LA-UR-12-24312
Approved for public release; distribution is unlimited.

Title: Overview of DOE-NE Proliferation and Terrorism Risk Assessment

Author(s): Sadasivan, Pratap

Intended for: DOE-NE MPACT Working Group Meeting, 2012-08-28/2012-08-30 (Idaho Falls, Idaho, United States)

U.S. DEPARTMENT OF ENERGY | Nuclear Energy

Overview of DOE-NE Proliferation and Terrorism Risk Assessment

Pratap Sadasivan, LANL
Technical Lead

MPACT Working Group Meeting
Idaho Falls, Aug 29, 2012

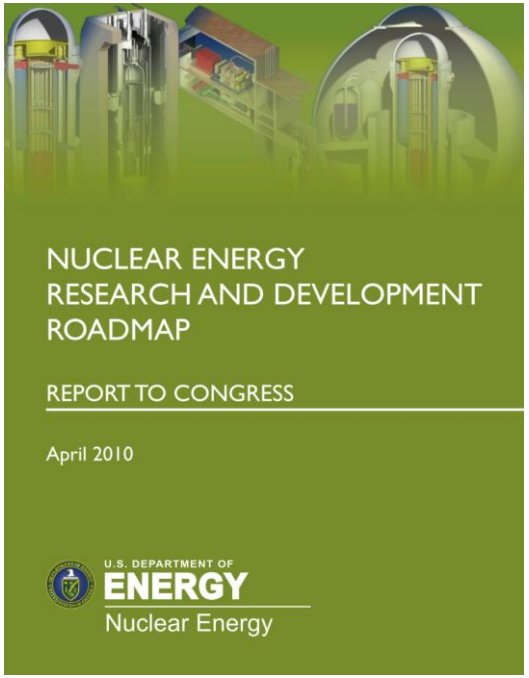
U.S. DEPARTMENT OF ENERGY
Nuclear Energy

Outline

- **Background on program**
  - DOE NE Roadmap and Research Objectives
  - Implementation plan for objective related to proliferation and terrorism risk
- **Vision and goals of the DOE-NE Proliferation and Terrorism Risk Assessment program**
- **Background**
  - Risk assessment
  - FY12 planning
- **Program Plans and Organization**
- **Project Elements**
- **Summary**

U.S. DEPARTMENT OF ENERGY
Nuclear Energy

Background
NE Research Objectives



1. **Develop technologies and other solutions that can improve the reliability, sustain the safety, and extend the life of current reactors**
2. **Develop improvements in the affordability of new reactors to enable nuclear energy**
3. **Develop Sustainable Nuclear Fuel Cycles**
4. **Understand and minimize the risks of nuclear proliferation and terrorism**

   Goal is to enable the use of risk information to inform NE R&D program planning

U.S. DEPARTMENT OF ENERGY
Nuclear Energy

Background
Implementation Plan for Objective 4

- **Integrated program of RD&D to address the risks of nuclear proliferation and terrorism**
  - Intrinsic Design Features to Minimize Risks:
    - Drive development of reactor and fuel-cycle options with intrinsic features to minimize the risks of nuclear proliferation and terrorism
  - Next-Generation Materials Protection, Accounting, and Control:
    - Breakthroughs in effectiveness and efficiency of nuclear materials protection, accounting, and control for advanced U.S. nuclear energy systems
  - International Frameworks and Institutions:
    - Support the development, demonstration, and strengthening of frameworks and institutions that minimize proliferation risks while enabling peaceful access to nuclear energy
  - Proliferation and Terrorism Risk Assessment:
    - Significantly advance the state of the art for proliferation and terrorism risk assessments

U.S. DEPARTMENT OF ENERGY
Nuclear Energy

Background
Risk Assessment – Key Issues

- **Rich pedigree for engineered-systems risk assessment**
  - Reactor Safety - WASH-1400 onward
- **Extension to non-engineered systems introduces complexities**
  - Intelligent, adaptive adversary
  - Risk is a function of adversary capabilities
  - Risk has a strong time-dependency
  - Social factors – behavioral characteristics
  - Sparse data – lack of empirical data
  - Uncertainties
  - Higher reliance on qualitative subject matter input
  - Risk communication
  - Multiple levels of information security

U.S. DEPARTMENT OF ENERGY
Nuclear Energy

DOE-NE Proliferation and Terrorism Risk Assessment program

- **Vision**

  Deliver a significant enhancement in the ability to understand and analyze the risks of nuclear proliferation and terrorism, and thereby to better inform decisions and investments in advanced nuclear energy systems and technologies.

