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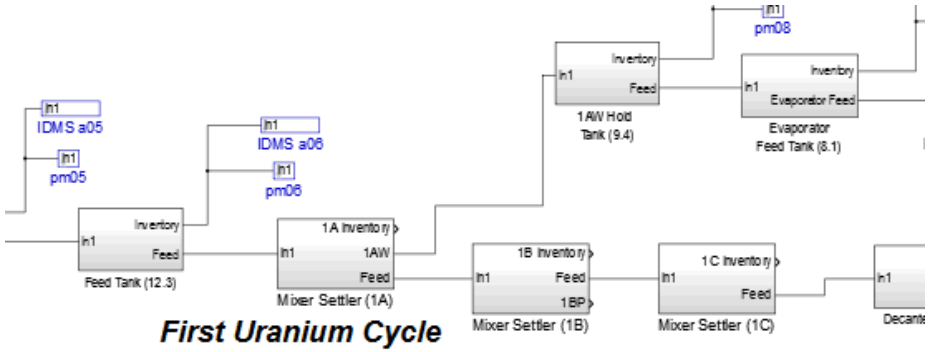

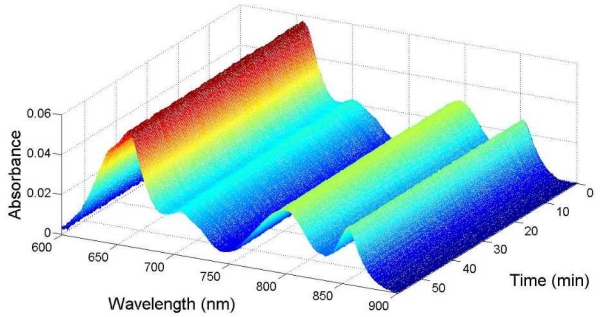

Baseline H-Canyon Accountability

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U.S. DEPARTMENT OF ENERGY | National Nuclear Security Administration

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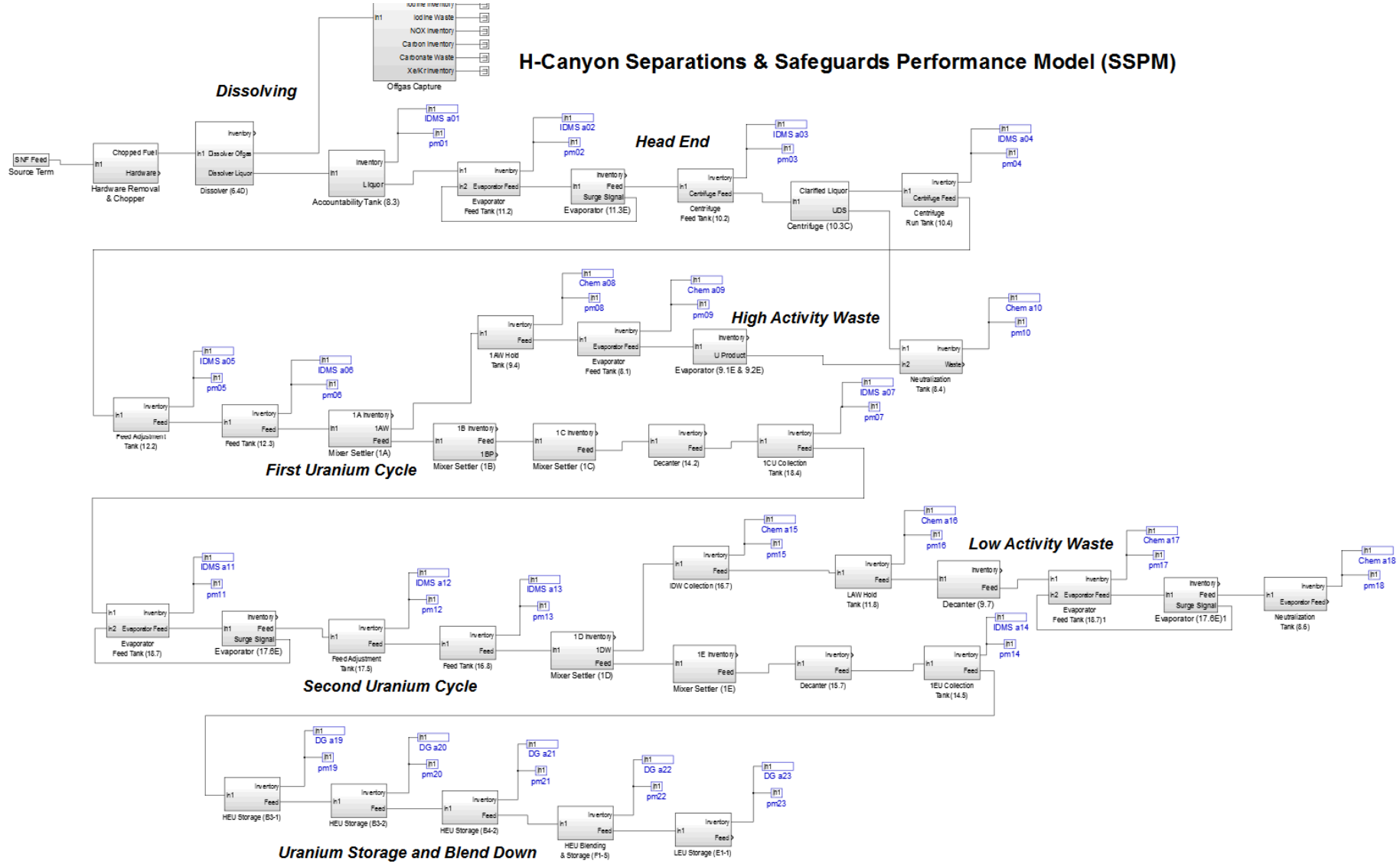
Overview and Approach

