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U.S. DEPARTMENT OF ENERGY

Nuclear Energy

Peaceful Use of Nuclear Technology (PUNT) Meeting, Beijing, China

An Overview of the US-China Cooperative on Advanced Fuel Cycle Research

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Background and Motivation

- **Both countries are interested in promoting a closed fuel concept and the enhancement of greater energy security**
- **Collaborate to further develop nuclear used fuel recycling technology**
- **Were GNEP partnership states; now become the core members of the International Framework for Nuclear Energy Cooperation**
- **Past and current interactions:**

Peaceful Uses of Nuclear Technology (PUNT)* – *Focus on existing nuclear power technology

  - *Nuclear Technology*
  - *Safeguards, Material protection, control and accounting (MPC&A)*
  - *High level radioactive waste management*
  - *Emergency management*

- **Recent add-on cooperation:**

***Bilateral Civil Nuclear Energy Cooperative Action Plan* signed in 2007**
Focus on advanced nuclear fuel cycle technology

3 plenary technical working groups meetings conducted.

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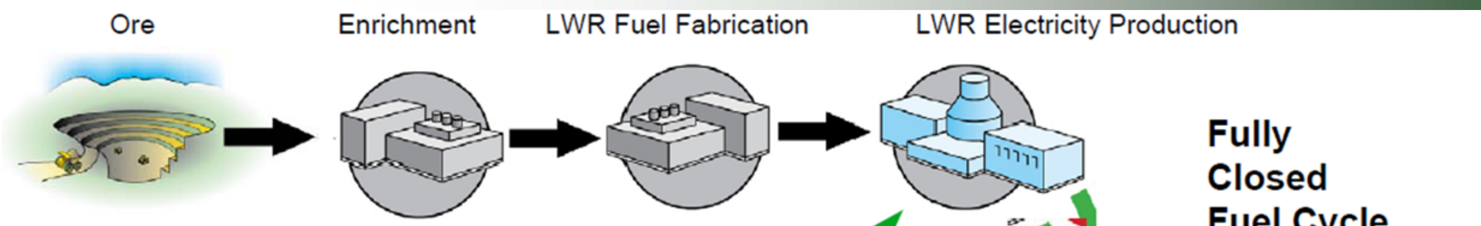
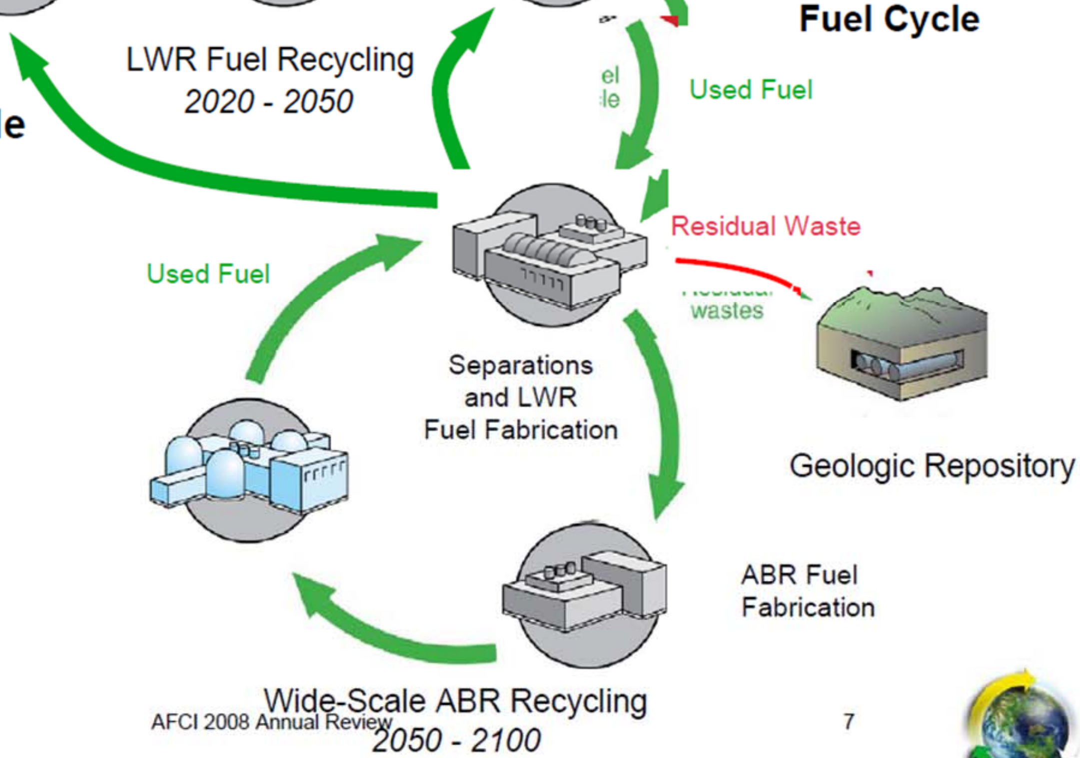
Closed Fuel Cycle





