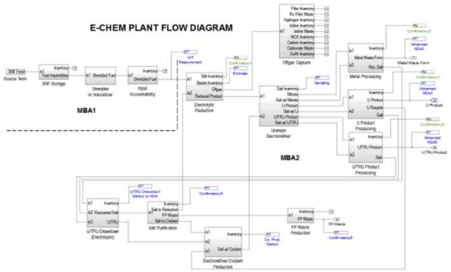
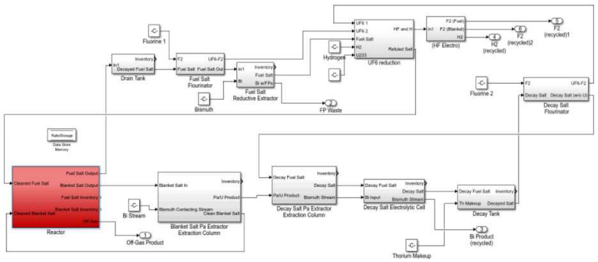
SAND2018-7315PE

Separation and Safeguards Performance Model (SSPM)





PRESENTED BY

Ben Cipiti & Nathan Shoman

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

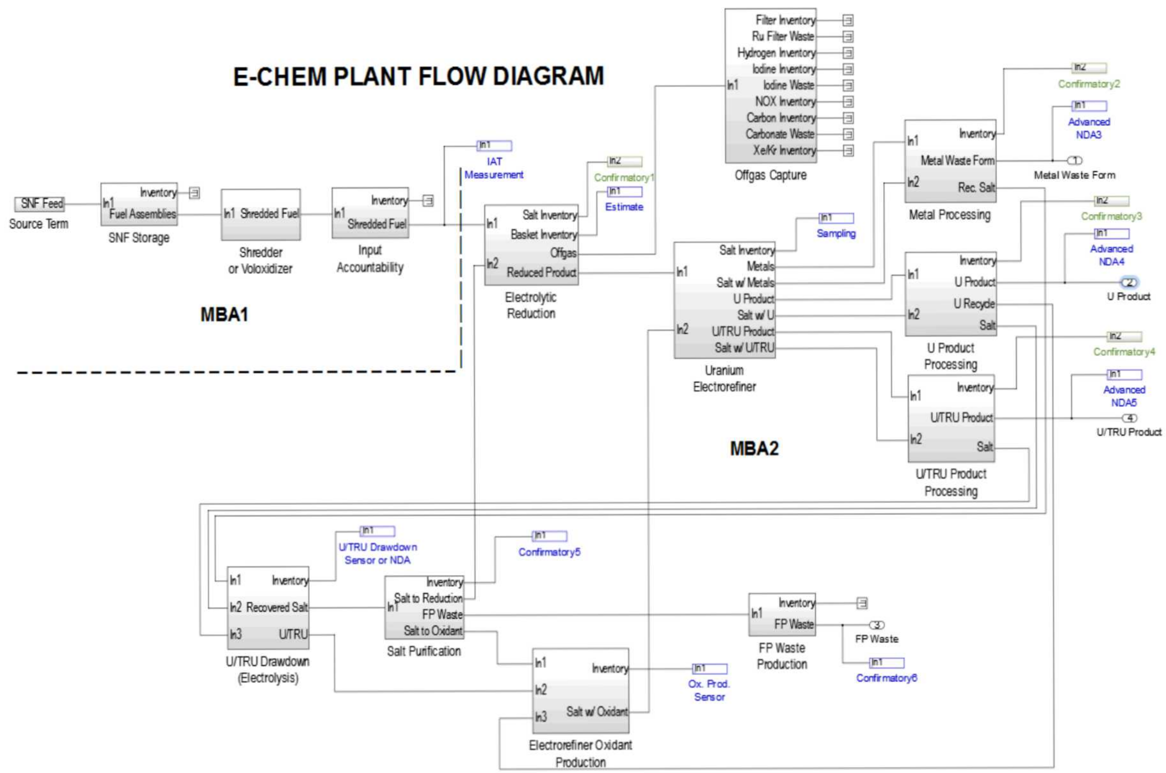
SSPM Overview

- **The SSPM was developed and has received the bulk of its funding from DOE NE, though the MPACT program**
    - Initial development focused on PUREX and UREX+ models
    - Development of pyroprocessing models started about 5-6 years ago
    - More recently the work has expanded to fuel fabrication and Molten Salt Reactors (MSRs)
- **The models have been used for more targeted analyses through NNSA funding.**
    - Supporting pyroprocessing research with S. Korea
    - Training and education programs through NA-21
    - Also some smaller projects in the past to examine the effect of improved measurements and new safeguards approaches.

