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Overview of RSN103: Reducing the Proliferation Risk of the Civilian Nuclear Fuel Cycle in East Asia

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Project Objective

- **Identify, build support for, and implement innovative approaches to reducing the proliferation risk of the civilian nuclear cycle in East Asia.**
  - **Innovative approaches" are those which go beyond and supplement (but not replace) existing elements of the nonproliferation regime including safeguards and export controls (for which NA24 has a set of successful programs), including:**
    - **Systems of fuel cycle service supply that reduce the incentive for states to acquire enrichment and reprocessing technologies;**
    - **Deployment of advanced tools for monitoring nuclear processes and managing the resulting data to increase transparency and confidence that material is not being diverted or stolen;**
    - **Development of regional consensus and norms related to traditional nonproliferation approaches such as safeguards and export controls**
  - **To be successful, innovative approaches must be built upon the robust implementation of traditional approaches**

Create a network of long-term, regional partnerships through *workshops, consultations and technical cooperation* that can support the realization of multiple NA-24 nonproliferation goals, including GNEP

Partners include: Vietnam, Malaysia, Indonesia, Australia, Japan, ROK, PRC, Taiwan, and Russia

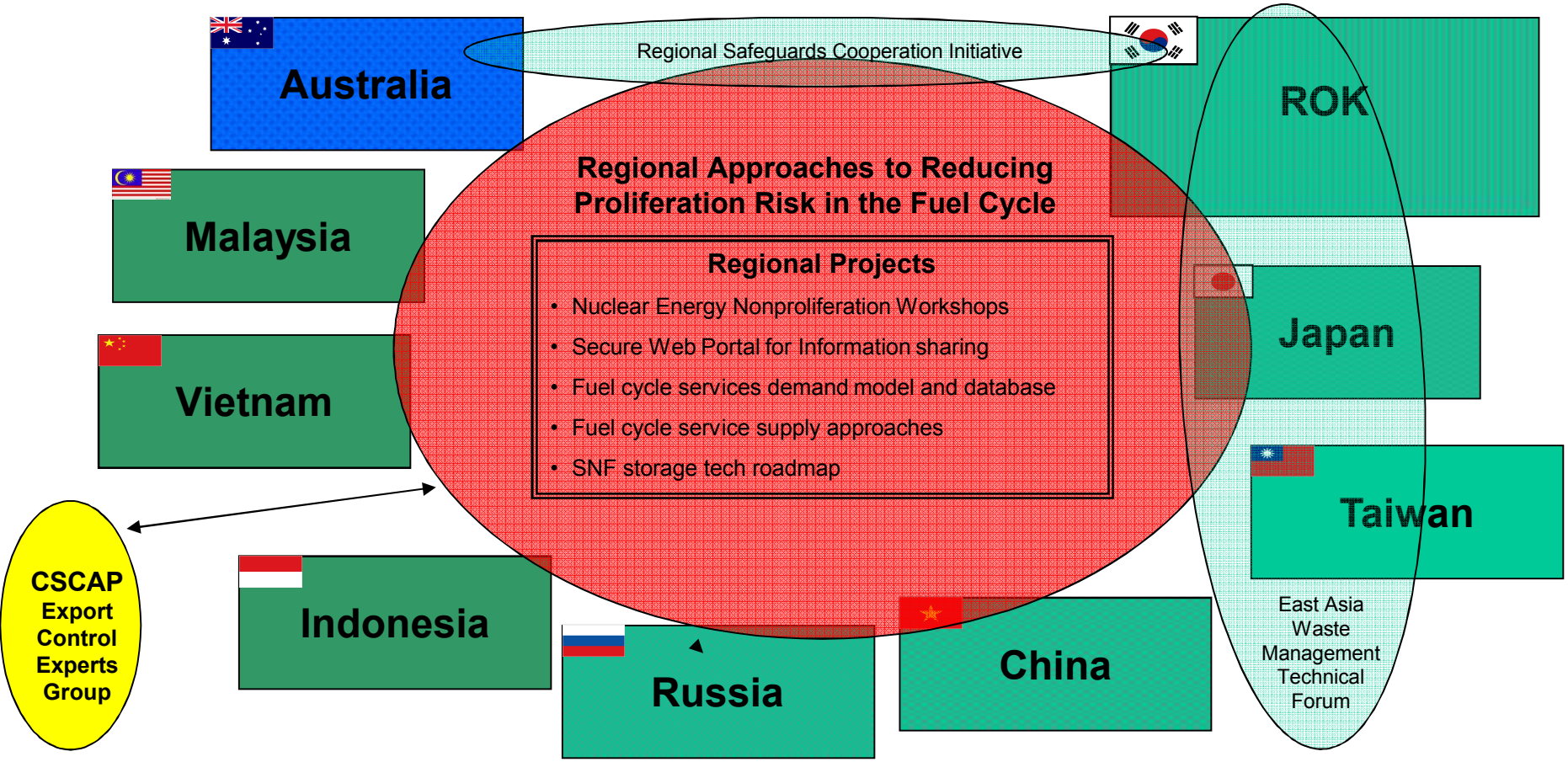
Second Level Goals for Achieving the Objective

- **Accomplish the building of support for, and implementing of innovative approaches by:**
  1. **Building support among current and future users of nuclear energy in East Asia for the adoption of a regime which would offer reliable supply of enrichment and spent fuel management services to states agreeing to forgo the acquisition of domestic enrichment and reprocessing technologies (supports GNEP's "Reliable Fuel Services Program")**
  2. **Identifying, developing, and demonstrating tools for collecting, managing, and providing nuclear process data for the purposes of increasing confidence in safeguards conclusions and providing additional transparency (supports GNEP's "Improved Nuclear Safeguards")**
  3. **Improving multilateral coordination and sharing of information related to the implementation of traditional nonproliferation tools such as safeguards and export controls**
  4. **Creating opportunities to obtain candid feedback from regional stakeholders and identify obstacles and opportunities related to the realization of NA-24 nonproliferation goals in East Asia**

Participants

- Actors from every state in East Asia using or considering the use of nuclear energy (region is critical due to rapid expansion of civilian nuclear infrastructure and current security environment)
- Nuclear energy *and* nonproliferation experts (nonproliferation goals are more likely to be achieved when these two groups engage in a constructive dialogue)
- Nuclear facility operators (utilities – primary actors in decisions about operations and spent fuel management); national nuclear energy research organizations (important for technology and policy development); universities and NGOs

Project Structure and Relationship to Other Activities



Current users of nuclear energy	Considering the adoption of nuclear energy	Considering nuclear/ potential provider of fuel cycle services	Provider of uranium	Potential exporter of reactors	Potential exporter of reactors AND possess E&R	Imported reactors only

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Established Forums for Engagement

- Regional Workshop (December 2004)
  - Established agenda for analysis
- Sandia International Security Conference (April 2005)
  - Session devoted to East Asia
- Nuclear Energy Nonproliferation Workshop (August 2005)
  - Review nuclear programs; Identify areas for cooperation
- Ongoing Cooperation with the Korea Atomic Energy Research Institute
  - Consultation on planning for new NP missions
- CSCAP meeting (March 2006)
  - Spent fuel storage facility standards
- East Asia Forum on Radioactive Waste Management Planning Meeting (June 2006)
  - Regional forum for technical cooperation on spent fuel management
- Second Nuclear Energy Nonproliferation Workshop (August 2006)
  - Developed fuel cycle services demand model
- 2006 East Asia Forum on Radioactive Waste Management Technical Conference (November 2006)
  - Identified collaborative opportunities

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Selected areas for technical cooperation identified by regional participants at Nuclear Energy Nonproliferation Workshops

Ongoing in RSN103

- Development of secure data sharing mechanisms
- Shareable model and database of future demand for enrichment services and future spent fuel arising
- Collaboration on issues related to the safe, secure storage and disposition of spent nuclear fuel and high-level waste
- Evaluation of technical requirements to develop reliable multilateral fuel cycle service supply systems
- Improved transparency
- Strengthening technical capabilities for implementing the Additional Protocol
- Collaboration on physical security of nuclear facilities, including vulnerability analysis
- Development of new safeguards technologies
- Development of near-real-time process monitoring technologies

