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National Nuclear Security Administration

Material Control & Accounting (MC&A) Modeling/Simulation Consulting

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Meeting Agenda

- Overview of project plan
- Discuss scope of work and time frame
- Determine modeling needs to best support China
  - What is the end goal of the model?
  - What platform (software) will be used?
- Preliminary discussions of modeling algorithms
- Related IAEA request for proposals with respect to the use of modeling for insider mitigation

Overview of the Project Plan

Project Goals

- As a follow-on activity to the Process Monitoring workshop, provide consulting on how to use modeling and simulation of bulk processes to support Safeguards by Design.
- We will use the U.S. Separation and Safeguards Performance Model (SSPM) to instruct how a similar model can be built to support China's reprocessing facilities.
- Such a model can help with nuclear materials accountability, process monitoring, and provide the ability to design these systems into the facility at an early stage.

Project Execution

- Initial planning meeting to define the specific modeling needs.
- Provide examples on how to set up material flows, unit operations, and simulated measurements for a PUREX reprocessing plant.
- Provide examples on calculations of inventory differences and statistical test algorithms.
- Suggest email exchanges to make progress in between meetings (will go through translation).
- Plan addition meetings as needed to go over the model development.

Project Execution (continued)

- The SSPM will be used for demonstration purposes, but we will not share the model.
- The goal is to share the algorithms that are used to build the model so that China can develop their own capabilities.
- Both countries have sensitivities about how MC&A data is used and shared, so it is better to keep the developed models independent.

End Goal

- Depending on progress, the Chinese points of contact should be able to develop a fairly good working model in 2 years.
- The model can be tailored to their specific needs.

Discuss Scope of Work and Time Frame

Work Scope & Time Frame

- Is the project plan still of interest to China?
- Any modifications to the project plan?
- Who will be the key points of contact?
- What level of effort can be spent on this project?
- Is two years the right amount of time?

National Nuclear Security Administration

Determine Modeling Needs to Best Support China

End Goal of the Model

- What would be the main purpose of the model from the Chinese perspective?
  - Use to optimize materials accountability systems?
  - Use to determine the role of process monitoring?
  - Implementation of Safeguards by Design?
  - Virtual testing of newer measurement instrumentation?
  - Material loss scenario analyses?
  - Use for transparency?
- What challenges has China faced that modeling and simulation could help with?

Modeling Platform

- The SSPM uses the Matlab Simulink platform
  - Available worldwide.
  - Many universities have subscriptions.
- But safeguards and MC&A modeling and simulation can be done on other platforms or just through coding.
- Is there a preferred software or code to use to develop this capability in China?

