AFCI/GNEP R&D Program

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Outline

- History of AFCI
- Budgets
- Organization and management
- AFCI to GNEP Transition
- R&D path forward
- Technology Readiness Levels
- Summary

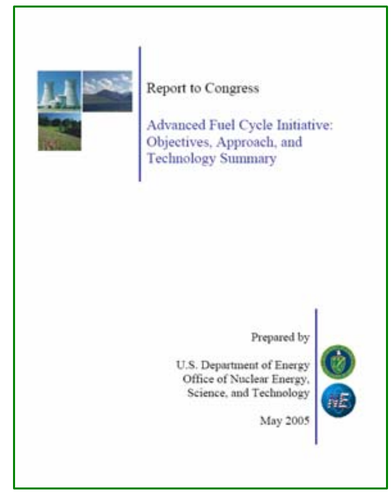
Recent History of DOE's Advanced Fuel Cycle Research

- **1999 - Accelerator Transmutation of Waste (ATW):** Roadmap issued by RW, outlined use of high-powered proton accelerators for destruction of all actinides from spent fuel
- **2000 - ATW:** research program initiated to explore transmutation technology ($9M)
- **2001 - Advanced Accelerator Applications (AAA) Program launched:** combined ATW with Accelerator Production of Tritium (APT) Program to optimize use of resources ($34M-NE, $34M-DP)
- **2002 - AAA refocused to AFCI:** emphasis on reactor based systems, accelerator transmutation focused on "final burn" role to minimize toxicity and support Generation IV (Gen IV) fuel development ($50M)
- **2003 - AFCI establishes new management structure:** National Technical Directors, Technical Integrator, and integration with Gen IV for fuel cycle development ($58.2M)

Advanced Fuel Cycle Initiative - Goals

- **Develop advanced nuclear fuels required for Generation IV Nuclear Energy Systems**
  - Ultra-high burn-up and recycle fuels for thermal systems
  - Advanced fuels for fast systems
- **Develop fuel cycle technologies that:**
  - Recover the energy value from commercial spent nuclear fuel, enhancing energy security
  - Reduce the inventories of civilian plutonium in the U.S.
  - Reduce the heat and toxicity of high-level nuclear waste bound for geologic disposal, enabling more effective use of the currently proposed repository
  - Are proliferation-resistant

AFCI Report to Congress
May 2005


Report to Congress

Advanced Fuel Cycle Initiative: Objectives, Approach, and Technology Summary

Prepared by

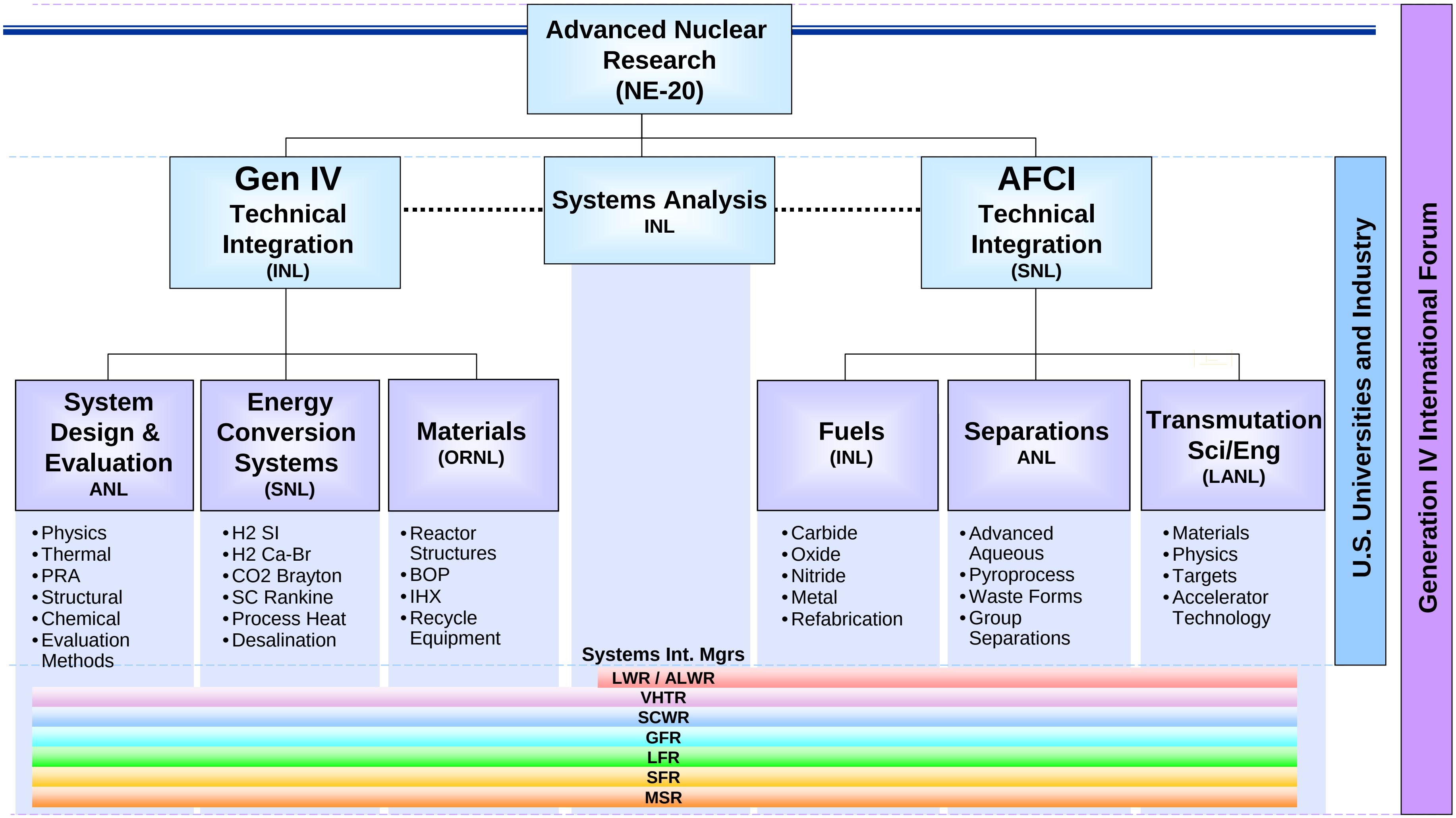
U.S. Department of Energy
Office of Nuclear Energy, Science, and Technology

May 2005

http://www.nuclear.gov/

AFCI Organization prior to GNEP:

Generation IV and AFCI integrated, National Technical Directors at Labs directed R&D with DOE direction and oversight



AFCI Program Major Accomplishments

- **Demonstrated lab-scale high-purity separation of uranium, cesium-strontium, plutonium-neptunium, americium/curium, and group transuranics from spent LWR fuel using aqueous treatment**
- **Fabricated and irradiated in the Advanced Test Reactor in Idaho non-fertile and low-fertile metallic, nitride and oxide fuel samples containing multiple transuranics. Post-irradiation examinations indicated fuels retained integrity**
- **Built a lead-bismuth test loop at LANL and completed 1000 hour corrosion test on several steels and alloys**
- **Improved the nuclear cross-section data bank with new data on Pu, Np and Am isotopes**
- **Conducted analyses to provide options to optimize thermal and fast spectrum transmutation**

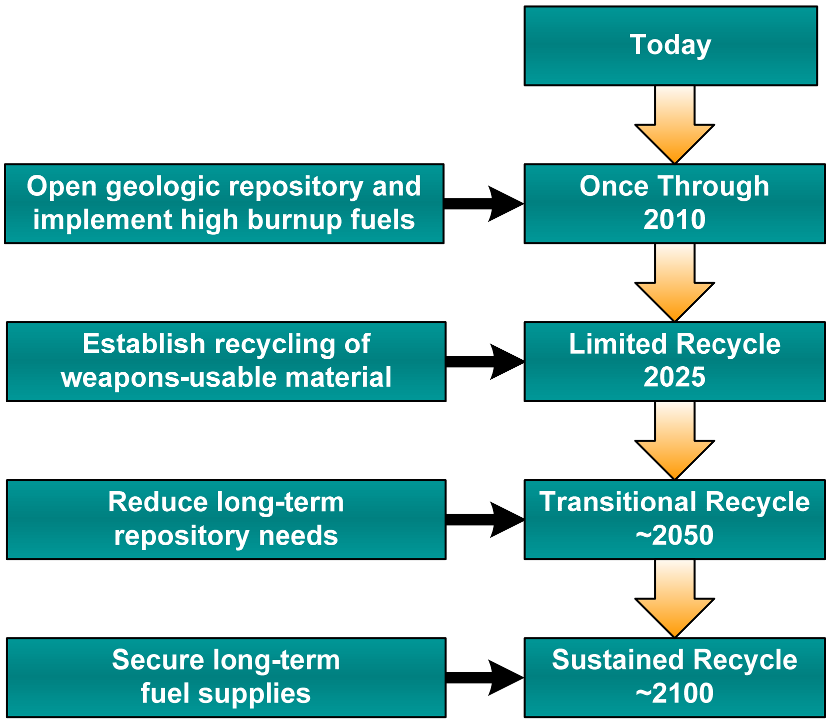
AFCI Program Major Accomplishments (Continued)

