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Safeguards Model Improvement and Archiving

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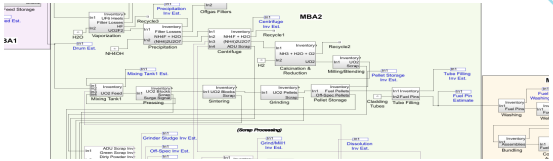
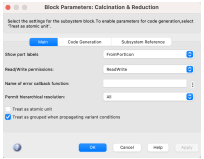
U.S. DEPARTMENT OF ENERGY

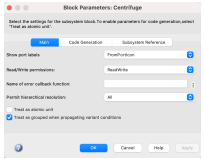
NNSA

SNL FY23 work package overview: Reprocessing Modeling Support

- Work package consists of several key thrusts
  - SSPM model and flowsheet archiving
  - SSPM dev toolkit
  - MAPIT development
- Overarching theme is to **improve access to mod/sim tools to support safeguards**
- Focus on open source availability and improving documentation







SSPM model and flowsheet archiving

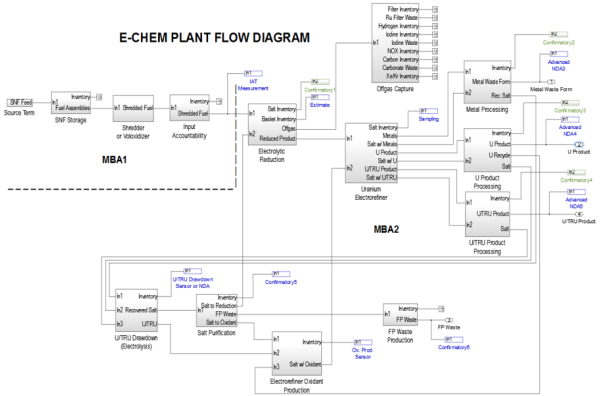
Team: Pat, Philip, Oliver

SSPM developed and used for over 15 years

- Nuclear fuel cycle facilities face significant economic challenges in meeting safeguards, security, and environmental regulations
- Future facilities need affordable and accurate material accountancy and plant monitoring systems for both domestic and international safeguards
- SSPM was created to examine the impact of different measurement technologies on traditional safeguards metrics
  - Originally started as internal Sandia LDRD circa 2008 (*Advancing the State of the Art in Materials Accountancy through Safeguards Performance Modeling, SAND2008-5100*)
  - Application has expanded to a variety of safeguards tasks
- A variety of sponsors, including DOE-NE and NNSA, have funded the development of several SSPM models
  - PUREX, UREX+, Enrichment, Fuel Fabrication, and Pyroprocessing

SSPM is a powerful tool designed to explore challenging safeguards objectives

- The SSPM is a transient mass tracking and safeguards model based in Matlab Simulink.
  - Spent fuel source term library – integration with SCALE
    - Full elemental and isotopic tracking (1675 isotopes)
  - Customizable measurement points
  - Simulation of gamma spectra with GADRAS
  - Integration of process monitoring data



Challenge: Knowledge retention across projects and staff changes

- SSPM results finalized in reports, but specific project aspects are sometimes lost
- New staff often lack the insight of original authors when model was created
- Time lost in some cases when projects are restarted and/or follow-on work is conducted
- Changes to overall mode philosophy may not be propagated to all models
  - More on this in the dev toolkit section
- Over reliance on institutional knowledge and delieverables has led to poorer documentation

FY23 progress and outlook

- Started archiving efforts by starting per flowsheet Git repositories
- Interviewing relevant staff with questions regarding flow sheets
- Started collecting relevant technical documents

Project goals

- Sharable and open documentation on flow sheet specifications
- Integration with dev-toolkit (how-to, tutorials, etc)
- Ties to historical SAND reports
- Utilization of Simulink-specific version control tools

Anticipated end of FY status

- Git repositories for all flowsheets
- Finish document collection
- No anticipated issues
- Estimated carryover: 10K