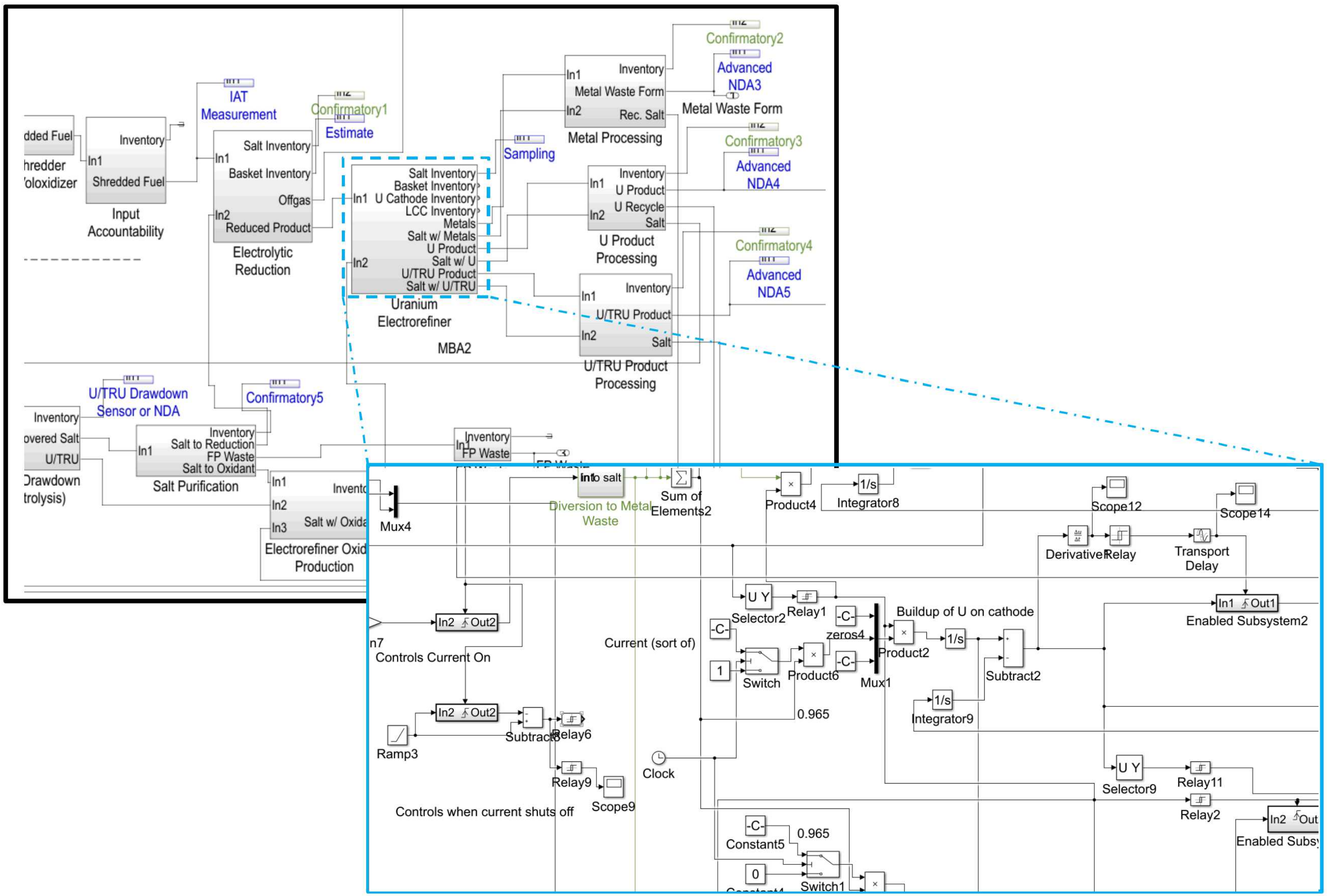
SSPM Capabilities

The SSPM is a transient mass tracking and safeguards model based in Matlab Simulink.