- The goal of this work was to develop a generic methodology for integrating process monitoring and advanced process modeling for both process control and safeguards. The H-Canyon facility was used to examine advanced technologies.
  - Process Monitoring or Process Control Data: The plant operator has a tremendous amount of this data, but typically it is not well integrated with safeguards.
  - Nuclear Material Accounting System: Based on sampling and precision laboratory measurements, but laboratory measurements are time-consuming and limit timeliness.
  - How can new on-line measurement technologies and more reliance on process monitoring measurements provide value?
    - Improve timeliness for responding to off-normal plant conditions
    - Improve timeliness for safeguards concerns (detecting diversion).
    - Potentially reduce the burden of laboratory analysis.

Testing at H-Canyon (Savannah River National Laboratory)

- H-Canyon can be used for various reprocessing operations to recover U, Np, Pu depending on mission need. The sampling aisle has been used to provide a test bed for measurement technologies.
- Technologies:
  - UV-Vis Spectroscopy tested on Pu solutions, provides real-time monitoring of chemistry of process solutions. Future work may include testing on low Pu solutions and Raman & NIR monitoring of feed, product, and waste streams.
  - HiRX will be tested as a potential replacement for HKED for routine accountancy measurements.
  - MIP Monitor (on-line gamma spectroscopy) may be used for monitoring of indicator isotopes in reprocessing streams.

H-Canyon Model Built in Matlab Simulink



Modeling Assumptions

- The H-Canyon model was developed based on historical operations and flow rates.
- Existing sampling points, measurements, and measurement uncertainties were modeled to determine overall Inventory Difference (ID) and σ_{ID}.
- Various process monitoring and new measurement technologies were examined for potential improvement to the safeguards metrics.

Example Results

- The use of UV-Vis Spectroscopy could potentially reduce the σ_{ID} for Uranium by 40% if applied to one location.
- The use of hiRX to replace the analytical measurement at the key sampling points can reduce the σ_{ID} for Uranium by 60%.

