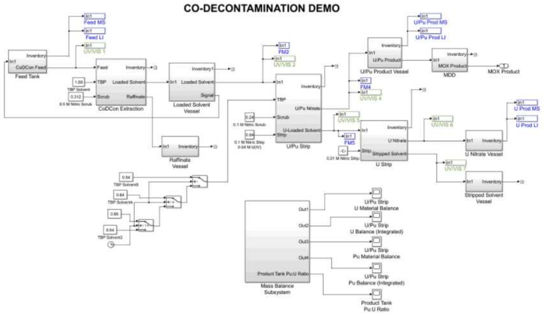
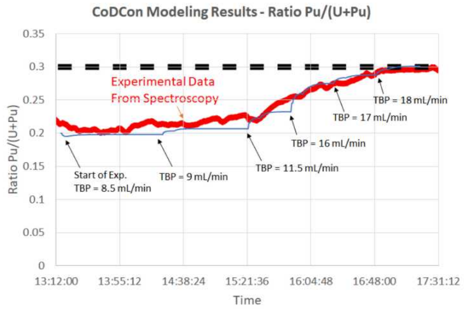
SAND2018-9903PE

CoDCon Dynamic Modeling: Experimental Benchmarking and Pilot Scale Model Development





PRESENTED BY

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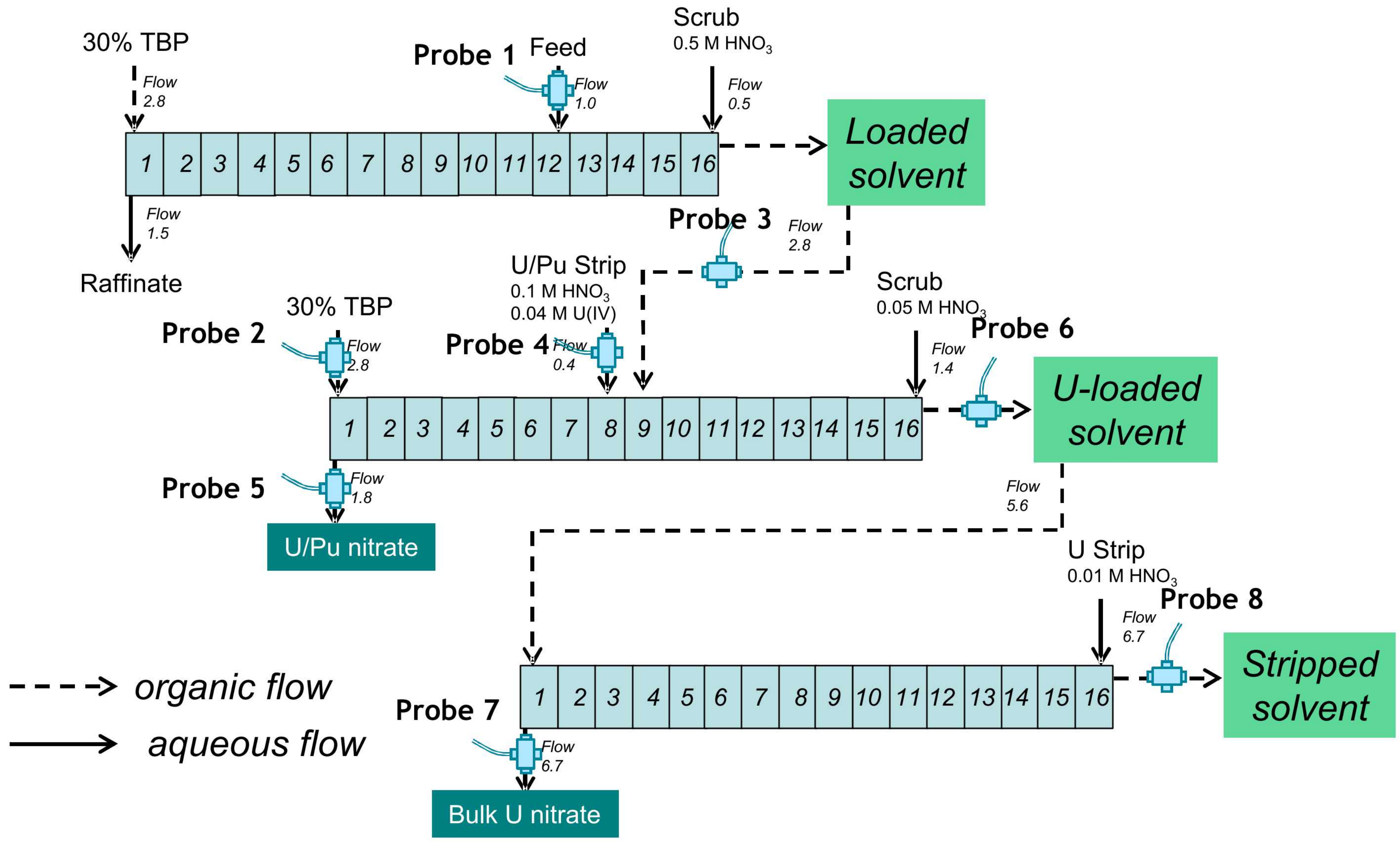
Presented at the MPACT WG Meeting, September 2018
SANDxxxx

Outline

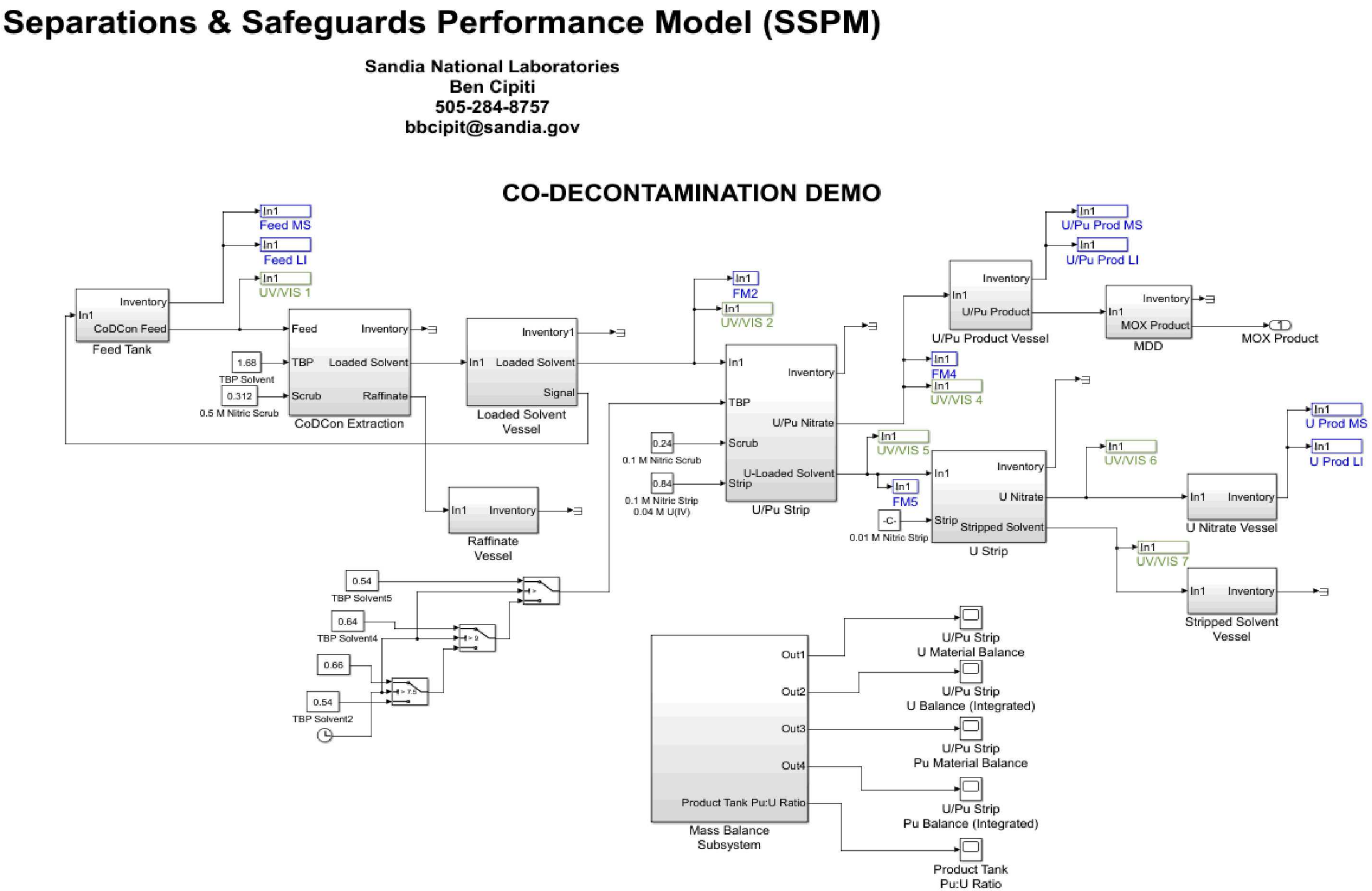
- **Overview of the Co-Decontamination (CoDCon) flowsheet and experiment at PNNL, Goals:**
  - Demonstrate improve proliferation resistance by preventing isolation of a pure Pu stream.
  - On-line spectroscopic analysis to demonstrate the ability to maintain a desired Pu:U ratio at all points in the process.
- **Experimental modeling support**
  - Benchmarking results
  - Modeling plant variations
  - On-line analysis and control
- **Zircex-CoDCon pilot scale model development**
- **Future work**

