NEUP Nuclear Energy University Programs
U.S. Department of Energy

July 27-28, 2010

Safeguards and Nonproliferation

Breakout Session #4

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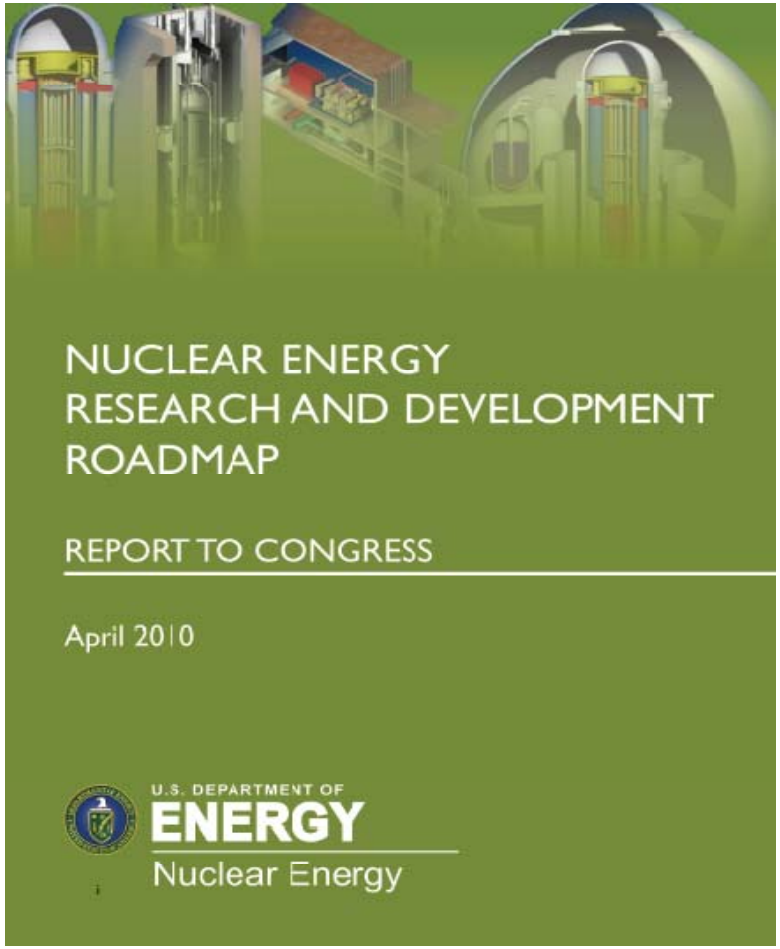
Overview

- NE Roadmap and program direction
- 2011 NEUP Work Scopes
  - "Safeguards"
    - **MPACT**
  - "Nonproliferation"
    - **Proliferation Risk Assessment**



NE's Four R&D Objectives:

