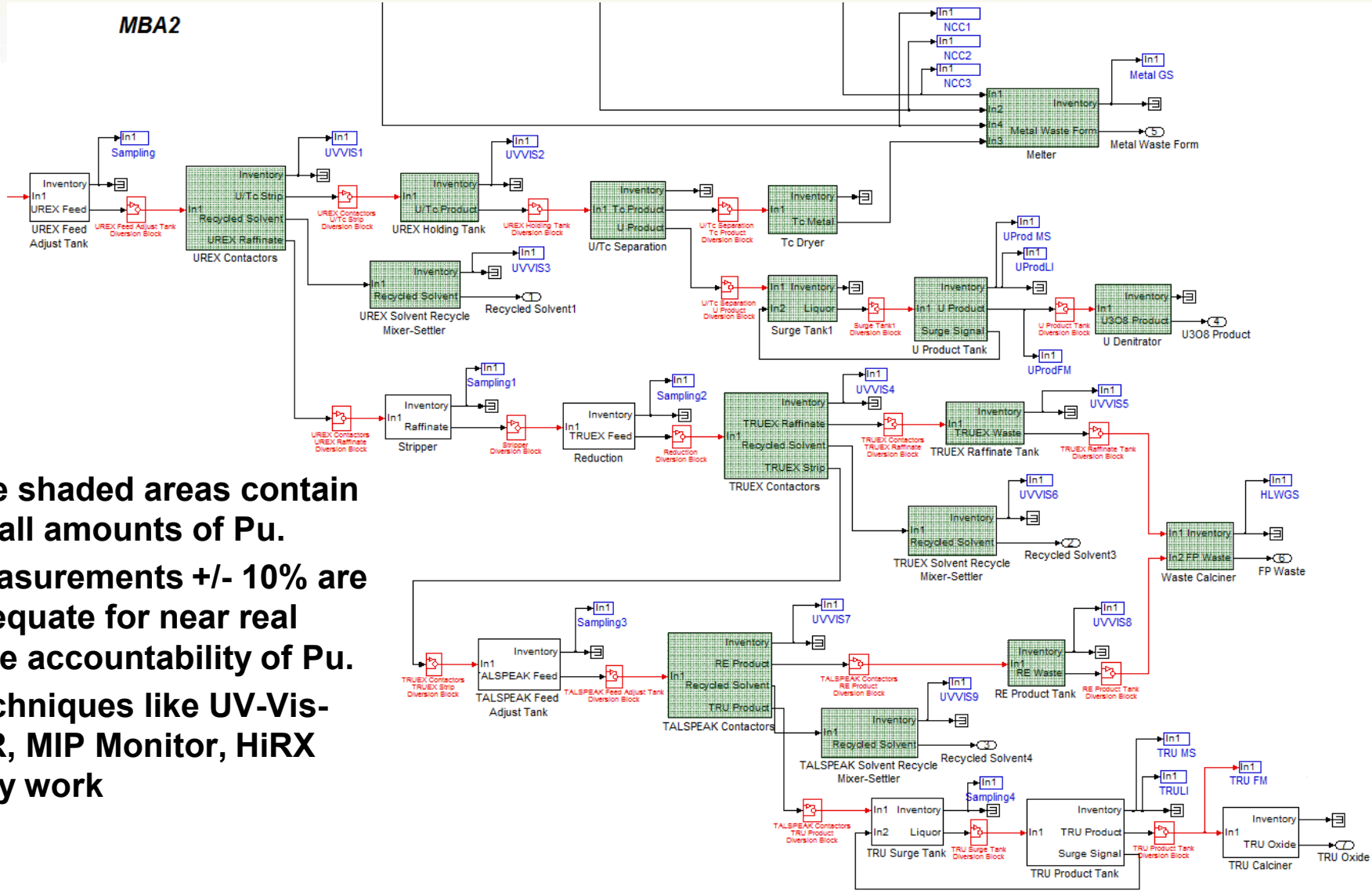


The physical protection subsystem can be used to evaluate the various pathways that diverted material may take out of the plant. MC&A and Process Monitoring alarms may improve response.