CoDCon Experimental Model

CoDCon Experimental Flowsheet

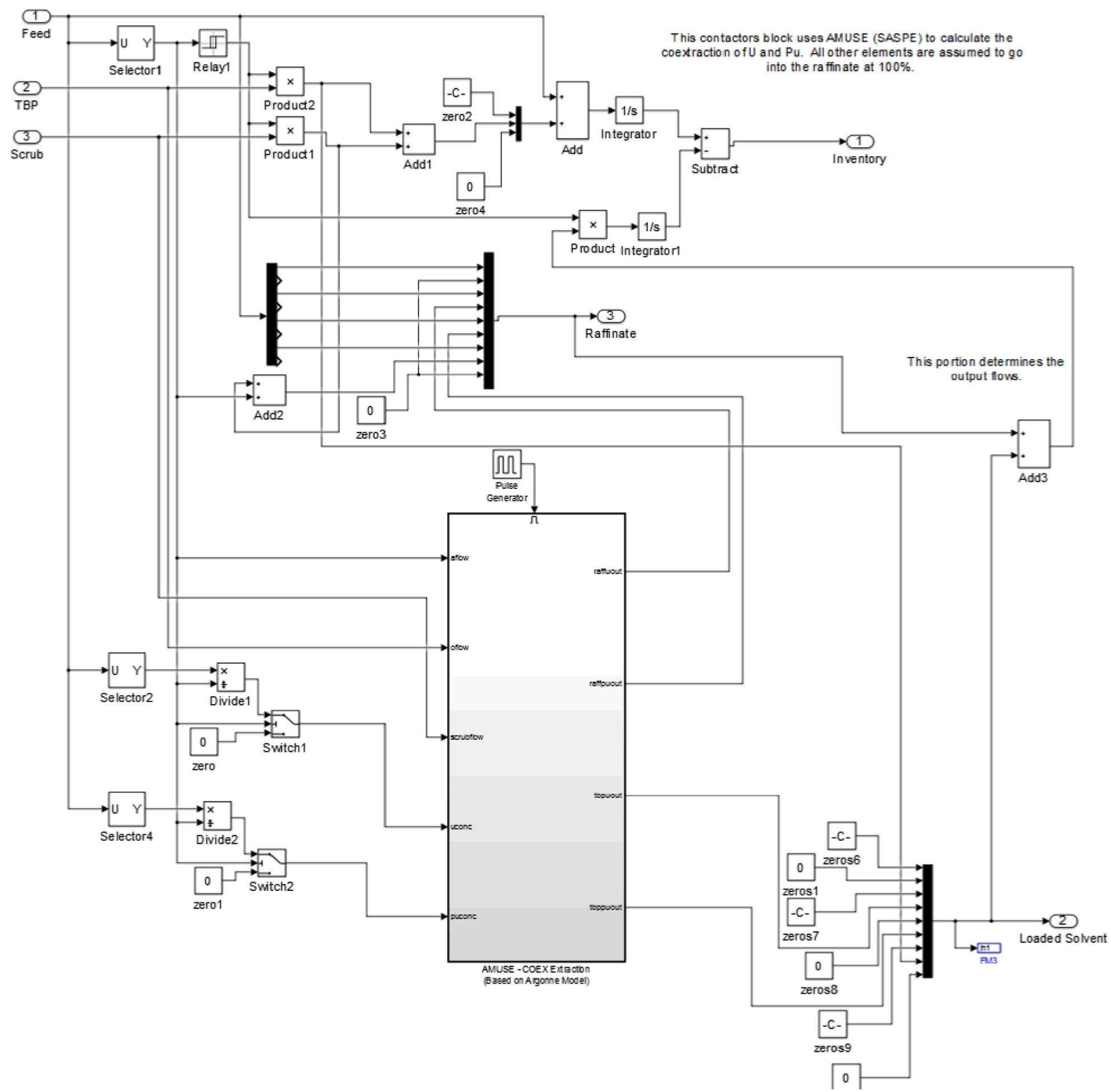


CoDCon Model Development



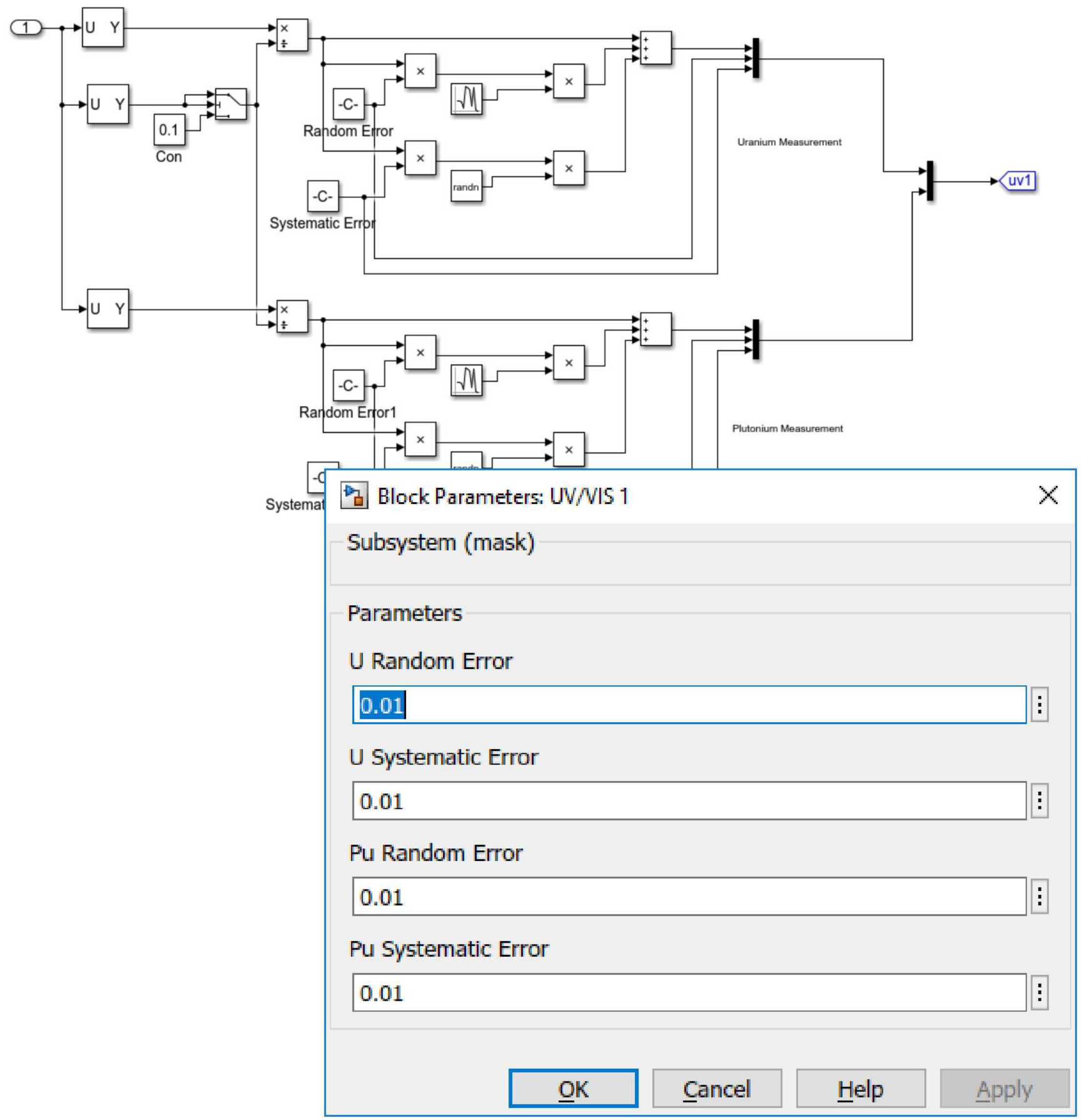
Contactor Bank Subsystems

- The contactor bank subsystem uses an embedded Matlab script to calculate the fractions of U and Pu in each centrifugal contractor.
- The mass balance takes into account where the streams enter and uses D values to calculate the ratio of material in the organic to the aqueous phase.
- The D values were initially calculated theoretically by ANL, and then modified based on experimental results.