- **Goals**
  - Improve on current methods, and develop new methods where needed,
  - Apply them to nuclear systems and technologies of interest to NE leadership, and
  - Contribute to the development and sustainment of an enduring proliferation/terrorism risk assessment capability through university engagement in the work.

Background
Key Considerations in Program Planning

Risk Assessment Roadmap

- Drew upon discussions and comments at several meetings and workshops held in 2010
  - INMM Workshop, Texas A&M, February 2010
  - Nuclear Energy Enabling Technologies Program Workshop, Session on Proliferation Risk Assessment, July 2010
  - DOE-NE MPACT proliferation risk meeting, Sandia National Laboratories, Albuquerque, NM, April 2010

R&D Elements

- Conduct basic research on proliferation/terrorism risk assessment.
- Develop and demonstrate new tools.
- Apply improved risk assessment tools to high-priority issues facing NE.
- Ensure NE R&D plans and priorities are risk-informed.

U.S. DEPARTMENT OF ENERGY
Nuclear Energy

Background
Key Considerations in FY12 Planning

- **National Academies project on "Improving the Assessment of Proliferation Risk of Nuclear Fuel Cycles"**
  - Identify key proliferation policy questions
  - Assess the utility of existing and historical methodologies and metrics
  - Assess the potential for adapting risk assessment methodologies developed in other contexts
  - Identify R&D and other opportunities for improving the utility of current and potential new approaches; and
  - Identify and assess options for effectively communicating proliferation risk information

This study will not address the risk associated with the physical security of the facility or materials against attack, theft, or diversion of nuclear materials.

In FY12, the DOE-NE PTRA program will focus on **terrorism risk** – physical security aspects of nuclear fuel cycles and facilities

U.S. DEPARTMENT OF ENERGY
Nuclear Energy

Program Plans

FY12 Milestones

- Initiate a portfolio of innovative, risk assessment projects, including prototype risk assessments focused on terrorism risk for once-through, modified-open, and full-recycle options

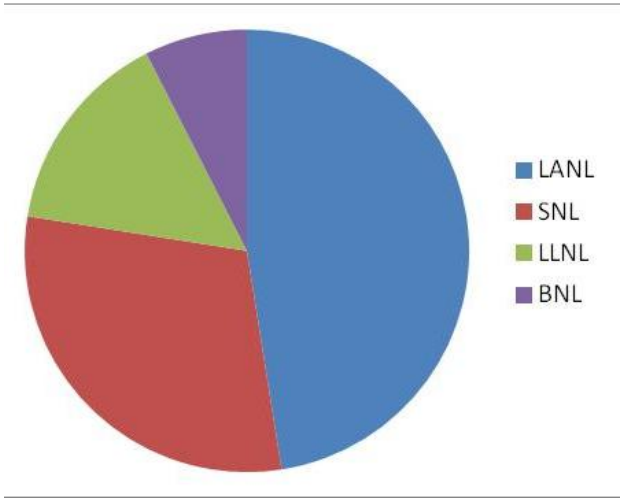
FY 13 Milestones

- Upon completion of the National Academy of Sciences review, identify additional proliferation risk assessment projects for initiation in FY 2013
- Deliver an updated proliferation and terrorism risk assessment RD&D roadmap and program plan, incorporating the findings and recommendations from the National Academy of Sciences study
- Initiate an expanded set of RD&D activities based on the NAS review, roadmap, and updated program plan
- Complete prototype risk assessments for once-through, modified-open, and closed-cycle options