Preliminary Discussions of Modeling Algorithms

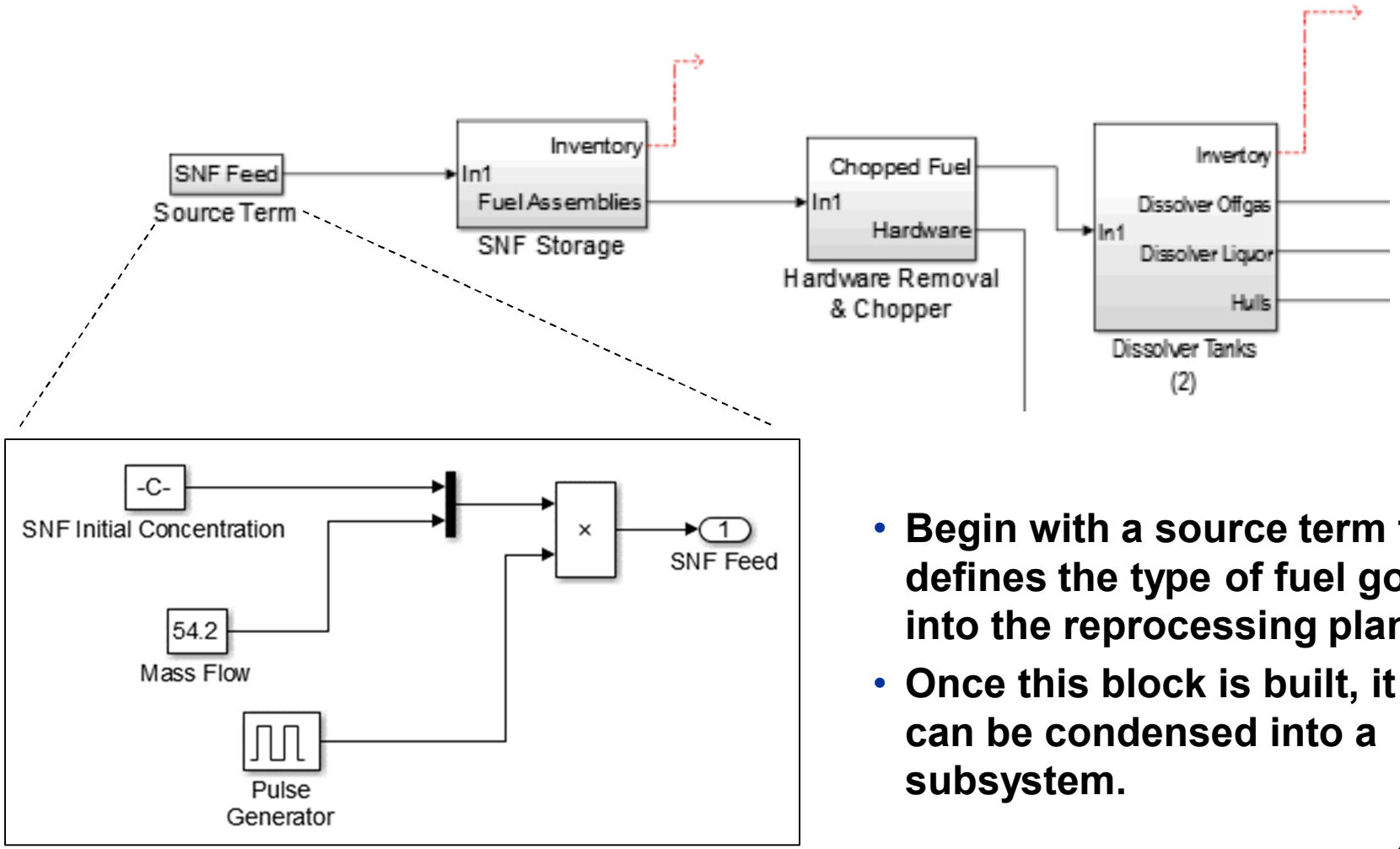
Modeling First Steps

- **A fairly accurate model of the facility and mass tracking of material is needed as the foundation.**
  - **Start with the flowsheet and model all tanks/vessels with accurate estimates of flow rates, volumes, and timing sequences.**
  - **Timing is important as it will determine when measurements can be taken and how to optimize the overall plant design.**
  - **The flows and inventories do not need to be perfect, but should be representative of the facility within +/- 10% or so.**
  - **Assumptions can be made about separation fractions (for pulsed columns or centrifugal contractors), or chemistry modeling can be used to increase the fidelity of the model.**

Time Scale and Initial Variables

- It is useful to determine the time scale that will be used in the model.
  - The SSPM uses hours as the time unit, and so keeps all mass flow rates in units of kg/hr.
- It may be useful to define initial variables (like spent fuel type, separation fractions, etc.) in a started file (an m file in Matlab) that places variables in the workspace at the start of a run.
  - But other approaches can be used depending on the modeling platform or code