Example of SSPM Analysis:
Improving Detection Timeliness through NRTA

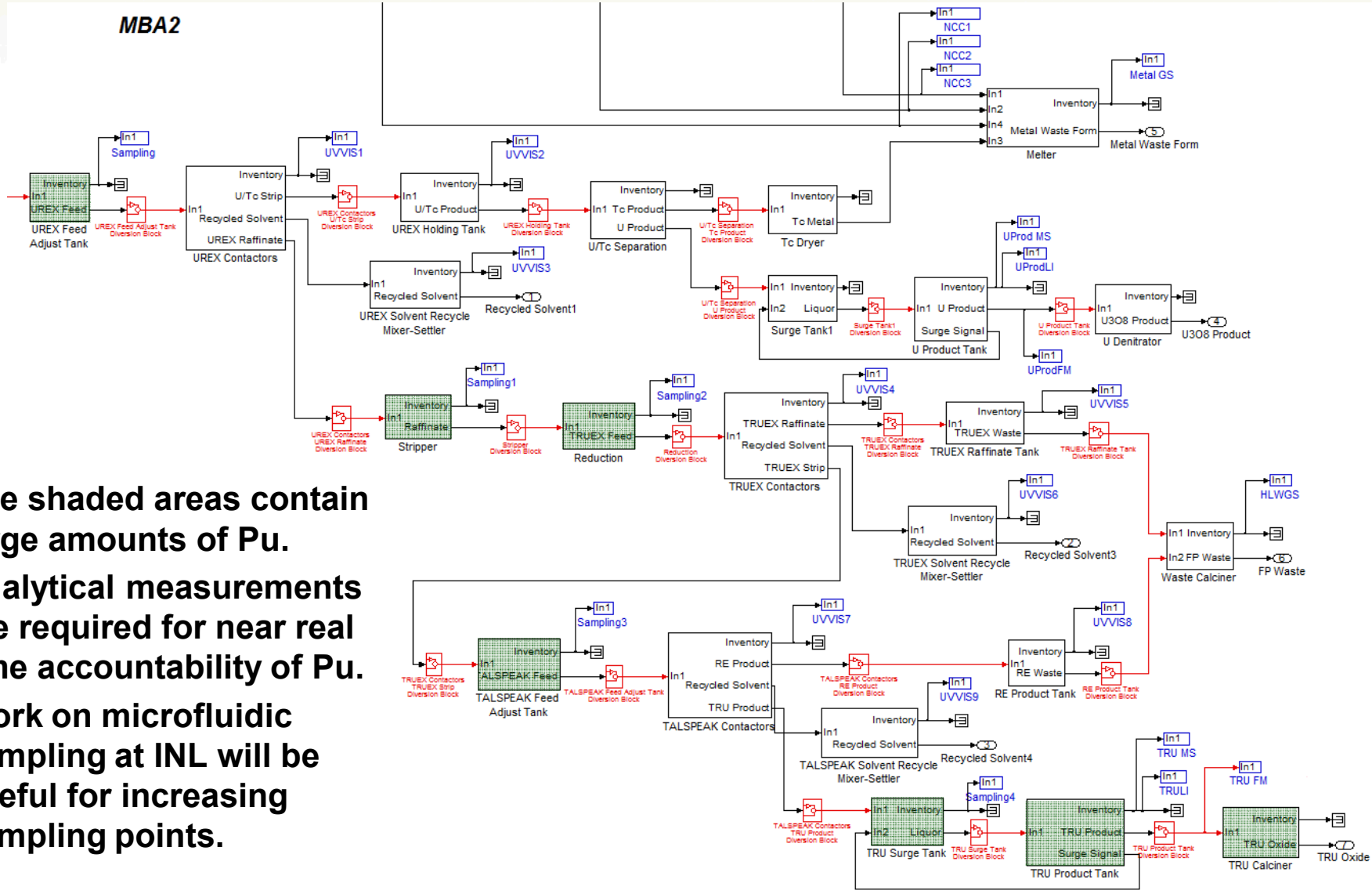
- **Integration of process monitoring data**
  - Standard plant monitoring data (bulk flow, mass, density, level, etc.) is being evaluated for efficient integration with traditional accountancy.
  - Bulk material balances have been setup for every processing unit in the plant, and a Page's Test is used to set alarm conditions for detecting material loss.
- **Evaluation of new measurement technology or new monitoring approaches**
  - A combination of new and existing technology may allow near real time tracking of actinides throughout the plant with low uncertainty. The SSPM was used to evaluate the improvement to detection timeliness.

