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DOE Nuclear Energy R&D Programs Addressing Proliferation Concerns for Advanced Nuclear Systems

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Outline

- **Office of Nuclear Energy R&D Programs**
- **R&D Program to Address Safeguards and Nonproliferation for Advanced Nuclear Systems**
- **Into the Future**

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Nuclear Energy is critical to securing the U.S. energy future

- **Today, 104 nuclear reactors generate ~20 percent of U.S. electricity.**
- **EIA predicts U.S. electricity demand will grow by 50 percent over the next 25 years - and expanded nuclear energy must be a large part of that, especially if we want to meaningfully impact CO_2 emissions.**
- **To maintain the 19 percent nuclear share requires building the equivalent of 30 one-thousand-megawatt nuclear reactors.**
- **For nuclear power to be sustainable it must remain safe with low proliferation risk, and we must provide options for effectively managing the used fuel.**

Catawba
South Carolina

Grand Gulf
Mississippi

Bellefonte
Alabama

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NE Program Priorities

1. **Deliver Clean Energy Products to Market**
2. **Develop Options to Current Fuel Cycle Management Strategy**
3. **Enhance International Collaboration and Reduce Proliferation Risks**
4. **Develop U.S. Nuclear Energy Research Infrastructure**

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How We Will Meet Our Priorities

1. Support Nuclear Reactor Systems

- **Ensure that we understand what is needed for safe, reliable operation of existing light water reactors as they age beyond 60 years**
  - LWR sustainability R&D program
- **Deploy new advanced light water reactors**
  - Nuclear power 2010 program
  - Standby support / risk insurance program
  - Federal loan guarantee program
- **Develop new advanced reactors**
  - Generation IV

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How We Will Meet Our Priorities (cont)

2. Provide options for managing the fuel cycle

- **Develop nuclear fuel cycle technical options**
  - Advanced fuel cycle initiative - fuel cycle R&D
- **Develop domestic nuclear fuel cycle policy options**
  - Engagement with government and industry officials

3. Enhance international cooperation and reduce proliferation risks

- **Leadership/engagement in international organizations**
  - Advance U.S. non-proliferation policy objectives
- **Expand collaborative research activities**
  - Leverage technical expertise, resources and facilities

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New Secretarial Initiatives

- **Energy Innovation Hubs**
  - Focus on critical science and technology for high-risk, high-reward research to revolutionize how the U.S. produces, distributes, and uses energy
  - Teams of experts from multiple fields to blend technology development, engineering design, and energy policy
  - Develop critical expertise needed for transformational discoveries
  - NE supports two Hubs - Modeling & Simulation and Extreme Materials

- **Regaining Energy Science and Engineering (RE-ENERGYSE)**
  - Broad educational effort across Departmental program offices to inspire students and workers to pursue careers in science, engineering, and entrepreneurship related to clean energy
  - Focuses on a number of critical areas that will build the foundation of a vibrant American workforce to participate in the green economy
  - NE will be supporting this initiative through competitive awards at universities and educational research institutions focused on advancing nuclear energy technologies

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Generation IV International Forum (GIF):

- International collaboration started in January 2000
- Based on advanced nuclear energy systems that are sustainable, safe, economical, proliferation resistant and physically secure
- Treaty-level agreement of the governments:
  - For research and development collaborations
  - Affords protection of intellectual property and sharing of rights
  - Supports the creation of 'multilateral R&D contracts' that can attract industry, universities and other countries into the collaborations
- US participation: Sodium-cooled Fast Reactors and Very High Temperature Reactors (VHTR)

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Gen IV Nuclear Energy Systems

- **Gen IV R&D**
  - Cross cutting research in materials, analytical methods, economics and proliferation resistance supporting all Gen IV reactor concepts
  - High-temperature gas cooled reactor research in fuels, graphite, metals and codes and simulation
  - Emphasizes university collaboration

- **Energy Innovation Hub for Modeling and Simulation**
  - Applies modern computing power and first principles modeling to nuclear technologies
  - Two tiers of activities
    - Near-term focuses on results useful to solve today's problems
    - Long-term focus is to revolutionize understanding, design, and licensing of nuclear technologies
  - Emphasizes collaboration with sister research center on Materials

- **Supports our need for reliable carbon-free nuclear technologies with improved sustainability, safety, economics, security, and proliferation resistance.**
  - Extend Gas-cooled reactor concept to industrial applications to replace conventional sources of process heat, such as burning fossil fuels,
  - Support used fuel management with advanced reactor concepts.
  - Extend operating life of existing light water reactors

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Fuel Cycle R&D

- **New name - Fuel Cycle R&D**
  - **Focused on science-based, long-term R&D**
    - Broader vision
    - Pursue higher-risk, higher-payoff opportunities
  - **Finding transformational breakthroughs to solve grand challenges**
  - **Expanded waste management focus**
    - Explore alternatives to Yucca Mountain repository
    - Options to include interim storage, alternative geologies for permanent disposal and recycling
  - **Extreme Materials Institute**
    - New activity in 2010
    - The Institute will focus and integrate the national effort to develop and test advanced materials needed to transform the performance of nuclear energy systems to levels never previously achieved.