U.S. DEPARTMENT OF ENERGY
Nuclear Energy

Project Organization

- **Program Management and Execution Structure:**
  - Responsibility transferred to NE-52 in April
  - PTRA independent program in FY12, but will be part of MPACT in FY13
- **Project Organization**
  - Program definition
    - Several workshops
    - White paper solicitations from Labs (Fall 2010)
    - Selections based on likely results in Y1
  - Directed Research:
    - Labs: LANL, SNL, LLNL, BNL
    - University partnerships (lab subcontracts):
      - LANL: Naval Postgraduate School, TAMU
      - SNL: UT Austin
      - LLNL : UT Austin
  - Competed
    - NEUP projects



U.S. DEPARTMENT OF ENERGY
Nuclear Energy

Project Elements

- **Innovative methods**
  - Adversary decision models
  - Adversary risk analysis
  - Expert elicitation
  - Treatment of uncertainties
- **Advanced Applications**
  - Prototypic Risk Assessments focusing on a range of nuclear systems of interest to NE,
  - Demonstrate best practices, compare methods, identify gaps
- **University Research**
  - NEUP projects
  - Collaborative partnerships with NLs
- **National Academies Study**
  - External advisory body

U.S. DEPARTMENT OF ENERGY
Nuclear Energy

BNL: Lessons Learned from Nuclear Regulatory Commission Experience

Objective

- Provide insights and lessons learned to DOE for risk-informing security and safeguards of its facilities based on related experience from NRC (and the nuclear industry) on risk-informing the safety management of the commercial fleet of nuclear facilities.

Approach

- Gather relevant material from risk-informed decision making by the NRC and identify areas within above stated DOE context that could benefit from lessons learned from the NRC experiences.
- Develop analogs and counterparts for safeguards and security of future US nuclear energy facilities

U.S. DEPARTMENT OF ENERGY
Nuclear Energy

LLNL: Decision Analysis Methods for Analysis of Nuclear Terrorism Threats with Imperfect Information

Objective

- Develop decision analysis methods for terrorism directed at current or possible domestic nuclear fuel cycles. Include adversary decision models, risk analysis, and treatment of uncertainties.
- Extend current methods to incorporate uncertainty in our knowledge of the adversary's capabilities and behavior as well as uncertainty about performance of countermeasures.

University Participants

- University of Texas at Austin

LLNL: Methodology

- **Develop an approach for risk assessment and management of terrorism threats directed at the domestic nuclear fuel cycle.**
- **Introduce probability distributions on uncertain parameters such as adversary objectives, countermeasure system performance, and consequences of an attack**
- **Generate probability distributions for events and, if appropriate, actions using best practices for expert elicitation in the domain of terrorism risk assessment**
  - Include correlations between events as required
  - Use game theory to enhance models of adversary actions
- **Update the probabilities using evidence about adversary activities**

LLNL: Implementation

- **Understanding adversary goals and actions**
  - Game theory, including the possibility of random strategies, based on two-person zero-sum games and/or Stackelberg games allowing the sequence of attacker-defender-attacker strategies
- **Accurate modeling of event correlations**
  - Scenario trees allow for the generation of multiple scenarios from uncertain sequences and events
  - Implementing the ideas from correlated decision trees allows for easier elicitation of relationships between events and provides computational advantages
  - Based on the use of Copulas to capture the dependence relationships
- **Solution of large correlated decision trees**
  - Methods for constructing large scenario trees will be enhanced by using correlations rather than assessments of conditional probabilities
  - Mixed integer programming formulations may be used to handle very large scenario trees

U.S. DEPARTMENT OF ENERGY
Nuclear Energy

Risk-Informed Security Analysis Methodology with Applications to Small Modular Reactors

Objective

- Risk-informed security analysis methodology will assess the relative level of appeal for the opportunities for sabotage or theft of material in nuclear facilities.

Approach

- Develop the metrics to analyze security risks in terms of level of difficulty.
- Use this data to develop the “rules” for game theory.
- Use a generic SMR design as an example application.