- Note that these results are based on the current assumptions for the measurement uncertainties, which may not be realistic if H-Canyon was processing spent fuel. More generic results focused on a PUREX plant design.

Generic Methodology

Based on a Generic PUREX Model

Integration of PM Data for PUREX Plants

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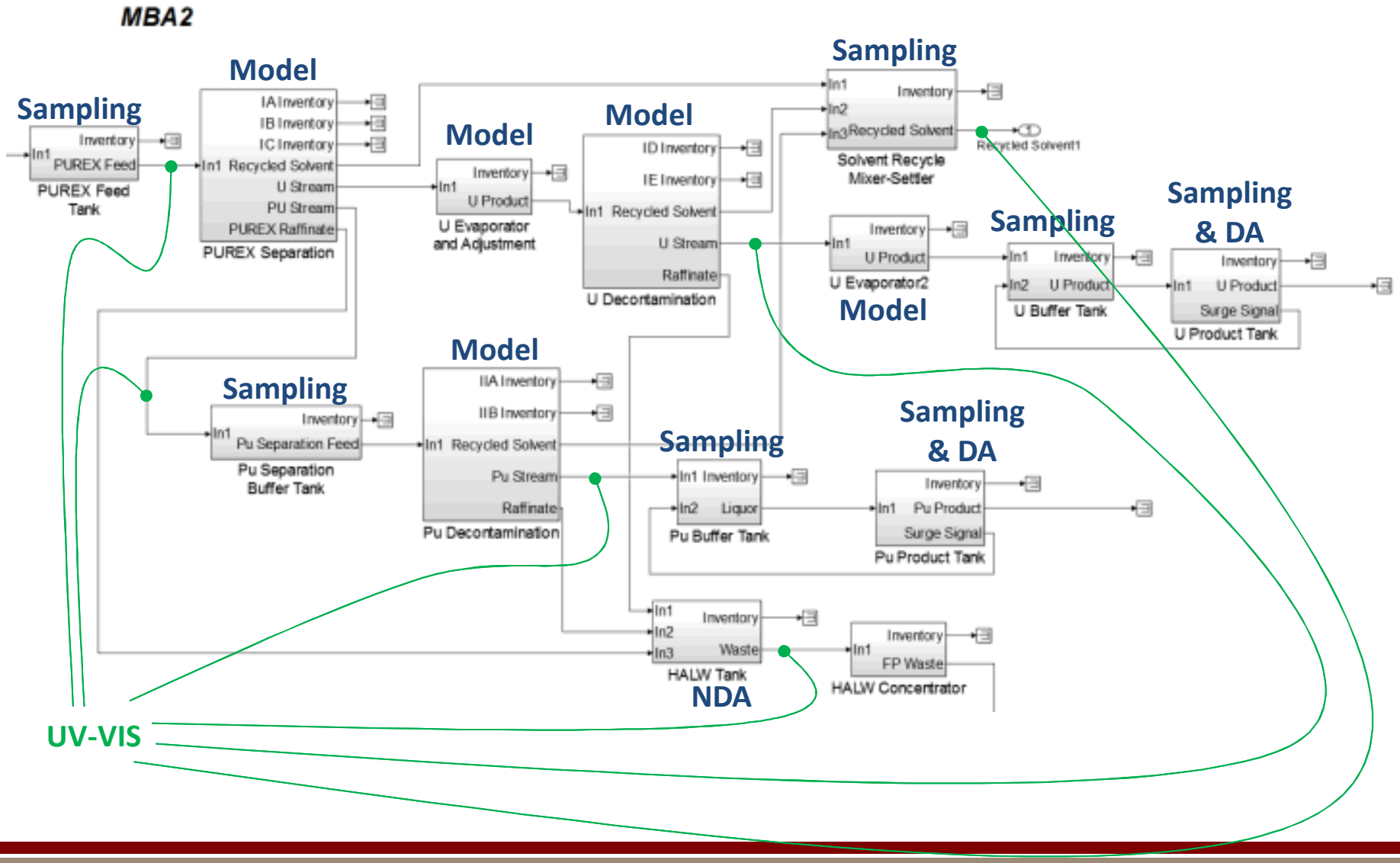
- Qualitative Approach
  - Use process data to inform the operator or inspector if process conditions do not look correct, could involve visual monitoring or bounding of data.
  - Additional sampling will be required to confirm problem.
  - More reliance on knowledge of the operator or analyzer introduces greater chance of human error.
- Quantitative Approach
  - Directly integrate the PM data into an interim material balance.
  - Allows for automatic calculation of alarm thresholds to reduce human error.
  - Puts a premium on rapid, precise measurements, accurate modeling, and automation