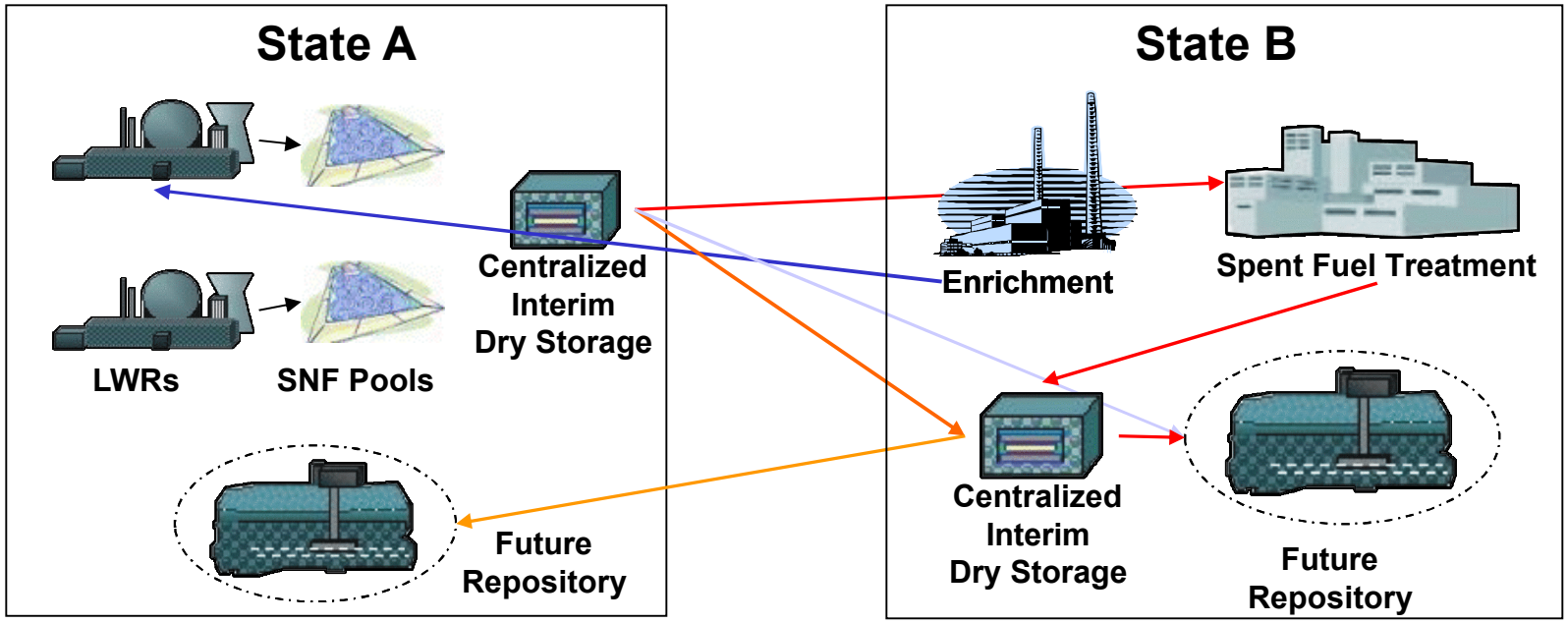
Project Approach

- Take expressed concerns of the states in the region seriously (e.g., If a state cites concerns about the supply of enrichment services as a reason for not supporting GNEP's reliable fuel services program, find ways to demonstrate that supply is sufficient)
- Focus on approaches which would be a priority for NA-24 regardless of how GNEP develops (e.g., even if GNEP dies, improving the security of spent fuel will be a key element of NA-24's nonproliferation strategy)
- At least until GNEP has more definition, focus on the concept of a fuel cycle services system rather than the specifics of the GNEP Reliable Fuel Services Program
- When possible, encourage states in the region to take the lead (increases the likelihood that approaches will be adopted; leadership roles increases investment and commitment to nonproliferation norms)
- Where appropriate, make efforts multilateral. The development of fuel cycle service systems and tools which increase confidence in the nonproliferation commitment of others in the region are inherently multilateral

Goal 1: Build Support for Participation in a Fuel Cycle Services System

- **Goal of fuel cycle services systems:**
  - **Create a reliable, guaranteed system to provide uranium enrichment and spent fuel management (interim storage, treatment, final disposition) to states agreeing to forgo the acquisition of domestic enrichment and reprocessing technologies.**
    - **System should also aim to improve the security of spent nuclear fuel**
- **Such a system can take many different forms**
  - **In its simplest form: State A operates reactors; receives enriched uranium from state B; send irradiated fuel to state B for management and disposition**

Reliable Fuel Cycle Services: Simple Version



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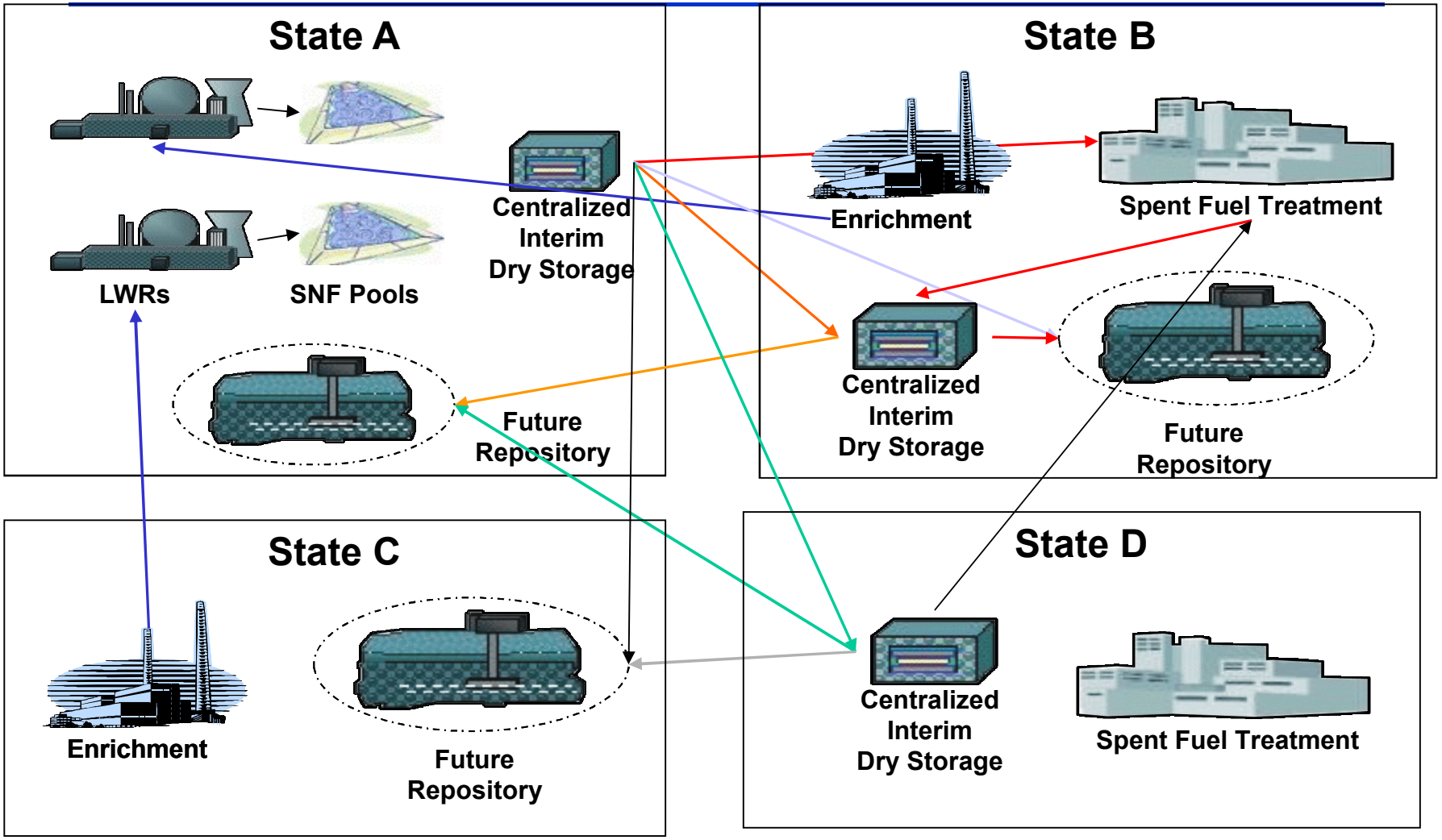
Reliable Fuel Cycle Services: Alternative, Multi-state Version



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Concerns about Participating in a Fuel Cycle Service System

- **Capacity: There will not be enough enrichment or spent fuel management services to meet growing demand**
  - Nuclear power plants are long-term investments which will operate for 40-60 years
  - To be economically viable, operators must be confident that fuel cycle services will be available (and affordable) for life of reactor fleet
  - Given the role of the state in the nuclear enterprise, the market does not operate perfectly and supply may not come on in a timely fashion
    - Nuclear projects often delayed
- **Credibility: The spent fuel take-back portion of the concept is not credible (and that's the important part!)**
  - Insufficient transportation, dry storage and spent fuel treatment capacity
  - No operating SNF or HLW repositories
  - Development of back-end facilities has faced significant hurdles all over the world
  - The long-term management and disposition of spent fuel poses risks for which the nuclear operator may be liable
    - Operators must feel comfortable that SNF is being managed safely and securely
  - If capability or necessary assurances from potential managers of spent fuel can not be obtained, producers of spent fuel will need to develop capabilities domestically.
    - This is a long process and would need to begin very soon
- **Political Risk: There is too much risk that the supply of enrichment or spent fuel management services will be interrupted for political reasons**
  - States such as the United States often point to nuclear energy as a means to reduce reliance on foreign sources of oil.
  - If relying on foreign sources of energy is risky for the United States, why isn't it risky for everyone else?