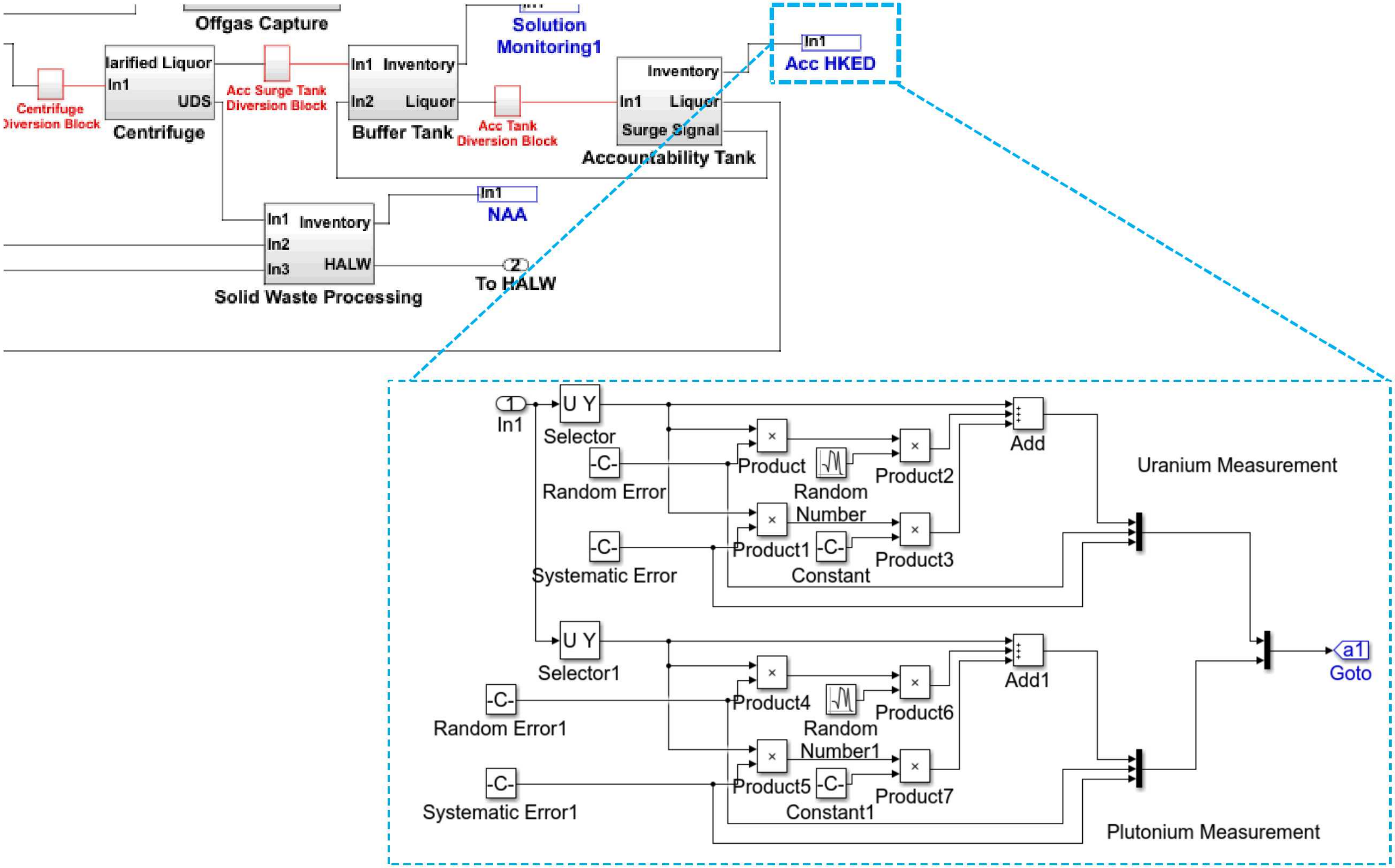
- Spent fuel source term library – integration with SCALE to accommodate most fuel types
- Full elemental and isotopic tracking, and bulk materials
- Customizable measurement points
- Simulation of gamma spectra with GADRAS **NEW**
- Automated calculation of MUF and error propagation in real time.
- Statistical tests for setting alarms
- Diversion scenario analysis
- Integration of process monitoring data



Significant Detail is Included in Each Subsystem to Realistically Mimic Operations and Timing



Measurement Blocks Simulate Safeguards or Process Monitoring Measurements



GUI for Increased Usability

Separation and Safeguards Performance Model

Required Input Parameters

Select a burnup and enrichment value: Select from below

Select a time since discharge: Select from below

Enter Duration in Hours of Each Simulation:

Diversion Scenario Parameters

Diversion Simulation OFF

Select the diversion location: Select from below

Enter diversion start time (hours):

Enter diversion end time (hours):

Enter diversion fraction (%):

Select the diversion type: Select from below

Single Model Run

Generate Single Run Parameters

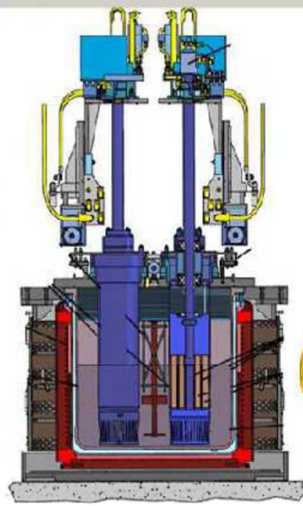
Parallel Processing Parameters

Enter Number of Simulations Per Run:

Number of Cores for Parallel Pool:

Push Run Onto Queue

Submit All SSPM Runs In Queue!



Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY

	U Random Error	U Systematic Error	Pu Random Error	Pu Systematic Error
IAT	0.0500	0.0500	0.0500	0.0500
Hulls	0.0500	0.0500	0.0500	0.0500
Oxide Basket	0.0100	0.0100	0.0100	0.0100
Salt Distillation	0.0100	0.0100	0.0100	0.0100
ER Salt Sample	0.0500	0.0500	0.0500	0.0500
ER LCC	0.0500	0.0500	0.0500	0.0500
ER Double Bubbler	0.0050	0.0050	0.0050	0.0050
Metal Processing	0.0500	0.0500	0.0500	0.0500
U Product	0.0500	0.0500	0.0500	0.0500
U/TRU Product	0.0500	0.0500	0.0500	0.0500
Oxidant Production	0.0500	0.0500	0.0500	0.0500
U/TRU Drawdown	0.0500	0.0500	0.0500	0.0500
FP Waste	0.0500	0.0500	0.0500	0.0500

Fuel Swapping

Isotopic Tracking: OFF

Select Source

Select Discharge Time

Start: 0

End

Randomize Source (Off)

Submit Fuel Swap Card

Check Cards

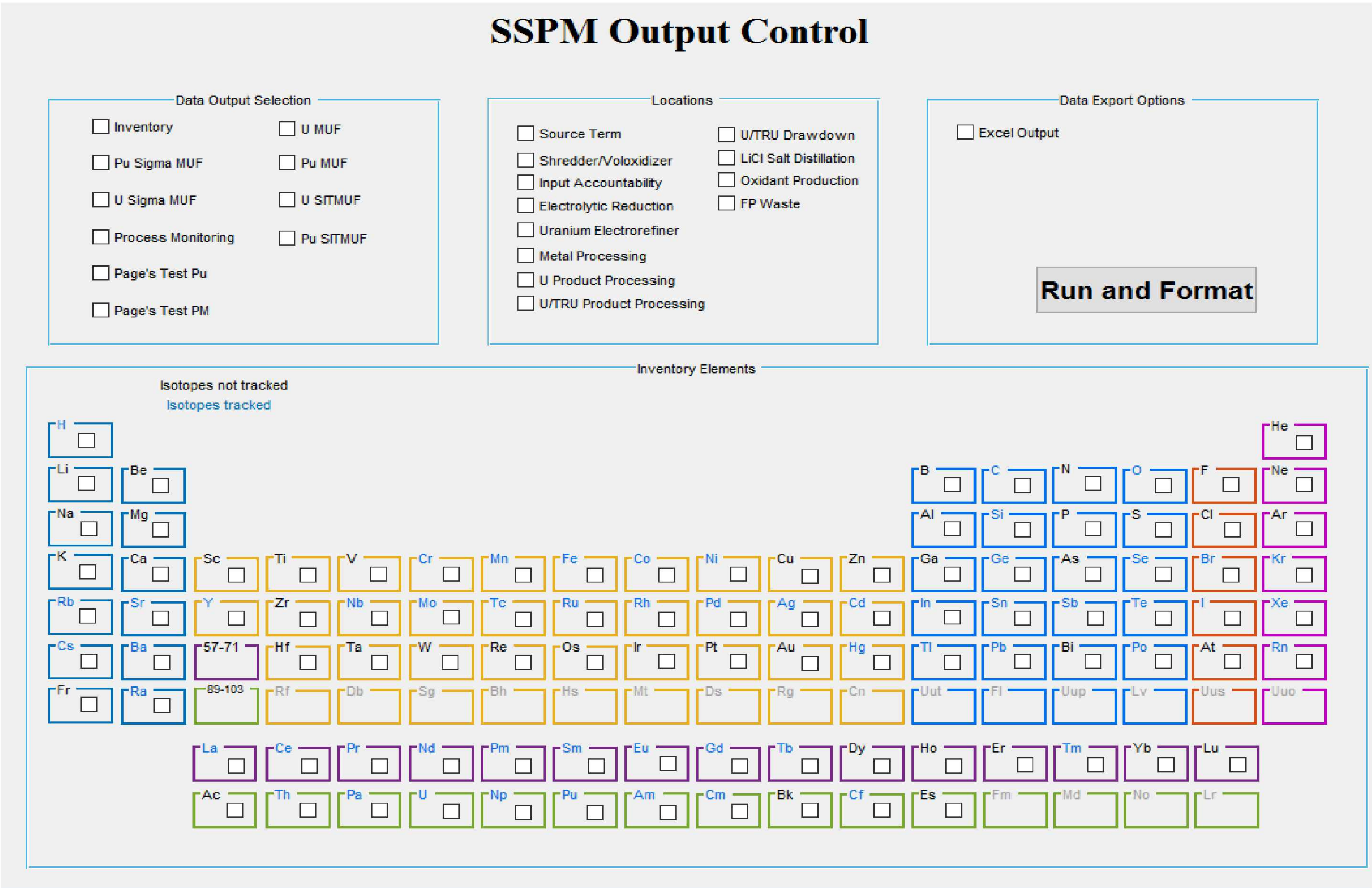
Reset

Ben Cipiti, Nathan Shoman
bbcipit@sandia.gov, nshoman@sandia.gov
505-284-8757, 505-844-1860

