Experimental Program to Stimulate Competitive Research

Annual Meeting

Advanced Nuclear Energy Systems

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Science and Technology

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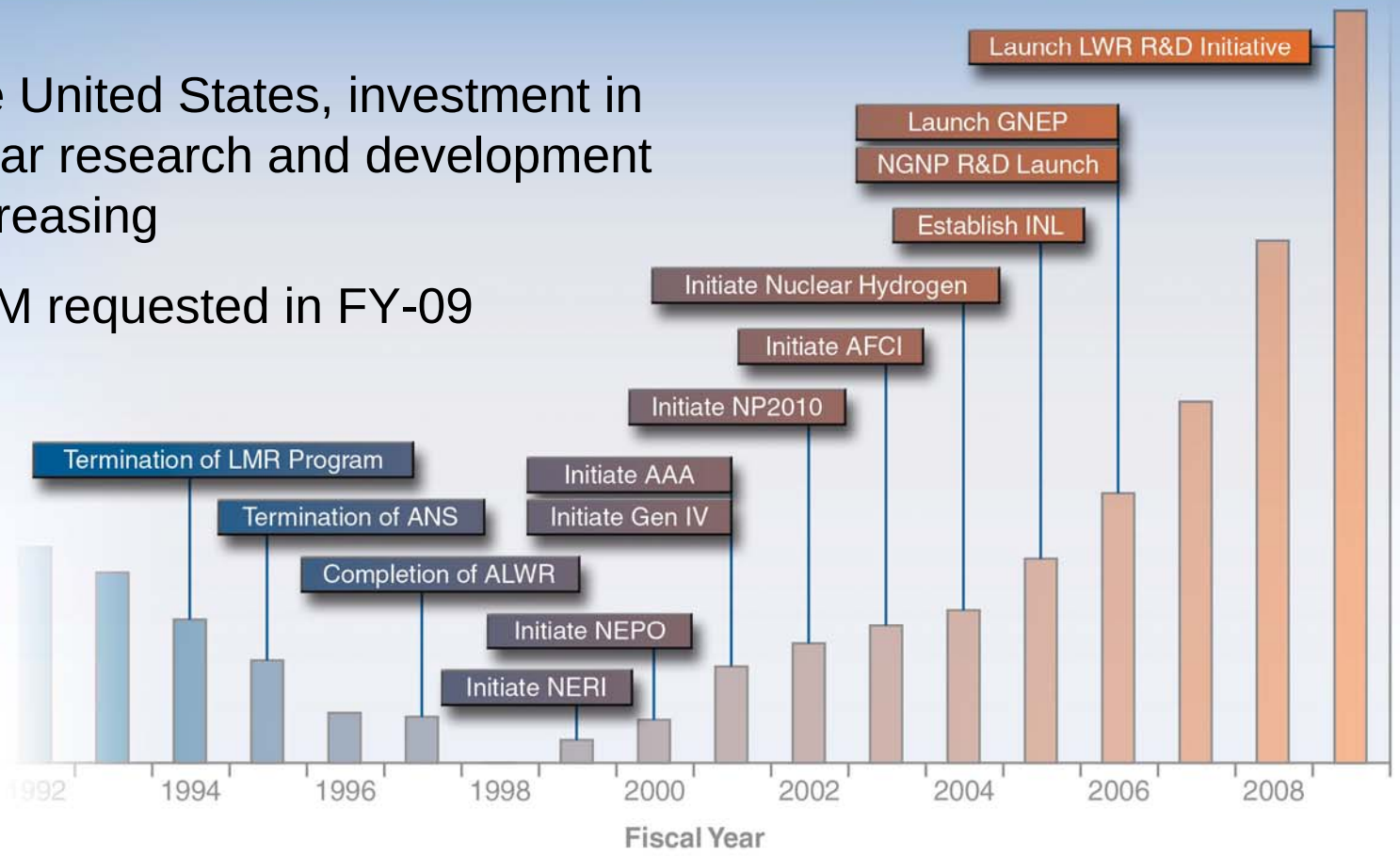
U.S. nuclear R&D investment is growing

- In the United States, investment in nuclear research and development is increasing
- $630M requested in FY-09