Addressing the "Capacity" Concern

- **Expressed Concern:**
  - "There will not be enough enrichment or spent fuel management services to meet growing demand"
- **Response:**
  - Develop detailed and transparent understanding of demand, supply, and trade in nuclear fuel cycle services
- **Mechanism:**
  - Develop a shareable model and database of future demand for enrichment services and future spent fuel arising linked to map-based visualization tools to plot supply sources and trade connections
- **What is the value of a model?**
  - Evaluate the viability of fuel cycle service supply concepts (economics, capacity, and reliability)
  - Provide data to estimate future requirements for enriched uranium (important to scale multinational approaches)
  - Provide data to estimate requirements for spent fuel take-back, treatment, storage, and final disposition
  - Develop international consensus on analytical methods and data (among both users and suppliers)
  - Provide a foundation for dialogue on the design of reliable fuel cycle service systems

Understanding requirements is critical to developing an economically competitive, reliable fuel cycle service system.

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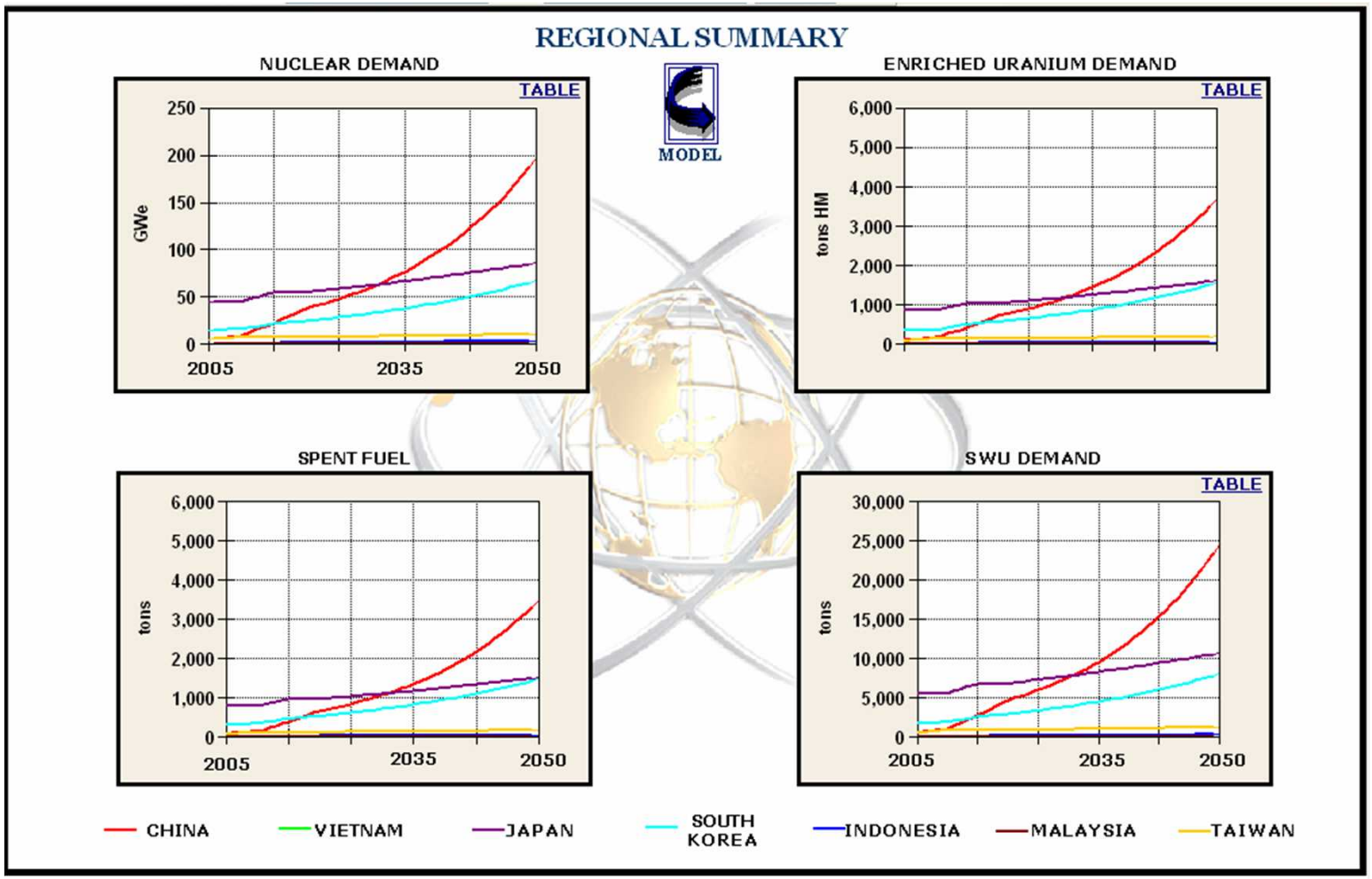
Demand model developed during August 2006 Nuclear Energy Nonproliferation Workshop



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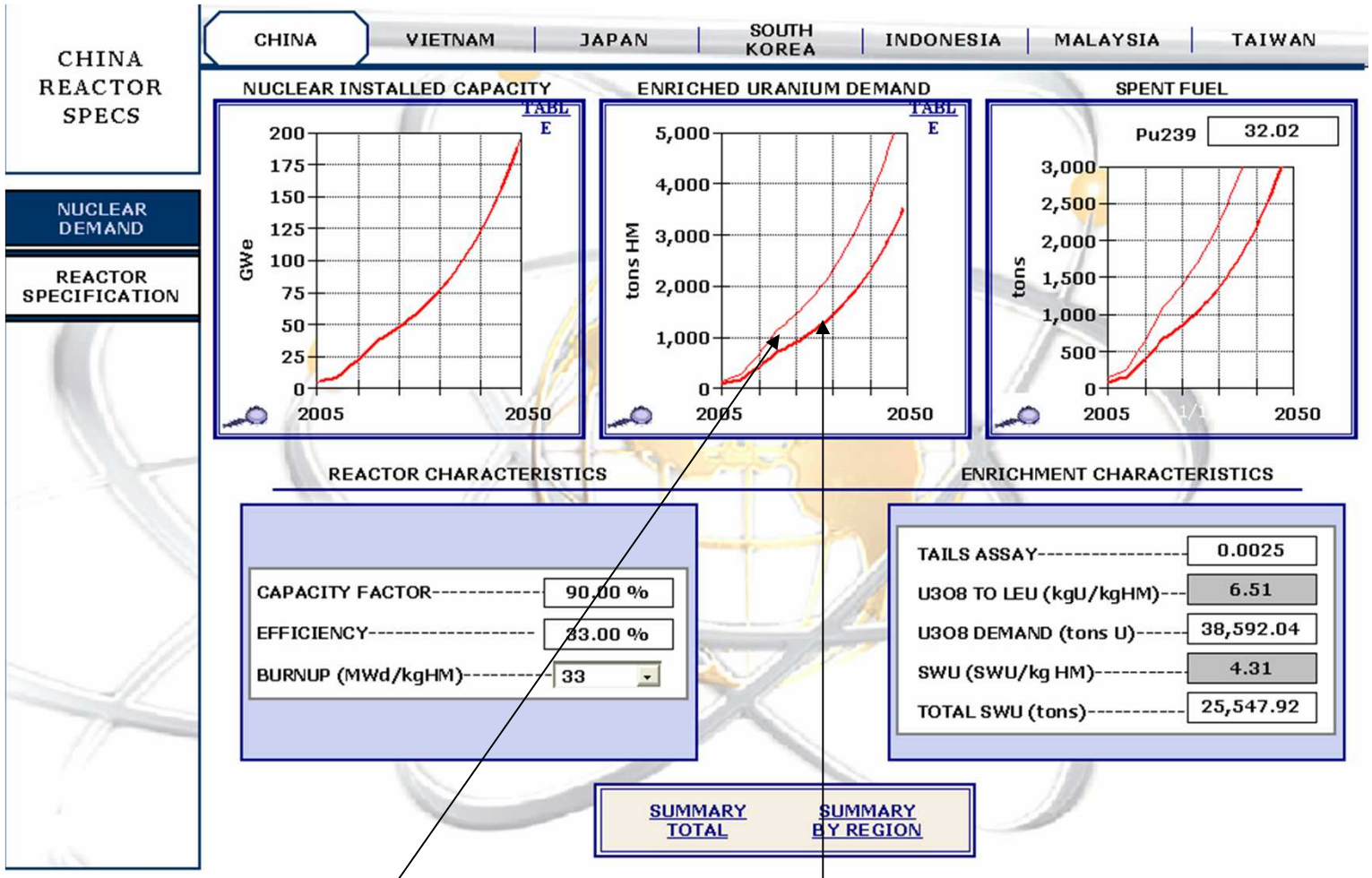
Model Run Example: Effects of alternative burnup rates on PRC enrichment demand and spent fuel arising