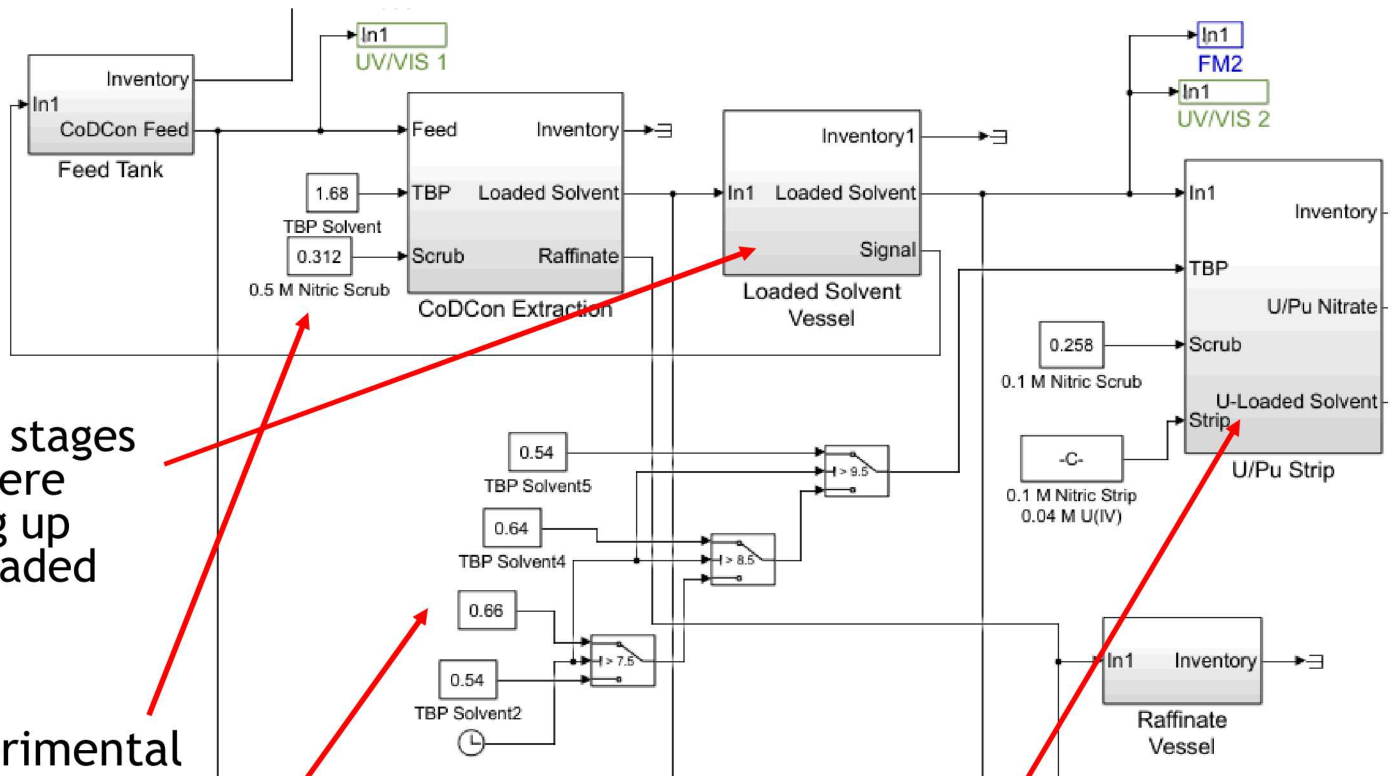


Measurement Models

- Measurement blocks are included for flowmeters and spectroscopic probes.
- The blocks simply assume a random and systematic error for each measurement.
- Real-time material balances are set up using the combined flowmeter and spectroscopy data.



Model Benchmarking: First Experiment



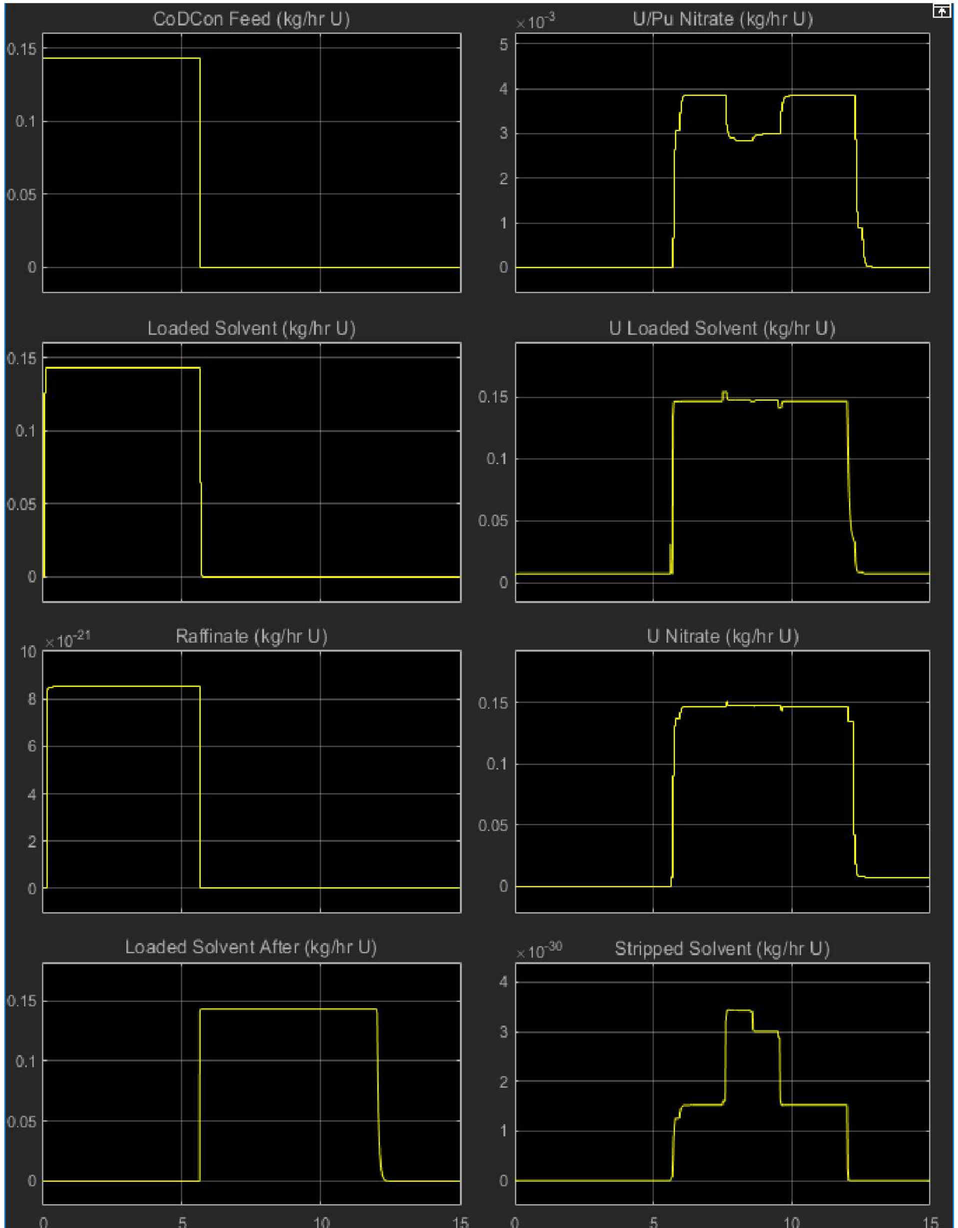
The first and second stages of the experiment were modeled by breaking up the runs using the loaded solvent vessel.