Initial Model Construction

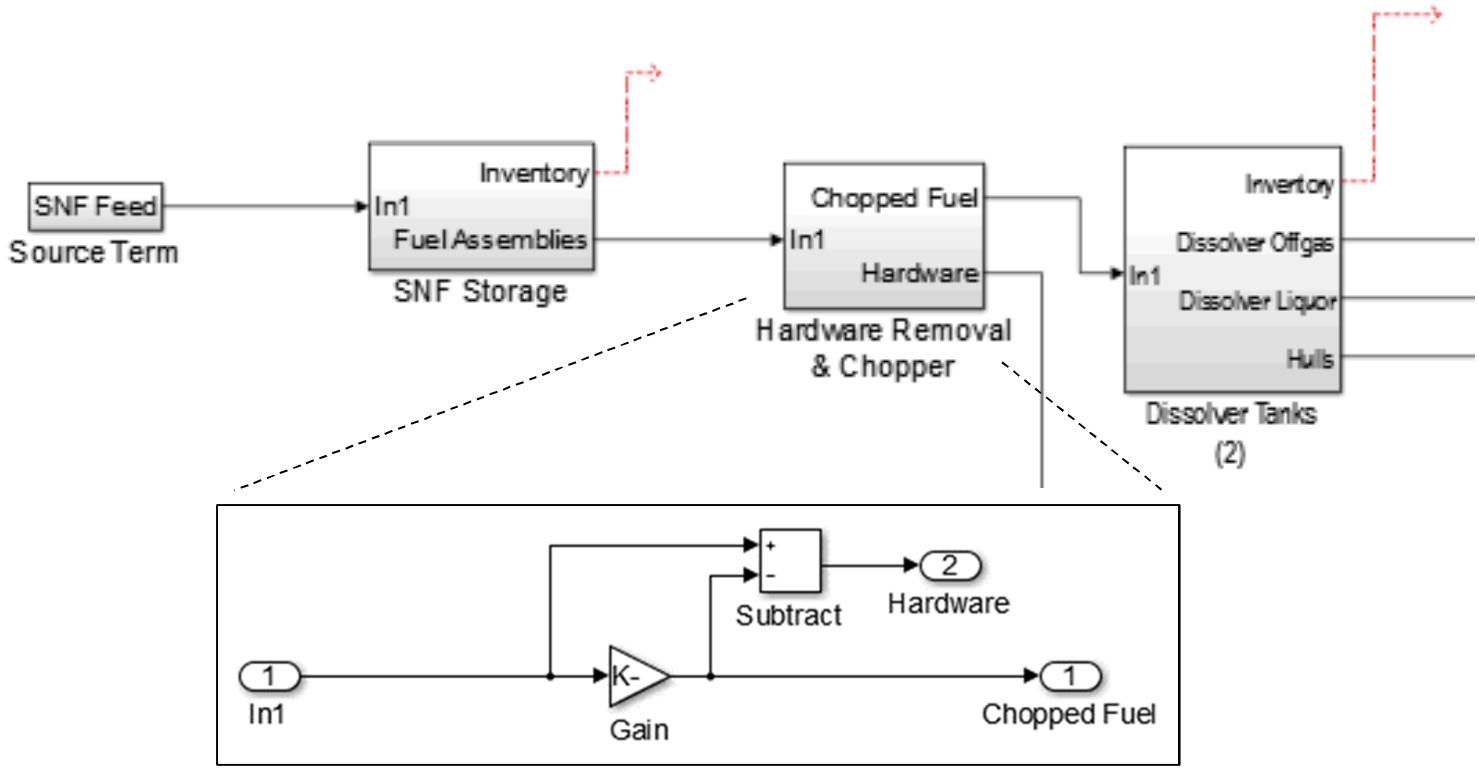


- **Begin with a source term that defines the type of fuel going into the reprocessing plant.**
- **Once this block is built, it can be condensed into a subsystem.**