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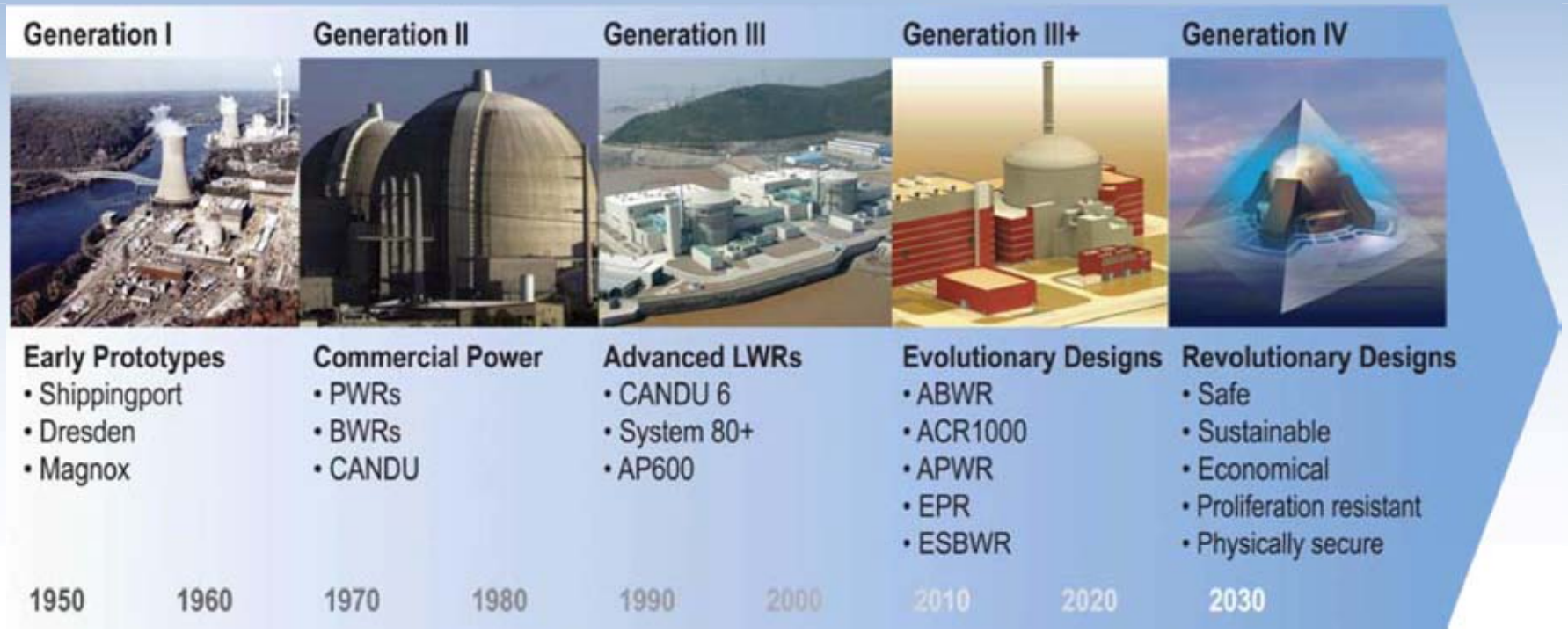
Expanding nuclear energy options



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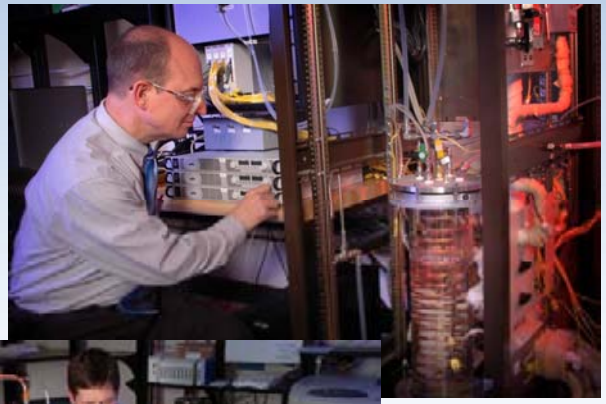
Generation IV– advanced concepts

GEN IV International Forum

U.S.A. | Russia | Switzerland | South Korea | South Africa | Japan | France | Canada | China | Euratom

- International collaboration on advanced reactor technologies representing improvements in waste intensity, performance, economics, and sustainability
  - 6 advanced reactor concepts
  - Deployable after 2030
  - Investment of 10 nations in collaborative R&D is over $100M per year
- US focus is on high temperature gas cooled reactor and sodium fast reactor
  - Beginning in FY-09, HTGR funded under NGNP and SFR funded under AFCI