- **Prepared for fast spectrum irradiations of transmutation fuels in Phenix fast reactor**
- **Started preconceptual design studies for an Advanced Fuel Cycle Facility that would provide capabilities for testing and improving advanced separations, fuels and safeguards technologies in an integrated manner leading to demonstrations up through engineering scale**
- **Established and maintained a robust university program**
- **Established excellent international collaboration program**

Redirection of AFCI – February 2006

- Secretary Bodman announced plans for GNEP in the FY 2007 budget rollout
- FY 2006 budget appropriation conference report language supportive of accelerating technology decisions and engineering scale demonstrations
- AFCI started to be refocused to support GNEP
- R&D Budget reduced; R&D not directly supportive of GNEP reduced in scope or stopped
- Focus on GNEP projects, especially Engineering Scale Demonstration of UREX+ separations suite in near term
- Reorganization planning started

Evolution of AFCI Fuel Cycle (from May 2005 Report to Congress)



Today – Spent fuel is stored indefinitely at reactor sites.

Once Through – Spent fuel is directly disposed.

Limited Recycle – Spent fuel is recycled a few times, then directly disposed.

Transitional Recycle – Spent fuel is recycled continuously and only fission products are disposed.

Sustained Recycle – Waste uranium is used for fuel, only fission products are disposed.

AFCI Fuel Cycle Evolution

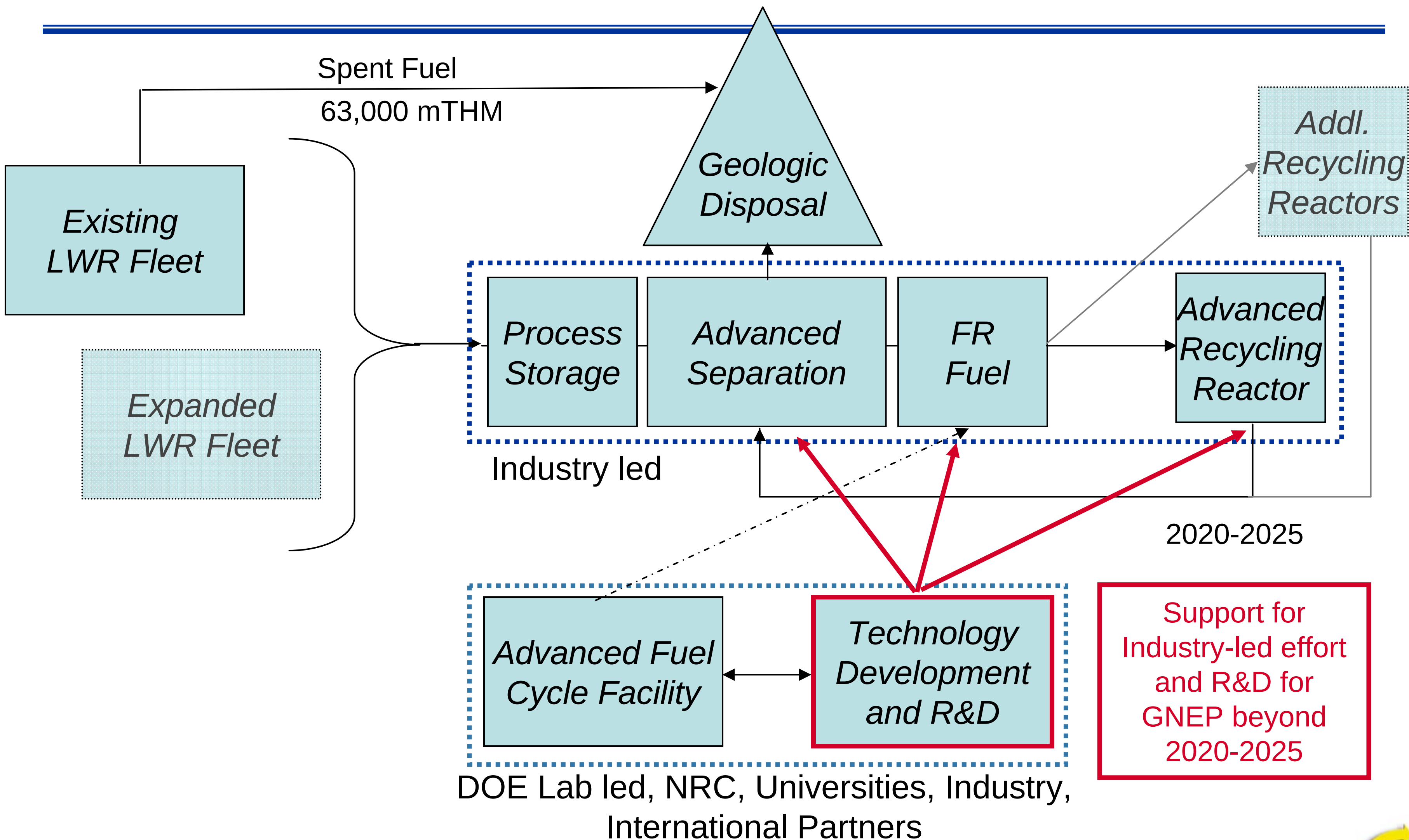
- **GNEP skips Limited Recycle and jumps directly to Transitional Recycle using fast recycling reactors. Sustained recycle is a Gen IV goal.**

AFCI Budget History

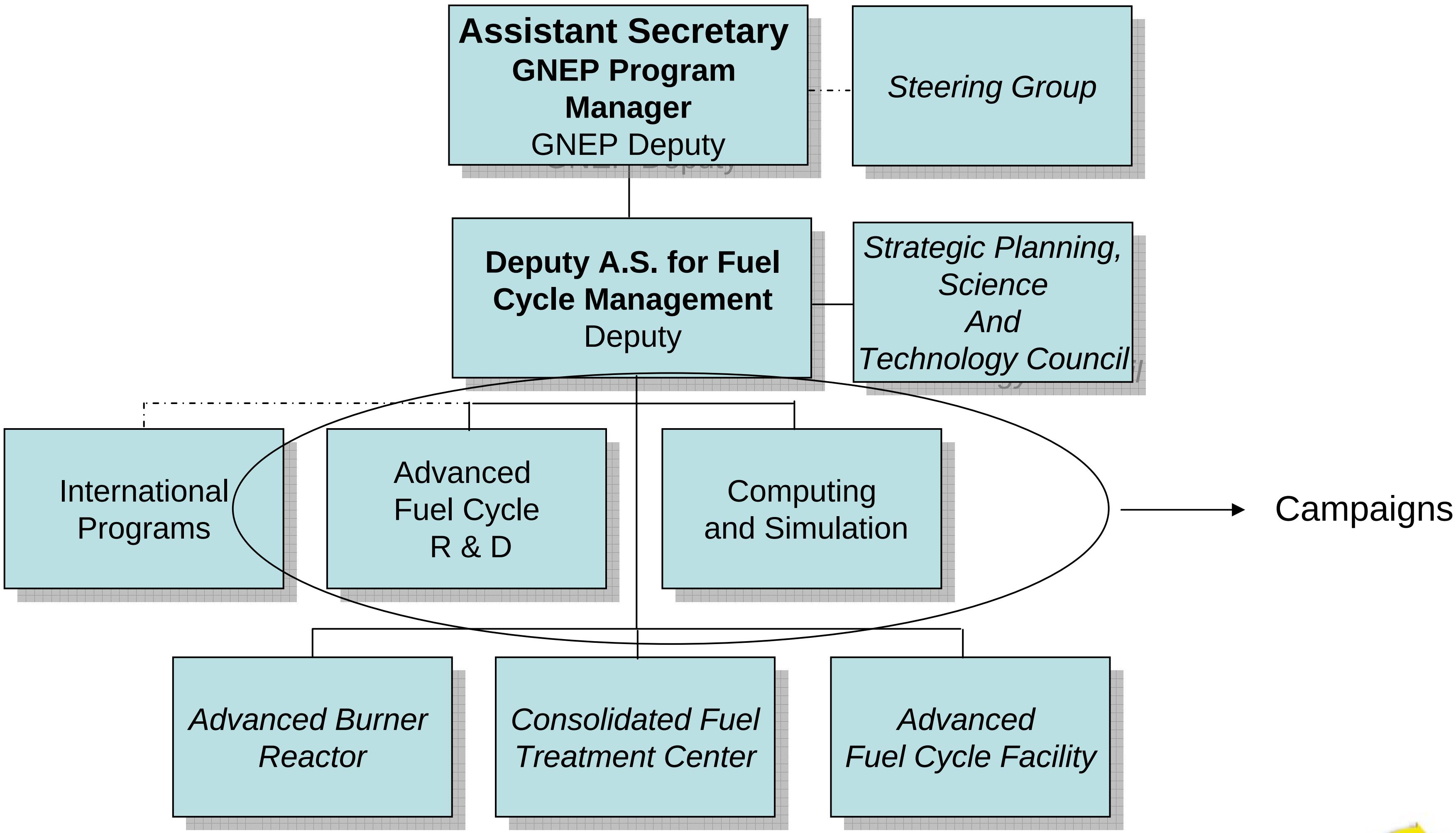
Fiscal Year	2002	2003	2004	2005	2006	2007 (Requested)
Funding ($M)	50.0	58.2	65.8	67.5	79.2	243.0