Blocks and Signals

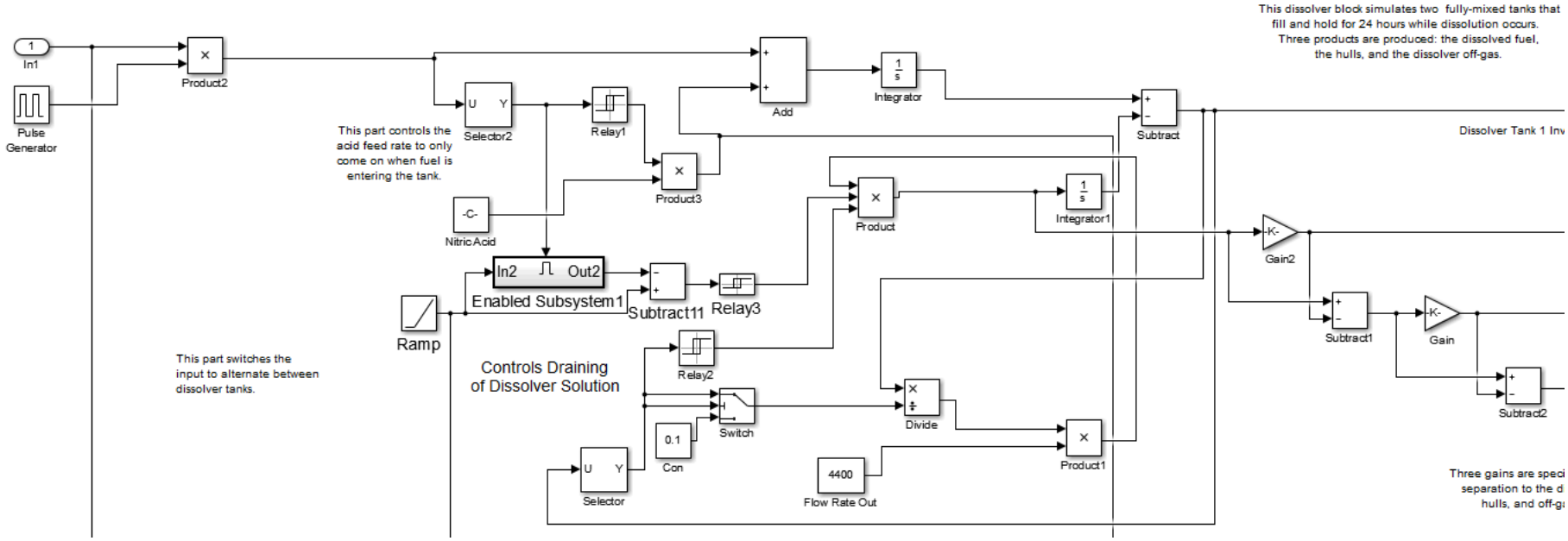
- Subsystems are used to represent particular unit operations or tanks. They contain math operations and control operations to model tank levels, separations fractions, inventories, and flow rates depending on the unit operation.
- Signals represent the mass flow rates as a function of time between blocks. As a baseline, the signal should contain the elemental mass flow rate for elements 1-99. But it can be expanded to include total bulk solids or liquid flow rates, specific chemicals, and specific isotopes if desired.