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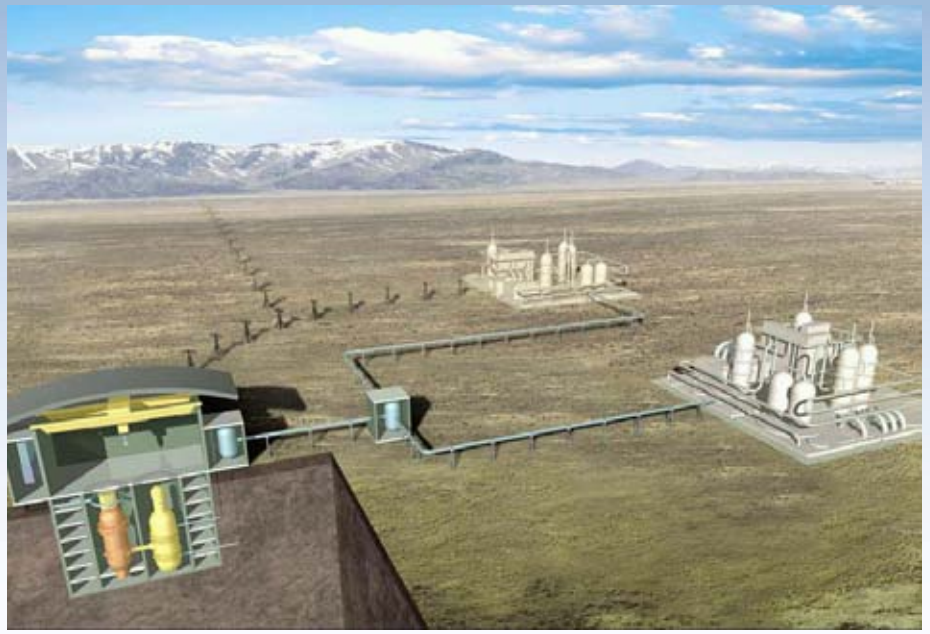
Next Generation Nuclear Plant – process heat applications

NGNP Next Generation Nuclear Plant

- Addressing barriers to development of high temperature gas reactor for process heat, electricity and hydrogen
- Particle fuels development
  - Design and Safety Analysis Computational Methods
  - Contemporary construction techniques
  - Regulatory framework
- 2021 operational date for NGNP demonstration at far end of acceptable schedule
- Nuclear hydrogen engineering demonstrations
  - High temperature electrolysis promising and can be coupled with NGNP, LWR, or SFR
  - S-I catalyst and membrane development work
  - Integration of nuclear hydrogen with upgrading of oil sands and production of synthetic liquid fuels



A public-private partnership will lead the development and demonstration of the NGNP