- **FY 2007 actual spending has been based on FY 2006 funding level during Continuing Resolution. Last week's appropriation action designated $120M for AFCI/GNEP. May get more.**
- **FY 2008 Budget Request is $405M. Includes $10M for NNSA support of GNEP, primarily in safeguards development**

Technology Development and R&D will address technology risks for the projects as well as support long term development for GNEP.



GNEP Program Organizational Structure Supports the GNEPStrategic Plan



GNEP Technology Development and R&D will be Executed Through Campaigns

- **Campaigns are integrated experimental and simulation efforts focused on developing key capabilities or products required for GNEP.**
  - Organized around national laboratories + universities + industry
  - Work will be planned and executed to clearly stated goals, objectives and milestones
- **Combine direct and supporting activities**
  - Transmutation Fuels
  - Separations Technologies
  - Fast Reactor Design and Analysis
  - Safeguards and Security
  - Waste Management and Advanced Waste Forms
  - Systems Integration and Analysis
- **Campaign activities will be managed by DOE/NE supported by national laboratories**
  - INL will provide program and technical integration
  - Other national laboratories support with unique capabilities

Separations Technology Development

<u>Scope and Objective:</u> Reduce risk in major uncertainties in separating spent fuel into products and waste forms. Develop methods to improve system operational effectiveness and efficiency using advanced modeling and simulation techniques.

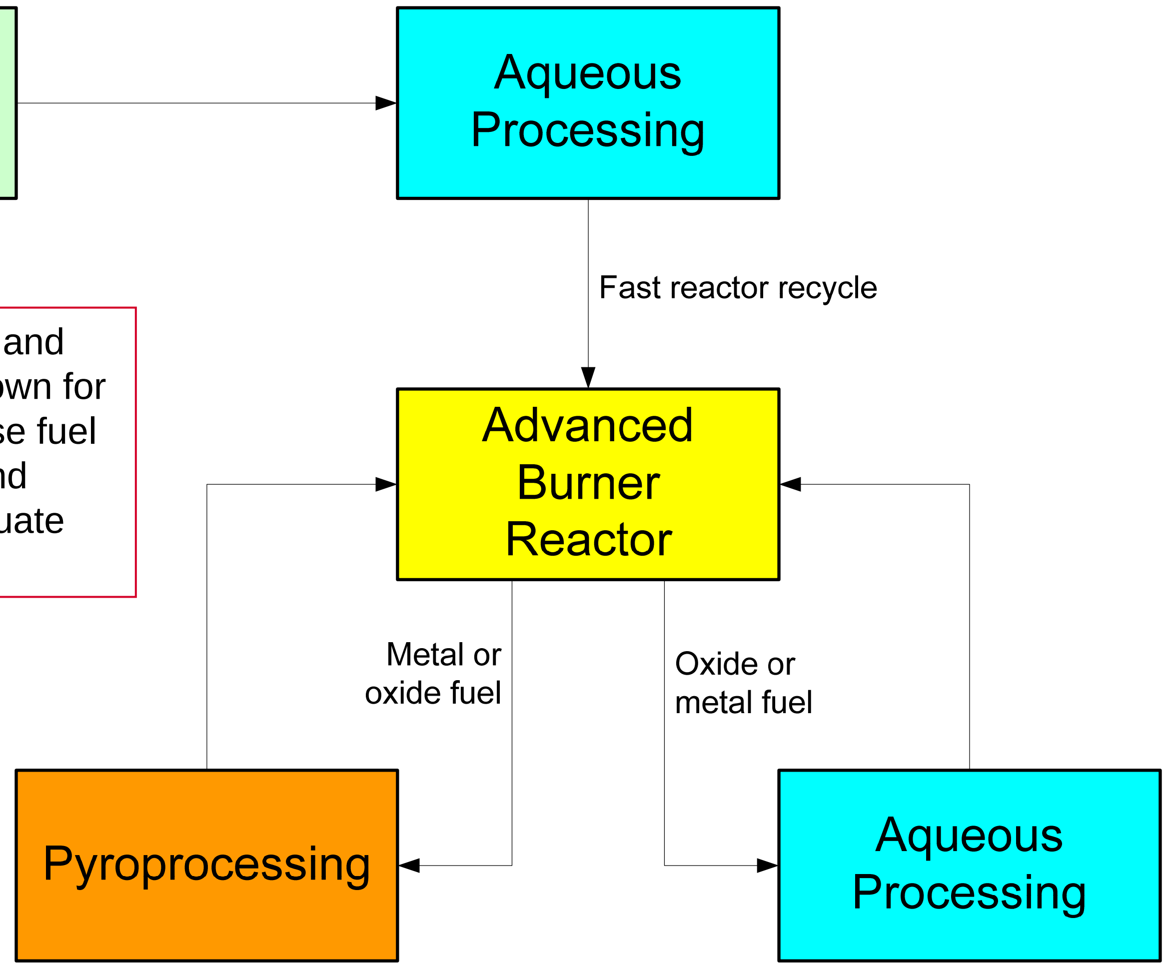
<u>Major Activities:</u>

- **Aqueous Technologies:** demonstrate technology repeatability and operational parameters through multiple tests – initial UREX+1a report by mid 2008

- **Simulation and Modeling:** demonstrate initial advanced simulation capabilities to model separations process performance - initial report by mid 2008

- **Pyroprocessing Technologies:** develop and demonstrate promising fast reactor fuel recycling approach

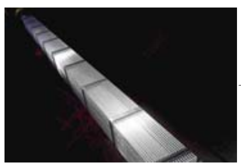
U.S. GNEP Spent Fuel Processing Scheme



Note: Both pyroprocessing and aqueous processing are shown for the ABR fuel recycle because fuel composition is undecided and experimental data is inadequate for final selection.

GNEP Initial Fuel Reprocessing

Spent Nuclear Fuel



Uranium – 94%
Plutonium - 0.9%
Neptunium – 0.1%
Americium – 0.1%
Curium – 0.015%
Fissions Products – 4.9%

- High Radiation Level
- Highly Radiotoxic
- High Level of Decay Heating

UREX+1a Process

- Pure Uranium → *Storage for future recycle*
- Long-Lived Fission Products → *Technetium and iodine in durable waste form for geologic disposal*
- Cesium and Strontium → *Near-surface decay storage*
- Transuranic Elements → *Recycle fuel*
- Residual Fission Products → *Geologic disposal (with fuel cladding and assembly hardware)*

Advanced Fuels Development

<u>Scope and Objective:</u> provide solutions for important parts of the fuel development process where there is high or moderate risk, so that a qualified transmutations fuel is available for use in the Advanced Recycle Reactor.