SSPM dev toolkit

Team: Pat, Oliver, Philip, Nathan

Challenge: SSPM requires government use due to potential sensitivities

- Paperwork to share SSPM even internally to U.S. Citizens at labs can take weeks
- User experience can vary based on flowsheet
- Results outside original model intent not well validated in some cases
  - Largely due to large of out-of-scope benchmarking
- Improvements in newer models might not be propagated to older models with different flowsheets
- Models often difficult to use due to lack of documentation for outside users and focus on SNL-based experts

Developing foundational tools for next-generation safeguards research and development

Goal: Open-source components used to build SSPM-based models

- Individual components could be combined to model flowsheets
- Components could be validated individually and could be monitored for accuracy
- Improved maintainability and accessibility to others in the community
- Currently in initial development stage

Anticipated end of FY status

- Develop libraries for 1-2 components for a fuel fab facility
  - Work required to "template" the process of developing components
- Develop testing suite for components
- Estimated carryover: N/A
  - Note: Project is exploratory and is being proposed as a work package for FY24


MAPIT
Team: Nathan, Pat

Material Accountancy Performance Indicator Toolkit

- **Goal:** Improve accessibility and transparency for material accountancy
- Written entirely in Python
- Automated error propagation
- Implementation of common statistical tests
  - MUF, σ_{MUF}, SITMUF, Page's trend test
- Robust I/O support
  - *csv*, *mat*, *npz* files
- Intuitive GUI
- Rich API


```
MUF = StatsTests.MUF(inputAppliedError = inputAppliedError,
                     inventoryAppliedError= inventoryAppliedError,
                     outputAppliedError = outputAppliedError,
                     processedInputTimes = processedInputTimes,
                     processedInventoryTimes = processedInventoryTimes,
                     processedOutputTimes = processedOutputTimes,
                     MBP = mbaTime)

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```
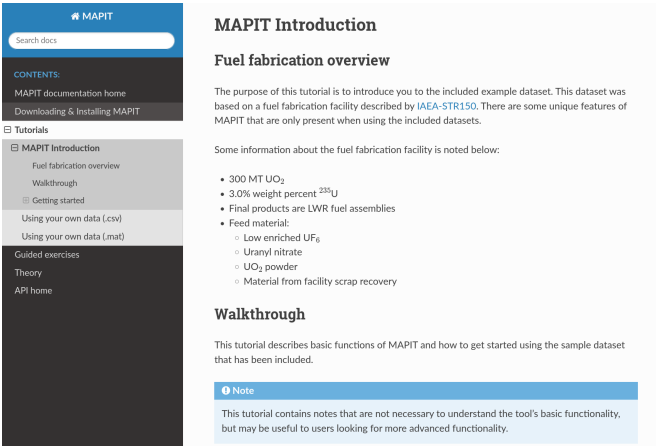
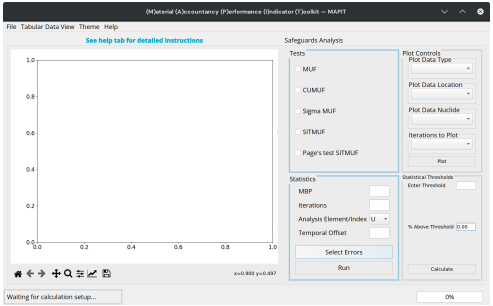

MAPIT: Wider use within community

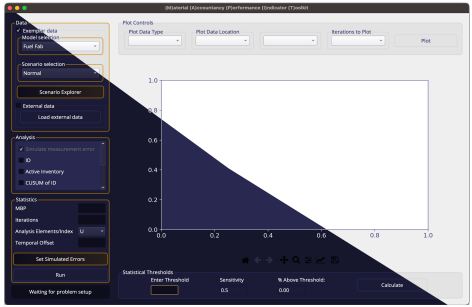
- Used for in-person bilateral engagement
- Featured in domestic NMCA training to provide visual and interactive exercises
- Showcased at INMM in Vienna
- Input from international users incorporated in latest release



FY23 Accomplishment: GUI overhaul



Old design



New design

- Feedback used to overhaul user interface while retaining functionality
  - Consultation with UI expert
  - Non-expert user feedback
  - Input from graphic designers

- More compact layout
- Support for HiDPI screens
- New visualizations
  - SEID contributions
- Ability to adjust font sizes

FY23 Accomplishment: API development

- Developed application program interface (API)
  - Currently based in Python
- Targeted towards advanced workflows and secondary analysis
- All capabilities in GUI available
- End-to-end pipeline shown in example notebook
- Documentation for all key functions available