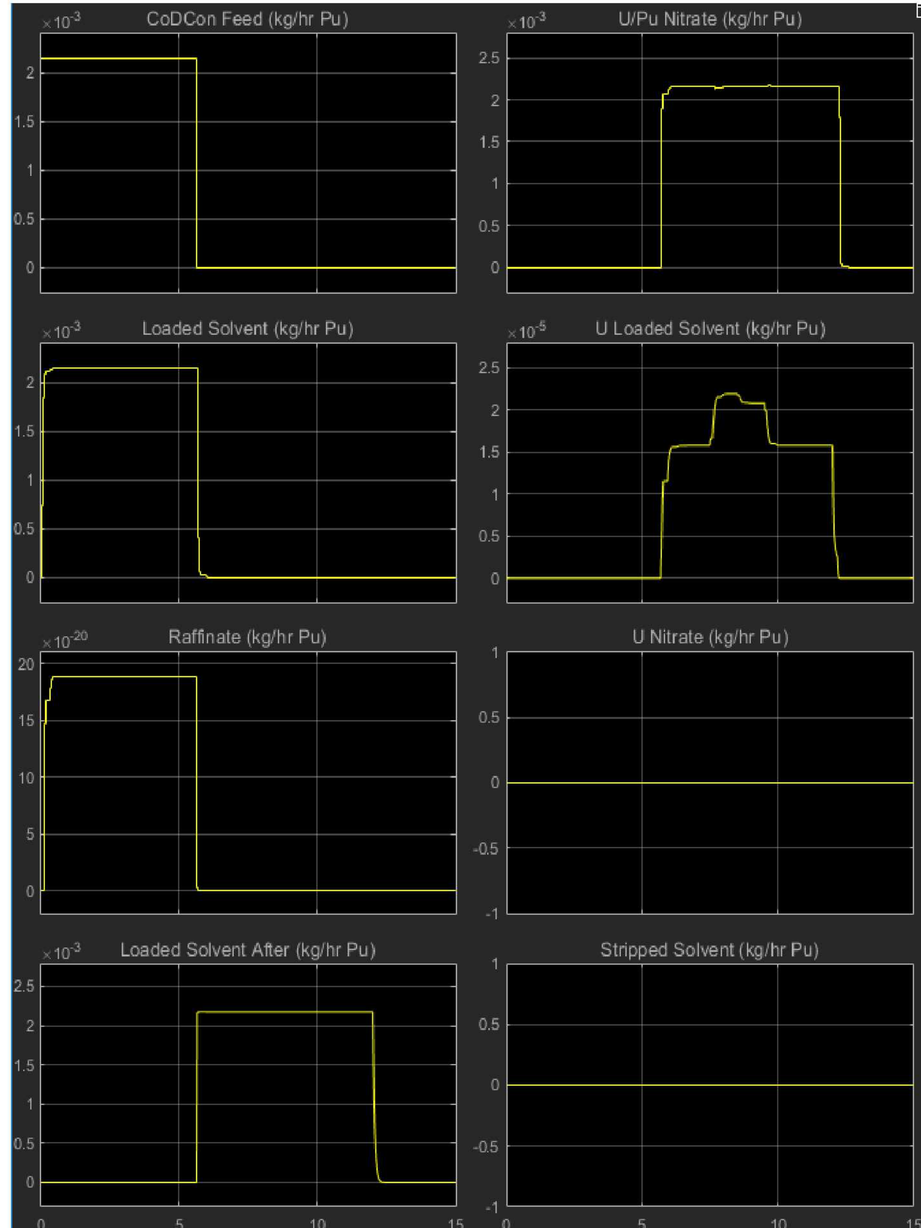
The actual experimental flowrates were modeled.

The fresh TBP feed flow rate was modified during the experiment in order to achieve the desired ratio for the U/Pu product.

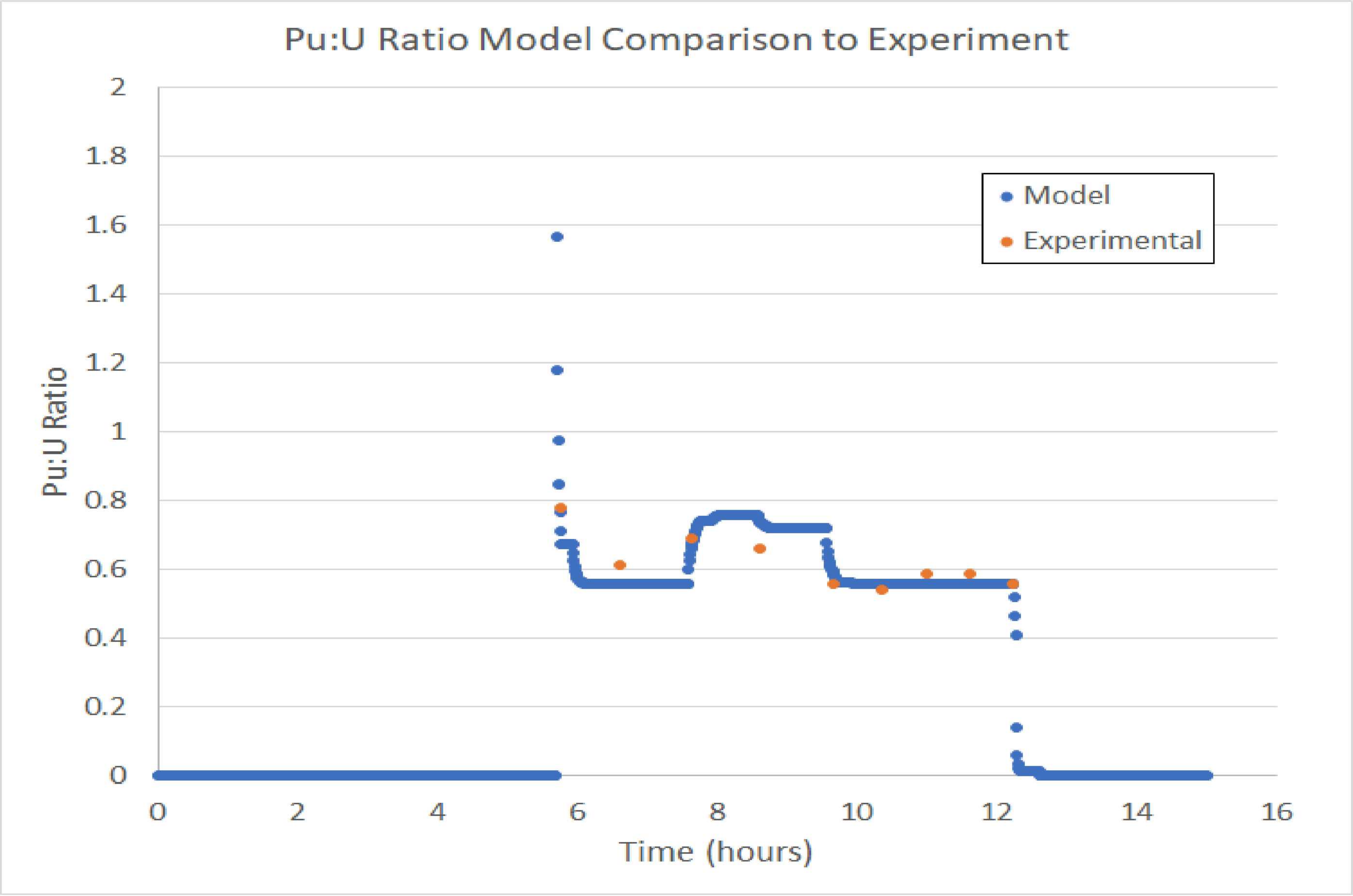
The D values for the second contactor bank were modified to reproduce experimental results