Project Participants

- SNL, University of Texas at Austin

U.S. DEPARTMENT OF ENERGY
Nuclear Energy

SNL - Risk-Informed Management of Enterprise Security (RIMES)

Objective: Sandia is developing a new security risk methodology that can be applied to fuel cycle facilities—will focus on Small Modular Reactors as an example application.

- Risk can be thought of as answers to 3 questions:
  - *What can happen?* *(scenario)*
  - *How likely is it?* *(probability / frequency)*
  - *How bad is it?* *(consequence)*
- Attack likelihoods are highly uncertain and change rapidly
  - *Depends on attacker's capability, motivation, intent*
  - *Depends on attacker's other opportunities inside and outside the system*
  - *Predicting likelihood makes risk hard to use for security decision making*

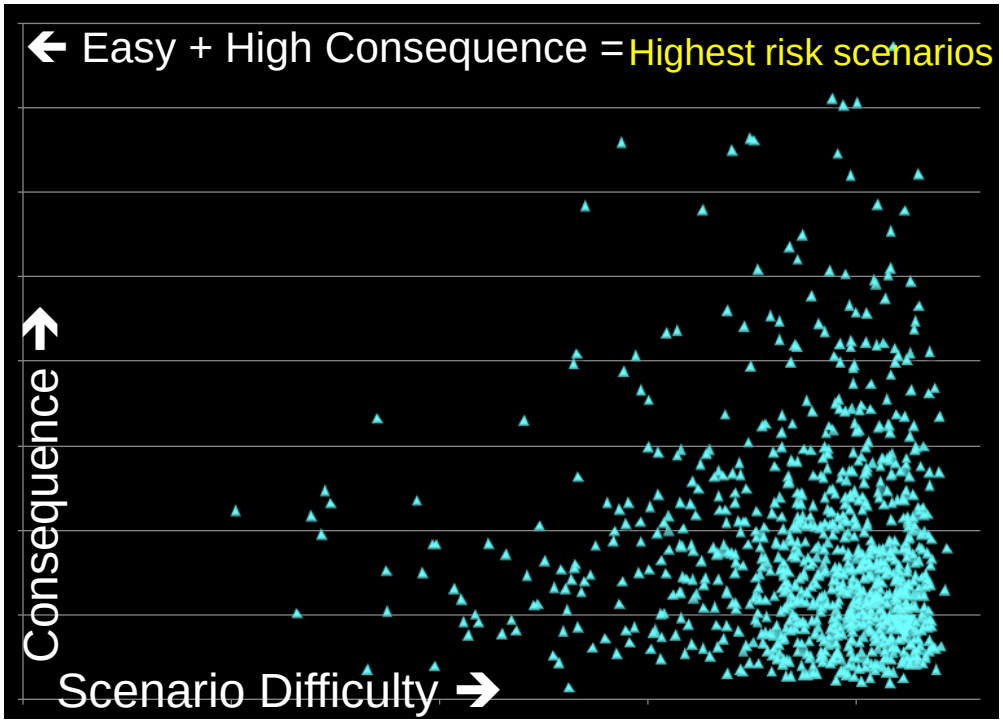
A different risk management approach: examine adversary criteria for selecting which attack scenario to pursue

Focus on level of difficulty instead of probability of attack

U.S. DEPARTMENT OF ENERGY
Nuclear Energy

SNL - Practical Security Risk Management

- Based on open literature of the near-term iPWR SMR designs, SNL is developing a generic SMR design to base the analysis on.
- Identify vulnerabilities or defeat methods
- Work these into scenarios that result in consequences
  - *Identify the expected consequences*
- Identify other easier ways for an adversary to generate comparable or greater consequences
  - *Initial security risk screening and prioritization*
- Use good systems engineering to find & rank mitigation options for higher risks
  - ↓ *consequence and/or* ↑ *difficulty*
- Continue throughout project life



U.S. DEPARTMENT OF ENERGY
Nuclear Energy

SNL - Game Theory

- SNL is working with UT-Austin to explore the applicability of game theory
- Game theory is a mathematical method for predicting human behavior in strategic, multi-player situations. It assumes that each player form rational beliefs about what other players will do and then chooses a response to those strategies that maximizes its own payoffs.
- Both sequential and simultaneous play games will be examined.