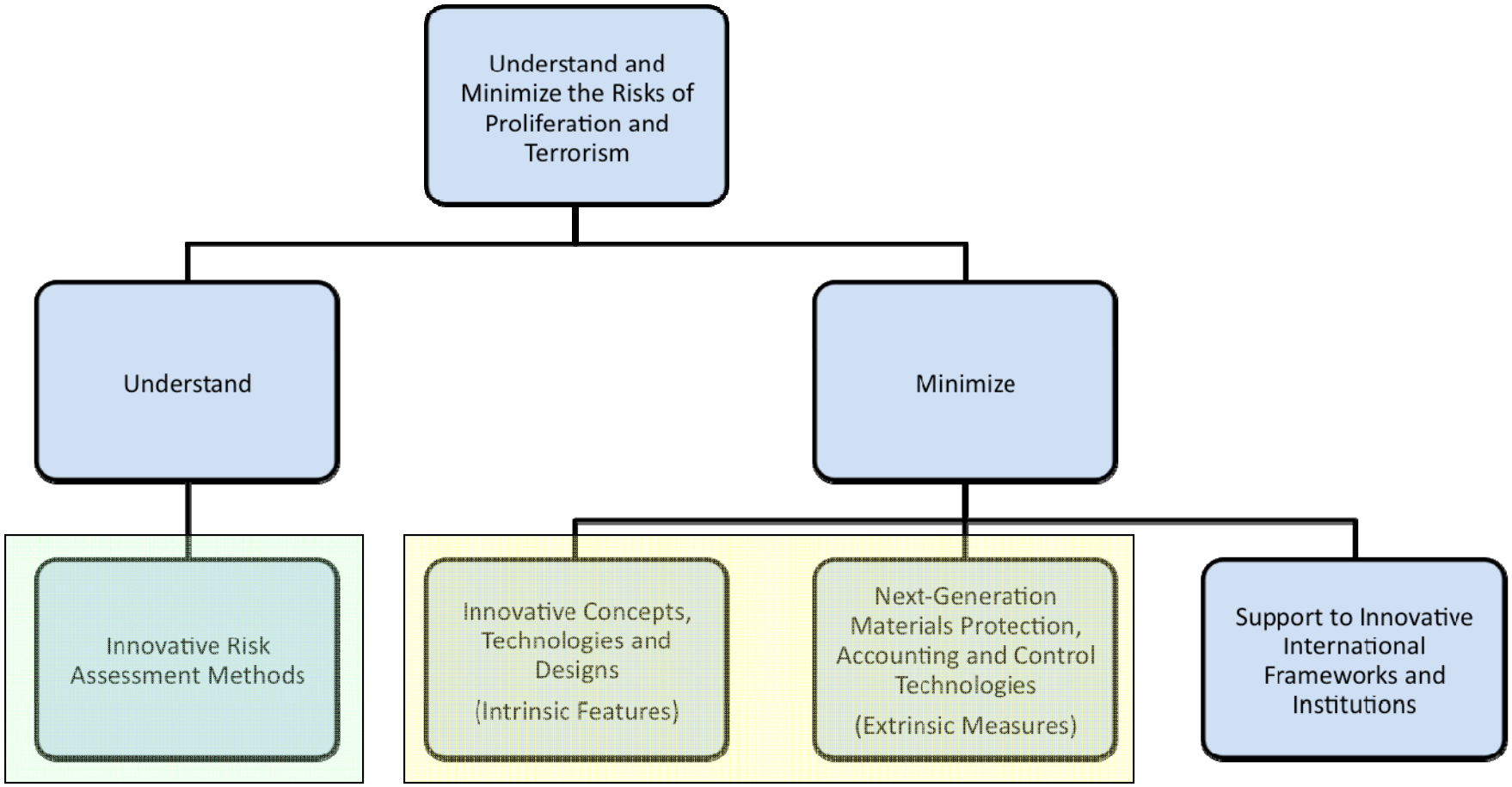
1. Develop Technologies and Other Solutions that Can Improve the Reliability, Sustain the Safety, and Extend the Life of ***Current Reactors***

2. Develop Improvements in the Affordability of ***New Reactors*** to Enable Nuclear Energy to Help Meet the Administration's Energy Security and Climate Change Goals

3. Develop Sustainable Nuclear ***Fuel Cycles***

4. Understand and Minimize the Risks of Nuclear ***Proliferation and Terrorism***

R&D Objective 4



NEET **Safeguards and Security By Design** **MPACT Campaign**

"Safeguards"

- Can be broadly defined, but generally separated into:
  - Domestic: Host state's set of system features measures to enhance *nuclear security* and accountancy.
    - **Threats: Theft, Sabotage**
  - International: Host state is considered the adversary
    - **Threats: Diversion, Misuse, Breakout**
  - Safeguards is often incorrectly assumed to mean "International" or IAEA Safeguards

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Materials Protection, Accounting and Control Technologies (MPACT)

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MPACT Campaign

- **Mission:**

  Develop innovative technologies and analysis tools to enable next-generation nuclear materials management for future U.S. nuclear energy systems

- **Challenges**
  - New reactor designs require new nuclear material management approach (Pebble bed? Thorium? Other Gen IV)
  - Large throughput facilities require shutdown for periodic inventory
  - Move from reactive to preventive systems approach

- **Grand Challenge**

  Develop online, real-time, continuous, accountability instruments and techniques that permit an order of magnitude improvement in the ability to inventory fissile materials in domestic fuel cycle systems, in order to detect diversion and prevent misuse

MPACT Main Technical Directions

- ***Advanced instrumentation***, including real-time active and passive methods for measuring and monitoring nuclear materials in advanced nuclear energy systems.