Model Results

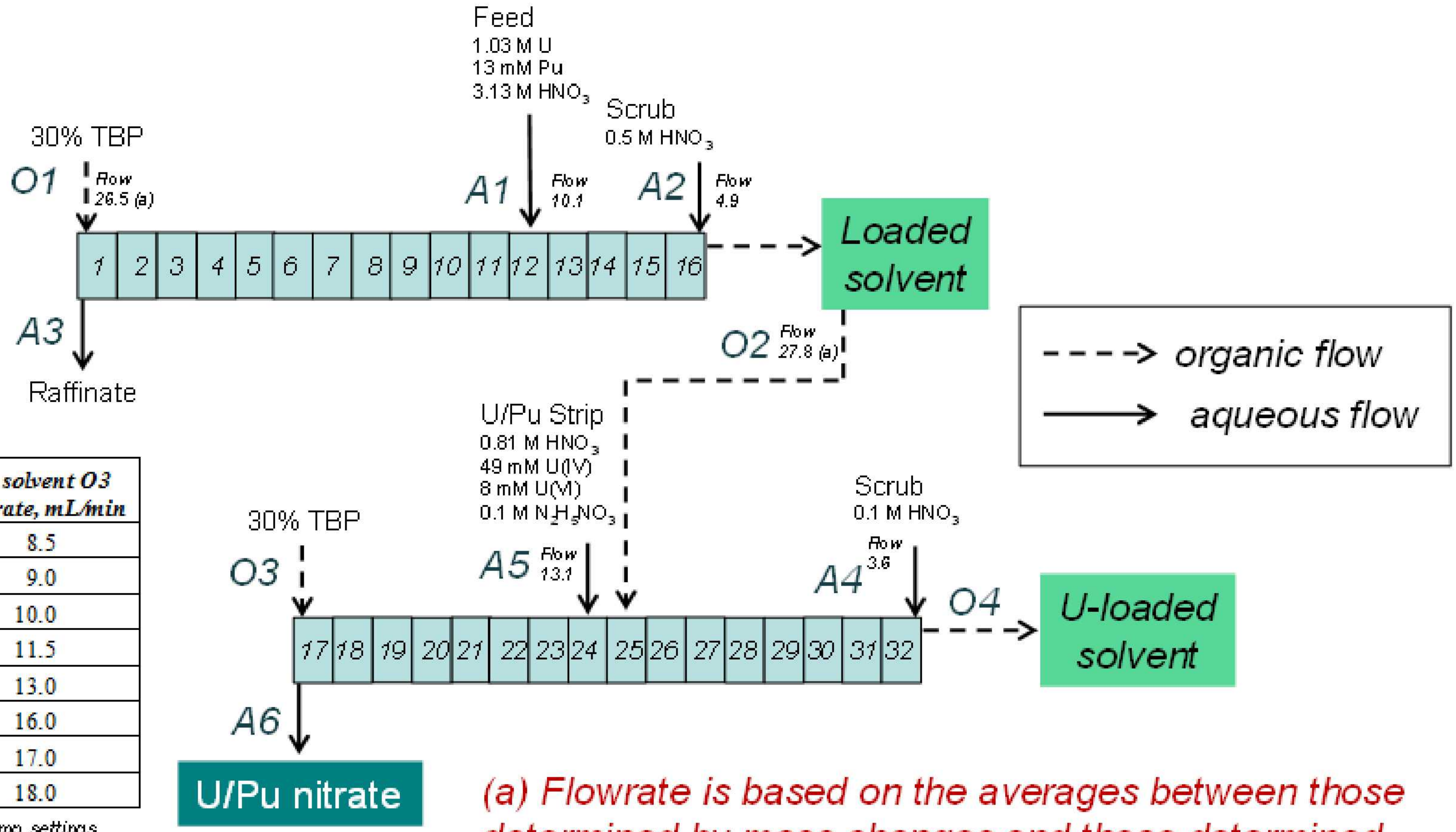




Benchmarking Comparison (First Exp.)



Second Experiment

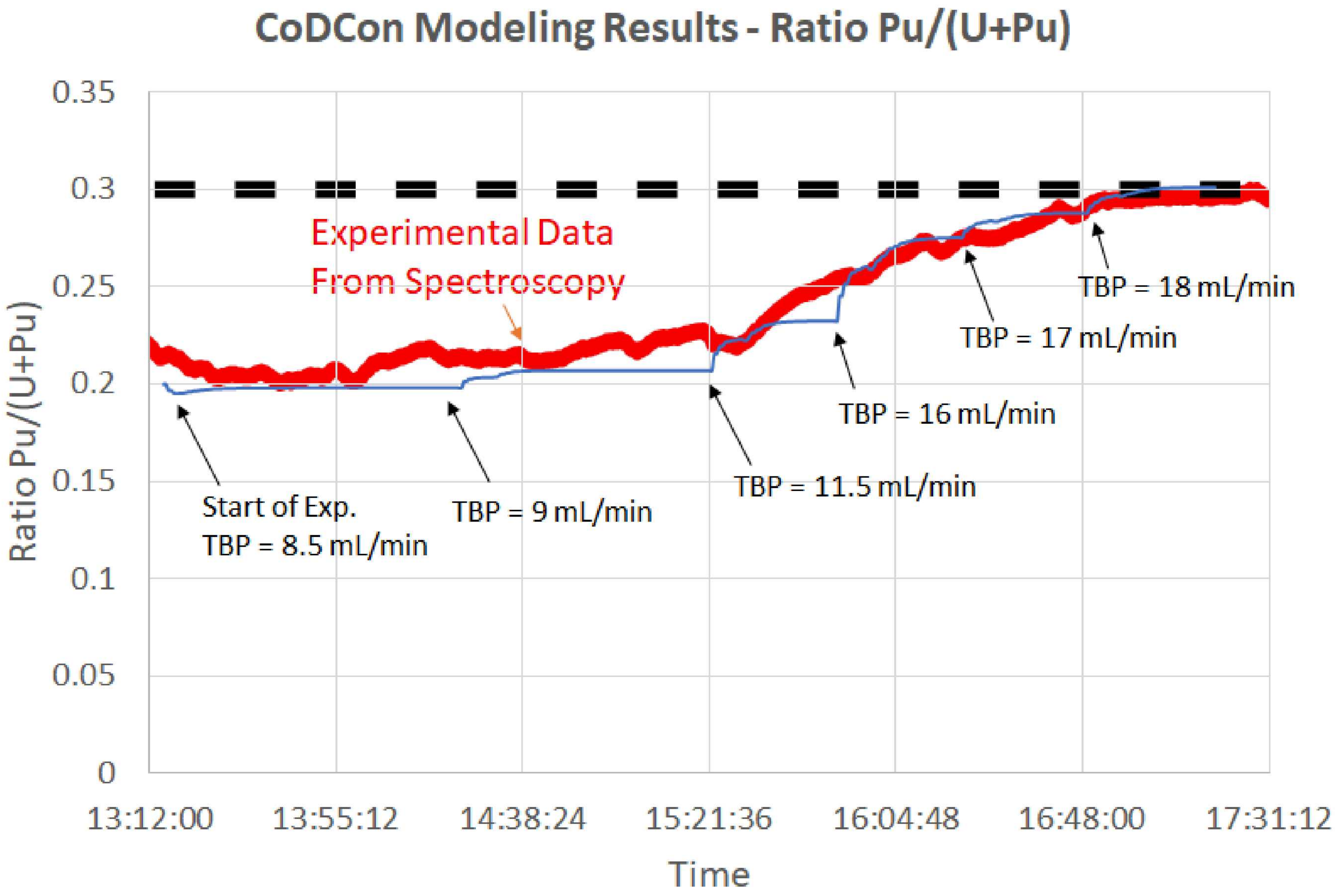


Run time, min	TBP solvent O3 flowrate, mL/min
0	8.5
53	9.0
73	10.0
109	11.5
129	13.0
138	16.0
167	17.0
194	18.0

These are based on the pump settings, but are consistent with measurements.

(a) Flowrate is based on the averages between those determined by mass changes and those determined by in in-line flowmeters. All others are based on mass.

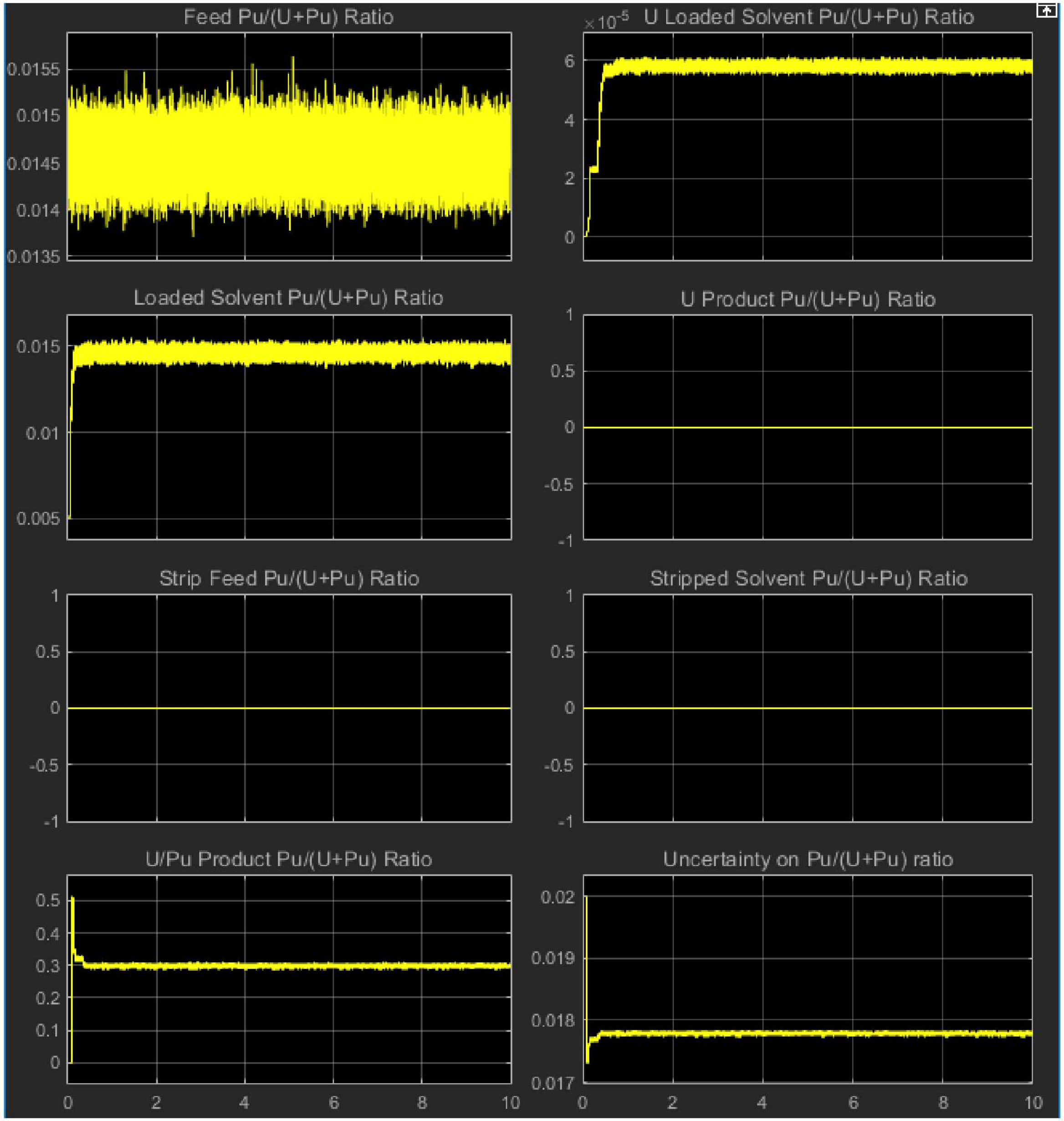
Benchmarking Comparison (Second Exp.)