(thin line – 33 MWd/kgHM; thick line – 53 MWd/kgHM)

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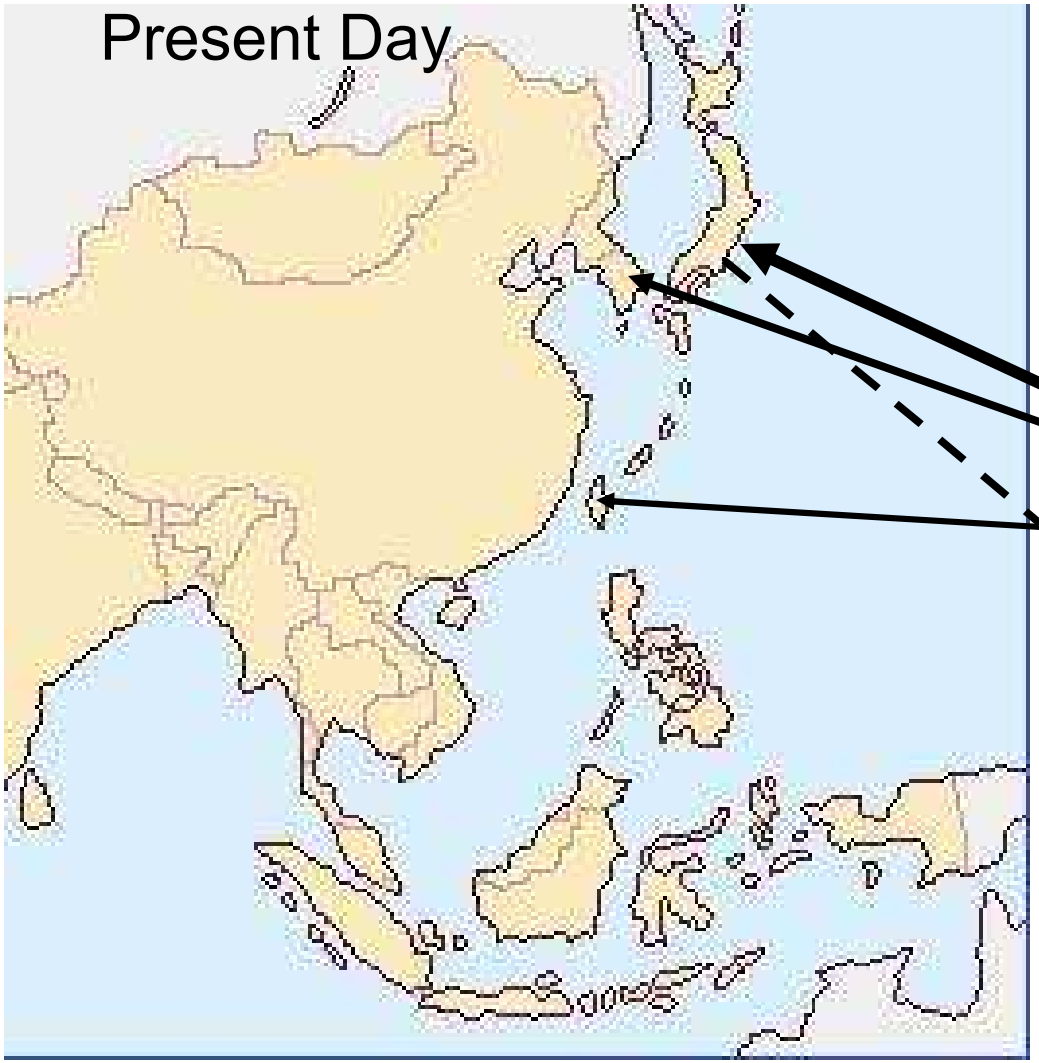
Supply and Trade Visualization Tools

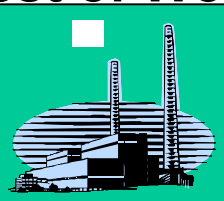


Width = magnitude

Enrichment

Spent Fuel

Rest of World



Enrichment

Spent Fuel Treatment

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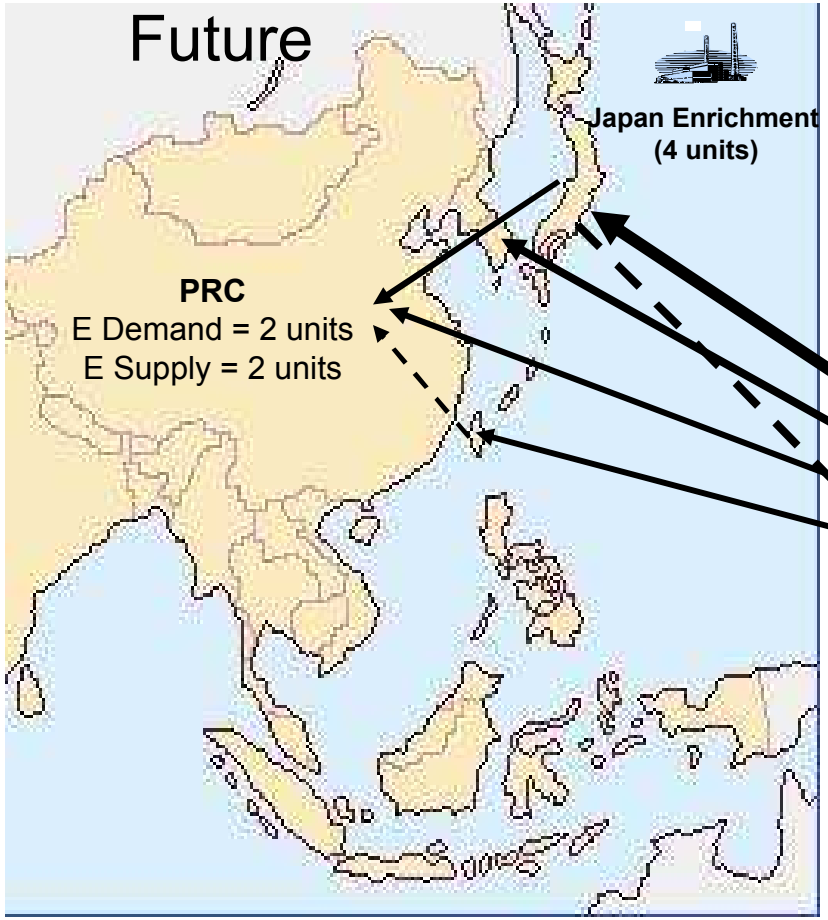
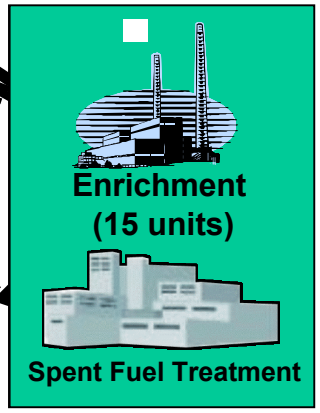
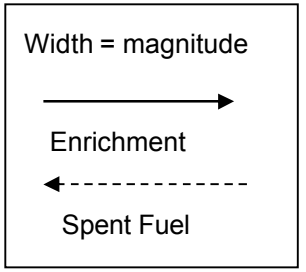
Supply and Trade Visualization Tools

Add Fuel Cycle Facilities	
Enrichment	**Treatment**
Japan (4 units)	China (1 unit)