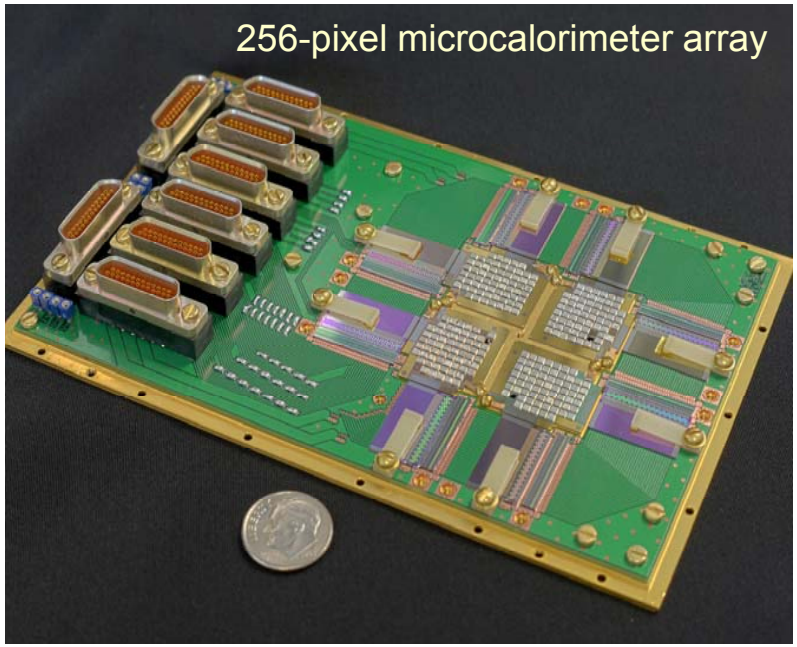
- ***Advanced concepts and integration***, including real-time information analysis enabling early detection of, and response to, any significant diversion, theft or loss of nuclear material.

- ***Modeling and simulation tools to support all of the above***, in close coordination with broader NE modeling and simulation initiatives.

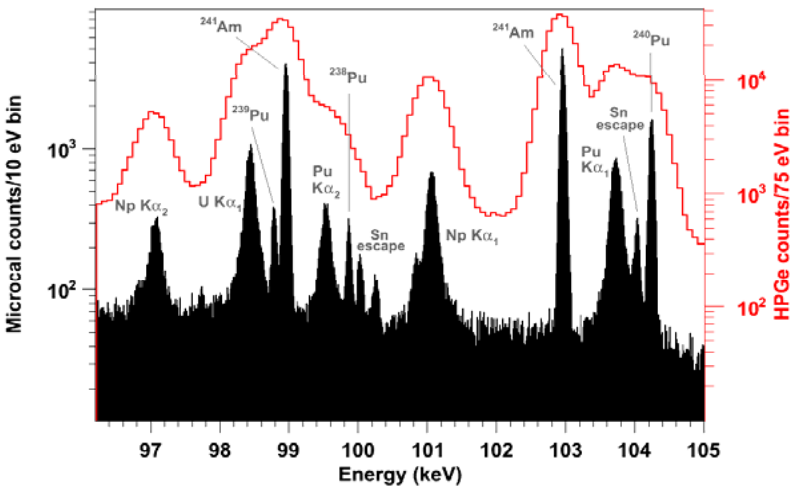
Microcalorimeter Array

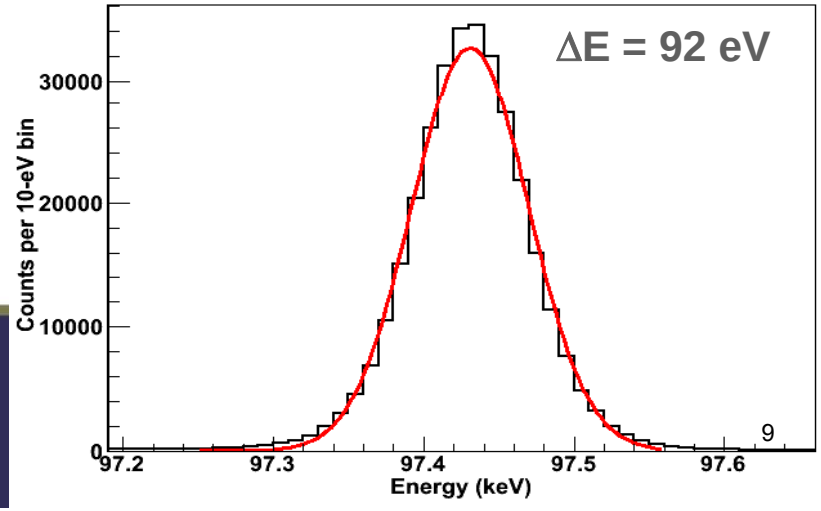
FY10 activity to date:

- 256-pixel array installed at LANL (fabricated at NIST-Boulder)
- 169 pixels (66%) producing data from ^{153}Gd check source; 92 eV FWHM at 97 keV
- 128-pixel simultaneous multiplex operation
- Failure modes for most remaining pixels understood and can be addressed in next array fabrication



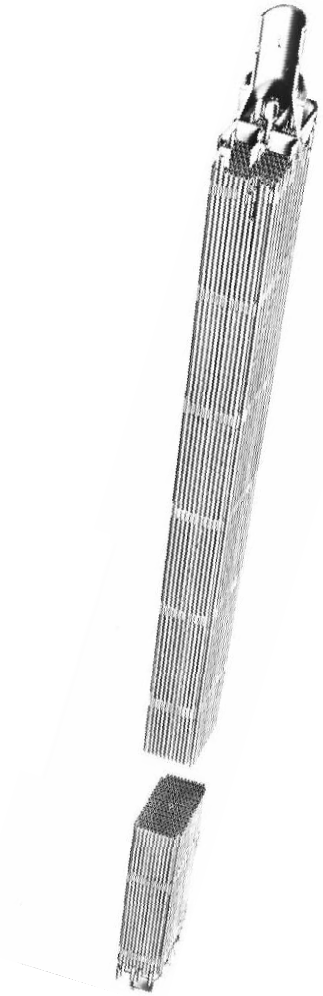
Microcal and HPGe plutonium source data from previous (smaller) 2009 detector array





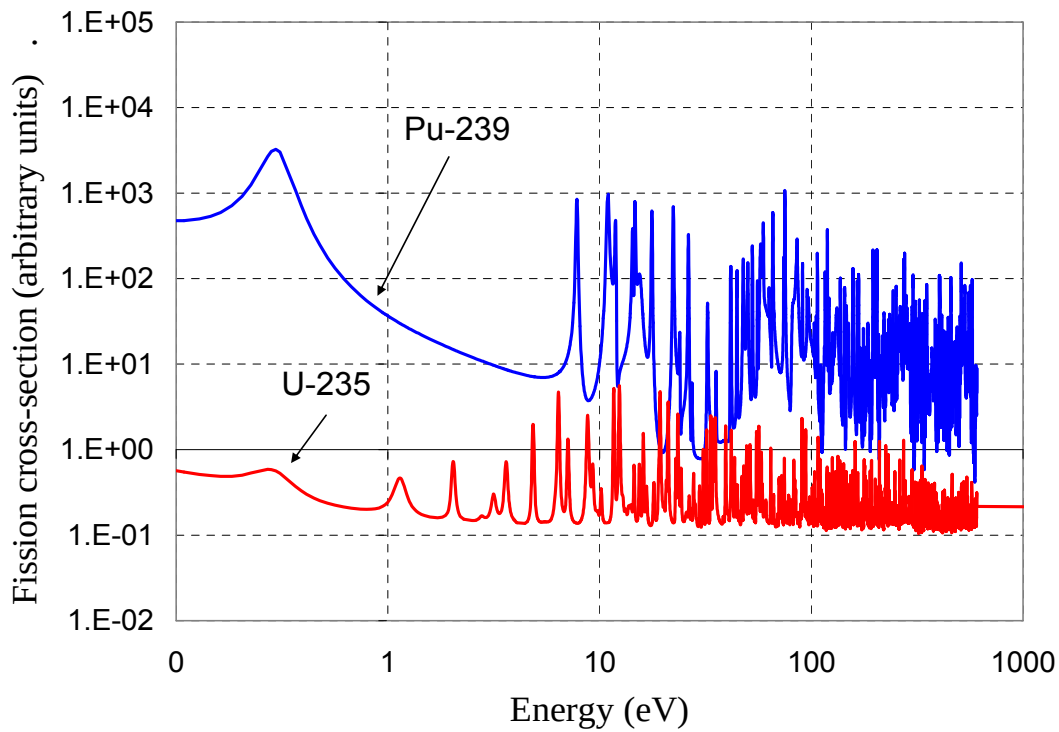
Direct Measurement of Pu in Spent fuel

- Current NDA methods: Infer Pu isotopic mass
  - Burnup calculations + “Easy” signatures (e.g. Cs-137, Cm)
  - Pu uncertainty ~10%
- Ideal NDA: Direct measurement of Pu
  - Independent (no operator-declared information)
  - Pu uncertainty <1% → partial defect detection
  - Timely, cost-effective, operationally tolerable
- Potential MC&A applications
  - Head end of reprocessing facilities
  - Spent fuel storage areas (e.g. shipper-receiver)
  - Burnup credit
  - Recycled-fuel fabrication facilities (e.g. MOX fuel)



