U.S. – ROK JOINT FUEL CYCLE STUDY

SAND2014-15272PE

Electrochemical Separation and Safeguards Performance Model

Ben Cipiti

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Mod/Sim Action Sheet

- Survey of simulation codes for echem safeguards
- Determine appropriate model detail required for safeguards
- Detailed comparison of PYMUS and SSPM echem models
- Review safeguards approaches for reprocessing and other fuel cycle facilities, including role of M&S in those approaches
- Determine appropriate model detail for unit operations
- Update modeling based on JFCS development

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Separation and Safeguards Performance Model

- **The SSPM was designed for evaluating advanced safeguards concepts and evaluating improved measurement instrumentation for reprocessing plants.**
- **Currently PUREX, UREX+, and E-Chem models have been built using the MATLAB Simulink software. Material flows are tracked throughout the plant and measurements are simulated for safeguards.**
  - Spent fuel source term library for user-defined runs
  - Mass tracking of elements 1-99, bulk solid & liquid (or salt), heat load & activity
  - Customizable measurement points with user-defined measurement error
  - Automated calculation of inventory difference and error propagation in real-time.
  - Alarm conditions, bias correction, and statistical tests

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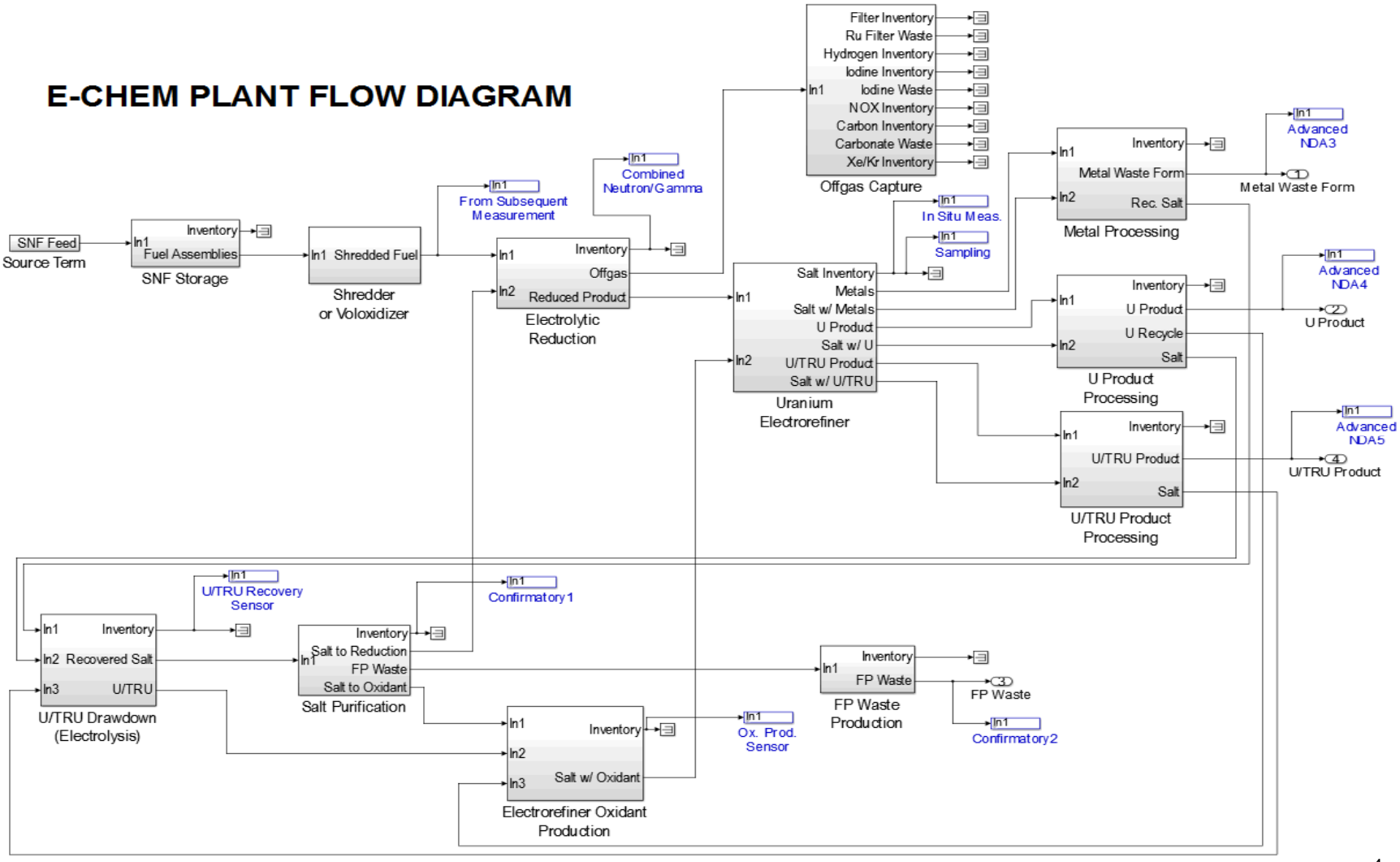
SSPM-Echem Version



Ref: M.A. Williamson & J.L. Willit, "Pyroprocessing Flowsheets for Recycling Used Nuclear Fuel," *Nuclear Engineering and Technology*, 43(4) (August 2011).