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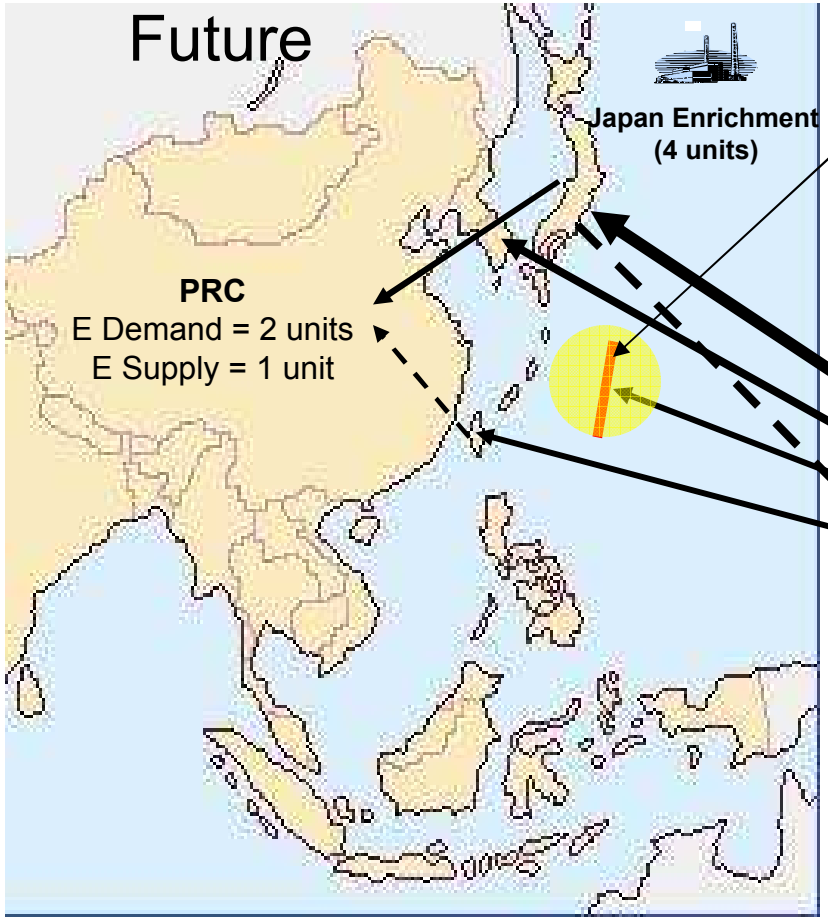
Supply and Trade Visualization Tools

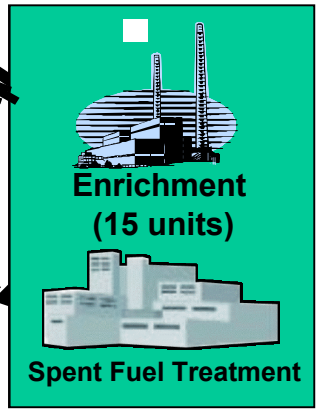
Political decision results in disruption of 1 unit of enrichment to PRC; Additional Japanese capacity available to replace disruption

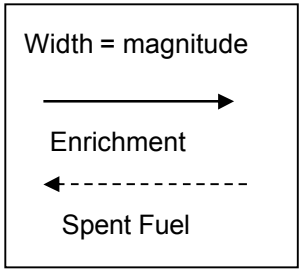


Supply Disruptions		
Supplier	**Recipient**	**Service Disrupted**
Rest of World	**PRC**	**1 Unit of Enrichment**

Add Fuel Cycle Facilities	
Enrichment	**Treatment**
Japan (4 units)	China (1 unit)

Rest of World





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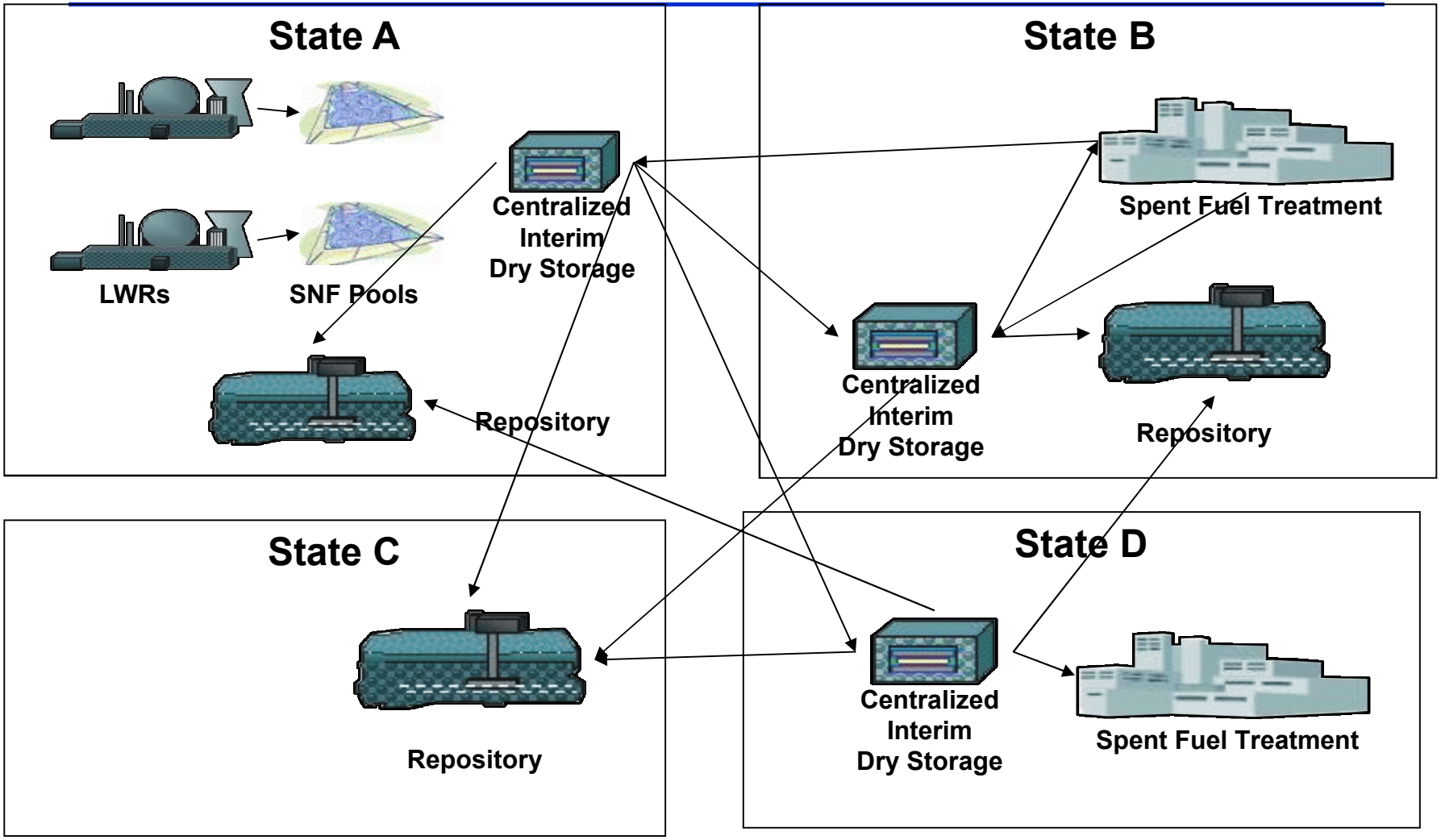
Addressing the "Credibility" Concern

- **Expressed Concern:**
  - "The spent fuel take-back portion of the concept is not credible (and that's the important part!)"
    - States can't take-back spent fuel and waste because they do not have the storage, treatment or disposition facilities
    - States won't take-back spent fuel and waste because it is too difficult politically
      - National laboratories can't help on this!
- **Responses:**
  - Initiate technical collaboration which supports the near-term deployment of critical take-back components in a way acceptable to all stakeholders
  - Focus on spent fuel management approaches which increase the security and protection of spent fuel AND facilitate the deployment of complete take-back system
- **Mechanism:**
  - Facilitate the development of necessary infrastructure
    - Develop a "technology roadmap" for centralized, interim spent nuclear fuel storage facilities
  - Develop modeling tools to assess repository performance and economic implications of fuel cycle service alternatives
  - Demonstrate elements of take-back mechanism (e.g., secure transportation)