Neutron Slowing-Down Spectroscopy

- Used for decades in cross-section measurements
- Probes unique resonance structure of fissile (and absorbing) isotopes

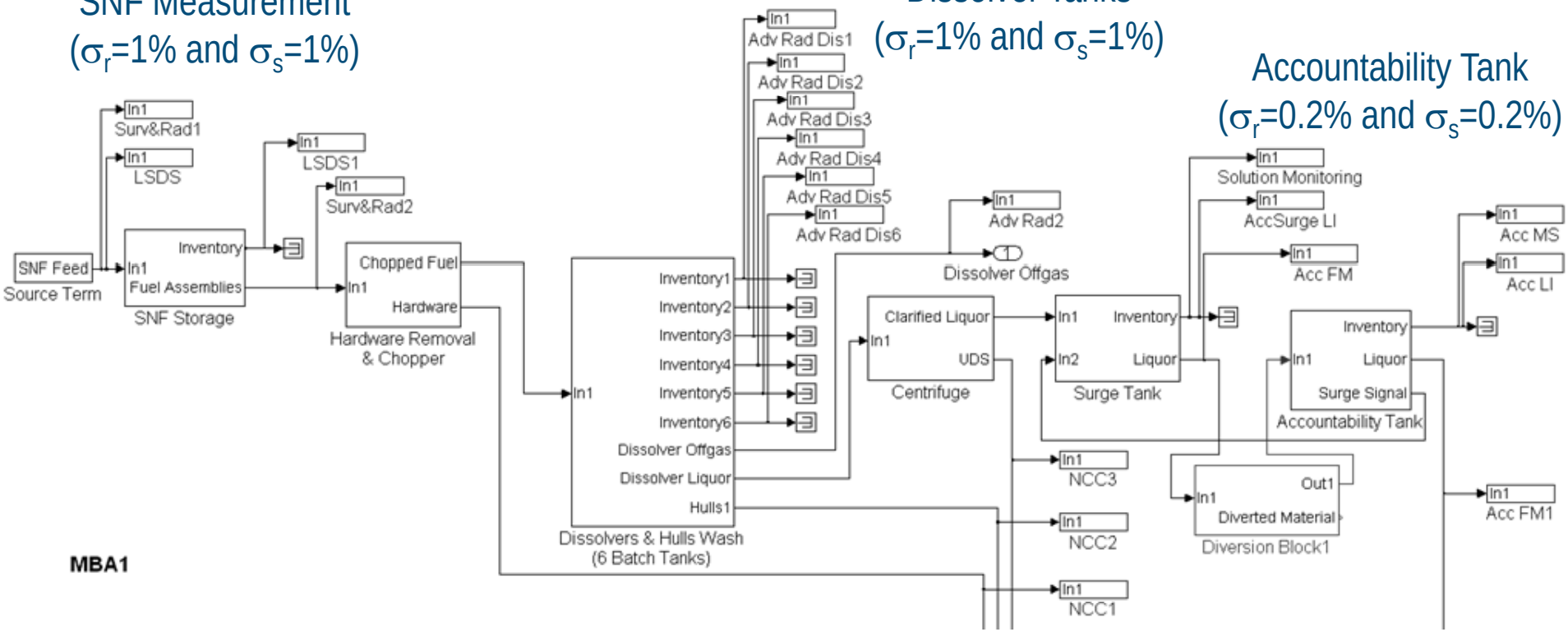


Near Real Time Accounting (NRTA) Modeling and Simulation in MBA1 (Head End)

SNF Measurement
(σ_r=1% and σ_s=1%)

Dissolver Tanks
(σ_r=1% and σ_s=1%)

Accountability Tank
(σ_r=0.2% and σ_s=0.2%)



Waste Streams
(σ_r=5% and σ_s=2%)

NE's R&D Does NOT focus on

- International Safeguards agreements (CSA,AP)
- Treaty Verification
- Arms control
- Remote monitoring for clandestine activity

Workscope Description (MPACT)

- Work Scope SGN-19 (MPACT):

  1) New sensor materials, detectors, & measurement techniques

  2) Novel methods for data integration and real time analysis

  3) Advanced concepts for achieving *real-time*, *online*, and *continuous material accountancy*

Proliferation Risk Assessment (NEET)

Breakout Session #4

Proliferation Risk Assessment FY2011

- Grown from a small work package within MPACT FY10, born into Nuclear Energy Enabling Technologies (NEET) as research element.
- Creation of project plan for quantification of proliferation risk to include evaluation of nuclear energy's role in a broader national and international security context.
- Initiate studies of current risk assessment methodologies (strength, key components, scopes, applicability) including:
  - Current methodologies in "prototype scenarios"
  - Effective coordination with other national security methodologies (including game theory and counter terrorism) and entities (DHS, DARPA, etc.)