Safeguards Challenge Areas

- **Inability to Flushout the Plant**
  - TRU builds up in the electrorefiner over many days before U/TRU extraction starts—flushing out is not feasible.
  - Requires a shift to near real time accountability (NRTA)
    - Measurements on inputs, outputs, and all inventories periodically
- **Lack of an Accountability Tank**
  - The nature of the coupled extraction-dissolution process in electrorefining means the electrorefiner cannot be used for accountability; alternative input measurement options:
    - *SNF assemblies*
    - *Voloxidation powder*
    - *Shredded fuel in baskets*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Safeguards Challenge Areas

- **Electrorefiner Inventory**
  - The TRU content in the electrorefiner is much greater than in any other area in the plant, so this will be the most important measurement:
    - *Salt sampling* (<0.5% uncertainty ??)
    - *Potentiometric sensor* (1-2% uncertainty)
    - *Voltammetry techniques* (1-2% uncertainty)
    - *UV-Vis-NIR* (~2%, process monitoring or used in other areas)
- **Product Measurements**
  - The solid U and U/TRU products will require new measurements not typically done for aqueous plants, measurement options:
    - *NDA techniques* (may work for U product, may not work for U/TRU)
    - *Anodic stripping voltammetry* (not representative of actual plant outputs)
    - *Melt sampling* (<0.5% ??)

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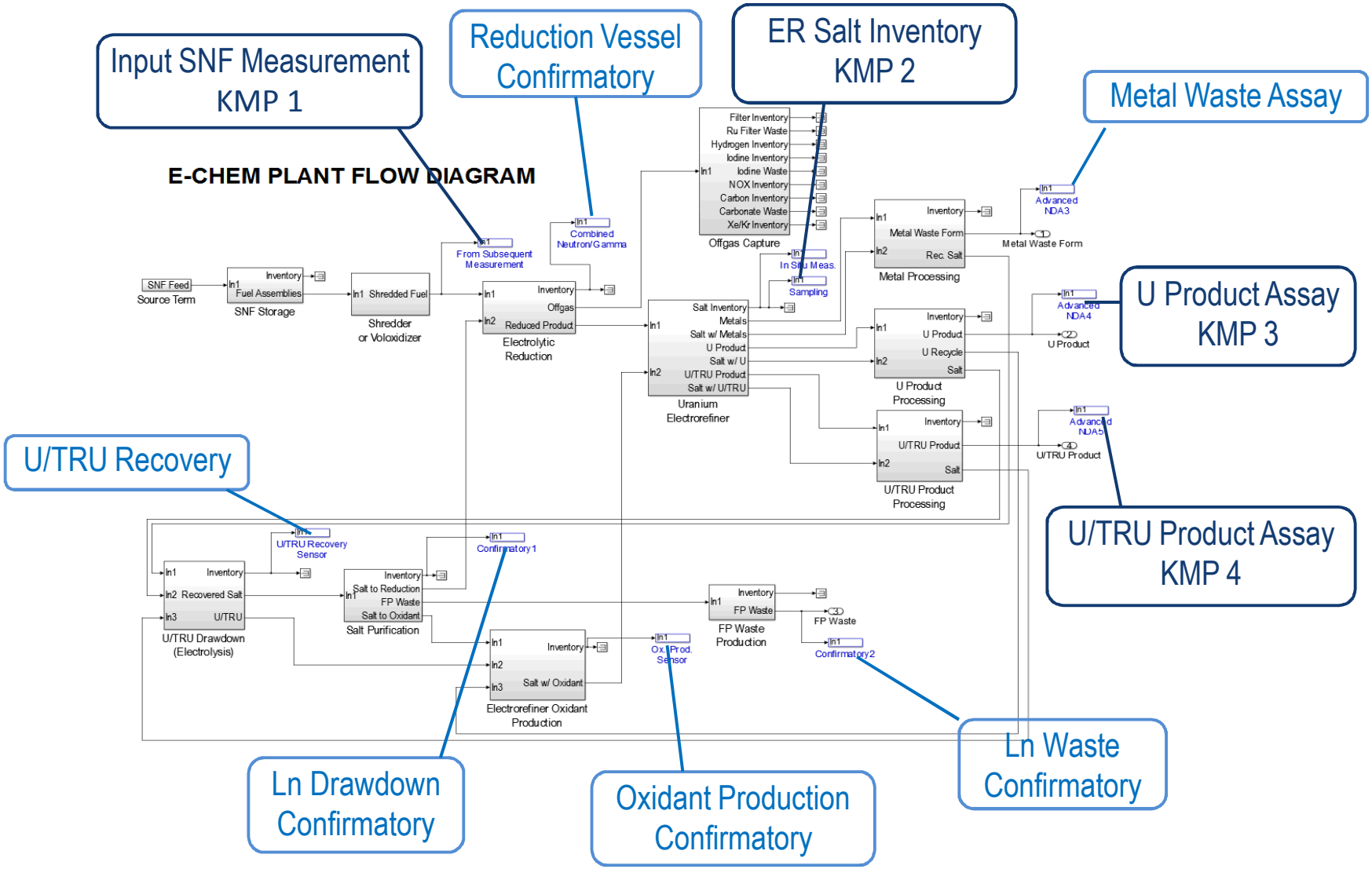
Accountancy Structure