Modeled Mass Balance Across the Second Contactor Bank

- A material balance was set up using the model and assuming a 1% measurement uncertainty for the probes.
- Deviation at the beginning on the experiment is due to material holdup in the contactor bank (lag in outputs).
- Deviation at the end of the experiment is due to flushout.
- Fluctuations were seen whenever the TBP flowrate was changed.

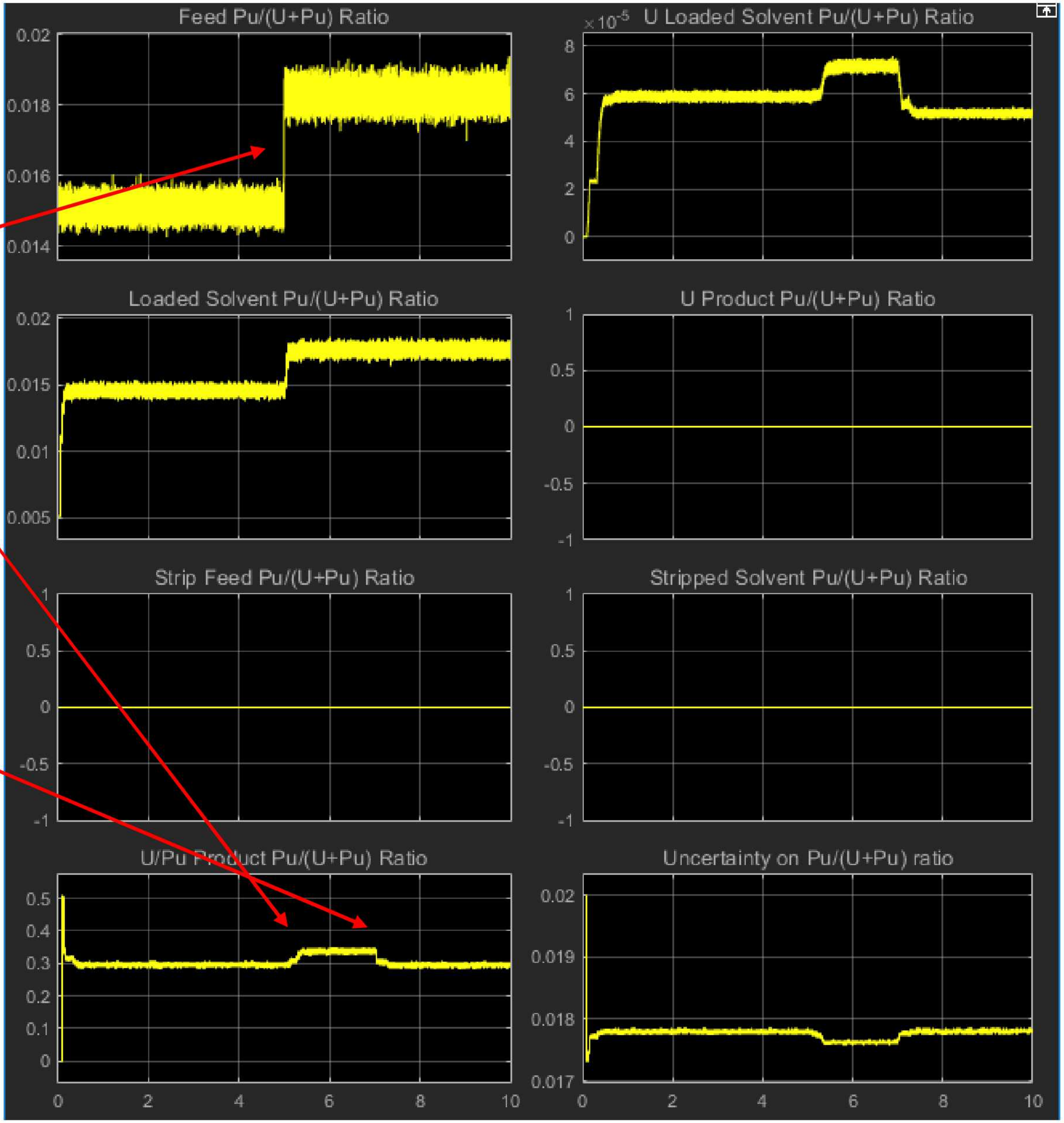
Variability Testing



- The benchmarked model was used to set up a baseline run at conditions such that a 30% Pu/(U+Pu) ratio could be achieved.
- The lower right plot shows the uncertainty on the ratio (assuming 1% measurement uncertainty on the probes). So the ratio can be maintained at 30% +/- 1.8%.

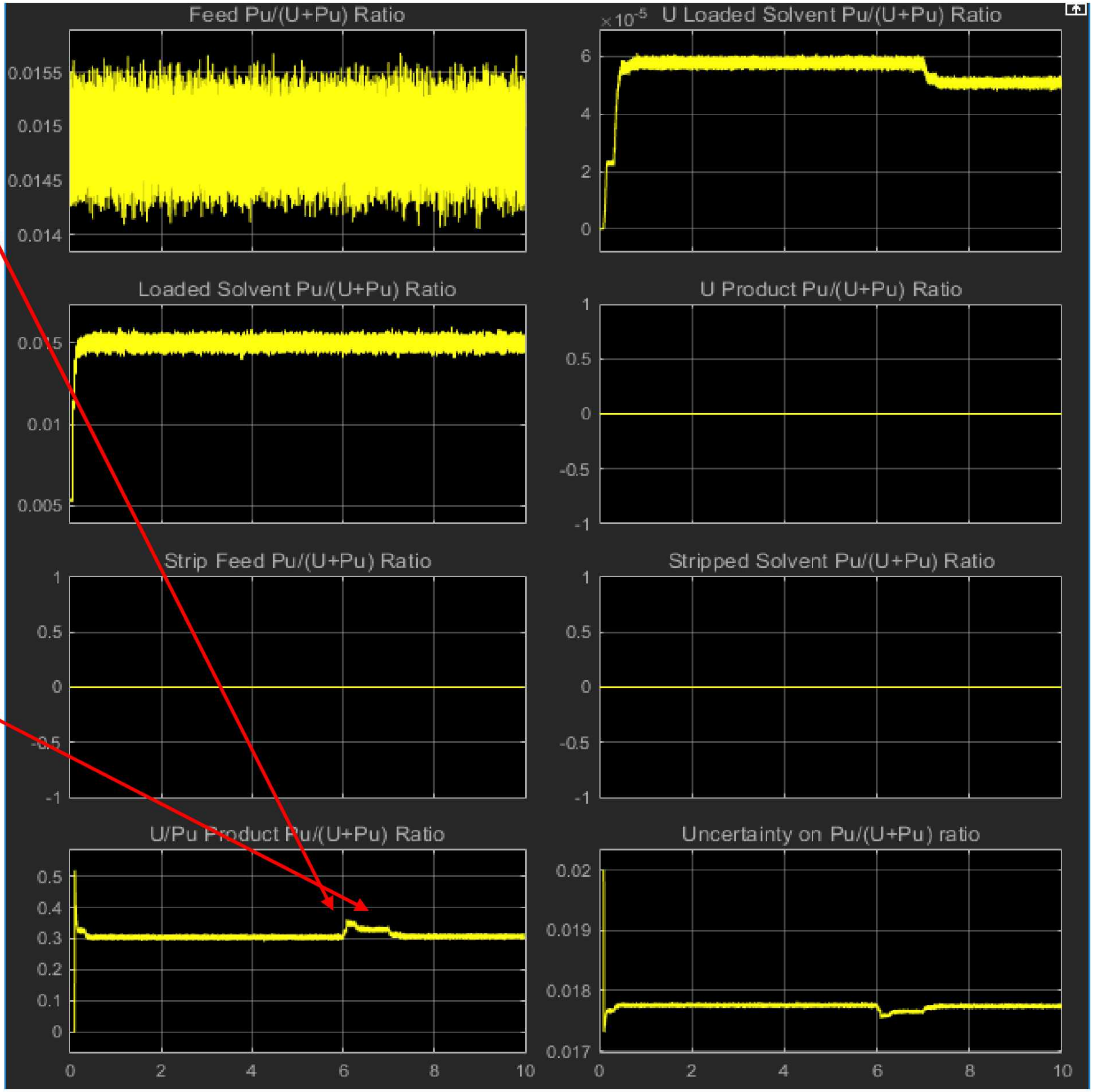
Variability Testing – Change in Fuel Feed

- The fuel feed changed at hour 5 to simulate a fuel with higher Pu content.
- There was about a 20 minute lag before U/Pu product output ratio increased above 30%.
- At hour 7, the TBP flowrate was changed from 7.5 to 5.8 ml/min to bring the ratio back down.