```
MUF = StatsTests.MUF(inputAppliedError = inputAppliedError,
                     inventoryAppliedError= inventoryAppliedError,
                     outputAppliedError = outputAppliedError,
                     processedInputTimes = processedInputTimes,
                     processedInventoryTimes = processedInventoryTimes,
                     processedOutputTimes = processedOutputTimes,
                     MBP = mbaTime)

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```

MAPIT_internal.core.StatsTests.MUF(*inputAppliedError, processedInputTimes, inventoryAppliedError, processedInventoryTimes, outputAppliedError, processedOutputTimes, MBP, GUIObject=None, GUIparams=None*)

Function to calculate Material Unaccounted For (MUF), which is sometimes also called ID (inventory difference). Specifically calculates the material balance sequence given some input time series.

$$\mathrm{MUF}_t = I_t - O_t - (C_t - C_{t-1})$$

I_t is input at time t

O_t is output at t

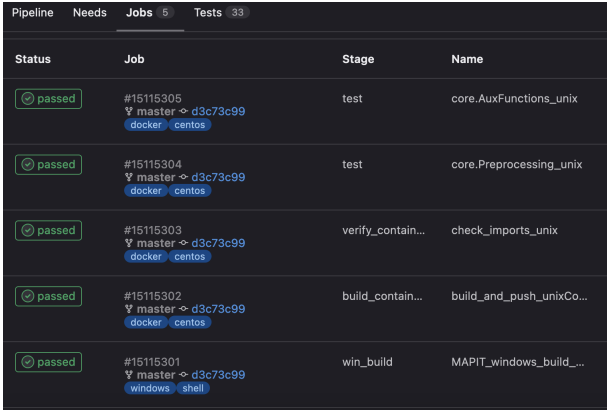
C_t is inventory at time t (note C is used to denote *container* to have clearer notation rather than using I with subscripts for both inventory and input)

Important

The lengths and shapes of appliedErrors and processedTimes should be the same. For example:

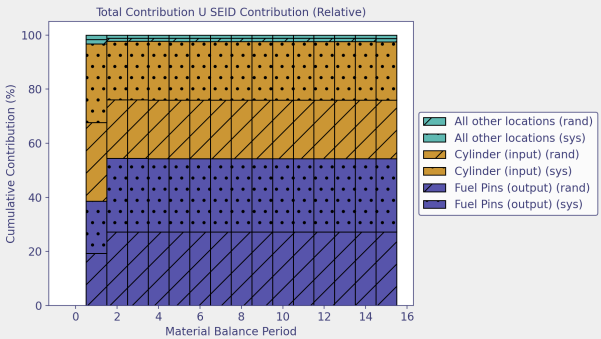
FY23 Accomplishment: Unit test implementation

- MAPIT designed in Python, which can run on multiple platforms
  - Challenge: Not all dependency packages available on all platforms
  - Continuous build health tests report weekly status (Windows, Mac, Linux)
- Ensure integrity of mathematical operations
- Tests functionality to ensure code base changes to not impact performance or accuracy



FY23 Accomplishment: Statistical tests and other improvements

- Added CUMUF tests
- Added capability for domestic or international use (terminology)
- Added visuals for SEID contribution
- Improved input/output capabilities
- Offloaded computation to separate threads to improve GUI responsiveness
- Improved install scripts for users new to Python
- General bug fixes and performance improvements



FY23 outlook

Additional planned tasks before end of FY

- Progress on high-performance capabilities (multi-threadding)
- Full inclusion into NMAC training course
- Initial progress on theory documentation
- Work on improving user guide
- No issues anticipated
- Est carryover: 10K
- Est total carryover (archiving task, dev toolkit task, MAPIT task): 20k

Acknowledgements

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