Elements and Flows of a Spent Fuel "Take-Back" System



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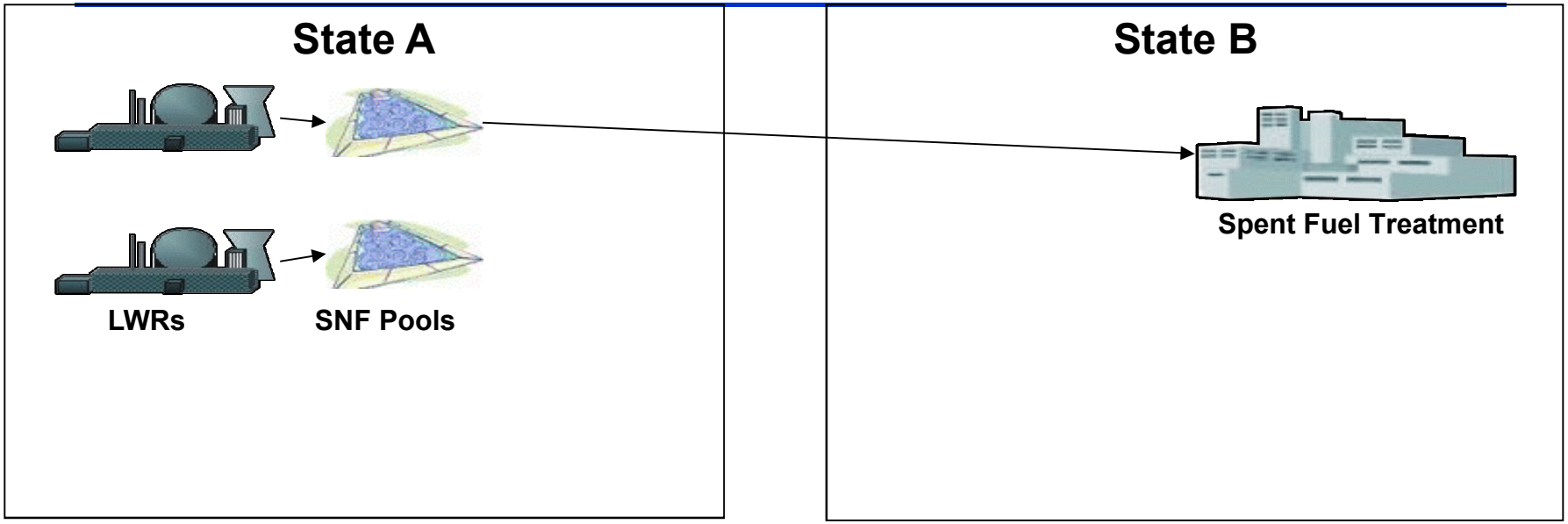
What Parts of the Spent Fuel Take-Back Infrastructure Currently Exists?



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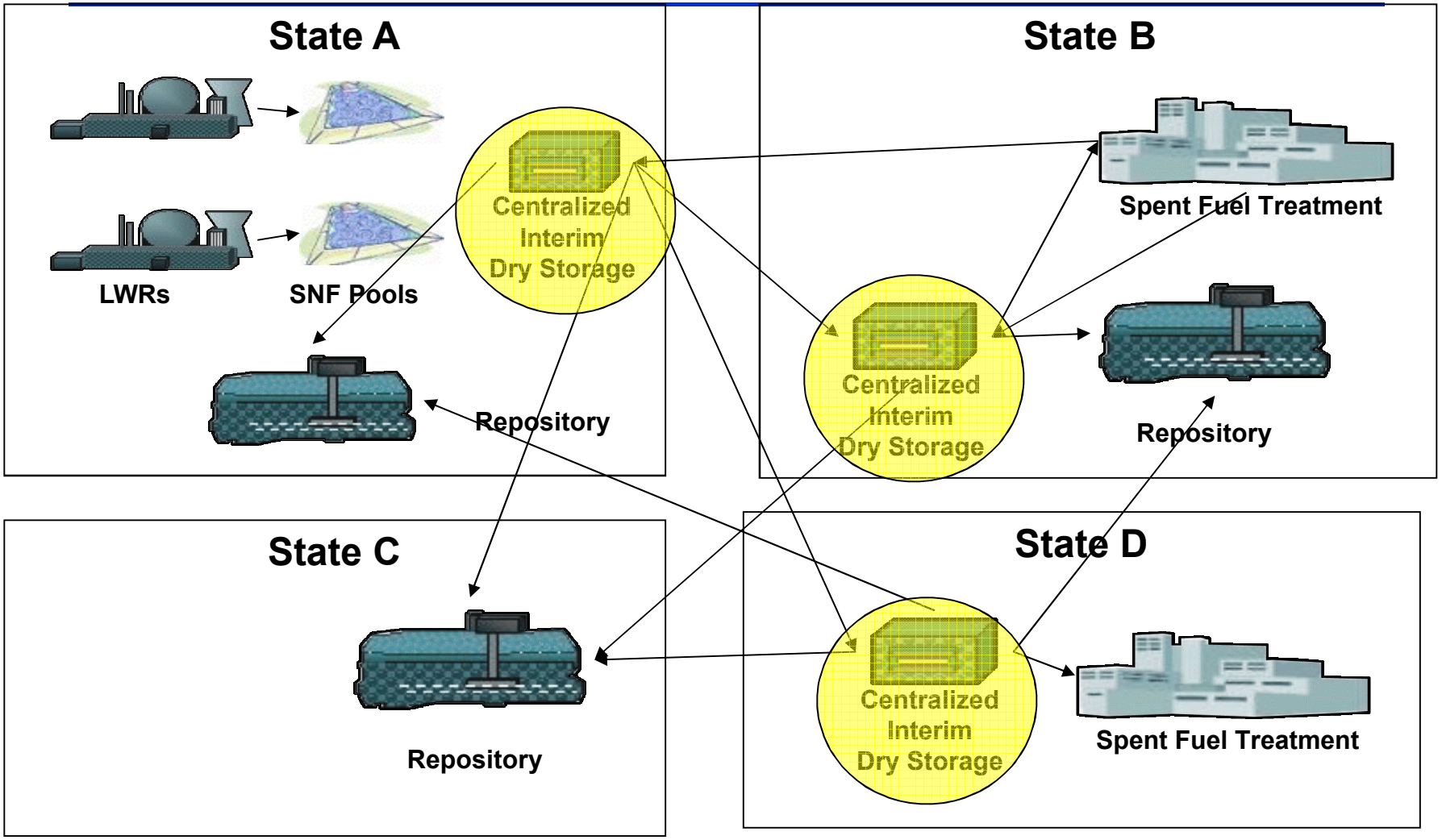
Making Take-Back Credible

- Development of centralized, interim storage capabilities
- Understanding of repository needs
- Demonstrating secure, efficient transportation consistent with a 1540 and AP world

"Take-back" – the promise of an efficient, economical, integrated, and final solution for the management of spent fuel – may not be realized for some time. Near-term approaches should focus on activities which move spent fuel from numerous spent fuel storage pools to more centralized, better protected storage and management facilities. This will reduce near-term proliferation risk, be attractive to nuclear operators, and facilitate the ultimate deployment of an integrated take-back system.

Centralized, Interim Storage is the *Sine Qua Non* of Take-Back



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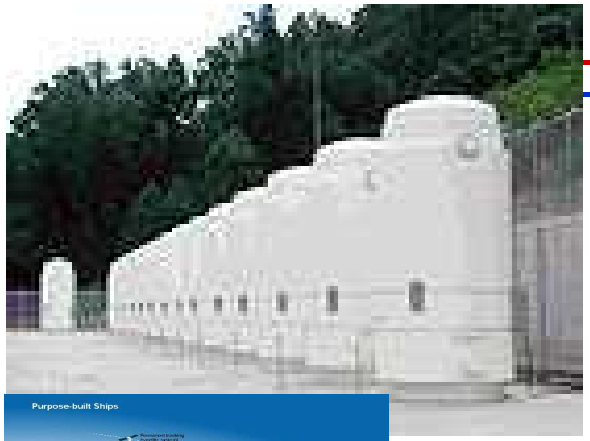
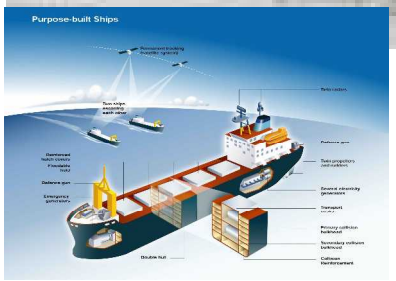
Safe, secure storage and disposition of spent nuclear fuel and high-level waste: Spent Fuel Storage





- **Why focus on Spent Nuclear Fuel Storage Cooperation?**
  - Challenges to long-term disposition strategies (including take back systems) extend the period of interim storage in most states
  - Growing number of distributed storage sites reduces security and transparency
  - Spent fuel storage is the sine qua non of fuel cycle service regimes
  - Regional cooperation on technical facility issues will facilitate acceptance of future regional solutions

Areas for Technical Collaboration and Standards Development

- Fuel acceptance criteria and characterization
- Safety (environmental management; operating procedures)
- Transportation
- Transparency and monitoring
- Security
- Safeguards