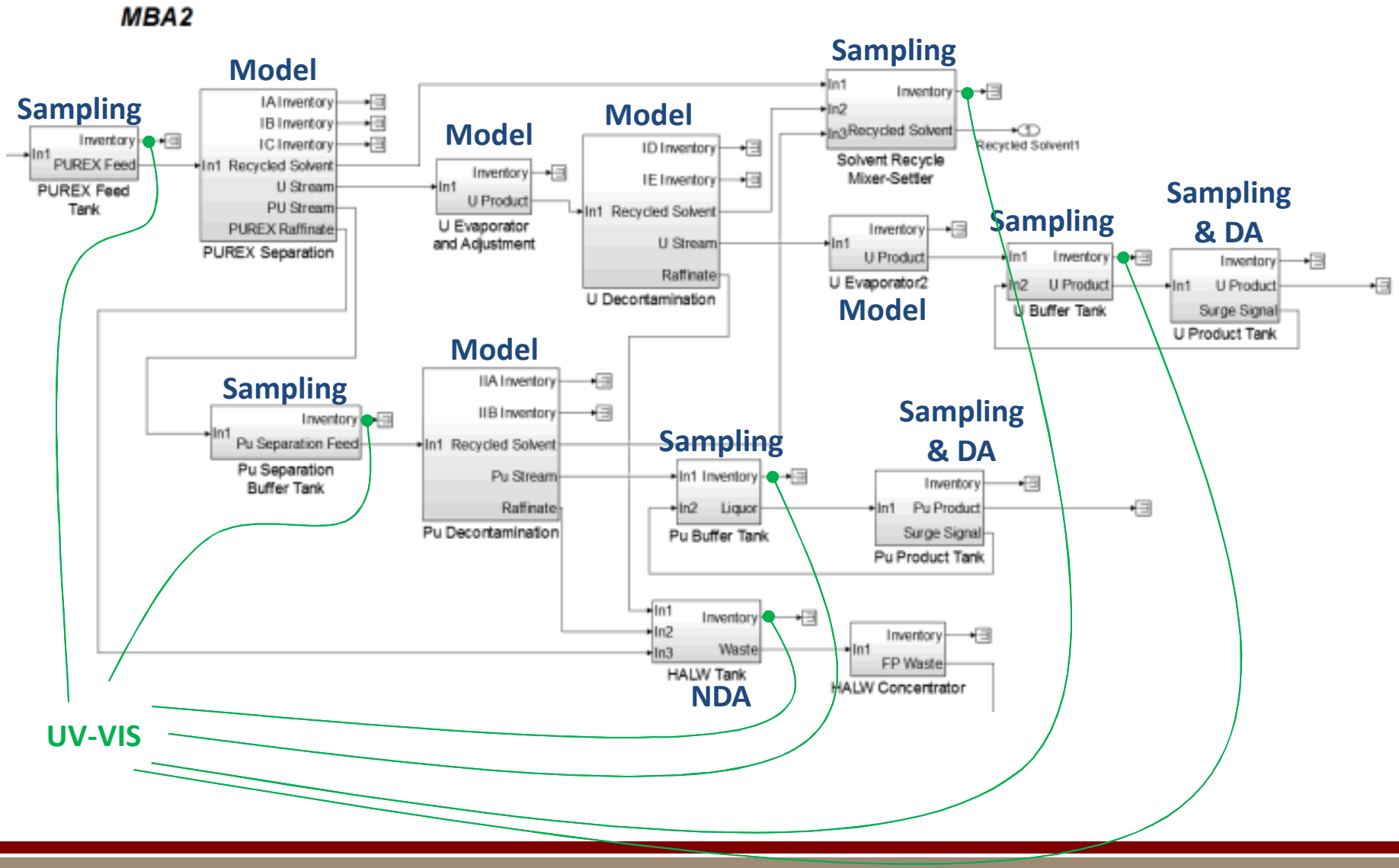
Example Qualitative Approach



Direct versus Substitution Diversion

- Rely on a bulk mass measurements for detecting direct loss of material—measurement uncertainties are low, and this equipment will be part of the plant.
- Spectroscopy will detect substitution diversions—concentrations change when substitution occurs. But need to account for process changes (like different fuel feed)—look for changes downstream that are not present upstream. Note that process streams have a lot of variability.
- This example uses UV-Vis spectroscopy to measure the composition of aqueous streams, but similar approaches could be used for gamma or neutron measurements of solids.

Example Quantitative Approach