U.S. DEPARTMENT OF ENERGY
Nuclear Energy

LANL - Analytical Framework for Terrorism Risk

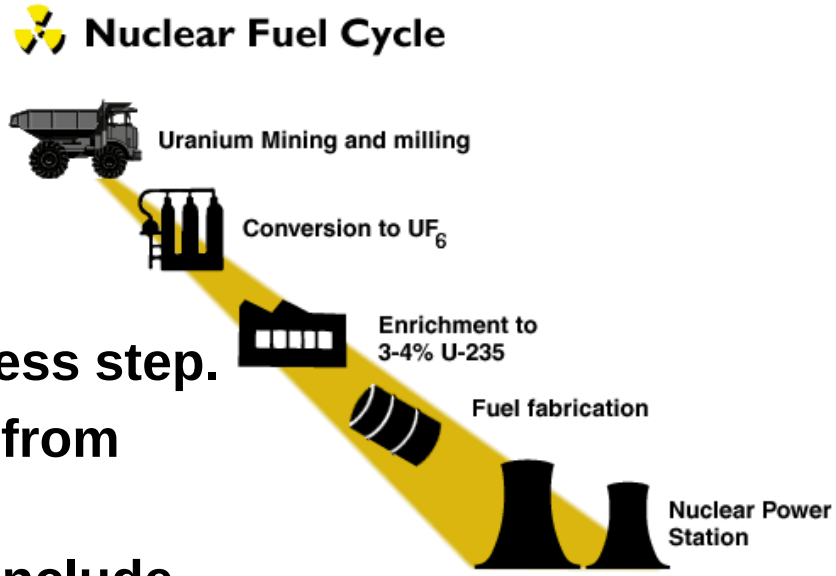
- **Objective**
  - Develop a systems representation for terrorism risk
- **Approach**
  - Develop metrics to represent operator's ability to prevent theft or sabotage.
  - Develop models for insider threats for domestic facilities and transportation scenarios
  - Systems model for fuel cycle terrorism risk for domestic facilities and transportation
  - Demonstrate approach
- **University Participants**
  - NPS

U.S. DEPARTMENT OF ENERGY
Nuclear Energy

LANL – NFC Processes and Time-Dependency

- **The Nuclear Fuel Cycle is a series of processes that each take:**
  - Material
  - Consumables
  - Time
  - Technology
  - Equipment
  - Facilities

  and make products for the next process step.
- **The actual fuel cycle used can vary from basic to complex.**
- **Accurate risk assessments should include the time for processing raw materials into products in each processing step and propagating those through the entire system.**