<u>Major Activities:</u>

- Develop metal and oxide transmutation fuels for qualification in an advanced recycling reactor by demonstrating remote fabrication capability for transmutation fuel by 2008
- Fabricate and irradiate transmutation reactor fuel test samples in U.S. and in foreign fast reactors to consume transuranics
- Continue long-term R&D for next generation facilities including data for modeling and simulation
- Pursue R&D for alternatives such as nitride fuels, dispersion fuels, sphere-pac fuels, inert matrix fuels, and transmutation targets

Transmutation Science

<u>Scope and Objective:</u> Support advanced recycling reactors, including reactor and transmutation physics and the development of advanced structural materials.

<u>Major Activities:</u>

- Support fast burner reactor design and development by reducing and refining uncertainties in behavior of major isotopes of importance to the ABR, primarily for plutonium, neptunium, and americium isotopes
- Perform mechanical testing and analysis of irradiated structural materials irradiated in the U.S. (e.g the FFTF and the EBR-2 reactors) and foreign reactors (e.g. Phenix, JOYO, BOR-60)
- Recommend selection of structural materials for use in fast reactor transmutation systems
- Support international activities for transmutation systems, e.g., MEGAPIE, MATRIX-SMI

Systems Analysis/Advanced Computing & Simulation

<u>Scope and Objective:</u>   Examine the possible combination of nuclear technologies to optimize the technical, economic, and environmental aspects of the GNEP system.

Utilize Advanced Simulation and Modeling to reduce overall risk in GNEP facility design and utilization

<u>Major Activities:</u>

- Conduct analyses of proposed integrated GNEP systems and deployment strategies to develop information to support the June 2008 Secretarial decision on the GNEP path forward

- Provide initial identification and qualification of modeling and simulation tools supporting spent nuclear fuel separations, transmutation fuel and fast reactor design in FY 2008. Use existing models where practical to complete initial analysis

Technology Readiness Level (TRL) Assessment

- TRL system developed by NASA and used extensively by DoD and DOE
- The TRL metric provides a systematic measurement that supports assessments of the maturity of a particular technology and the consistent comparison of the maturity between different technologies.
- GNEP will use TRL assessment of each technology to help determine R&D and technology development needs and priorities.
- TRL level is not the only indicator of technical maturity. Other risk factors such as infrastructure, resources, etc. will also be used.

TRL	Category	Description
1	Concept Development	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development.
2		Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative and there may be no proof or detailed analysis to support the assumptions.
3		Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology.
4	Proof-of-Principle	Integration of basic technological components for testing in laboratory environment. Includes integration of “ad hoc” hardware in the laboratory.
5		Integration of basic technological components with realistic supporting elements for testing in relevant environment.
6		Model or prototype system testing in relevant environment.
7	Proof-of-Performance	Demonstration of prototype system in an operational environment at the engineering scale.
8		End of system development. Technology proven to work in operational environment at the engineering to full scale.
9		Full scale application of technology in its final form at mission conditions.

U-Pu fuels with high maturity exist whereas transmutation fuels are in early phases of development.

TRL	TRL Function	Generic Definition	Fuel Development-Specific Definition
1	Technology Down-Selection	Basic principles observed and formulated	Technical review leading to identified technical options. Identification of criteria for candidate selection.
2		Technology concepts and/or applications formulated	Fuel candidates selected from options, based on selection criteria.
3		Analytical and experimental demonstration of critical function and/or proof of concept	Calculational analysis and lab-scale experimentation and characterization addressing feasibility, including: fabrication process development, property measurement, and ex-pile tests.
4	Final Process Selections and integration	Component and/or bench-scale validation in a laboratory environment	Establish proof of concept. Fabrication of irradiation testing samples in accordance with QA requirements. Design parameters and features established. Performance phenomena identified with proof-of-concept irradiation testing.
5		Component and/or bread board validation in a relevant environment	Irradiation testing of prototypic rods / compacts under nominal representative conditions (e.g., fission densities, fuel and cladding temperatures, cladding damage rates) is performed and assessed.
6	Full-scale integrated testing	System/subsystem model or prototype demonstration in relevant environment	Prototypic rod/compact and assembly/element irradiation in representative environment, under full range of relevant normal and off-normal conditions. Representative compositions. Design parameters investigated. Information is sufficient to support a Fuel Specification and a Fuel Safety Case
7		System prototype demonstration in prototypic environment	Fabrication of reference fuel derived from production supply sources irradiated to design conditions and utilization. Irradiation in representative environment. Prototypic design. Prototypic fabrication processes. Representative compositions.
8	Full-scale demonstration	Actual system completed and qualified through test and demonstration.	
9		Actual system proven through successful mission operations.	

Transmutation Fuel
TRU-metal, TRU-oxide
(roughly same TRL)
Metal experience: mostly U.S.
Oxide experience: mostly International (French and Japan)

Driver Fuel/ Analog Transmutation Fuel
Metal (U-Pu-Zr)
- Not formally qualified
- Not used in industrial-scale

Driver Fuel
Analog Transmutation Fuel
Metal (U-Zr)
Oxide (U,Pu)
- Qualified for reactor operations
- Successful mission operations
- Operational database wider for MOX, especially considering International experience

AFCI/GNEP University Programs

- **UNLV Transmutation Research Program ($5M in FY 2006)**
- **University of Nevada – Reno ($1.75M in FY 2006)**
- **Idaho Accelerator Center – Idaho State ($2M in FY 2006)**
- **University Research Alliance – Fellowships ($600K in FY 2006)**
- **NERI University Program**
  - 19 projects selected in FY 2005
  - 13 projects selected in FY 2006
  - $4.4M in ’06; $8M in ’07

- **Intend to retain a large university component in GNEP, focused on peer reviewed, competitively selected projects that directly support the laboratory-led R&D and technology development activities**
- **Desire to expand the Fellowship program to include PhDs**

Summary

- GNEP R&D program evolved from AFCI program that developed programmatic approaches to spent fuel waste management issue.
- AFCI emphasis was on R&D at national laboratories with support from universities, and a strong international collaboration
- These aspects remain in GNEP, but with a shift in emphasis to industry-led facility design supported by AFCI resources and with a larger role for advanced simulation and modeling
- In support of GNEP, R&D in the near-term will support technology development needs of GNEP facilities and in the long-term develop sustainable separations, transmutation fuel and recycle technologies and validated simulation and computational techniques to advance the development and approval of fuel cycle technology.
- Technology readiness will be evaluated using the TRL approach, along with assessment of external risks

BACKUP

SEPARATIONS

GNEP Spent Fuel Processing Methods have been Designed to Provide Substantial Repository Benefits

- **Minimize the loss of transuranic elements to high-level waste streams**
  - High recovery efficiency, goal greater than 99.9% of all transuranics
- **Substantially reduce the sources of greatest heat load imposed on the repository**
  - Short-term heat generators: cesium and strontium
  - Long-term heat generators: plutonium, americium, and curium
- **Potentially reduce the radiotoxicity level of the high-level wastes such that they are less toxic than the original uranium ore within a disposal period of 1,000 years**
  - Assurance of container integrity during that period
- **Substantially reduce the long-lived fission products and transuranic elements that are projected to contribute strongly to the radiation dose to future populations near the repository site**
  - Technetium-99, iodine-129, neptunium-237

Criteria for selection of LWR Spent Fuel Process

- Ability to accommodate very high throughputs (>2,000 t/y) economically
- Ability to achieve very high decontamination of the actinide products from lanthanide and other fission products
- No separated plutonium stream
- Flexibility to adapt to fast reactor recycle of partial transuranic mixture if required to ameliorate near-term fabrication issues

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- Led to choice of an aqueous solvent extraction process (UREX+1a) as the reference process
  - Suite of UREX+ processes available to meet future requirements

Suite of UREX+ Processes

Process	*Prod #1*	*Prod #2*	*Prod #3*	*Prod #4*	*Prod #5*	*Prod #6*	*Prod #7*
UREX+1	**U**	**I, Tc**	**Cs/Sr**	**TRU+Ln**	**FP**		
UREX+1a	**U**	**I, Tc**	**Cs/Sr**	**TRU**	**All FP**		
UREX+2	**U**	**I, Tc**	**Cs/Sr**	**Pu+Np**	**Am+Cm+Ln**	**FP**	
UREX+3	**U**	**I, Tc**	**Cs/Sr**	**Pu+Np**	**Am+Cm**	**All FP**	
UREX+4	**U**	**I, Tc**	**Cs/Sr**	**Pu+Np**	**Am**	**Cm**	**All FP**