Variability Testing – Plant Upset

- The nitric acid scrub flowrate in the second contactor bank was reduced from 4.3 to 2.2 mL/min at hour 6 to simulate a plant upset.
- At hour 7, the TBP flowrate was changed from 7.5 to 6.8 ml/min to bring the ratio back down.



Experimental Model Next Steps

- The third CoDCon experiment will be performed next week, and will include surrogate fission products.
- It is hoped that the model can be used in a predictive way during the experiment, but some additional benchmarking is expected.
- PNNL plans to set up a real time material balance using the flowmeters and spectroscopic probes for the fourth experiment in FY19.
- The benchmarked model will form the basis for the CoDCon part of the pilot scale process model.

Zircex – CoDCon Pilot Scale Model

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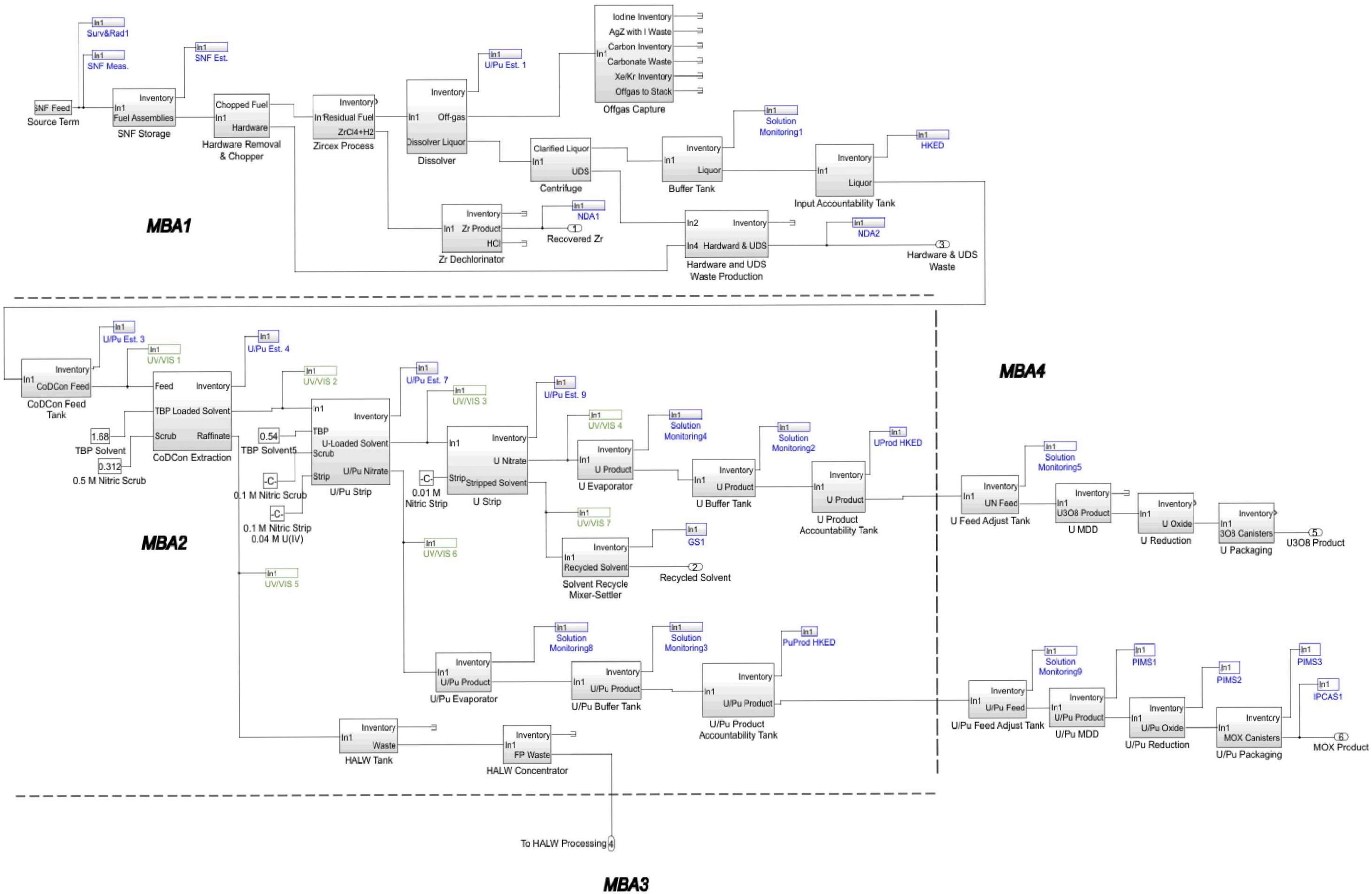
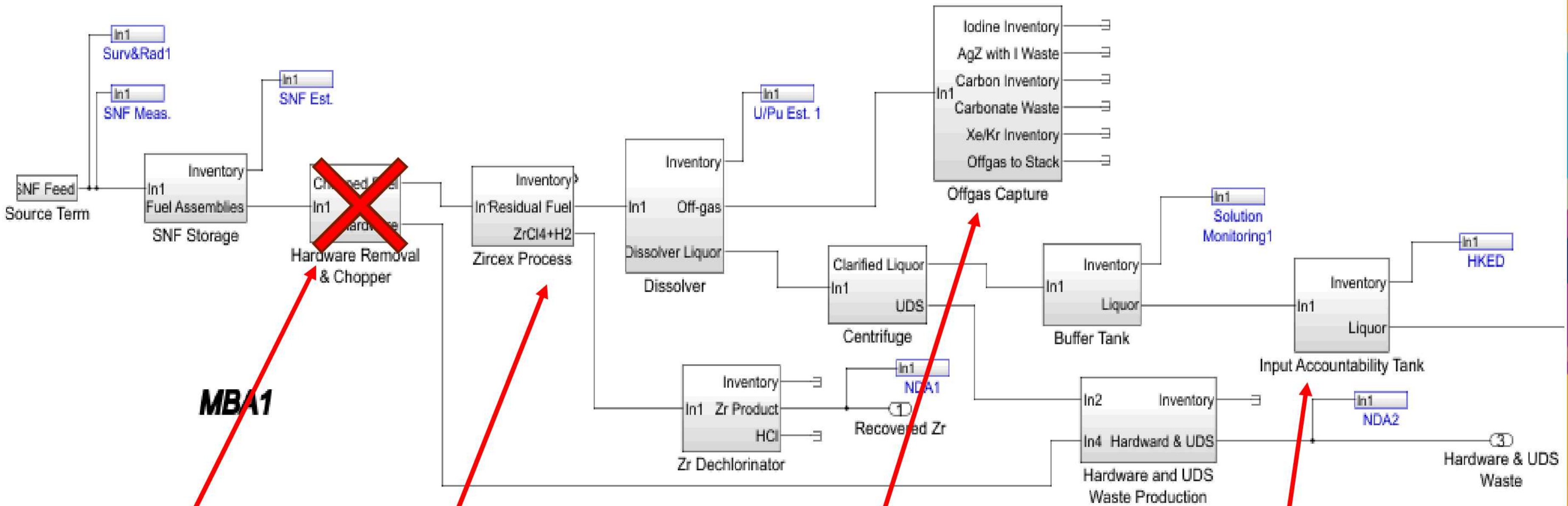
- DOE NE is currently funding an effort to process used naval fuel (HEU) into high-assay (~20%) LEU feed stock.
  - Multiple advanced reactor vendors may need high assay LEU
  - Other vendors may need this material (medical isotope production).
- The Zircex process (gas phase hydrochlorination) is used to remove Zr from the fuel, followed by dissolution and aqueous processing.
- The goal of the modeling effort is to put together a pilot scale process and safeguards model for a Zircex-CoDCon flowsheet.
- This effort will also pull from recent work on reference flowsheet design from MRWFD (off-gas processing, MDD for the back end).