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Grand Challenges for Fuel Cycle R&D

- **Developing separations technologies and systems with lower proliferation risk, very low process losses and minimal undesirable waste streams;**
- **Providing nuclear fuels or targets with multi-fold increases in performance over previous generation fuels, with very low fabrication losses, and that permit high levels of transmutation of long-lived radiotoxic elements;**
- **Designing waste forms with predictable, long-term behavior and enhanced resistance to long-term degradation suitable for a variety of potential geologic repository environments**
- **Understanding how to provide process control and accountability instruments and techniques that permit an order of magnitude improvement of real time ability to detect fissile materials in fuel cycle systems;**

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Safeguards is an important part of Fuel Cycle R&D

- **Proliferation concerns *can be a showstopper* for advanced nuclear energy systems.**
- ***Safeguards will be needed* for any nuclear energy system where $\sigma_f > 0$ (there is no intrinsic solution – need robust system of safeguards and security within an overall nonproliferation framework).**
- **As nuclear energy systems evolve and advance, *so too must safeguards technologies* (integrated system of nuclear technology, safety/safeguards/security, waste management).**
- **NE works with others, mainly NA, to advance U.S. nonproliferation goals through the development of advanced safeguards technologies.**
- **Accountancy & Control (domestic) vs Verification (international)**

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Domestic Fuel Cycle Safeguards

- **This activity develops technologies to enable next generation safeguards for the nuclear fuel cycle of the future, thereby reducing proliferation risks and enhancing confidence and acceptance of nuclear energy**
- **A science-based approach entails integrating experiment, theory, and modeling & simulation within a framework of predictive capabilities**
  - *Instrumentation development based on fundamental knowledge of applicable physics and chemistry, where empirical relations are not required, identification of new data needs as appropriate to enable new approaches*
  - *Modeling and simulation development in a manner that enables discovery based application, thereby significantly decreasing development time and cost*
  - *Materials science capabilities that not only provide robust and reliable fielding of advanced instrumentation, but enable science informed design of new sensors and associated advanced components*
  - *Information science applied to the safeguards enterprise such that synergy is achieved from the totality of data available, full integration of information and real-time analysis*