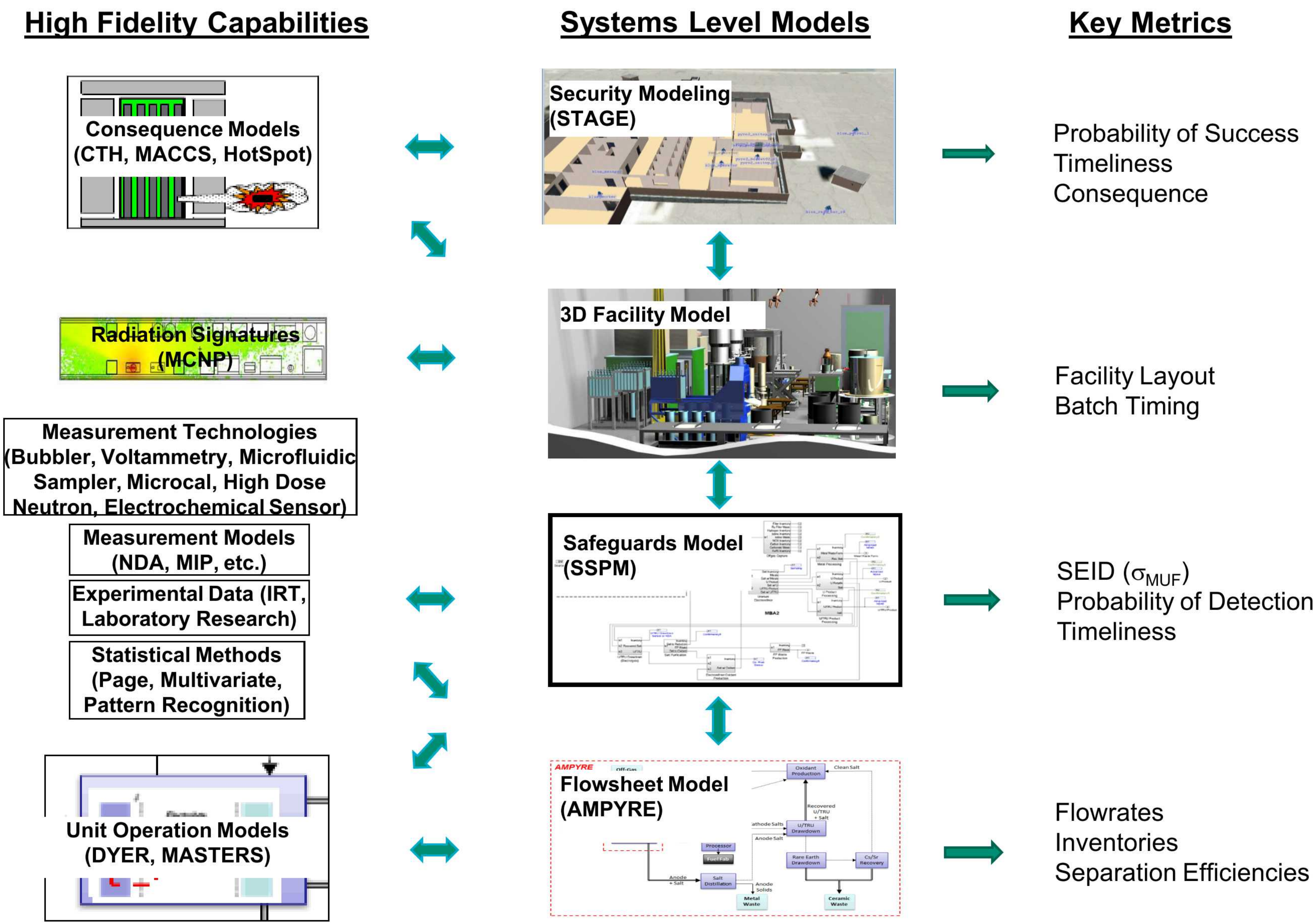
Serial Usage: Enter required parameter data and push "Generate Single Run Parameters". Parameters will be exported to the base workspace. The model must then be run manually from the model file.