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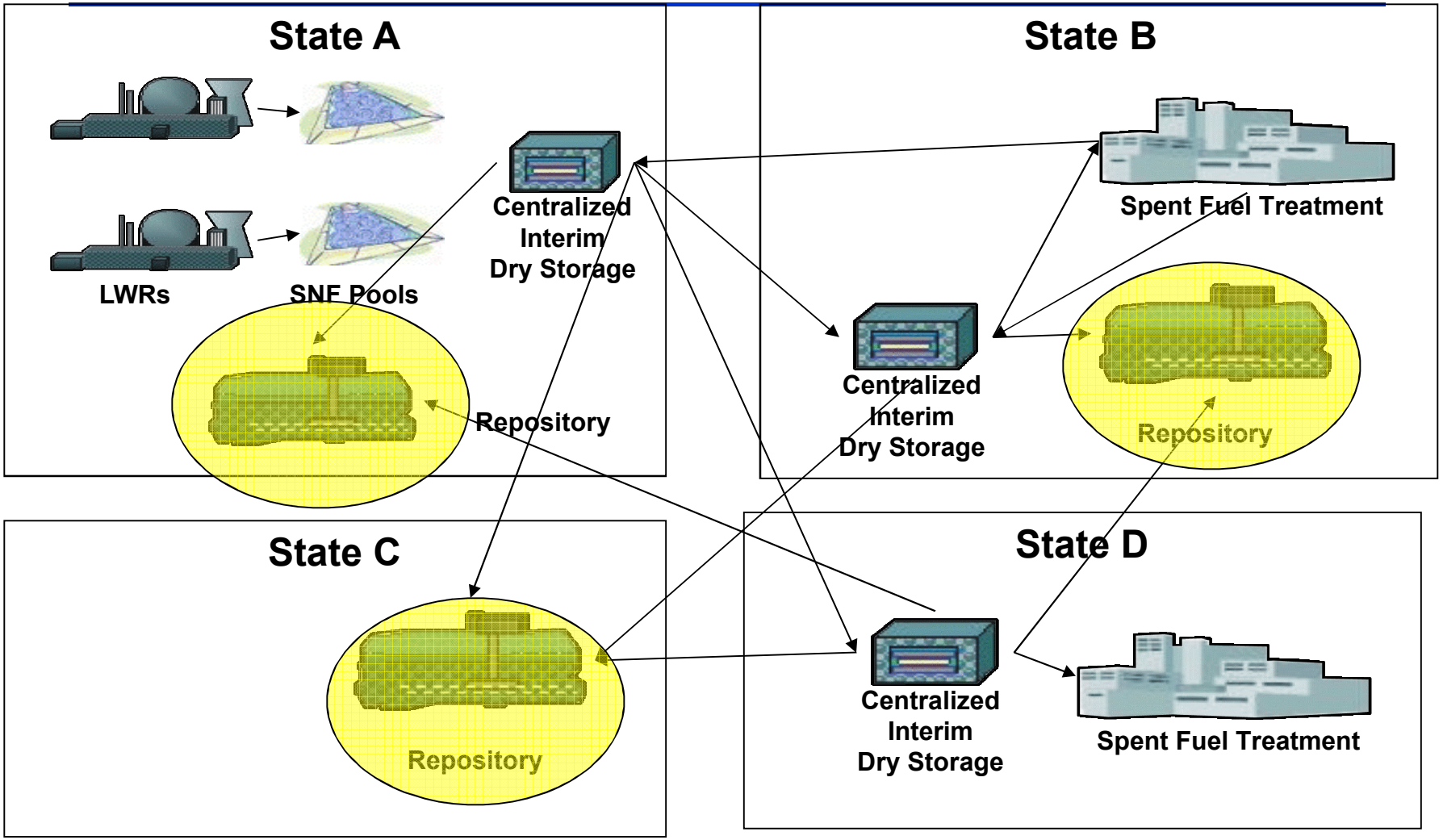
Spent Nuclear Fuel Storage Technology Roadmap

- Technology roadmap to guide technical collaboration on the development and deployment of a spent nuclear fuel (SNF) centralized interim storage system.
- Roadmap makes no assumptions about the location of facility or origin of fuel to be stored
- Assumes that all states will likely need to develop such a facility and will have an interest in the facilities developed by others meeting certain standards
- Before states will consider the use of storage facility in another state, they will want assurances that it meets certain standards

Final Spent Fuel and High Level Waste Disposition



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The Role of Repositories in Take-Back Regimes

- Take-back arrangements may keep spent fuel and waste material resulting from treatment permanently or return waste in a proliferation resistant form to originator
- Either way, a repository is a necessary element
- States may resist entering into long-term fuel cycle service system arrangements until a final disposition path is identified (and perhaps viable)
- Characterizing, siting, and developing repositories must be done with a final waste form in mind
- The characteristics (volume, heat load, toxicity) of that waste form will differ depending on the back-end process chosen
- If a state participating in a fuel cycle services regime is going to end up having to dispose of the waste resulting from the treatment of its spent fuel, it will need to start preparing very soon.
- If regional repository options are ever going to be viable, potential waste forms will need to be identified

Regional collaboration on repository performance can help expedite repository availability and facilitate the consideration of multilateral alternatives

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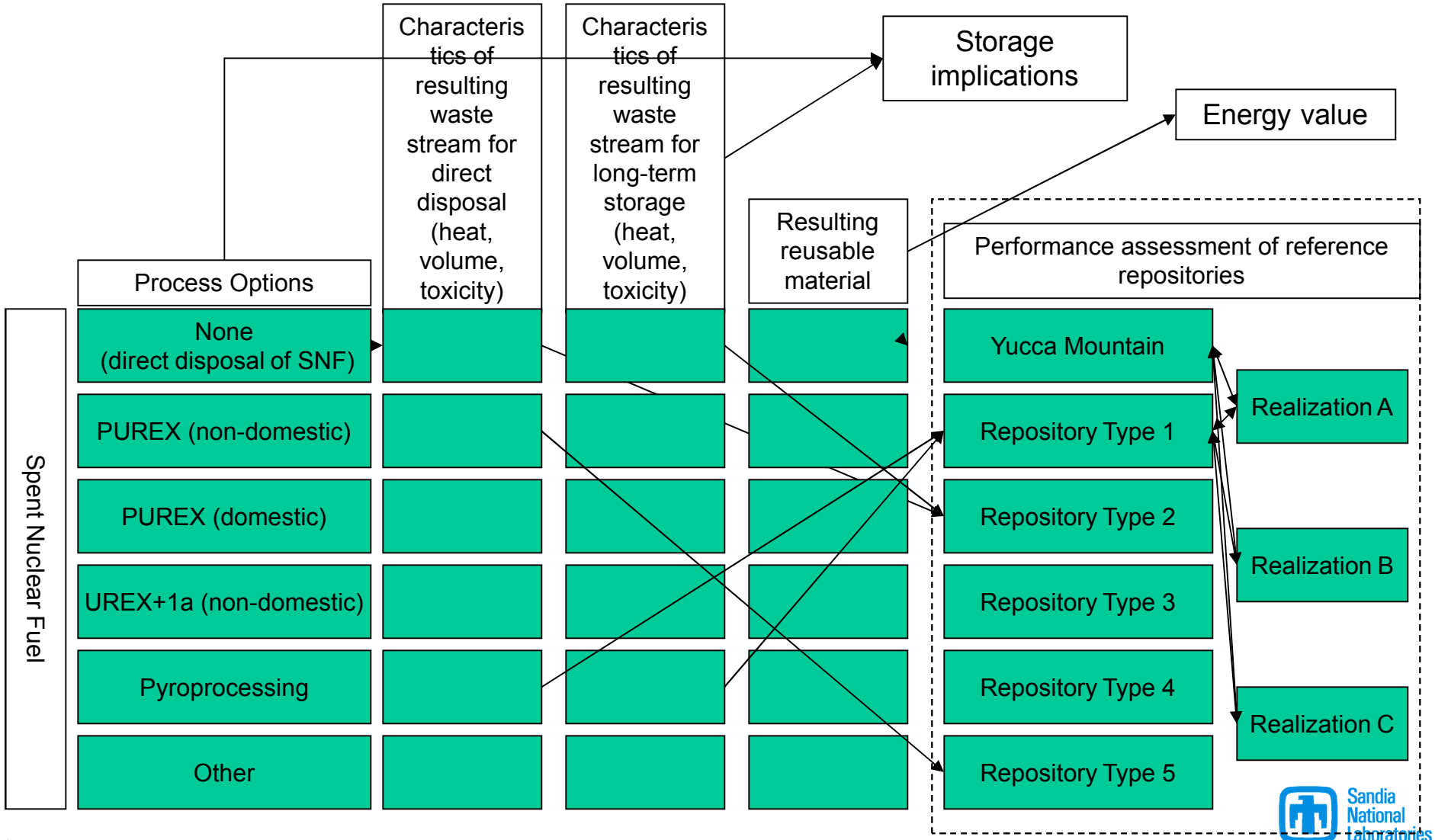
Back End Fuel Cycle Choices and Repository Performance Assessment