- **Used nuclear fuel separated into re-useable and waste components**
- **Plutonium-bearing fuel fabricated and used in LWRs**
- **TRU bearing fuel or targets used in Fast reactors (ABR) to consume additional transuranic elements**
- **Residual waste goes to geologic repository**

Description of the Action Plan

- **The US-China Bilateral Civil Nuclear Energy Cooperative Action Plan represents a programmatic commitment for both countries;**
- **It is set up in 3 phases;**
- **Expectation from both sides:**
  - ***Results of the near-term cooperative activities will be substantial and will have large positive impacts for the nuclear energy vision of both countries;***
  - ***In addition, the near-term cooperation also lays the groundwork for long-term cooperation in advanced nuclear research and development.***

3 Phases of the Action Plan

- **Phase I – Near Term, from April 2008 through May 2009**

  Goal: "to rapidly initiate near-term cooperative work having immediate impact on relevant nuclear energy challenges."

- **Phase II – Mid Term, from June 2009 through May 2012**

  Goal: "to address the more complex challenges associated with advanced technologies such as advanced reprocessing experiments, fast reactor design/safety and associated separations technologies."

- **Phase III – Longer Term, from June 2012 and forward**

  Goal: "to focus on development and demonstration of advanced concepts and technologies that would help to demonstrate future advanced nuclear energy systems."

4 Focus Areas & Working Groups

- **Advanced Fuel Cycle Technology / Separations Technology;**
- **Advanced Fuel Cycle Technology / Fuels and Related Materials Development;**
- **Fast Reactor Technology;**
- **Safeguards and Physical Protection.**