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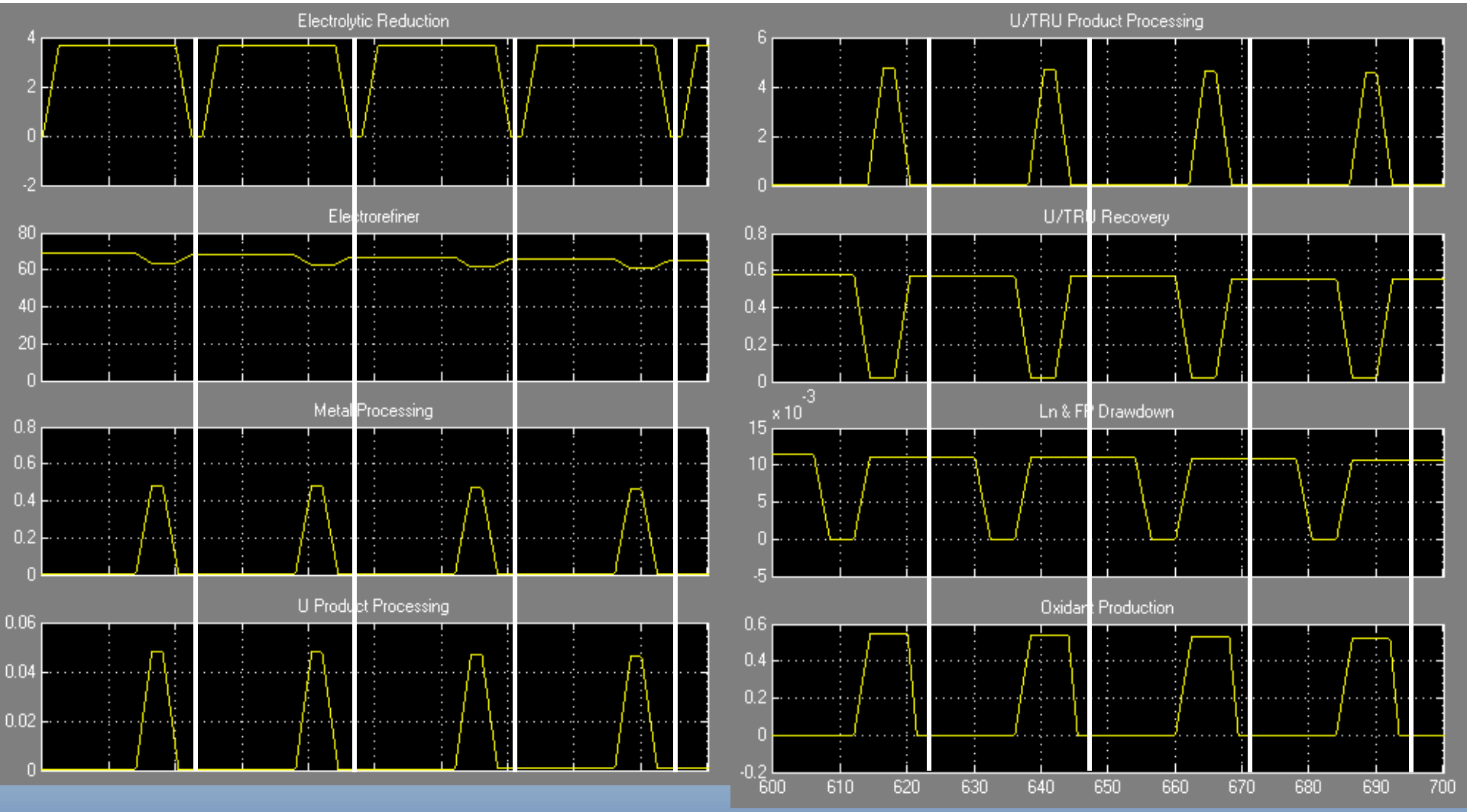
Measurement Timing Sequence
(Pu inventories shown at steady-state)