Near Real Time Accountability in MBA2



- **The shaded areas contain small amounts of Pu.**
- **Measurements +/- 10% are adequate for near real time accountability of Pu.**
- **Techniques like UV-Vis-NIR, MIP Monitor, HiRX may work**

A Few Areas in MBA2 Need Precision Pu Measurements (Sampling)



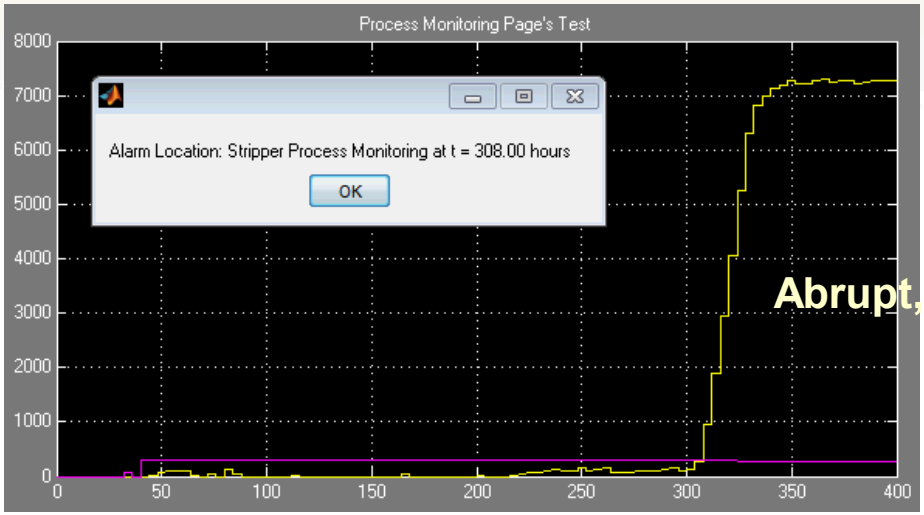
- **The shaded areas contain large amounts of Pu.**
- **Analytical measurements are required for near real time accountability of Pu.**
- **Work on microfluidic sampling at INL will be useful for increasing sampling points.**

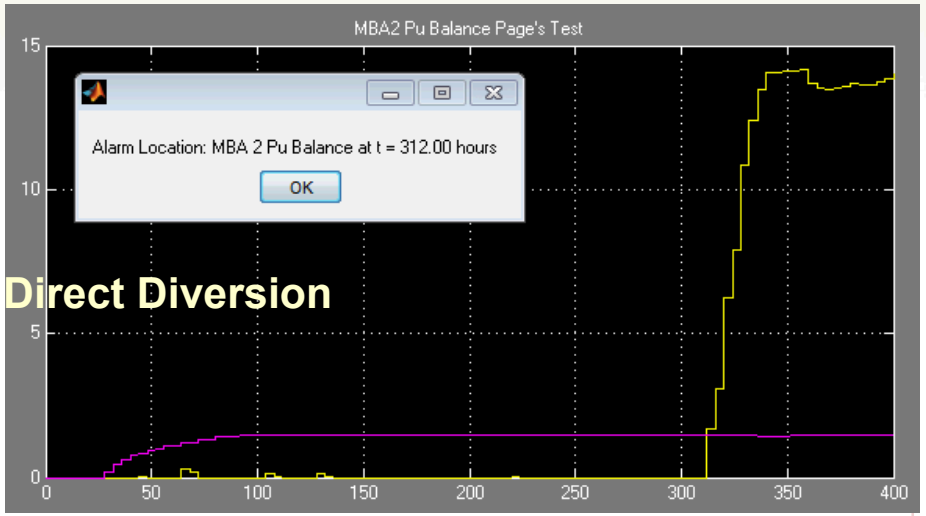
Near Real Time Monitoring Strategy for MBA2

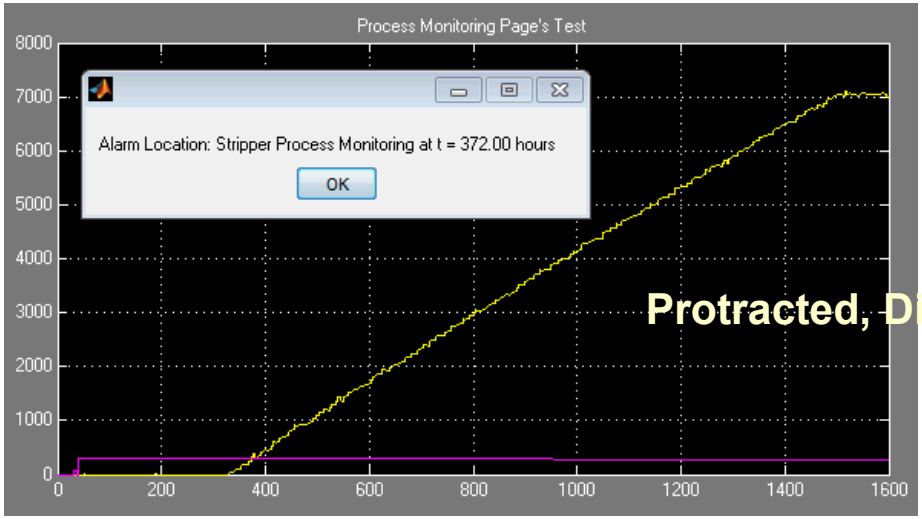
- **The integrated monitoring system for MBA2 includes:**
  - Bulk material balances over every processing unit utilizing existing process monitoring measurements (can be very low uncertainty).
  - The use of advanced micro sampling techniques to allow more analytical measurements of key inventory tanks (low uncertainty).
  - The use of a variety of simple NDA measurement techniques or confirmatory measurements in less important areas of MBA2 (higher uncertainty okay).