- All processes provide the same repository benefits
- UREX+1 and UREX+1a are designed for homogeneous recycle of all transuranics to fast spectrum reactors
- UREX+2, +3 and +4 are designed for heterogeneous recycling, possibly as an evolutionary step, to preclude the need for remote fabrication of recycle fuel

Major Technical Challenges (LWR Spent Fuel Processing)

- **Maintain costs of spent fuel processing within reasonable bounds with the more complex processes required in order to meet GNEP objectives**
- **Minimize losses of transuranics to high-level waste**
  - Corollary: maximize value of recycled product (value of electricity produced)
- **Minimize waste volumes and costs of waste processing**
- **Minimize releases of gaseous products to the environment**
  - Tritium, iodine, krypton
- **Obtain reliable technical results in support of industrial-scale plant design when pilot-scale R&D facilities are not available**
  - Multi-laboratory synergies
  - International collaboration

Pyroprocess Development

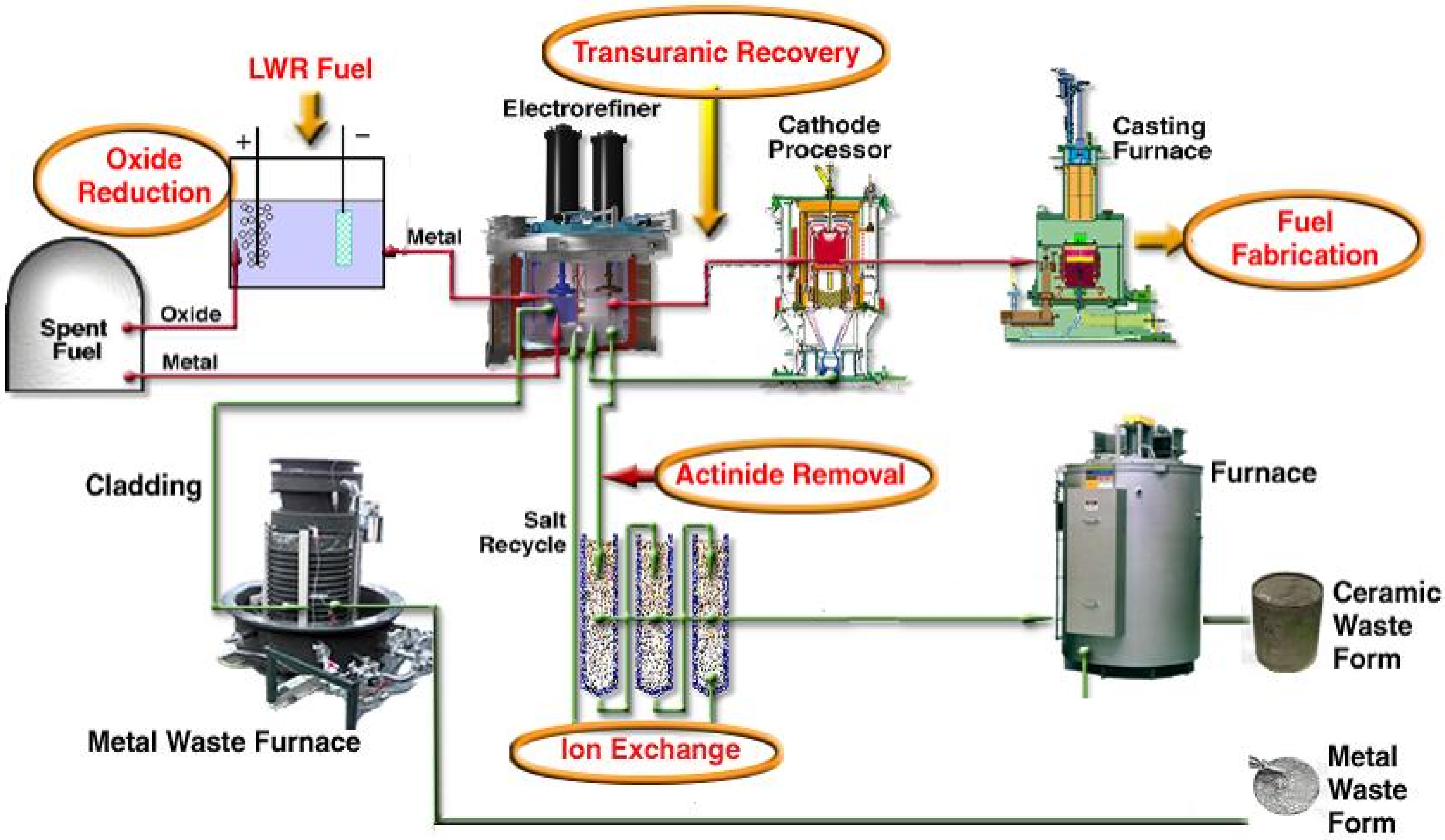
- **Pyroprocessing technology holds great promise for application to fast reactor recycle fuel processing**
  - Compact equipment, high temperatures (molten salt operations)
  - Insensitive to scale; deployable at small size
  - Criticality issues of lesser concern than with aqueous processes
- **Process has been applied in the conditioning of EBR-II spent fuel since 1996**
  - Process recovers enriched uranium for down'blending; transuranic elements are not recovered, but sent to waste
  - Remaining inventory:
    - *~21 metric tons blanket (depleted U with ~0.5-1.0% Pu)*
    - *~1.5 metric tons driver fuel (~57% enriched U metal)*
- **Pyroprocess seems to be well-suited to the processing of sodium-bonded metallic fast reactor fuel; perhaps less so for oxide fuel due to the need to carry out a reduction of the oxide to metal**
- **Russian process for direct electrorefining of fast reactor oxide fuel has some potential for use in GNEP**

Advanced Pyroprocess Development

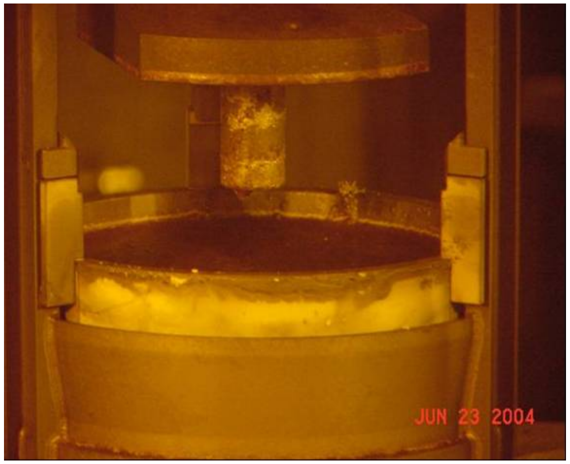
- **A portion of the pyroprocess flowsheet is being demonstrated in the course of EBR-II spent fuel conditioning**
  - Processing about 150 kg spent fuel per year
  - Highly-enriched uranium is recovered and down-blended
  - TRUs are not recovered, but sent to waste

- **GNEP program planning includes activities aimed at developing the complete pyroprocess**
  - Process is directed toward treatment of Advanced Burner Reactor spent fuel in low-throughput plants collocated with reactor parks on the order of 1 GWe capacity

Pyrochemical Processing Flowsheet



Group Actinide Recovery



- Transuranic recovery tests have focused on use of a liquid cadmium cathode (LCC) and electrolysis.
- LCC technology developed in the early 1990s.
- Limited work on electrolysis has been performed at ANL, but more testing is scheduled for FY07.
- LCC laboratory and engineering-scale tests were performed in FY04 and FY05.
- Tests included separation of cadmium from recovered actinides.
- LCC testing has also been performed by CRIEPI and JAEA in Japan.