Separation of Hardware



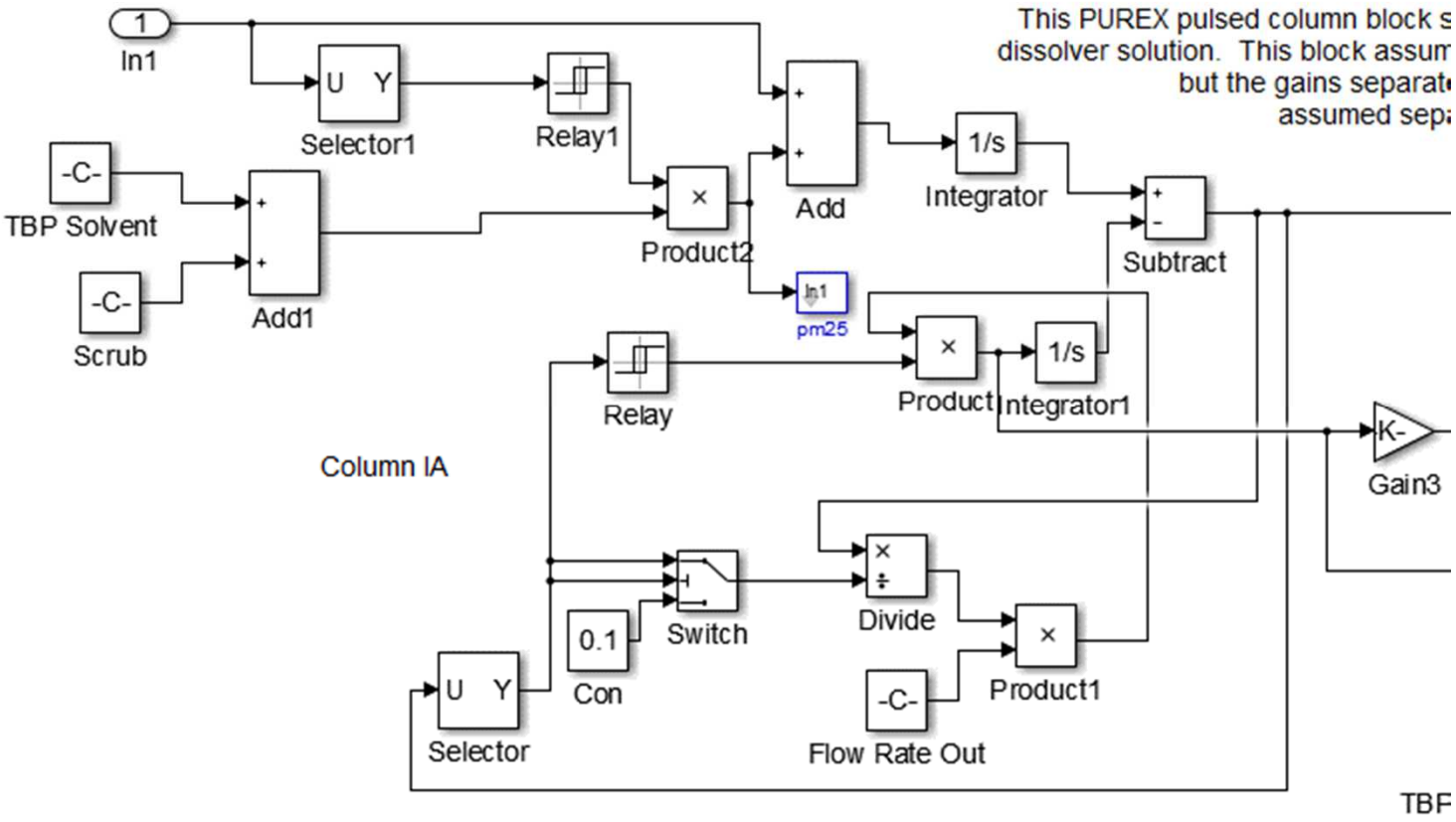
- **Any unit operation that contains a separation step can include a "Gain" block to remove various components from the fuel.**
- **In this case, the gain block removes all cladding and assembly hardware.**

Dissolution



- **Dissolution gets more complex. "Relays" and "Switches" are used to control when acid is added and when to shut off when the tank is full.**
- **"Transport Delay" blocks are used to pause operations to allow time for mixing and dissolution.**
- **"Gain" blocks are again used since not all of the fuel dissolves.**