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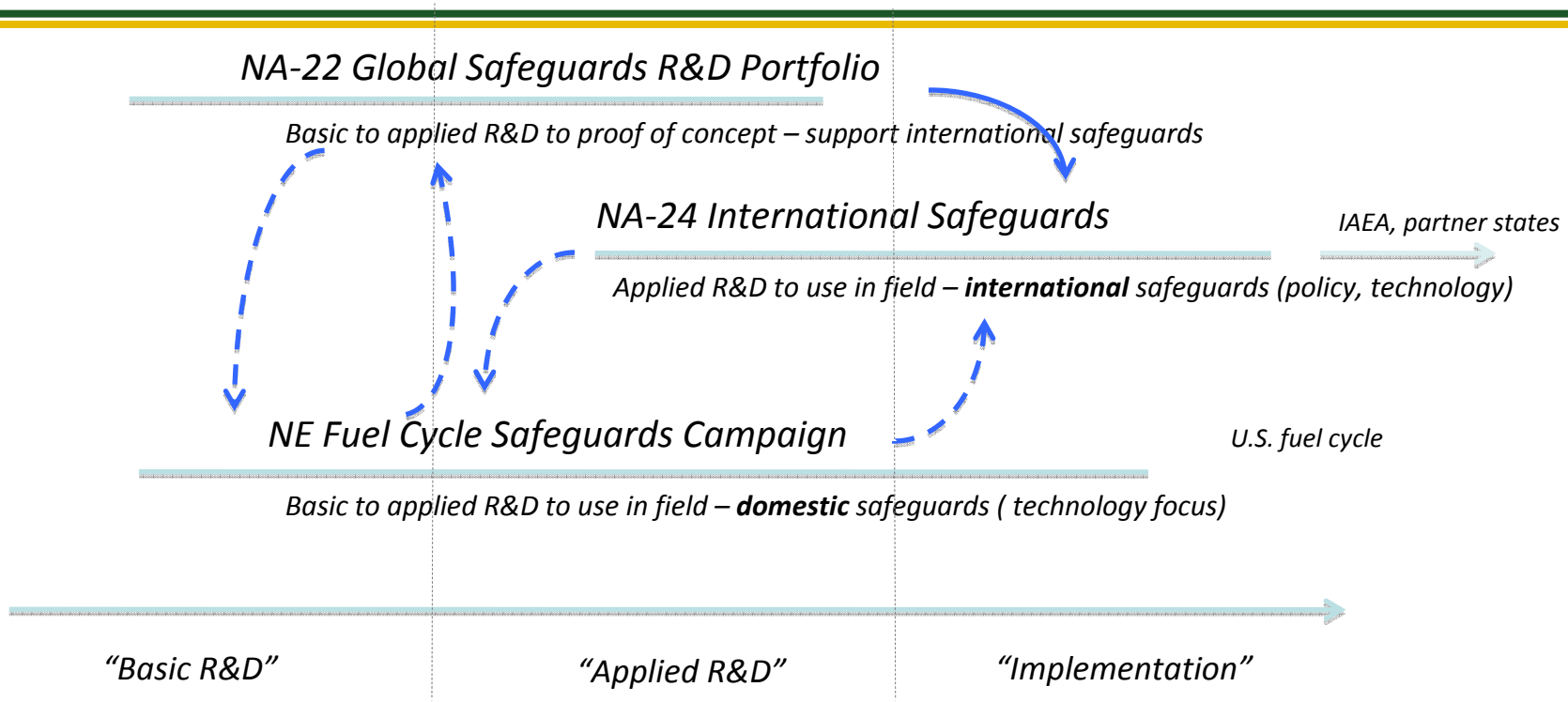
Synergies between NE and NA



NA has new programs – Next Generation Safeguards Initiative and Global Safeguards R&D – focused on developing new technologies, policy, and human resources needed to support the growing international safeguards and nonproliferation mission – NE Safeguards activities compliment these initiatives to support the future U.S. fuel cycle

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Safeguards thrust areas

- **Base program is organized around three themes**
  - Advanced instrumentation – online/at-line, near real-time monitoring, radiation/non-radiation based, active/passive, destructive and nondestructive; including process monitoring, basic data
  - Advanced Safeguards Approaches – incorporation of safeguards and physical protection requirements into facility at design stage, codifying these in formal manner, safeguards performance and other assessments
  - Advanced control and integration – knowledge extraction of facility operation, integration of disparate data, intelligent data analysis and control, basic information management for regulatory purpose, data validation, security, authentication, remote interaction of inspection personnel

Adv Concepts & Integration

- **Modeling & simulation support all thrust areas**
  - Radiation transport and detection, materials behavior in harsh environments, development of radiation and non-radiation based signatures, performance assessments/optimization, virtual inspector presence, data visualization

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University collaborations are important for both short term advancement and long term sustainability

- **Current collaborations in NE Safeguards activities include**
  - ISU/IAC Active interrogation – Harmon, Hunt, Wells
  - UNLV Process monitor, neutron detection – Beller, Cerefice, Hechanova
  - TAMU Safeguards envelope – Ragusa, Charlton
  - UCB Active interrogation – Vujic
  - MIT Integrated safeguards design – Golay
  - Glasgow Trend analysis, operations research – Howell
  - Wash Safeguards performance – Ricker
  - OSU Multi-isotope process monitor – Christensen
  - UNM Safeguards Performance – Prinja
  - UMich Active interrogation – Pozzi

A critical component of the safeguards campaign is university collaboration, with an eye towards development of the next generation work force and expanding the R&D base for advanced safeguards

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Into the Future

- **Develop the next generation of advanced reactors to support our nation's energy needs, including alternate applications and actinide management.**

- **Establish a long-term, science-based fuel cycle R&D program**
  - Pursue breakthrough technologies to address fuel cycle challenges
  - Engage end-users and key stakeholders to inform the R&D effort
  - Continue to evaluate a broad suite of fuel cycle options and their safeguard requirements
  - Perform comprehensive systems analysis studies to evaluate options and explore deployment alternatives and implications

- **Continue international collaboration with other nations to leverage expertise and resources**
  - Multi-national forums (e.g., GIF, IAEA,GNEP international, NEA)
  - Bi-lateral and multi-lateral R&D agreements