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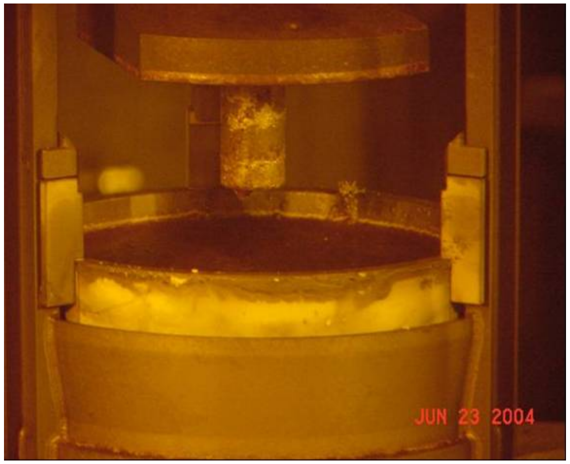

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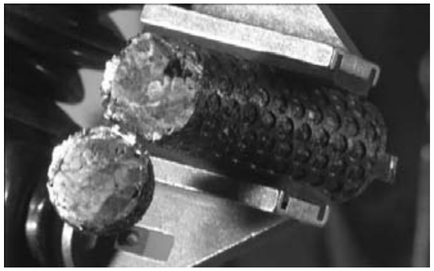
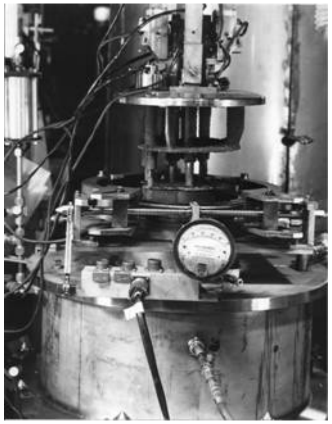
Oxide Reduction Tests with Spent Fuel





- Oxide reduction is performed to produce a metal feed to electrorefine in standard pyrochemical process.
- Work has focused on reduction step.
- Integrated reduction/electrorefining tests are ongoing.
- Six reduction tests were performed using BR-3 spent fuel (LWR fuel).
- Tests with irradiated MOX fuel will be performed in FY07.

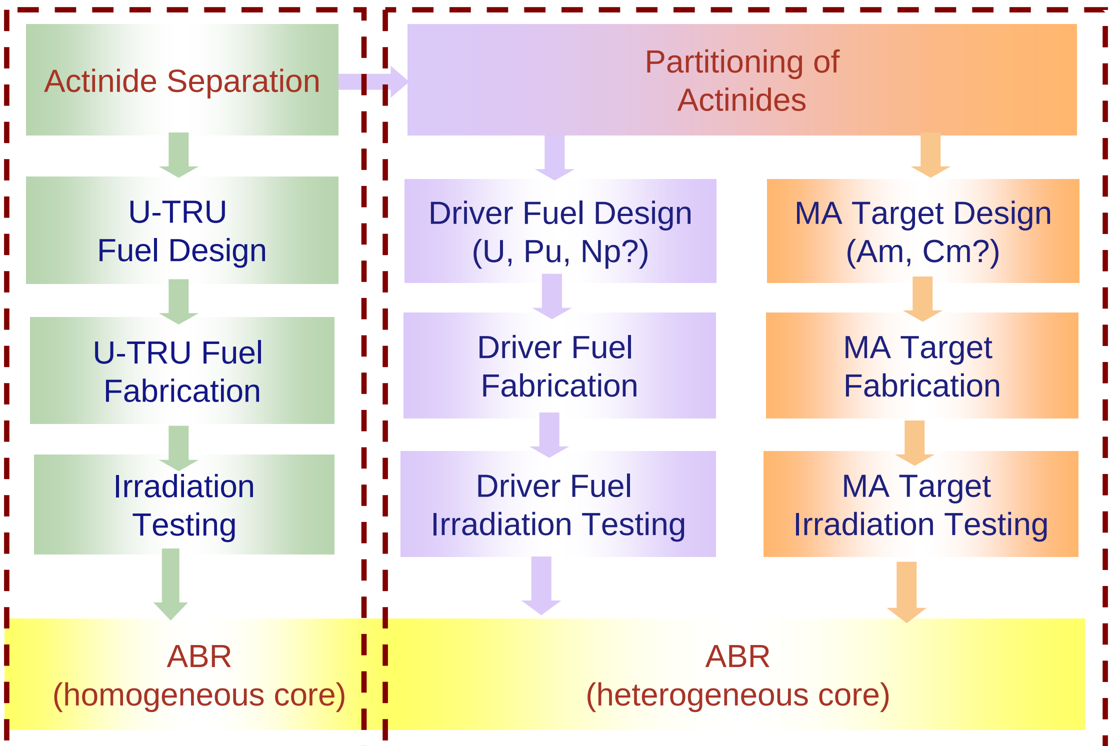
Major Technical Challenges (Pyroprocessing)

- Achieve high recovery efficiency for all actinides (uranium is easy, minor actinides are difficult)
- Reduce fission product contamination of uranium and transuranic products to acceptable levels (also need to establish what is acceptable for recycled transuranics)
- Reduce volume of ceramic waste by recycling electrolyte salt
- Reduce actinide losses to the metallic and ceramic waste forms
- Develop efficient method for extraction of cesium and strontium fission products from electrolyte salt
- Progress from laboratory-scale equipment to industrial-scale equipment for fast reactor oxide fuel processing
- Develop means for on-line measurement of transuranic content in process streams

BACKUP SLIDES

FUELS

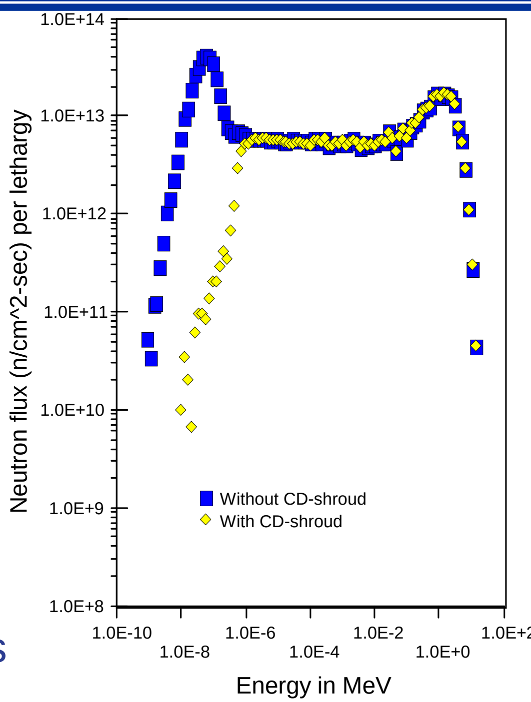
The definition of the transmutation fuel depends on the fuel cycle strategy and the reactor design

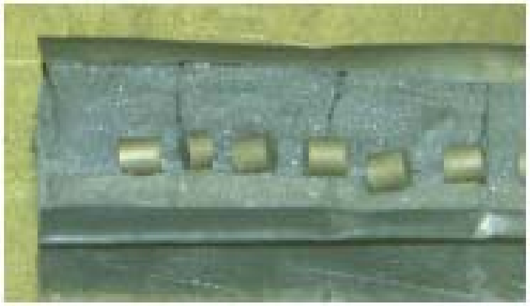


- Fuel development and qualification is a critical element closed fuel cycle.
- Fuel development must be very closely coordinated with the separations and burner reactor strategies.
- *The most direct path to achieving GNEP objectives is though U-TRU fuels unless such fuels prove to be technically or economically infeasible.*

Considerable progress was made under AFCI in developing basic concepts for transmutation fuels.

- Nitride and metal fuels were fabricated
  - Fuels containing U, Pu, Am, Np
  - Different processes are tested
- A series of ATR irradiations completed for TRU bearing metal and nitride fuels
- U-Pu-Np fuel samples fabricated and irradiated for potential LWR transmutation.
- Inert matrix fuel concepts (ZrO_2 - MgO matrix) are tested for potential LWR transmutation.
- An initial concept for carbide dispersion fuels developed, primarily for GFR applications.
- High-temperature matrix materials testing started.
- Candidate clad materials evaluated.
- Material and fuel samples from high-dose FFTF irradiation recovered and catalogued.





Metal and nitride transmutation fuel samples are fabricated for irradiation in Phenix Reactor (France).

- Four FUTURIX-FTA nitride and metal fuel samples and sodium-bonded rodlets are fabricated and shipped to France for irradiation in Phenix reactor.
  - Nitride pellets are fabricated at LANL, sodium-bounding and pin fabrication completed at INL.
  - Metal fuel slugs and the sodium bounded pins are fabricated at INL.
- Extensive FCCI studies by diffusion couples on metal fuels completed [with emphasis on AIM-1 SS clad (Phenix clad)].
- Additional metal fuel characterization completed and the handbook is updated.

Metal and oxide TRU fuels are candidates for the first generation transmutation fuel.