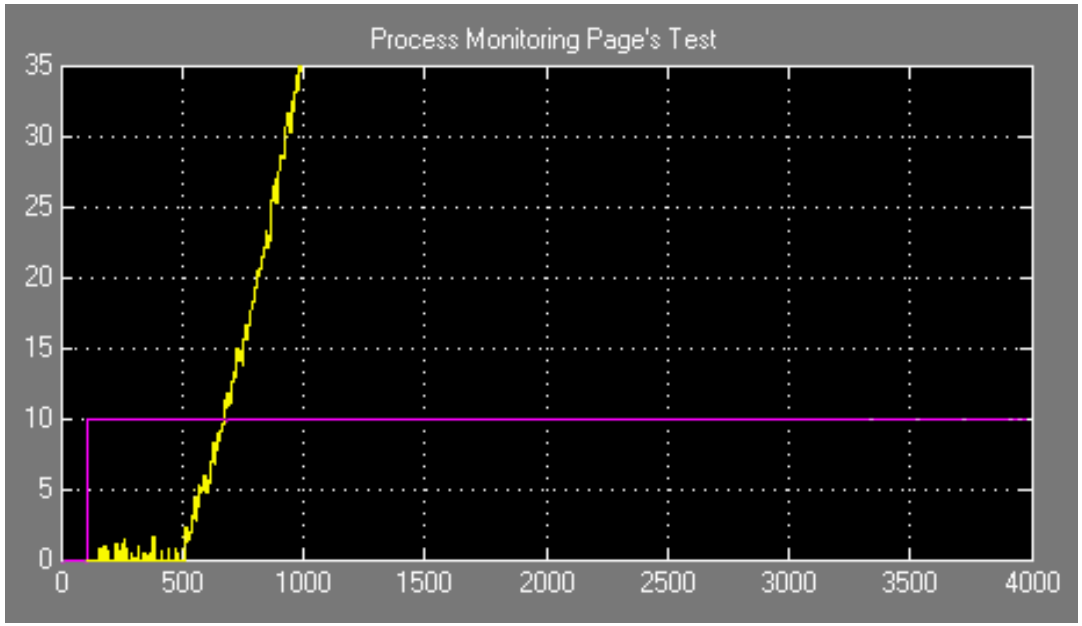


Quantitative Approach

- The key difference with the quantitative approach is that it would require installing spectroscopies directly on the vessels, or on recirculation lines on the vessels.
- The level measurement along with concentration measurement from spectroscopy would be used directly as the inventory measurement in a daily material balance.
- Sampling of the input and output accountability tanks would still be used for the yearly physical inventory taking, and to retroactively improve the results of the interim balance periodically (once per month for example). Sampling of internal vessels would not be required for routine operation (but periodic calibration will still be required).