Parallel Usage: Select number of iterations per run and number of cores you would like to use. Once ready push the run onto the queue. If you have other model runs you would like to run push those onto the queue. If not, submit all runs for automated simulation.

Uniform Data Output Control



MPACT - Virtual Facility Distributed Test Bed



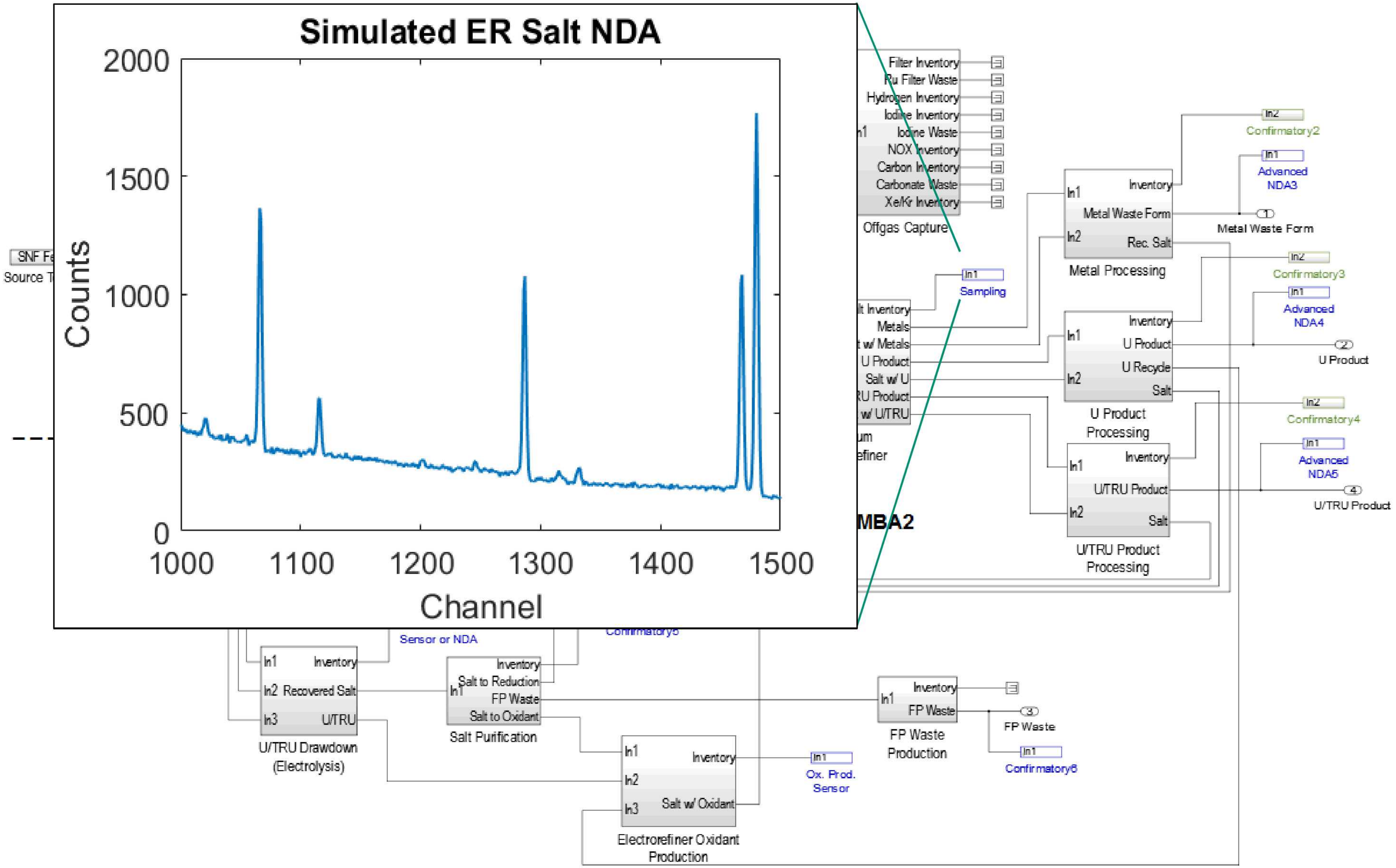
Safeguards Development: Machine Learning

- Past pyroprocessing work developed a safeguards approach based on sampling and DA, but measurement uncertainties are still unknown and there are concerns about representativeness of samples.
- We are examining other approaches that make more use of NDA measurements along with Machine Learning techniques to provide an alternative safeguards approach.
  - IAEA would like to eliminate the need for an on-site laboratory, and shipping samples is becoming more problematic.
  - We would like to provide an alternative approach that requires only unattended measurement systems coupled with a machine learning algorithm
  - Work has been limited to scoping studies due to limited funding.