Monitoring System in the SSPM

- **In order to be consistent with the Short and Interim Inventory Verification for the Rokkasho Reprocessing Plant, the model is based around a ten-day NRTA material balance.**
  - All input and output batches are measured and integrated over ten days.
  - All plant inventory is measured once every ten days
- **The SSPM uses the measurement data to calculate the inventory difference (or MUF) once every ten days.**
- **The overall error (σ_{MUF}) is also calculated continuously.**
- **The Page's test of SITMUF is used to set alarm conditions for material loss.**

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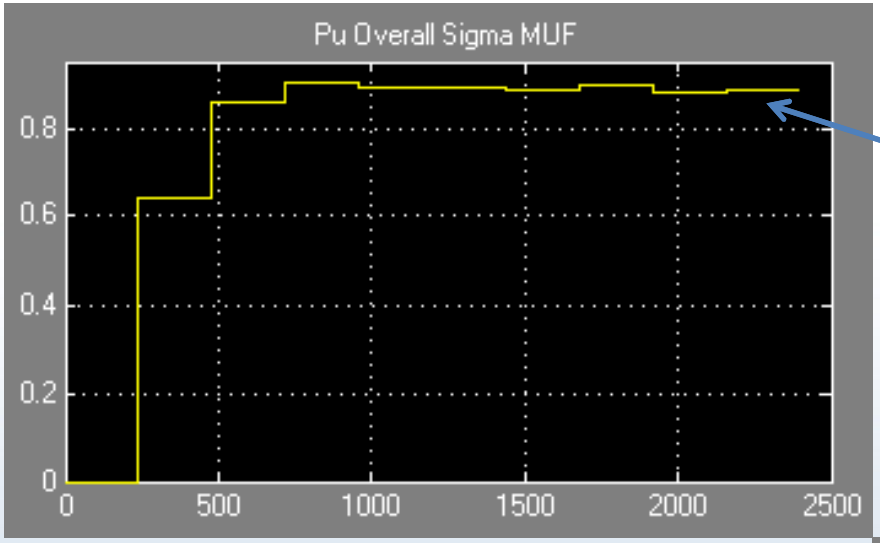
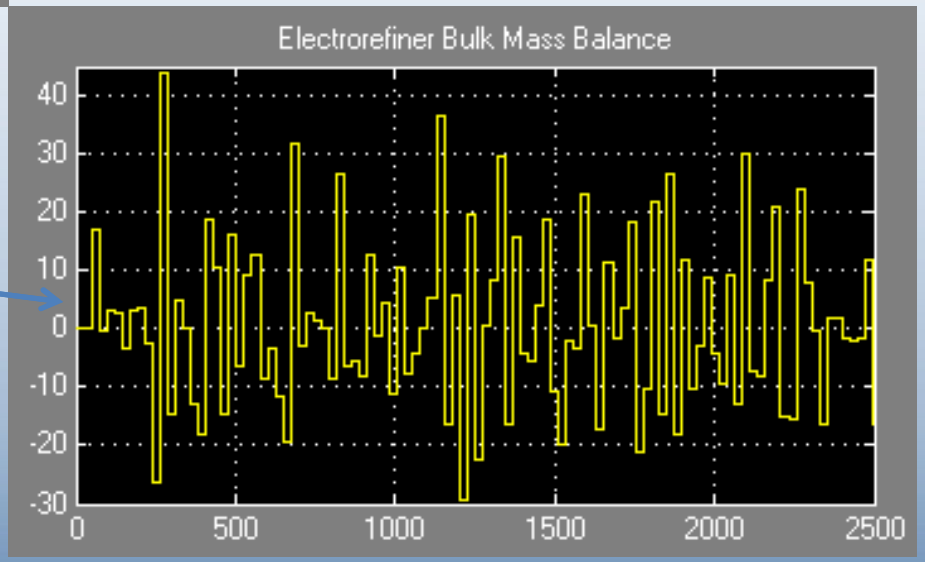
Example Notional Model Outputs



Pu σ_{MUF} as a function of time, one of the key safeguards metrics

Mass balance across the electrorefiner, for process monitoring

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Discussion on Comparison to PYMUS

- One approach is to directly compare results of the SSPM and PYMUS under the same modeling assumptions. We can compare the σ_{MUF} using the same measurement assumptions and material balance period. This can probably be done sooner and will yield useful insight.
- Another approach is to share models, but approvals could take longer, and it will take some time to learn to use the other code.
- Need to determine what we want these codes to do, and how they will be used in the program.