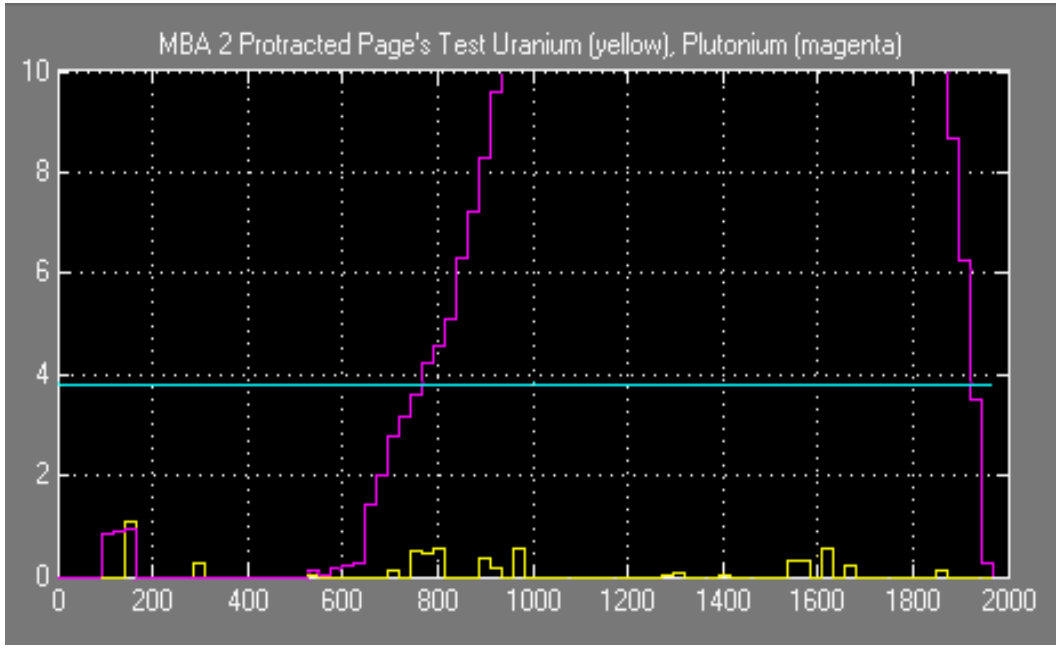
Protracted, Direct Material Loss

- The SSPM was used to examine the direct loss of 1% of a Pu process solution for 3000 hours using a generic PUREX model and a daily material balance.



- A Page's test on a bulk balance was used to set up the alarm condition.
- This direct loss was detected 200 hours into the diversion, due to the very low measurement uncertainty of the bulk measurements.

Protracted, Substitution Loss



- A substitution loss was also tested. 3% of the process solution was removed and replaced with nitric acid for 1000 hours using the PUREX model.
- A Page's test was setup on the U and Pu balance using the spectroscopy data coupled with the bulk measurements.
- This loss was detected 250 hours into the diversion.

Discussion

- The bulk measurements provide detection of direct loss (leaks or diversion), and daily balances provide timely detection of abrupt loss.
- Spectroscopies help to protect the plant from substitution loss or process upsets, and also provide timely detection, but detection will be limited by the measurement uncertainty.
- Spectroscopy will reduce the number of internal samples and associated burden on the laboratory, but it needs to be balanced with the maintenance demands.
- The use of PM data for international safeguards raises questions about joint use.

Conclusions

- A H-Canyon safeguards model has been developed and was used to determine the impact of the test bed technologies.
- A generic methodology was developed for integrating PM technologies with nuclear material accounting to provide more timely detection of plant anomalies.
- Both qualitative and quantitative approaches were considered and should be explored more for various applications (process control versus safeguards).
- The approaches are being considered to continually optimize and refine plant monitoring approaches given the latest accounting and process monitoring measurement technologies.