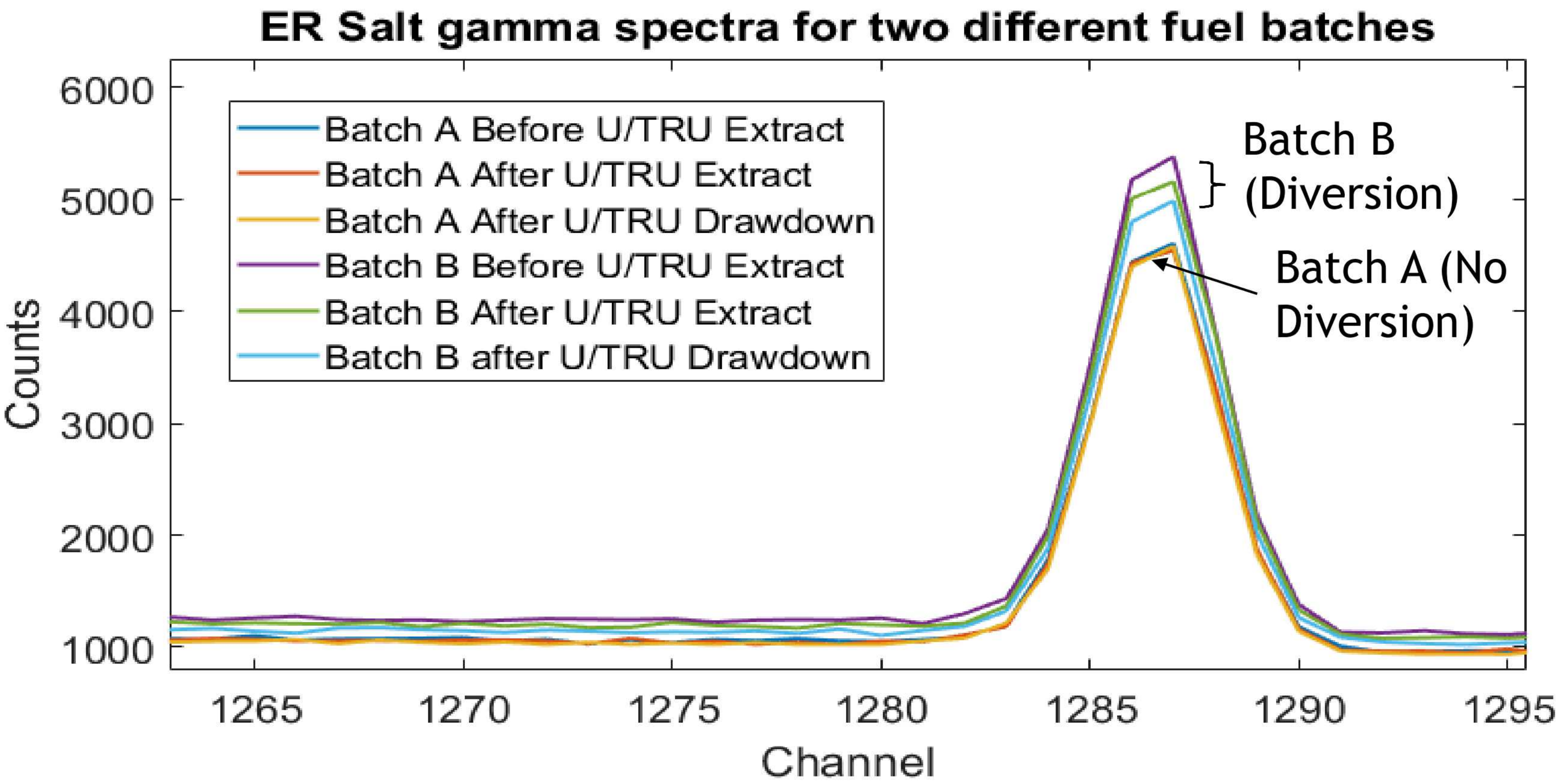
Machine Learning

- Machine Learning may be used to correlate a variety of data streams: overall Pu balance, bulk mass balances, NDA measurements, current & voltage monitoring.
- The key is to quantify how or if all of this data provides assurance.
- Instead of a detection probability, a machine learning technique may generate a classification value (1 or -1) daily. A normal scenario may see a -1 classification in 5/90 calculations. A protracted diversion scenario may see an increased rate of -1 classification values (20/90). We need to explore more how to use this data.

