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U.S. DEPARTMENT OF ENERGY | Nuclear Energy

Safeguards and Security Performance Modeling

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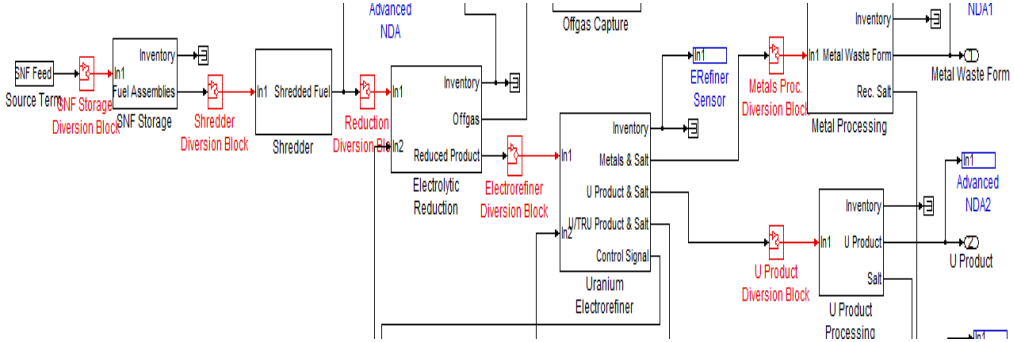

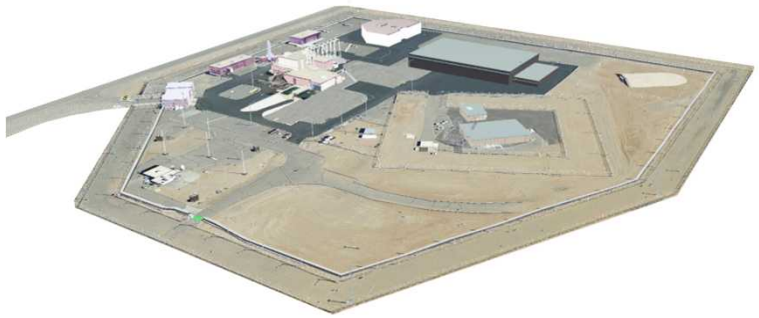

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Overview

- **Reprocessing and safeguards technologies are relevant on a global scale, even though it may be some time before reprocessing is done in the U.S. Nuclear energy growth in China, India, and South Korea is leading to a move toward reprocessing.**
- **Building in safeguards now (part of Safeguards by Design) is the best non-proliferation strategy.**
- **MPACT has a larger goal to provide a virtual test bed 2020 milestone for safeguards systems and technologies for fuel cycle facilities.**

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Safeguards Modeling

- The Separation and Safeguards Performance Model (SSPM) was developed in the MPACT campaign for safeguards analysis of reprocessing facilities.
- UREX+, PUREX, and Electrochemical models have been developed as program priorities have changed.
- The models have been developed until they reached a good end point, and future work will focus on integrating with other MPACT modeling activities, the H-Canyon test bed, and measurement technologies to support the 2020 milestone.
- DOE NE, NA-24, and NA-25 have used the SSPM for specific problems, and MPACT continues to maintain good communication with these related program areas.

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FY15 Accomplishments

- The Electrochemical SSPM model has been finalized and represents a generic Echem plant design.
- A process monitoring analysis of Echem was completed to examine new approaches to safeguards system design.
- A preliminary safeguards system design was developed.
- A thorough diversion scenario analysis was completed to examine measurement technology requirements to meet safeguards goals.
- The integration of safeguards with physical security was examined as an approach for improving the timeliness and effectiveness of responding to insider material diversion.

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Echem SSPM in Matlab Simulink

Separation & Safeguards Performance Model (SSPM)