Zircex-CoDCon Pilot Scale Model



Zircex-CoDCon Pilot Scale (Front End)



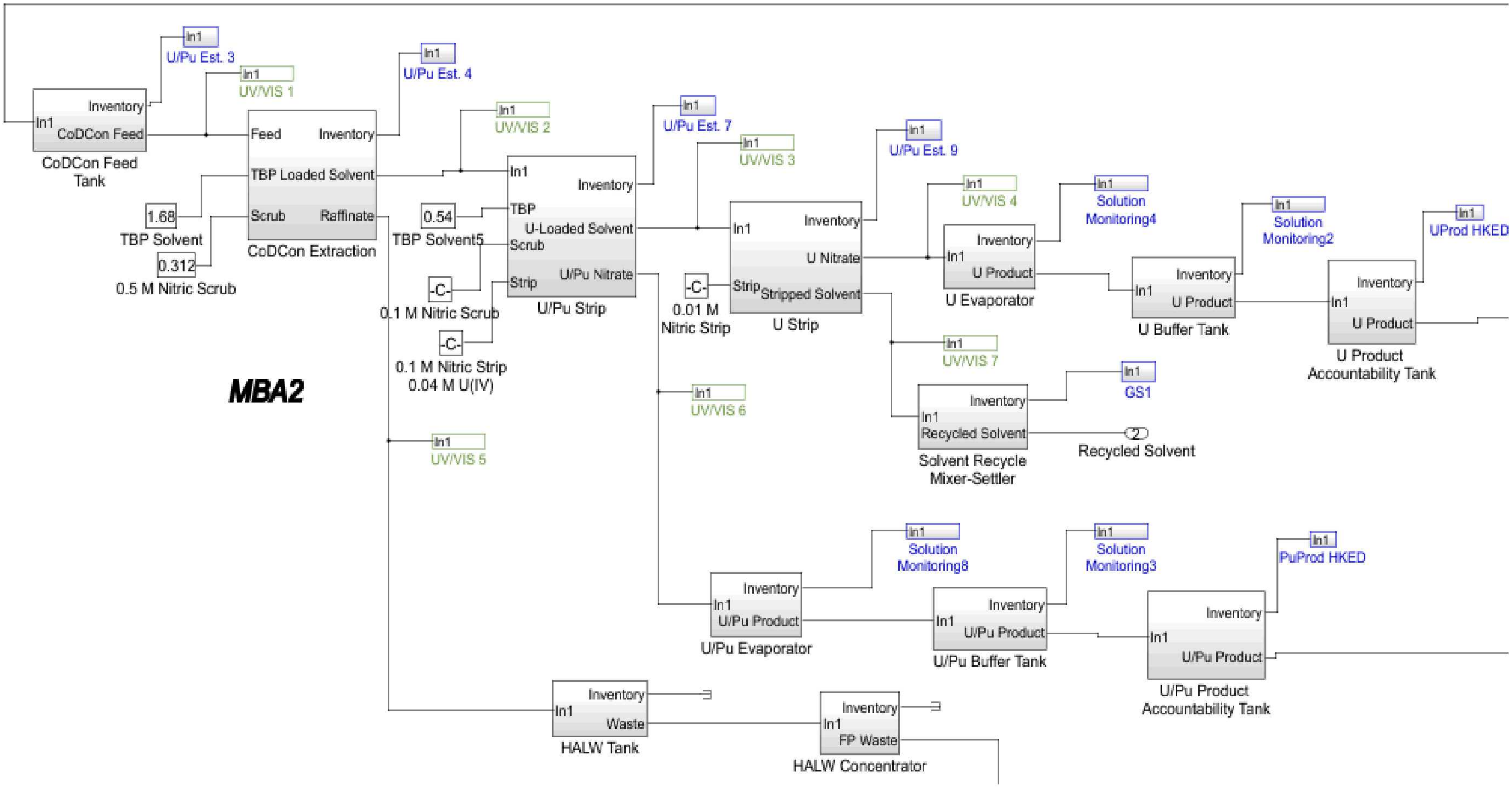
No hardware removal/chopper step

Zircex process is a key difference from existing aqueous reprocessing plants.

The results of the sigma off-gas team will be used to better inform off-gas capture

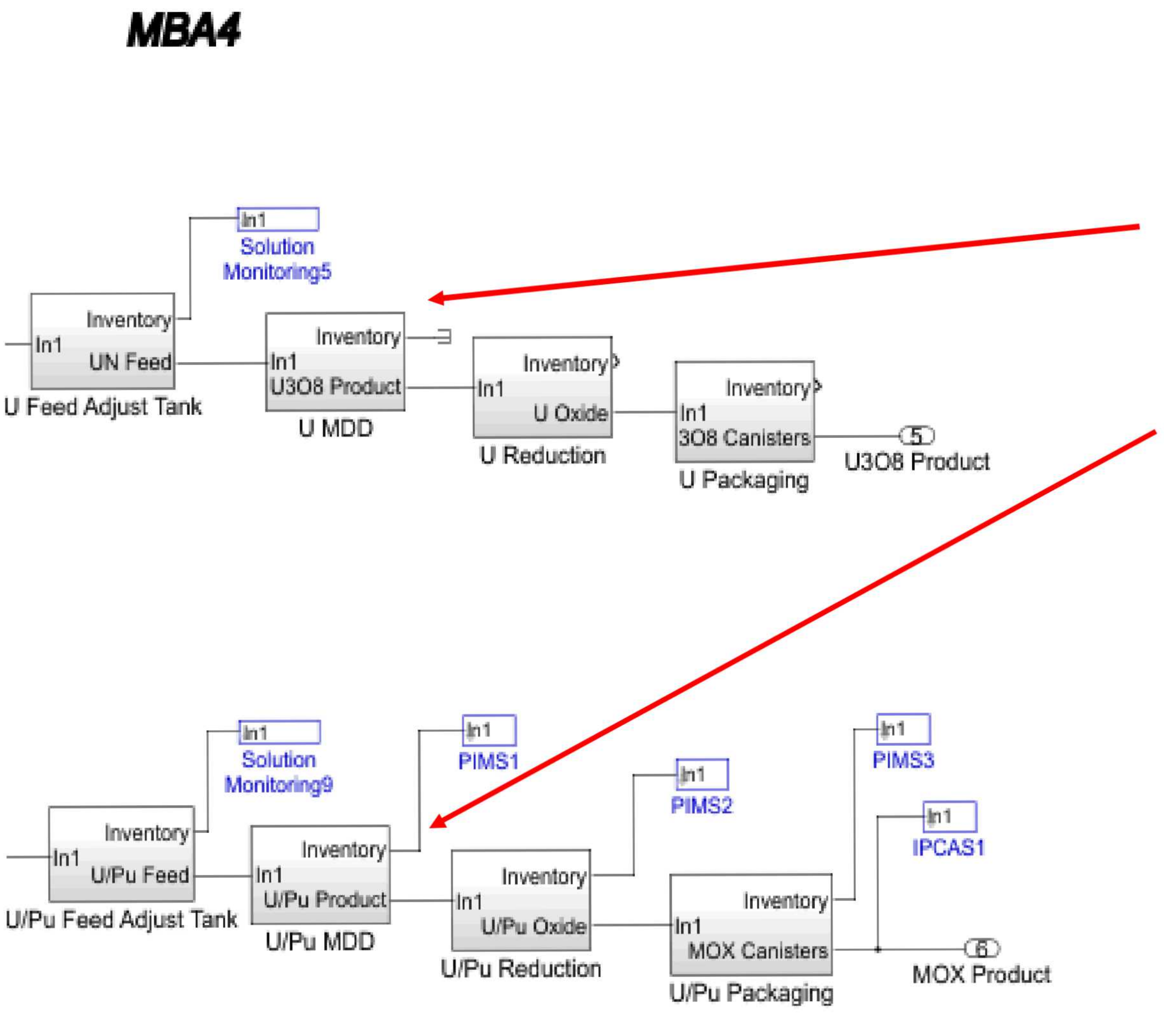
Remainder of the front end is similar to any aqueous plant.

Zircex-CoDCon Pilot Scale (Separations)



The CoDCon flowsheet, as developed and benchmarked through the testing at PNNL, is used for the separations are of the plant. Key outputs are U and U/Pu nitrate products. Fission products and minor actinides are sent to waste processing.

Zircex-CoDCon Pilot Scale (Back End)



Modified Direct Denitration is assumed for the back-end conversion to U_3O_8 and MOX.

Zircex – CoDCon Pilot Scale Model Status

- The plant model has been laid out, but needs more review and comment.
- Relying on “Material Recovery and Waste Form Development Campaign Full Recycle Case Study” reference for many of the processing system.
- Future work will need to determine the design parameters (throughput), and then balance the model based on that.
- A safeguards approach will be implemented taking into account the most updated options including on-line monitoring
  - This could provide a next generation safeguards system design.