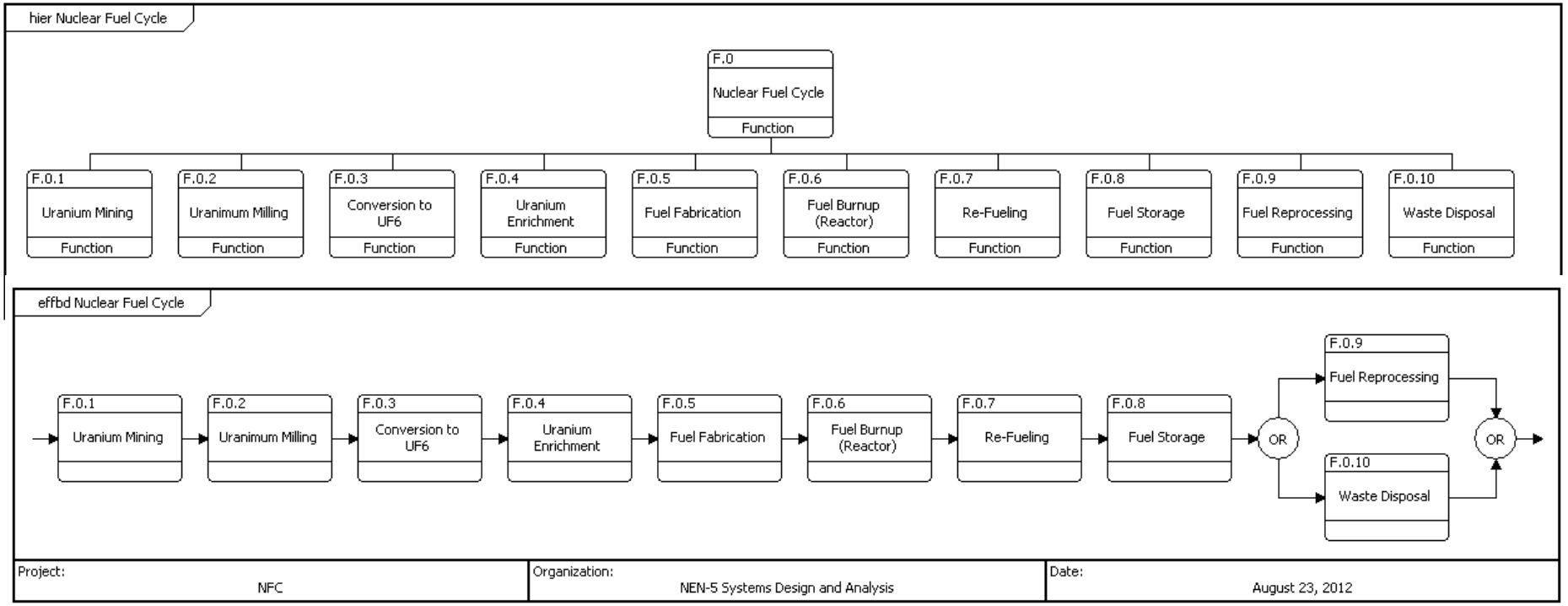


Requires the capability to rigorously connect the processes of the NFC system and model them as a timeline. Also, requires the capability to propagate risk attributes through the system.

U.S. DEPARTMENT OF ENERGY
Nuclear Energy

LANL – System Representation of Nuclear Fuel Cycle

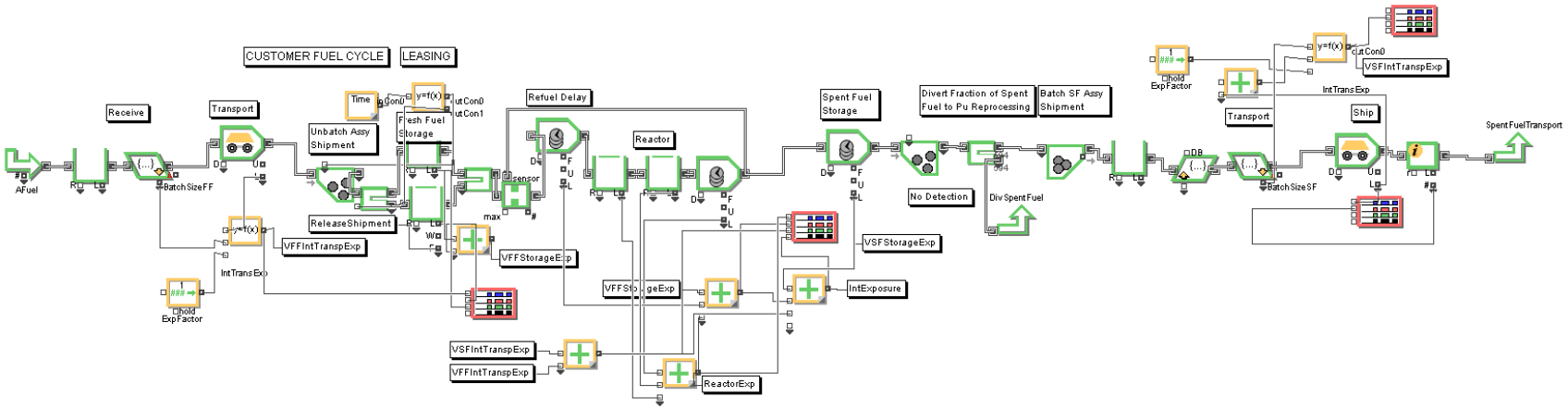
- **Use Model-Based Systems Engineering (MBSE) to develop Systems model of NFC**
  - Functional and Physical Decompositions of processes
  - Functional Flows for processes
- **Apply relevant time scales and risk attributes to each process step.**