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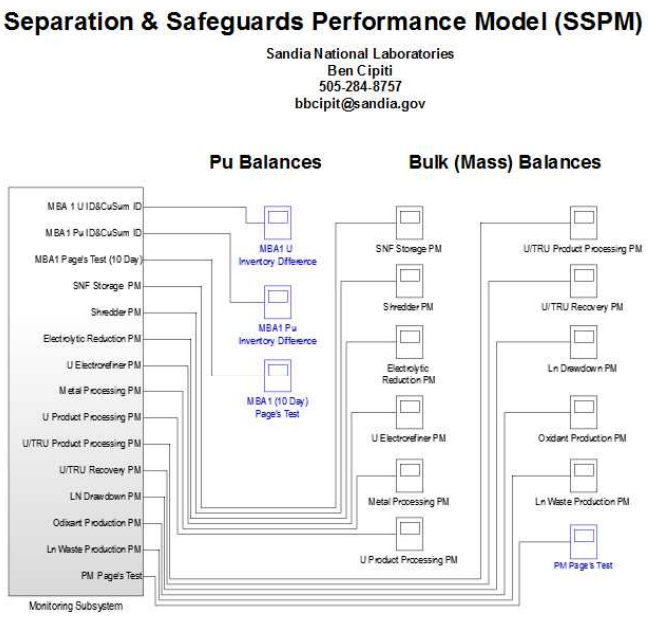