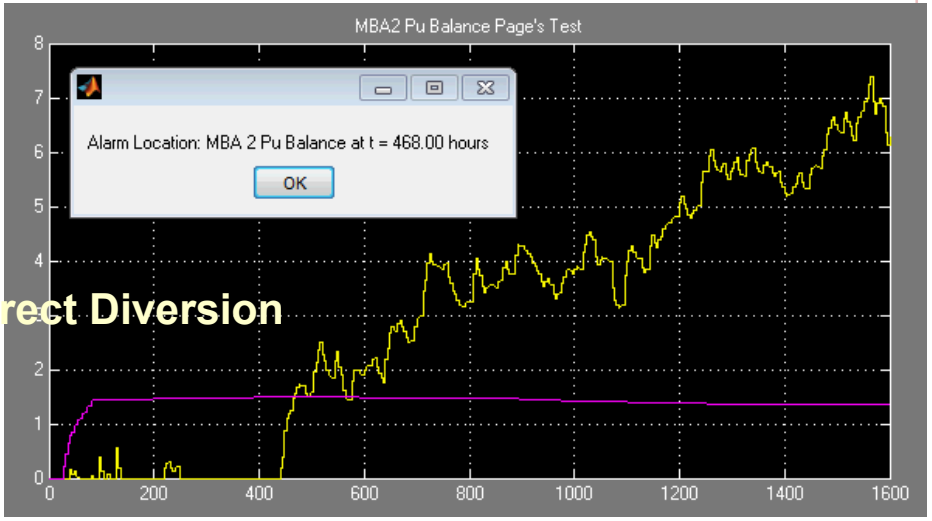
Advanced Monitoring System Results:

Direct Diversions of 8 kg of Pu









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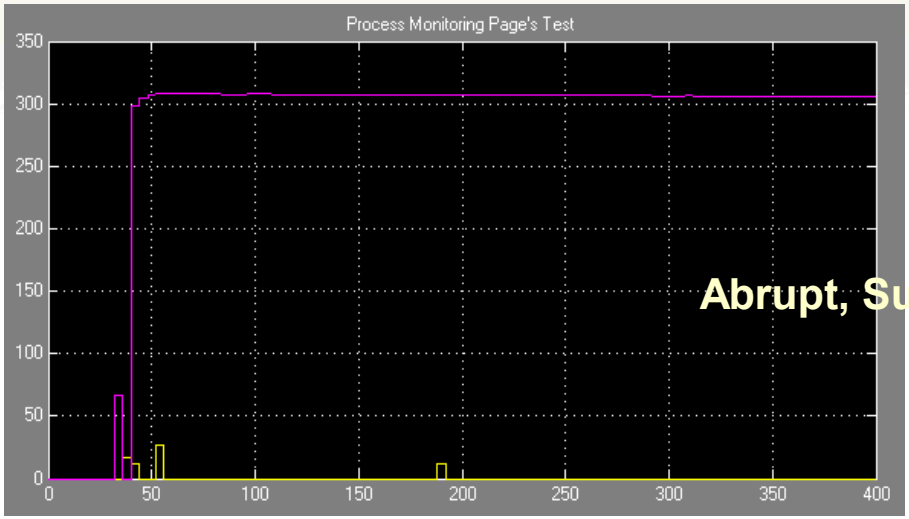
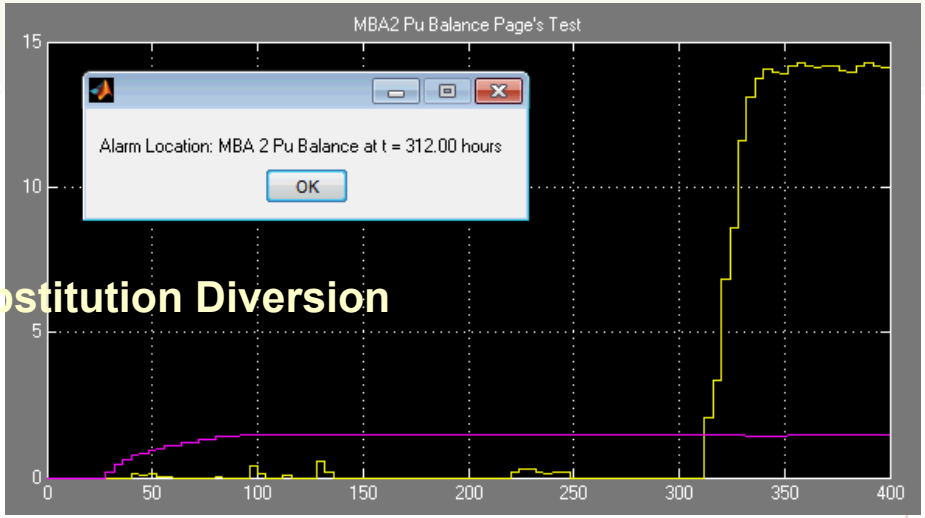
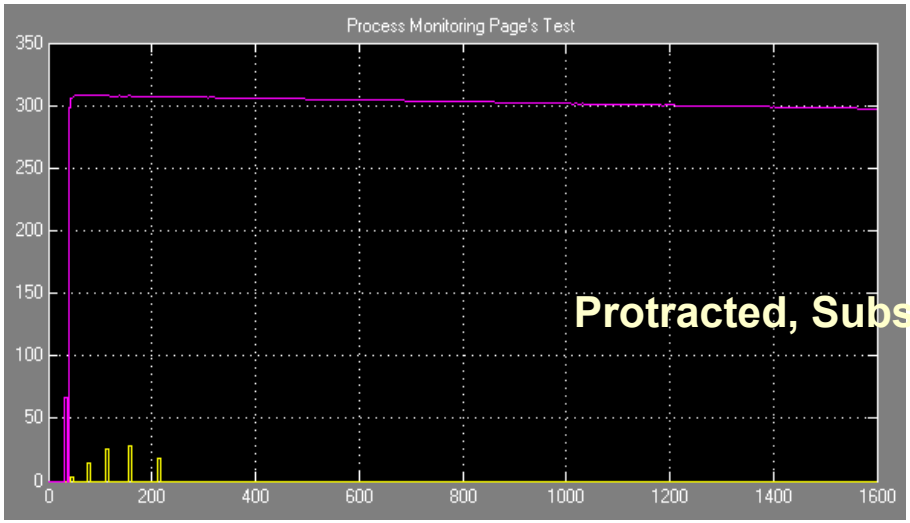
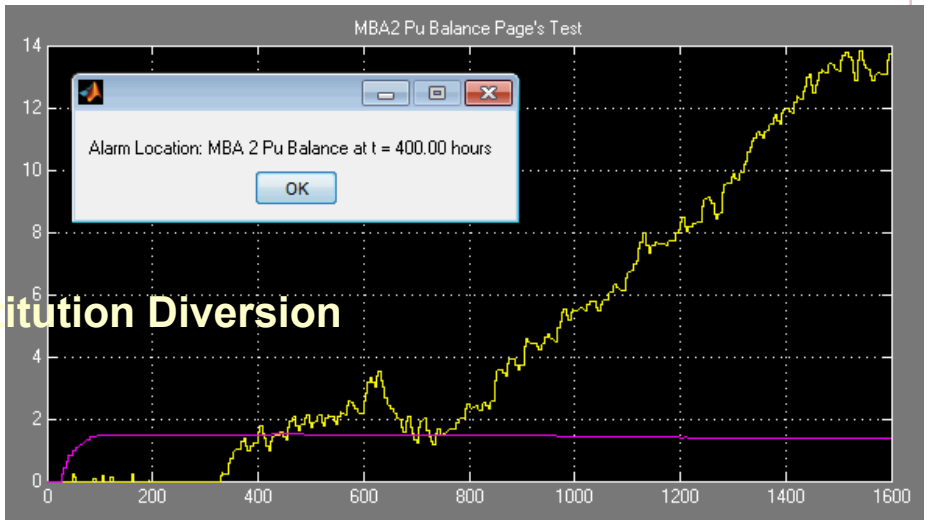
Advanced Monitoring System Results:

Substitution Diversions of 8 kg of Pu









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Conclusions

- **Modeling of future safeguards systems allows for rapid design and analysis of monitoring strategies for new plants.**
- **Although the safeguards system design is the main purpose of the model, more detailed chemical modeling could improve diversion scenario analyses. Potential areas of collaboration:**
  - SEPHIS and AMUSE integration
  - More detailed dissolution models
  - More detailed contactor models
- **This research is emphasizing efficiency and cost-effectiveness, but future work will examine the cost-benefit in more detail.**