"Proliferation"

- "Spread of nuclear weapons, fissile material, and weapons-applicable nuclear technology and information, to nations which are not recognized as 'Nuclear Weapon States'".

- NPT definition doesn't specifically call out sub-state and/or terrorist groups, but the word often takes on a broader meaning.

Issues for Proliferation Risk (and Physical Security) Assessment

- Can and has been a show stopper
- How to characterize and measure it
- How to evaluate it
- How to use it (for nuclear energy systems)
  - Absolute vs. relative assessments
  - System risk reduction and management
  - Global nuclear architecture construction
- How to communicate it (to various audiences)
  - Comprehensive vs. focused evaluations
  - Managing multiple objectives
  - Building international consensus/norms

Safety Analogy

- **It is usually not enough to simply state something *can* happen**
  - *Likelihood* and *consequences must* be weighed

- **Safety by Design**
  - Exceptional performance in industry by incorporating safety into design at early phases (airbags, crumple zones, circuit breakers)
  - Safeguards and Security should be incorporated at conceptual design phase

- **Risk Informed Approach to Safety**
  - Successful for licensing and regulation of technology
  - Lessons learned can be applied to proliferation risk

Risk Equation

$$R =/\alpha \sum \pi_i \, p_i \, c_i$$

π_i = probability (frequency) of attempt

p_i = (conditional) probability of adversary success

c_i = consequences

The three terms are sometimes called Threat, Vulnerability and Consequences.

Challenges

- Probability of attempt
  - Lack of Data
  - Intelligent, adaptive adversary
  - Changing capabilities and intentions
  - Surprise
  - Incompleteness
- Probability of adversary success
  - Lack of real-world data
  - Effectiveness of new or future technology and approaches
- Consequences
  - Uncertainties
  - Non-standard consequences, e.g., how nations and societies respond
- Resource requirements

Key Deviations from Safety Analogy

- Proliferation risk depends on *who* is doing the proliferating
- Potential adversaries may act and react intelligently
- Metrics will inevitably involve non-quantitative and/or subjective judgments.
- International Safeguards System (IAEA) and regional safeguards networks must not show preferential treatment in safeguards verification…
  However:
- IAEA is moving to an "information driven" safeguards approach in which the characteristics of a state are taken into account in the inspection reports and assessments of risk.

Toward a Quantitative, Risk-Informed Proliferation Analysis

- Dozens of "Tools" exist for Proliferation Risk Assessment

Methodologies:

PRPP (GIF)

MAU (TAMU)

INPRO (IAEA)

etc…

Systems Simulators:

SAPRA (Areva)

COSI (TAMU)

etc…

Analyses:

Tech-Neutral frameworks (MIT)

RIPA (SNL)

etc…

Proliferation Risk Assessment

- Developing new tools and approaches for understanding, limiting, and managing the risks of proliferation and physical security for fuel cycle options – Including Modified Open-cycle.

- Will focus on assessments required to inform domestic fuel cycle technology and system option development.

Work Scope Description (XPRA)

- Work Scope SGN-19 (XPRA):

1) Exploit approaches for analyzing difficult-to-quantify proliferation risk factors or indicators (e.g., capabilities, motivations, and intentions)

2) Evaluate diverse decision factors (including economics, public health and safety, public perceptions, environmental benefits and proliferation and terrorism risk reduction) for different fuel cycle options to understand the tradeoffs and potential synergies between these decision criteria.

3) Apply these tools to study nuclear energy system options and display results in a useful format for decision makers.

Final Slide

Value of Risk Evaluations

- Introduce mitigation features into the design process at the **earliest** possible stage of concept development

- As the design matures, increasing detail can be incorporated in the model of the system:
  - progressive refinement and feed back
  - A 'meter stick' to test MC&A

- Results can inform choices and decisions