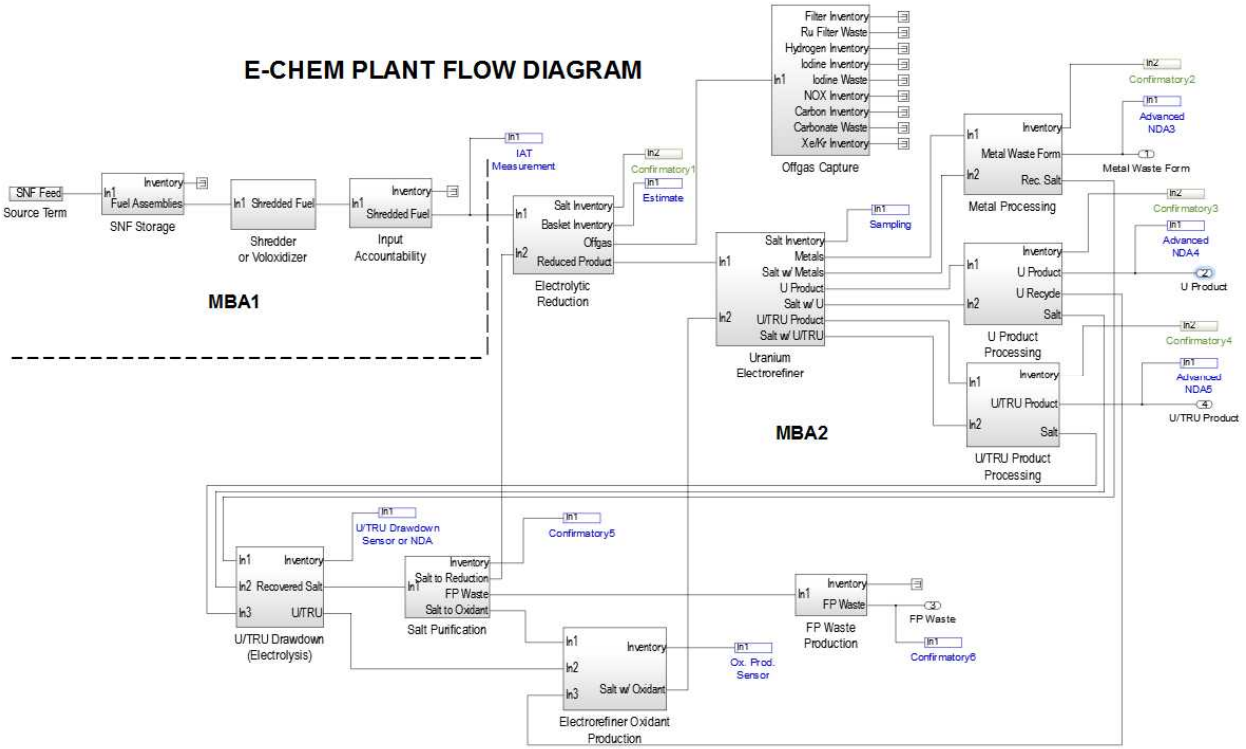

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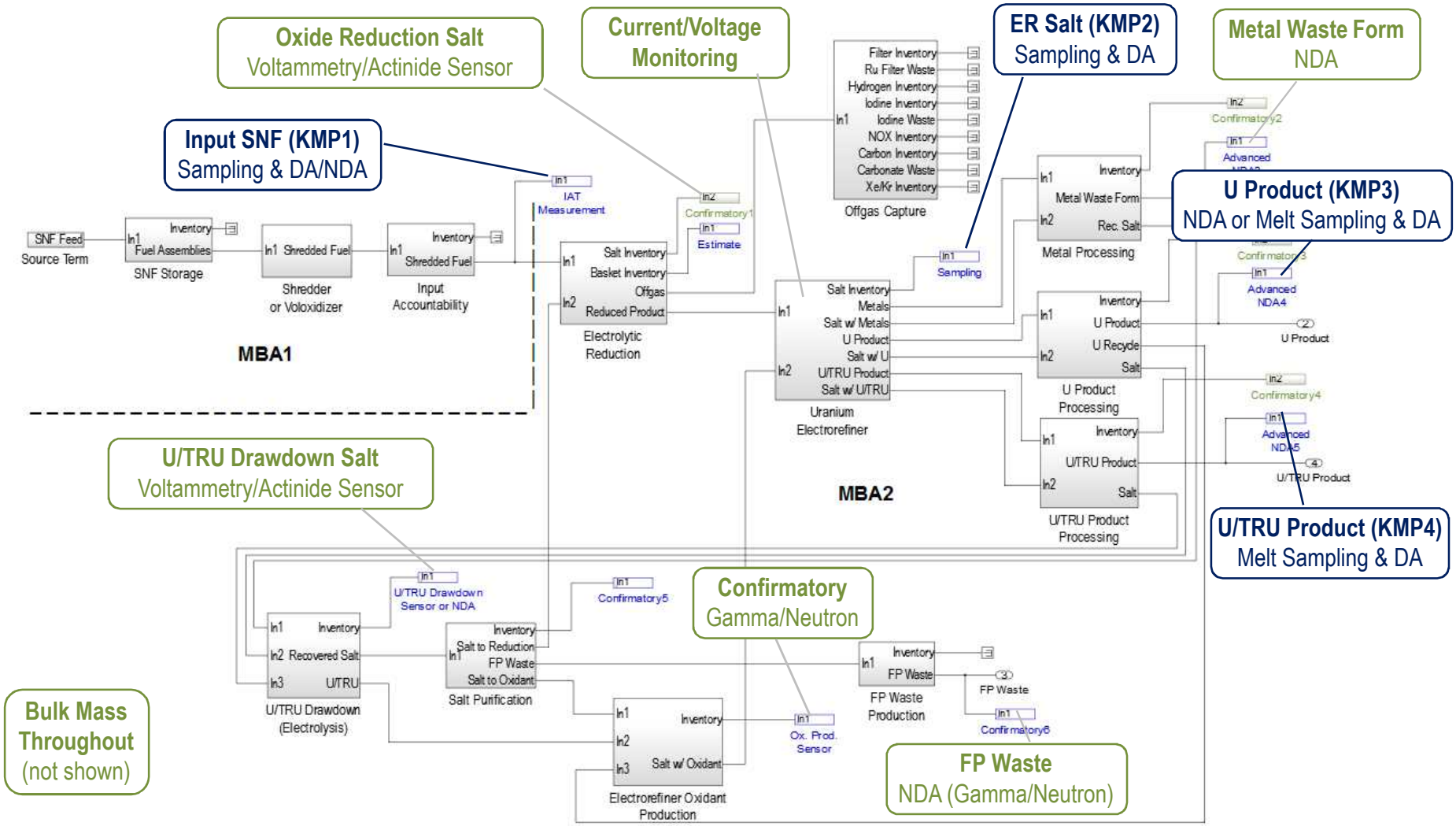
Preliminary Safeguards Design



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Key Safeguards Modeling Results

- **For a 100 MT/yr facility, the key measurement points need to achieve 1% measurement uncertainty in order to meet IAEA safeguards goals. (Smaller plants can relax the uncertainty requirement.)**
  - This measurement uncertainty will be difficult to achieve for the input measurement and outputs, although melt sampling can be used for the outputs.
- **The plant design modeled here includes a significant buildup of actinides in the electrorefiner salt, which means that the salt measurement is the most important in the plant.**
- **Electrochemical plants are designed to maintain actinide inventories in the salt for steady-state operation, so flushouts may not be practical—this requires reliance on an interim inventory verification.**