Candidates for First Generation Transmutation (< 20 years)

Oxide Fuels (powder processing)

- Successful small-scale fabrication and irradiation on limited amount of samples (France, Japan)
- Effect of group TRU on fabrication process unknown
- Effect of lanthanides on fabrication
- Large-scale fabrication amenable to hot-cell operations must be developed
- Limitations on linear power

Metal Fuel

- Successful small-scale fabrication and irradiation on limited amount of samples
- Large-scale fabrication without loss of Am must be demonstrated
- Fuel-clad interactions at high burnup must be investigated
- **Effect of lanthanides on FCCI must be addressed**

Back-up Options for Initial Candidates

- Sphere-pac or vibro-pac fuel technology
  Risk trade-off: fabrication versus performance

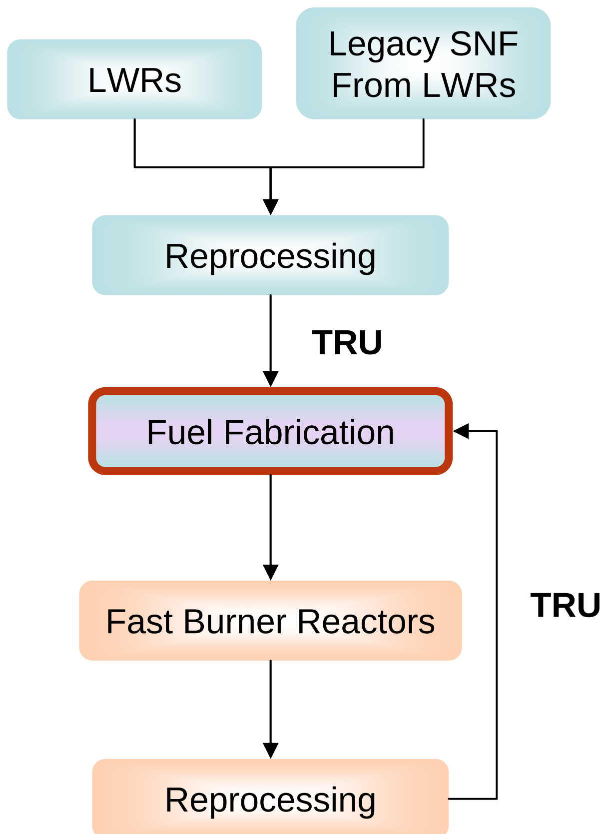
- Am recovery and use in moderated targets
- Fabrication using powder metallurgy
- Development of advanced clad materials (possibility of using liners)

Long-Term Options (2nd or 3rd Generation) for Increased Efficiency (> 20 years)

- **Nitride**
  - High TRU loading potential
  - Fabrication process requires further work
  - N-15 enrichment.
- **Dispersion**
  - High burnup potential
  - Fabrication process requires further work
  - Separations process must be developed

Transmutation fuel development is considerably more challenging than conventional fuels.

- Multiple elements in the fuel
  - U, Pu, Np, Am, Cm
- Varying thermodynamic properties
  - e.g. High vapor pressure of Am
- Impurities from separation process
  - e.g. High lanthanide carryover
- High burnup requirements
- High helium production during irradiation
- Remote fabrication & quality control
- Fuel must be qualified for a variable range of composition
  - Age and burnup of LWR SNF
  - Changes through multiple passes in FR
  - Variable conversion ratio for FR



Fuel fabrication process must be developed using existing facilities prior to large-scale demonstration.

Fabrication → Characterization → Irradiation → PIE

Fabrication

- Glove-box fabrication very slow
- Hot-cell facility needed.
- Stockpile materials limited (Am, Np, Reactor Grade Pu)
- Actual separated and co-precipitated materials needed

Medium schedule risk

Characterization

- Additional state-of-the art characterization equipment needed

Irradiation

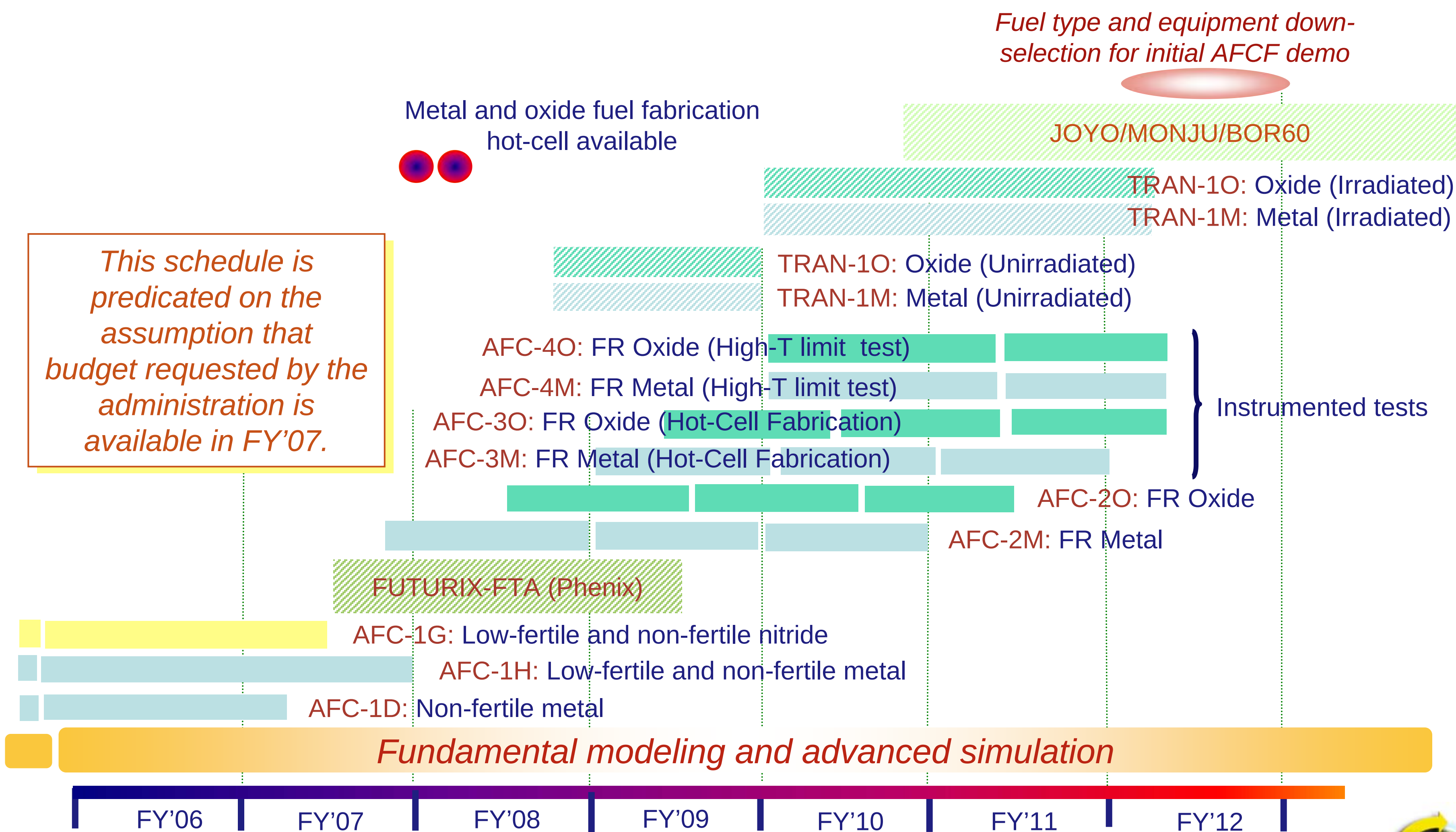
- Domestic fast-spectrum irradiation capability does not exist.
- ATR/HFIR irradiations with cadmium filter.
- More aggressive collaboration agreements (Joyo, Monju, BOR60)