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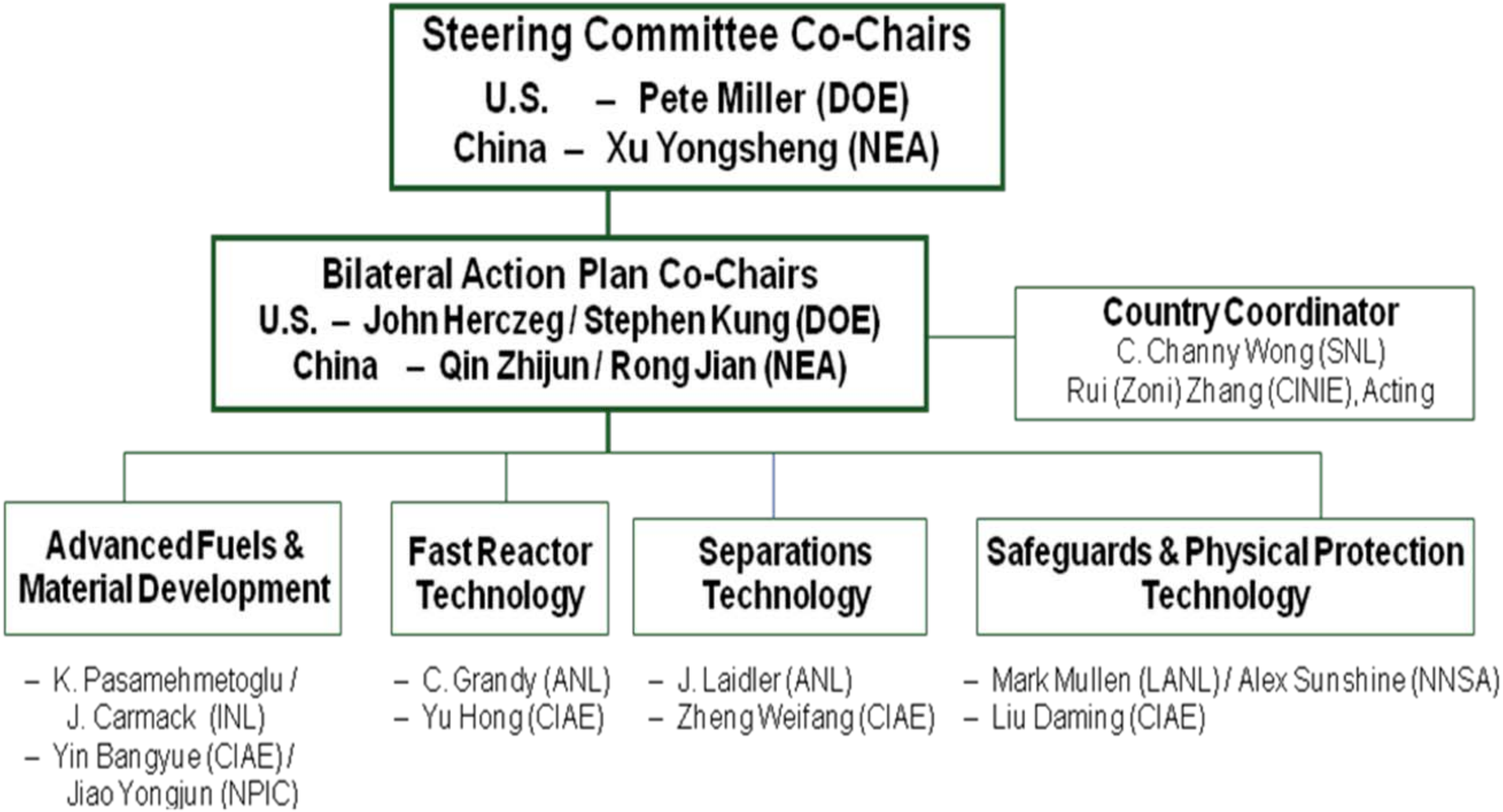
Organizational Chart



Separation Technology

- **Interest:**
  To advance reprocessing and waste form production methods that enhance proliferation risk reduction, provide economic benefits, and reduce environmental impacts.

- **Goal:**
  To develop a simplified separations process (or processes) with excellent recovery efficiency and reduced waste generation. This includes a reduction in emission of radio-nuclides from future plants, either in gaseous or liquid form.

Separation Technology (cont.)

- **Forms of Interactions in Phase I & II:**
  - *Annual information exchange meetings,*
  - *Observers and staff exchange, and*
  - *Joint experiments*
- **1st meeting at Oak Ridge National Laboratory in Jan.2010**
- **2nd meeting in Beijing in early 2011; Topics covered:**
  - *Behavior of acetohydroxamic acid (AHA) in separation process,*
  - *Minor actinide recovery processes,*
  - *Iodine and tritium management, and*
  - *Other emerging subtopics*
- **Two-day tutorial on pyroprocessing to CIAE staff members**
- **Visit to U.S. laboratories involved in pyroprocess development later this year**

Separation Technology (cont.)

- **Other cooperative activities and joint experiments:**
  - *To collaborate on design evaluation of a hot cell facility in CIAE for pyroprocess testing,*
  - *To review controlled-atmosphere equipment for pyroprocess tests in the China Reprocessing And Radiochemistry Laboratory (CRARL),*
  - *To develop off-gas management systems for both aqueous and dry processing,*
  - *To study an efficient product conversion method for solidification of the product(s) of aqueous processing,*
  - *To investigate the behavior of acetohydroxamic acid in head-end extraction processes, and*
  - *To test process monitoring and control instrumentation for aqueous and non-aqueous processes, including safeguards applications.*

Fuels and Materials Development

- **Interest:**

  Further develop metallic fuel technology for fast reactor applications

- **Goal:**

  To explore the use of actinides, separated from used light-water reactor (LWR) fuel, as new fuel for fast spectrum reactors

- **Areas for collaboration:**
  - ***Advanced casting methods with low losses,***
  - ***Advanced cladding materials,***
  - ***Irradiation testing and Post-Irradiation Examinations (PIE) of the metal fuel and cladding in the longer term, and***
  - ***Modeling development from research in Areas #1, 2, and 3***

Fuels and Materials Development (cont.)