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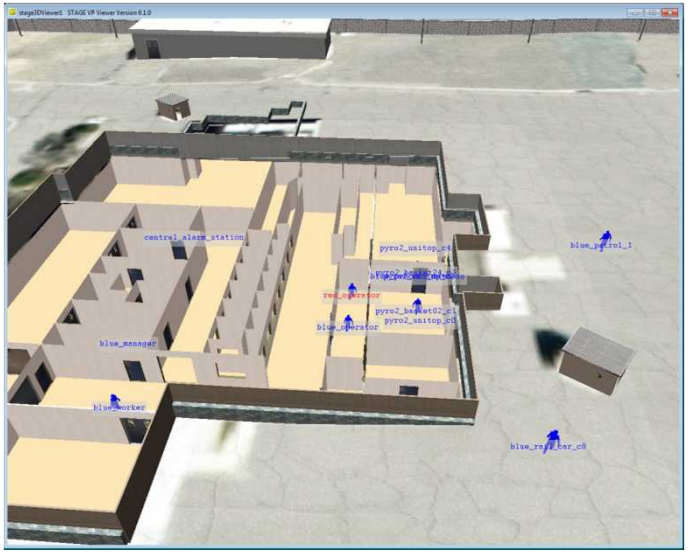
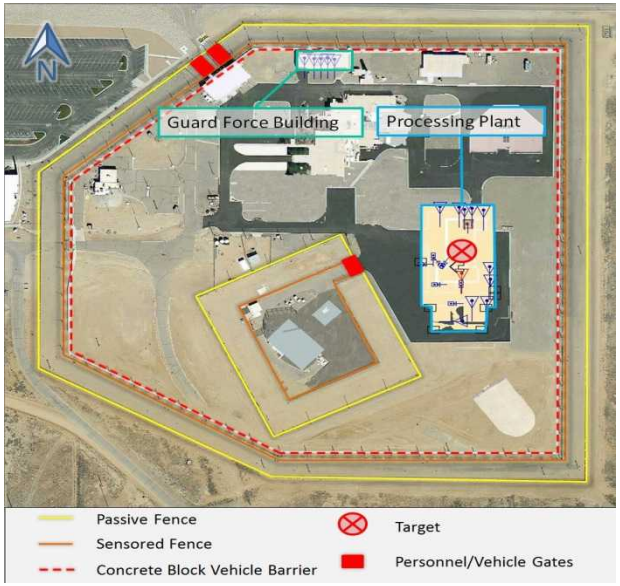
Integration of Safeguards and Security

- Materials accountancy and process monitoring data can provide timely detection of material loss.
- This data is difficult for an insider to "beat", so integration with physical protection can help protect against the insider threat.
- The Presagis STAGE software has been used along with the SSPM to completely model diversion scenarios.





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Insider Diversion Scenario Examined

- The SSPM was used to determine the probability of detection as a function of time for 5 scenarios ranging from abrupt to protracted loss.
- STAGE was used to model the 3D aspects of the diversion out of the facility.
- The baseline case only relied of the physical protection elements (guards, cameras, portal monitors, etc.) to detect the theft.
- The improved case used the probability of detection data from the SSPM to alter the response of the physical protection system. Any detection led to a facility lock-down.

STAGE Modeling Results

- All results are notional and will vary based on an actual facility design; the analysis was provided as a comparison.
- In some cases the response force win percentage was lower than expected for the baseline case.
- The integration with materials accountancy data and process monitoring significantly improved the response force win percentage.
- Integration also dramatically reduced the ability of the insider to remove a goal quantity of material (the diversion was interrupted well before a goal quantity could be removed).

Path Forward: 2020 Milestone

- **Modeling work at SNL, LANL, and ANL will be integrated in order to provide a virtual test bed for safeguards system design and testing.**
  - Modeling of improved statistical tests at LANL has been incorporated into the SSPM (SNL).
  - Unit operation models (ANL) can be evaluated for integration to provide the ability to examine process monitoring measurements better.
  - Radiation signature mapping (LANL) provides environmental markers within the facilities to help model measurement system response.
  - STAGE modeling of the facility adds the physical protection elements (SNL).

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Path Forward: 2020 Milestone

- **The H-Canyon Test Bed and other testing capabilities around the complex provide performance data on the new measurement technologies.**
  - This performance data can be fed directly into the virtual facility models.
  - But the modeling can also inform what additional testing may be necessary.
- **The ultimate goal is to be able to design, test, and provide metrics for advanced safeguards and security systems for the back end of the fuel cycle.**
  - As an example, UV-Vis Spectroscopy, HiRX, and the MIP Monitor are all being tested at H-Canyon. A future reprocessing plant may use HiRX for routine accountability measurements, UV-Vis for real-time monitoring of process solutions, and the MIP monitor to monitor solids or more difficult to measure material at the front end and back end.