U.S. DEPARTMENT OF ENERGY
Nuclear Energy

LANL – Model NFC Process and Time-Dependency using Modular Activity Models

- Use the MBSE model to develop a activity models for the individual processes that include the risk attributes.
- Assemble the processes activity models into a full Fuel Cycle model and propagate the times for a given scenario.
- Modular development of process activity models allows for assembling models of different fuels cycle options on the same NFC backbone



U.S. DEPARTMENT OF ENERGY
Nuclear Energy

LANL - Fundamental Studies

Objective

- Fundamental studies to improve aspects of proliferation and terrorism risk assessment

Approach

- Best practices for expert elicitation in the domain of proliferation and terrorism risk assessment, including analysis of potential biases and errors that have been shown to arise in other fields from failure to properly address the inherent limitations of expert judgment
- Treatment of uncertainties
- Risk communication, including display and presentation of results

Project Participants

- LANL, TAMU

U.S. DEPARTMENT OF ENERGY
Nuclear Energy

Fundamental Studies: Expert Elicitation

- **Review of formalized expert elicitation techniques and methods for understanding uncertainties and bias (including the impact of how questions are phrased).**
- **Analysis of how to apply expert elicitation in proliferation and terrorism risk analysis**
- **Generate a guidelines document on its application.**
- **Create an online expert elicitation test that can be used to demonstrate the value in following the guidelines.**
  - Control test where the guidelines are intentionally ignored to demonstrate the results acquired when poor expert elicitation methodologies are used.
- **Recommendations for application of this methodology to proliferation and terrorism risk analysis.**

U.S. DEPARTMENT OF ENERGY
Nuclear Energy

Fundamental Studies: Expert Elicitation – Policy perspective

- **Analyze how one elicits information from experts drawing from the Political Science discipline, paying close attention to the following models, analyzing how decisions are made in general, and in international security in particular:**
  - The epistemic community framework
  - Decision-making analysis
  - Foreign Policy analysis
  - Elite interviewing framework
- **Using these frameworks, analyze how to apply the lessons to proliferation**

U.S. DEPARTMENT OF ENERGY
Nuclear Energy

Fundamental Studies: Risk Communication

Definitions:

- **Risk communication is defined as "a science-based approach for communicating effectively in high-concern situations" (Coveelo, Peters, Wojtecki, Hyde 2001)**

- **A 1989 National Research Council study defined it as "an interactive process of exchange of information and opinion among individuals, groups, and institutions, often involves multiple messages about the nature of risk or expressing concerns, opinions, or reactions to risk messages or to legal and institutional arrangements for risk management"**

U.S. DEPARTMENT OF ENERGY
Nuclear Energy

Risk Communication in Proliferation Context

1. What is the risk
   - Further proliferation
   - Connection between the spread of nuclear energy and weapons proliferation
2. Who defines the risk?
   - Experts from multidisciplines
   - Government
3. Who is the target audience?
   - General public
   - Government agencies
   - Technical/non-technical
4. What is the medium?
   - Poster/Pamphlet
   - Report

- How do we formulate risk message in ways that are accurate, clear and not misleading?
- How do we deal with uncertainty?
- What would the risk compare to?
- How do we deal with communicating classified information?
- How would we ensure completeness of the message?
- Successful risk communication will:
  - Improve or increase the base of accurate information that decision makers use
  - Satisfy those involved that they are adequately informed within the limits of available knowledge

U.S. DEPARTMENT OF ENERGY
Nuclear Energy

Closing Comments

- The PTRA program supports DOE-NE's goal of using risk information to inform R&D program planning
- The FY12 PTRA program is focused on terrorism risk
- The program includes a mix of innovative methods that support the general practice of risk assessments, and selected applications.