Coupling with GADRAS

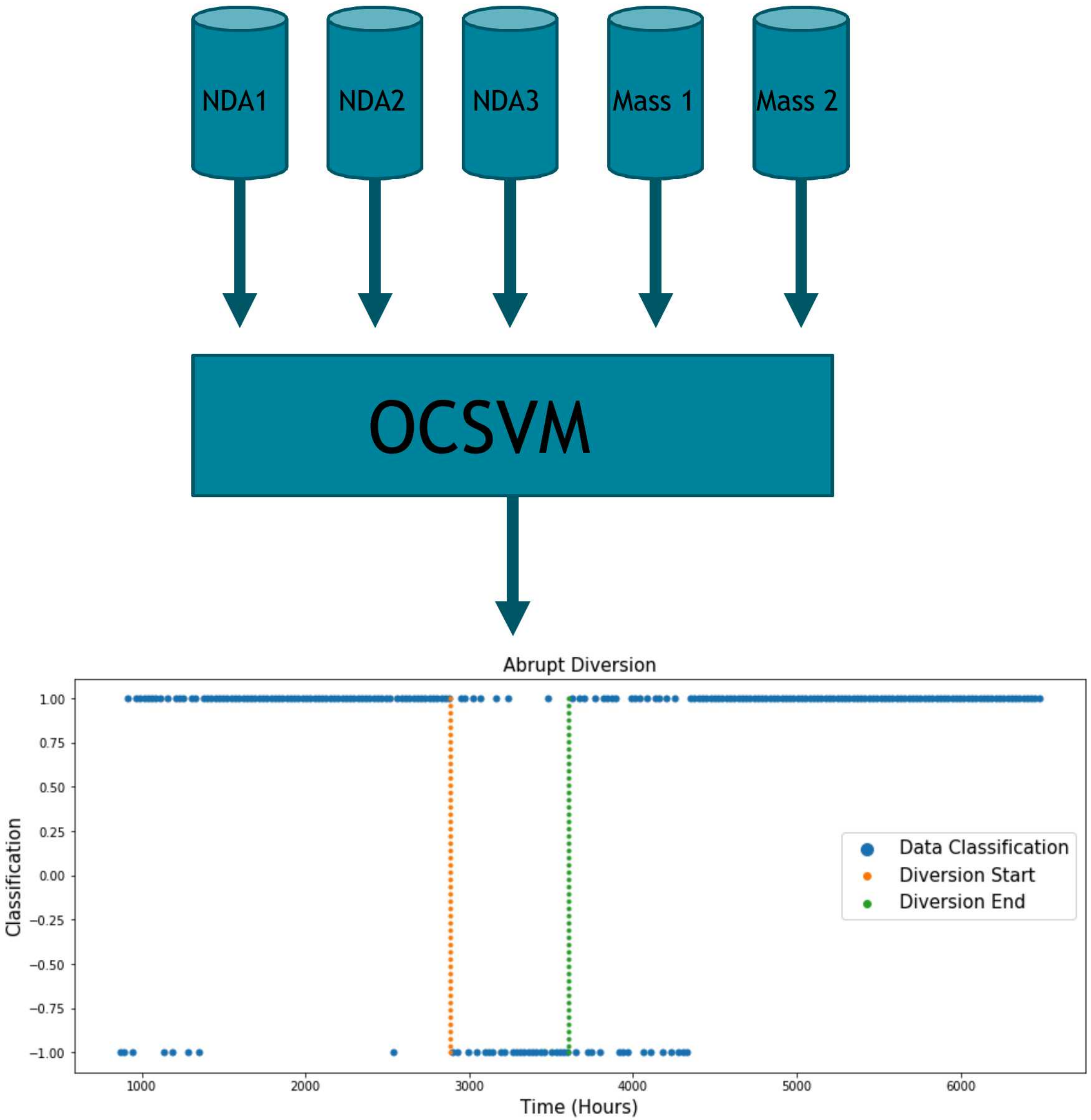


Example Substitution Diversion Results



- The SSPM tracks full elemental and isotopic compositions—coupling with GADRAS allows us to simulate gamma spectra for a sample from a particular location.
- This plot shows the effect of diversion on a particular peak.

One Class Support Vector Machines



- **Machine Learning helps us to automate the analysis of a lot of data:**
  - Bulk measurements and bulk balance
  - NDA gamma and/or neutron measurements
  - Possibly current, voltage, voltammetry, etc.
- **An actinide balance can still be performed, but the overall uncertainty will be higher.**
  - Can still be used for book values, but the overall approach has much more reliance on other indicators.

Current and Future Work

- The SSPM plays a significant role in the MPACT program to support the Virtual Facility Distributed Test Bed. The model will continue to expand to cover other needs in the overall DOE NE program.
- We see a lot of potential in exploring machine learning concepts to take advantage of process monitoring or other NDA data in cases where traditional safeguards approaches may be difficult, like pyroprocessing.
  - It takes a great deal of simulation data to develop these algorithms. In the future, we will examine these newer approaches compared to traditional material balances and hope to have more data to present.