High schedule risk

PIE

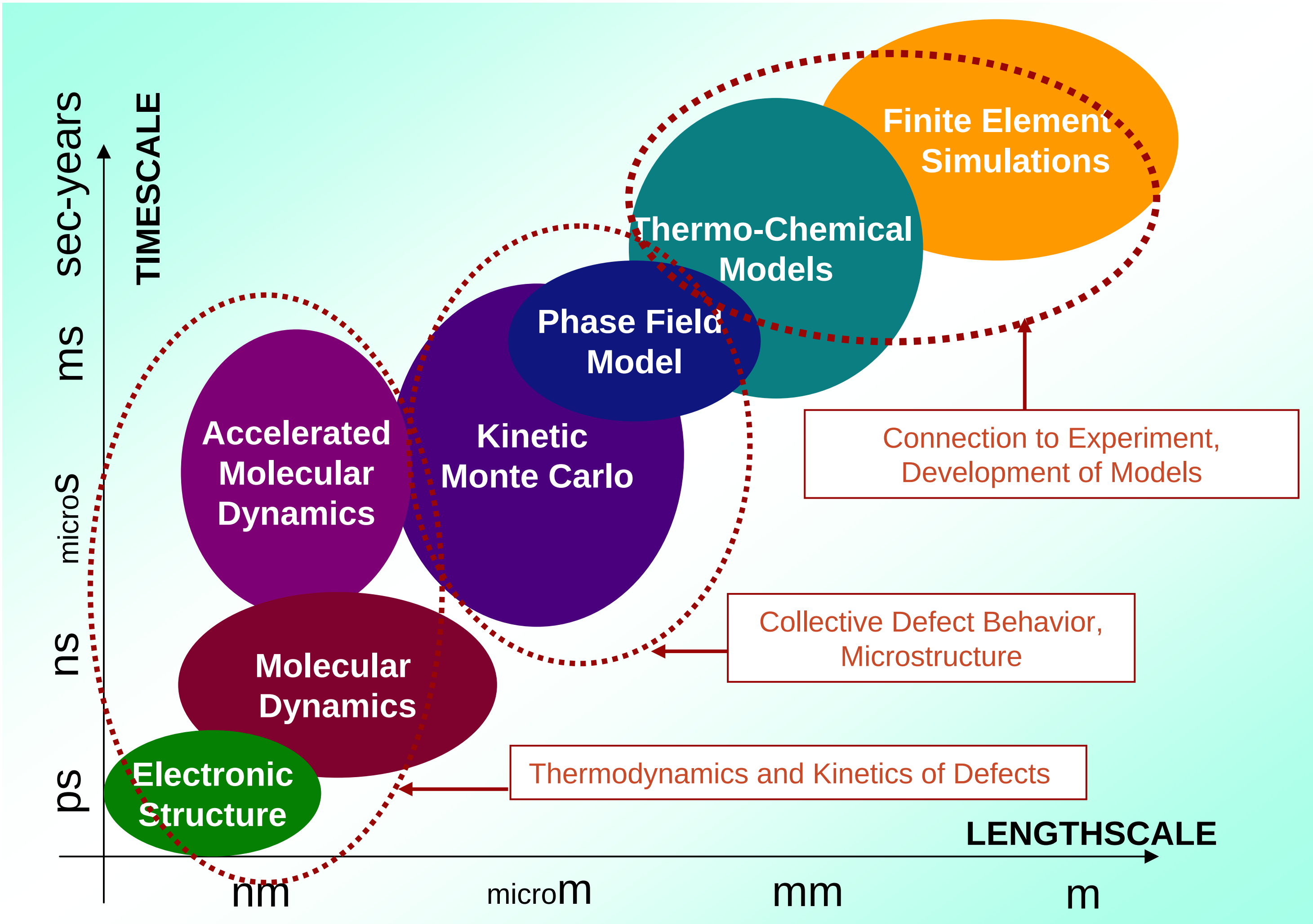
- Infrastructure requires serious refurbishment
- e.g. shielded microprobe, thermal characterization of hot fuels

Future irradiation schedule reflects emphasis on fast-reactor transmutation fuel down-selection in 2012 for the initial demonstration.



Multi-scale modeling approach is being used to develop fuel performance suite of codes. μ

Long-term pay off: Incremental improvements in reducing the number of tests and qualification duration



BACKUP

TRANSMUTATION SCIENCE/

FAST REACTOR TECHNOLOLGY DEVELOPMENT

Key Fast Reactor Technology Development Needs

- Closed Fuel Cycle Demonstration
  - **Previous experimental and demonstration SFRs used Pu or enriched U fuel forms**
  - **Must demonstrate closed fuel cycle with transmutation fuels (grouped TRU)**
- Establishment of Domestic Infrastructure to support SFR technology
  - **U.S. infrastructure severely eroded to support development of sodium-cooled fast reactor technology**
  - **Need to rebuild U.S. infrastructure while relying on international partners to meet schedules and goals as appropriate**
- Capital Cost Reduction
  - **Competitive SFR costs are a key to extensive GNEP fuel cycle utilization**
  - **Demonstrate viability of design options for cost reduction (previous examples)**
  - **Clarify capital costs for modern SFR design and construction**
- Reactor Safety Validation and Licensing
  - **Assurance of passive safety response with TRU fuels**
  - **Verifying techniques for evaluation of bounding events for licensing**

ABR Prototype: Technology Development

- Addresses Technology Development for ABR Prototype
  - Performs feasibility studies for select ABR Prototype components
    - Steam generator testing, accelerated aging of critical materials and components, passive fission gas monitoring , etc.
  - Performs key features testing of ABR Prototype critical components
    - Sodium pump performance testing, fuel handling machine testing, reactor shutdown system testing, seismic isolation bearing testing, water flow simulation stability testing, etc.
  - Performs testing of key ABR Prototype plant components to verify performance characteristics and safety responses in a prototypical environment
    - Primary pump testing, control rod drive mechanism testing, fuel handling system operations, testing, and recovery, qualification of structural materials, performance of reliability testing of shutdown systems, etc.
  - Ends with ABR Prototype safety tests
- Addresses economic issues of fast reactors
  - Develops and tests advanced fast reactor features that can contribute to improved economic performance

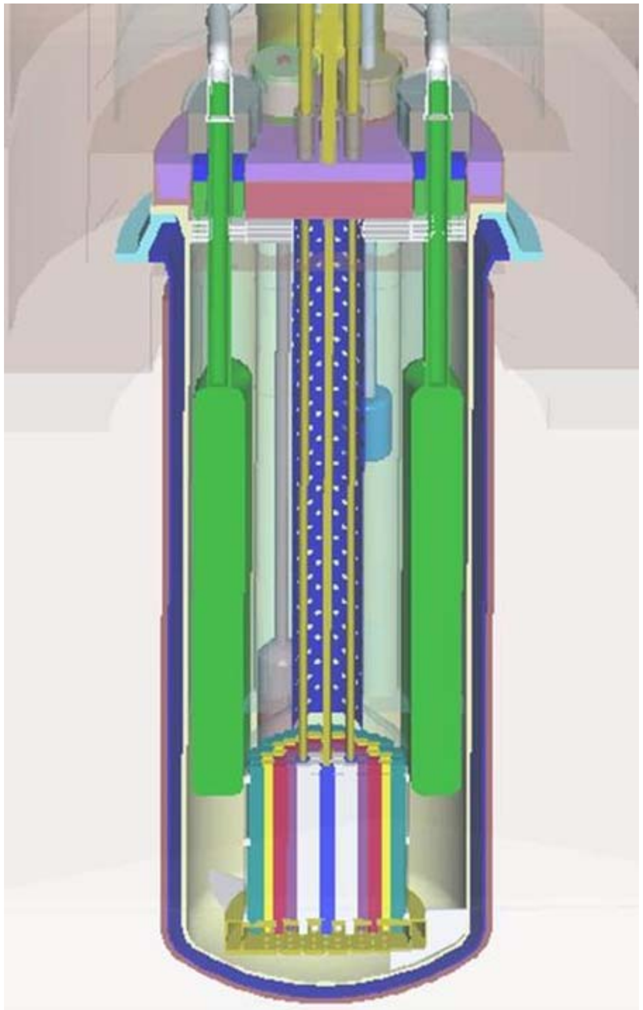
Additional Support Facilities Needed to support ABR development

- Water and/or sodium loop testing facilities for component testing
- Materials testing capability in fast spectrum (e.g., Phenix, JOYO, proposed gas test loop with fast flux booster at ATR, proposed Materials Test Station at LANSCE)
- Irradiation facility for differential and integral cross-section measurements of transuranics (e.g., DANCE, APS)

Use of Advanced Modeling and Simulation Tools for Fast Reactor Design

Simulation goals

- Develop improved methods to optimize the design, analysis and performance of sodium cooled burner reactors – using latest T/H, Neutronics, CFD tools
- Increase confidence in passive safety
- Decrease costs from excess margins
- Optimize fuel cycle through improved representation of fuel burn-up and fuel cycle operations (in-core and ex-core)
- Develop structural / seismic safety analysis



Advanced Safeguards Technologies

- **"Integrate Safeguards into facility designs"**
- **Proliferation Resistance and Physical Protection Working Group**
  - Established by Gen IV in 2002; developed methodology and metrics
  - Methodology being applied to advanced recycle facilities
- **Facility project managers have safeguards and security teams in place; recent Rokkasho experience being applied to designs**
- **Idaho Accelerator Center**
  - Developing real-time materials accountability and control monitoring systems using electron accelerators