Separations

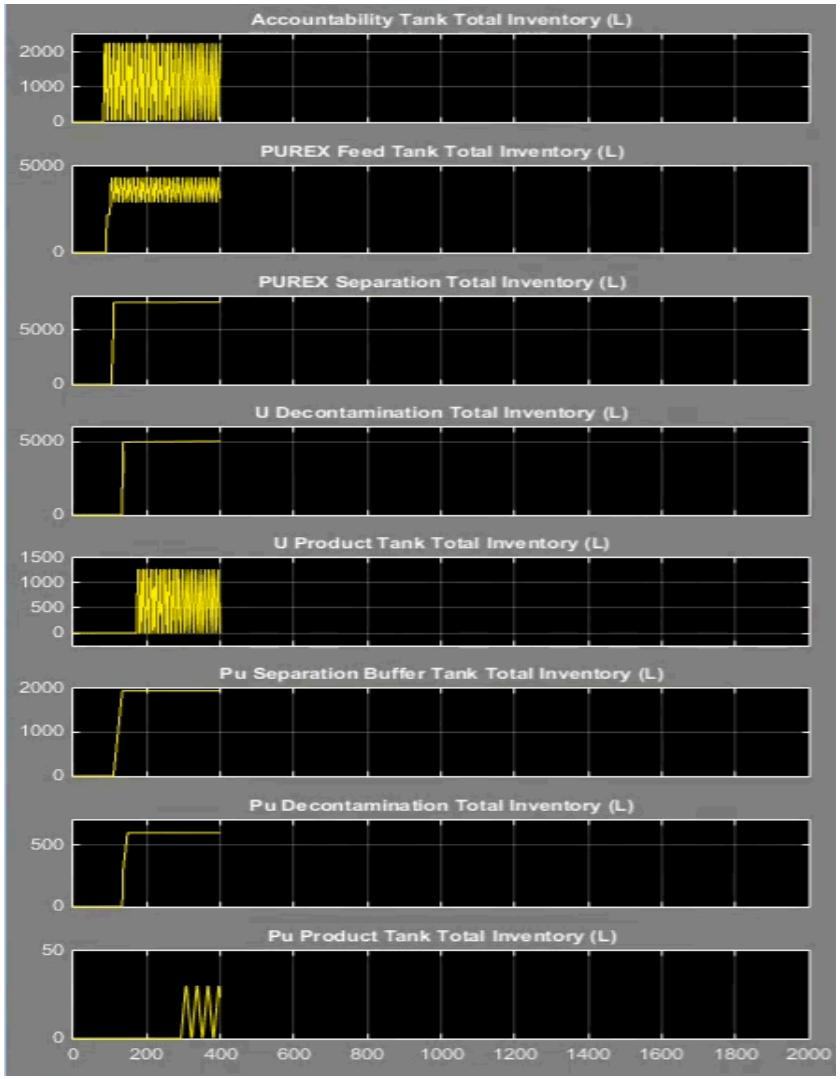


- **Separation columns or contactors are also complex and rely on "Gain" blocks to simulate the correct separation efficiencies.**

Other Vessels

- Many of the unit operations were similarly:
  - Once a tank block is built, it can be copied and pasted for any surge or accountability tank.
- Other unit operations like evaporators or denitrators simply remove some of the water or bulk liquid flow rate from the signals.
- Construction of the model should begin with assumptions, and then more detailed models can be added later as needed.

Scopes



- The “Scopes” are useful for testing operation of the model while it is being built.
- These can be used to keep track of the tank levels and actinide quantities as the model runs.

Interim Goal

- A good first step is to build the model from fuel receipt until output accountability tanks.
- Test the model to determine if the unit operations act as expected before adding additional unit operations downstream.
- Iterate on the model as needed until a good foundation is complete.

Future Work

- Once the model is built and running properly, measurement blocks can be added to the model:
  - Accountability measurements
  - Bulk measurements
  - Process Monitoring measurements
- Then the inventory balance (or Material Unaccounted For – MUF) calculation can be added.
- Finally statistical tests may be added.
- After all this has been accomplished, the model can be used for various analyses including safeguards design, process optimization, and material loss analysis.

IAEA Request for Proposals on Modeling for Insider Mitigation

Coordinated Research Project

- The objective of the CRP is to enhance existing preventive and protective measures against insider adversaries to reduce the risk of theft of nuclear material and sabotage at nuclear facilities.
- The insider is recognized as a threat to all IAEA member states.

Specific Research Objectives

1. Develop predictive model using psychosocial data to improve trustworthiness programs.
2. Develop predictive model for identifying colluding insider adversaries.
3. Develop tools and methods for optimizing the use of nuclear material process monitoring to increase the probability of detecting theft.
4. Conduct research and development on technologies to enhance control of nuclear material and personnel.
5. Develop risk-based analysis tool for selecting MC&A measures for specific facility types.