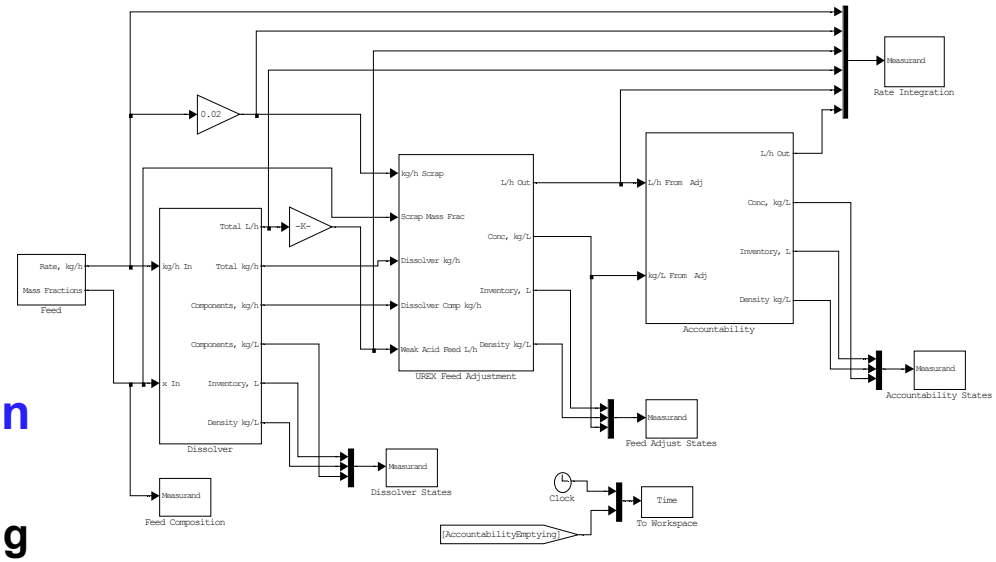


Goal 2: Development and Demonstration of Plant Monitoring and Data Management Tools

- **What is the problem?**
  - International proliferation concerns about the development of nuclear energy go beyond verification practices as currently accepted.
  - Increasing confidence that existing and advanced nuclear fuel cycle facilities which will serve as the foundation for any multilateral fuel cycle service system are not being misused is critical to building support for the overall system
  - Advanced plant monitoring and data management tools will be needed to reduce the burden on operators and inspectors as additional, complex facilities come on line. This reduced burden will increase compliance and free the IAEA up to focus on other tasks.
- **Objectives**
  - Increase confidence of no diversion through more information and increased transparency
    - More information
    - Less measurement error
    - More timely information
    - Better analytic tools
    - Better management and sharing of information
  - Minimize inspection activities and burden on operators
    - Free up IAEA resources
    - Facilitates compliance
  - Increase transparency of operations
    - Create culture of “going above and beyond” obligations

Advanced Accountancy Modeling

- Identify minimum key monitoring points to obtain necessary confidence limits against material diversion
- Optimize sampling strategy in terms of location, frequency, accuracy and precision to help guide design of the next generation of sensors
  - Design tool for process monitoring and safeguards design
  - Identify requirements for advanced instrumentation



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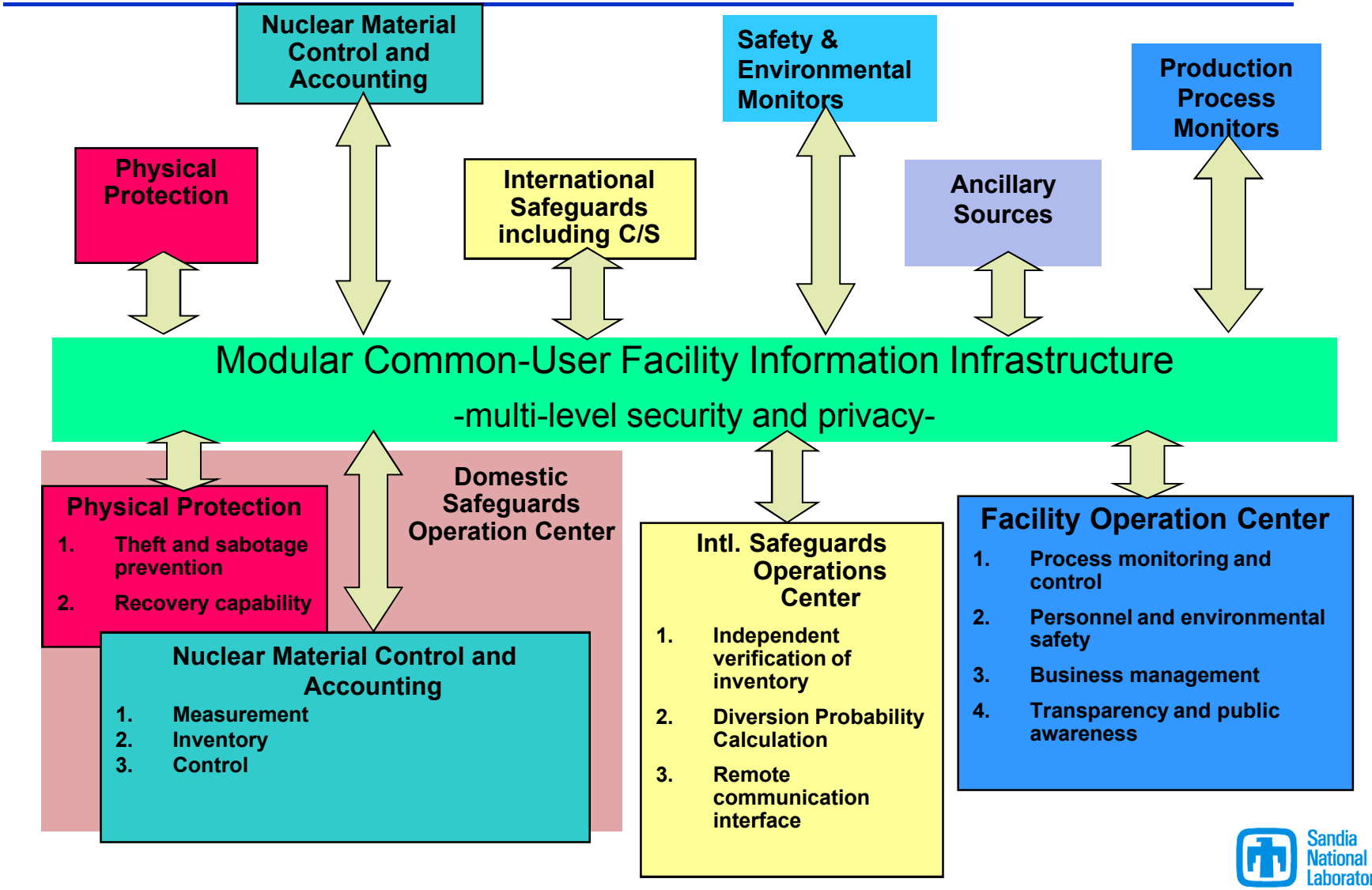
Supporting Infrastructure

- **Advanced data security for authentication, encryption, tamper indicating processing systems**
  - **To permit valid conclusions to be drawn from safeguards data, it is essential that this data is known to be authentic.**
  - **Failure to integrate authentication measures early in the design may result in systems that are expensive, or possibly impossible, to deploy securely.**
- **Data management system**
  - **Support full range of facility design, operational and processes information**
  - **Integrate data from disparate functions and sensor types**
  - **Provide multi-level security**
  - **Provide automated anomaly detection**
  - **Create opportunities for increased transparency**

Facility Information System Architecture



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Goal 3: Facilitate information sharing and collaboration to strength implementation of traditional nonproliferation measures

- Regional stakeholders frequently express the desire to have mechanisms that would facilitate information sharing
  - Transparency
  - Improved operation
  - Technical collaboration
- Information sharing already occurring bilaterally
- Secure, user-friendly tools create the opportunity to expand such cooperation
- First step toward more robust regional cooperation including the development of formal mechanisms

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Goal 4: Creating opportunities to obtain candid feedback from regional stakeholders

- Understanding objections, concerns, and emerging risks is critical to designing effective policies and engagement activities.
- Through technical workshops and demonstration activities, a deeper understanding of regional positions and policies can be developed

- Regional Workshop (December 2004)
- Sandia International Security Conference (April 2005)
- Nuclear Energy Nonproliferation Workshop (August 2005)
- Ongoing Cooperation with the Korea Atomic Energy Research Institute
- CSCAP meeting (March 2006)
- East Asia Forum on Radioactive Waste Management Planning Meeting (June 2006)
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