Ongoing activities:

- ***Joint Development of Cladding Materials*** *– To improve reactor performance; baseline alloys for cladding study are TI 316 for China and HT9 for U.S.*
- ***Casting Technology*** *– Two alloys (1) U-Zr (10% ≤ Zr ≤ 30%) and (2) U-Pu-Zr (20% ≤ Pu ≤ 30%) China will conduct irradiation testing of selected metal fuel samples, including U-Zr and U-Pu-Zr. The U.S. will conduct similar tests, with the addition of Am and Np. Interests are: phase diagram/phase stability, and microstructure characterization for different processes.*
- ***Characterization and PIE Technique*** *– Examine and understand the behaviors of fuels and materials after being irradiated in the fast spectrum test reactor; parameters of interest are thermal diffusivity and thermal conductivity.*
- ***Fuel Performance Modeling and Simulation*** *– Develop models that could be used for planning and analysis of joint experimental irradiation work*

Fast Reactor Technology

- **Interest:**
  Reactor fuel performance, reactor safety, liquid metal systems and component design and development, and reactor analysis code comparison and validation

- **Ultimate Goal:**
  To commercialize this fast reactor technology; this implies capital cost reduction, improved reliability, improved safety, development and demonstration of recycle fuels, and safeguards by design

- **Phase I Collaboration:**
  - *Information exchange on comparative fast reactor performance for different fuel types (oxide and metal),*
  - *Benchmark comparison of fast reactor safety codes, and*
  - *Tour of the China Experimental Fast Reactor (CEFR)*

Fast Reactor Technology (cont.)

Phase II Collaboration:

- ***Reactor Core Design –***
  - To cross examine and to confirm core performance characteristics
  - To evaluate CEFR start-up core physics test;
- ***Fuel Cycle Systems Analysis –***
  To perform systems analysis based on the potential fuel cycle scenarios considered in China and the U.S.;
- ***Advanced Modeling and Simulation –***
  To apply advanced method and simulation for fuel cycle analyses;
- ***Reactor Safety Analysis –***
  To construct different benchmark problems and compare code predictions; Benchmark problems being considered are: (1) natural circulation decay heat removal in CEFR, and (2) Experimental Breeder Reactor (EBR)-II shutdown heat removal (SHRT);

Fast Reactor Technology (cont.)

Phase II Collaboration:

- ***Fast Reactor Fuel Performance –***
  - To review the performance of both oxide and metallic fast reactor fuels in relation to potential reactor transients, unprotected loss-of-flow, transient overpower, and loss-of-heat-sink accidents in prototypic reactor designs; and
  - To explore and plan the testing of CEFR-irradiated MOX and metallic fuels in TREAT;

- ***Sodium-Cooled Fast Reactor Lessons Learned –***
  To share the experience of the start-up, commissioning, operations and maintenance of the EBR-II reactor and the CEFR reactor plants;

- ***Advanced Materials Irradiation Testing –***
  To utilize the CEFR as a source of fast neutron irradiations for further development of advanced fuels and advanced structural materials for fast and thermal reactor applications

Safeguards

- **Many activities currently happen through the PUNT agreement, which mostly focuses on the existing nuclear power technology**
- **Goal of the Planning Group:**
  To determine and support a need to develop new safeguards technology to cover new areas for nonproliferation
- **Planned activities:**
  - *Workshop on advanced safeguards technologies for reprocessing facilities*
  - *Sodium Fast Reactor safeguards technology*
  - *Verification technologies for fuel receipts (UO2, MOX, metal).*

Conclusions

- **Both US and China are interested in a closed nuclear fuel cycle in the future**
- **Collaboration between 2 countries has been established to conduct cooperative activities for the Advance Fuel Cycle Research and Development**
- **Since many of the resources are limited, the joint research and development (R&D) effort has many significant mutual benefits**
- **Many of the challenges in R&D are thermal-hydraulic related. It will be great to generate more interest and involvement in the academic community**

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