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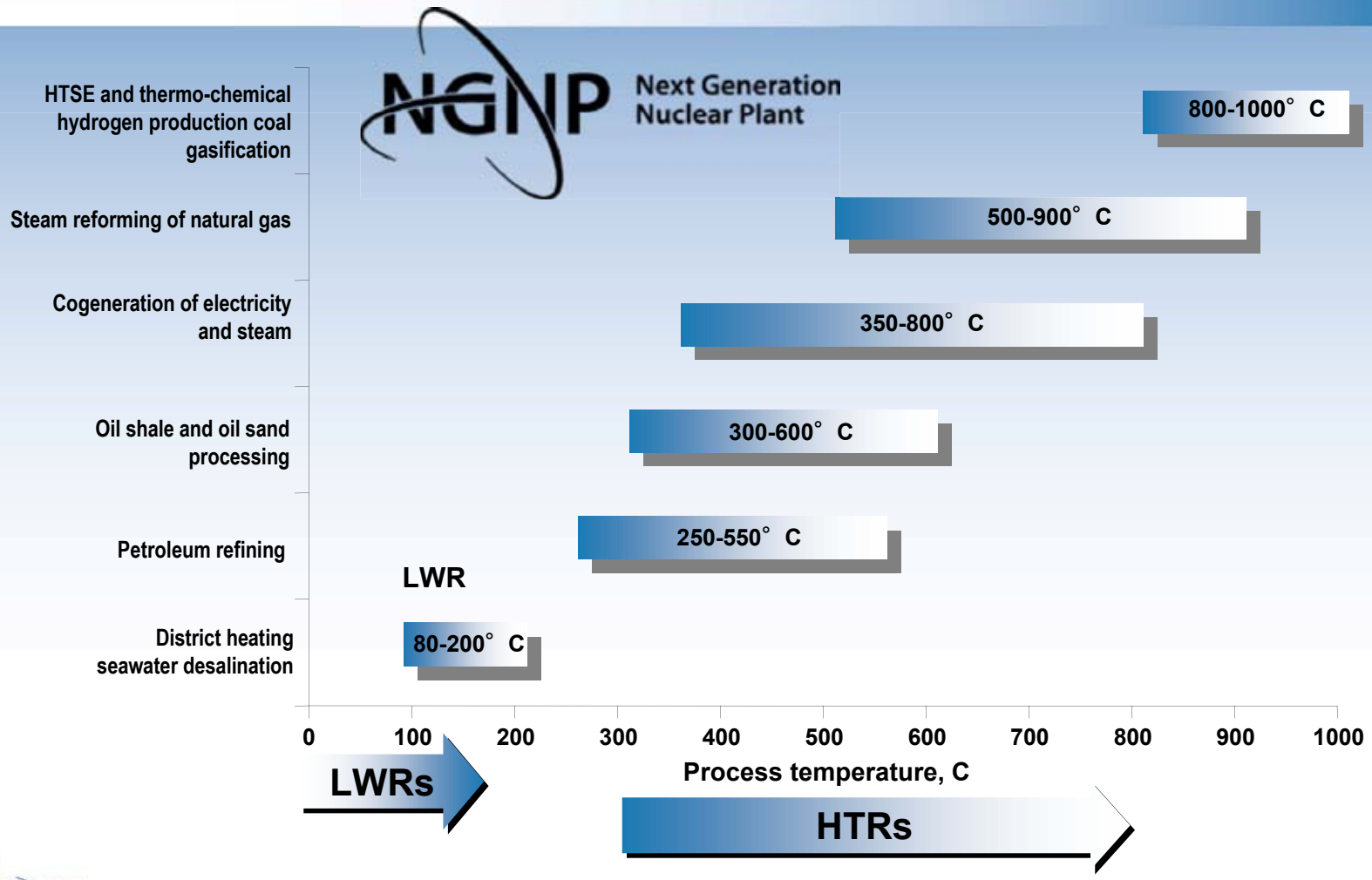
Different industrial processes require temperatures only attainable by HTRs



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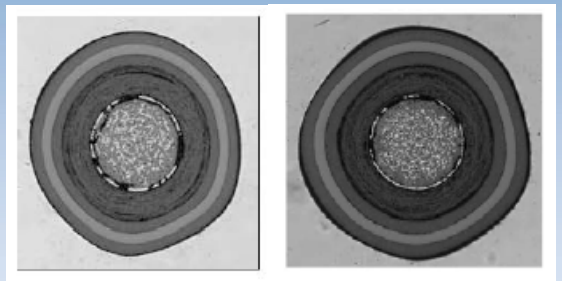
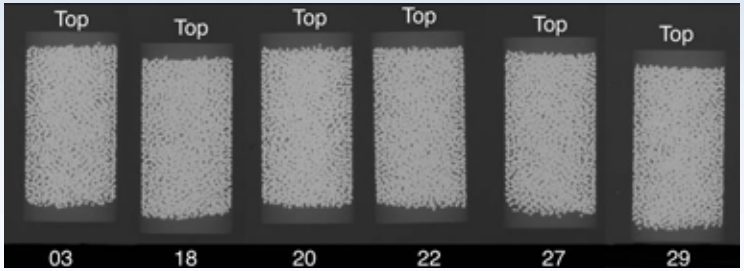
NGNP Fuel Development Program

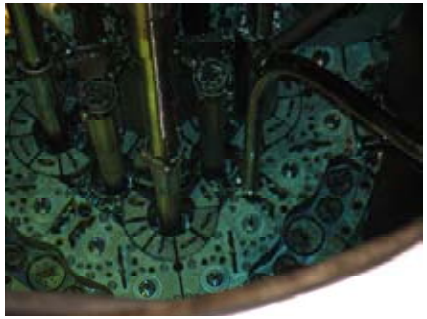
- Fuel is enriched UCO kernel with traditional German TRISO coating layers
- Goal is to qualify TRISO-coated particle fuel under normal and accident conditions through testing
- Currently irradiating lab-scale high-quality low-defect UCO TRISO in AGR-1 capsule (Average temperature 1100°C; peak temperature 1250°C). Currently at 11% FIMA with no failure> Irradiation will continue to 16% FIMA
- Currently fabricating TRISO fuel at production scale and preparing for safety testing of fuel



LEUCO coated particles



Insertion into INL ATR



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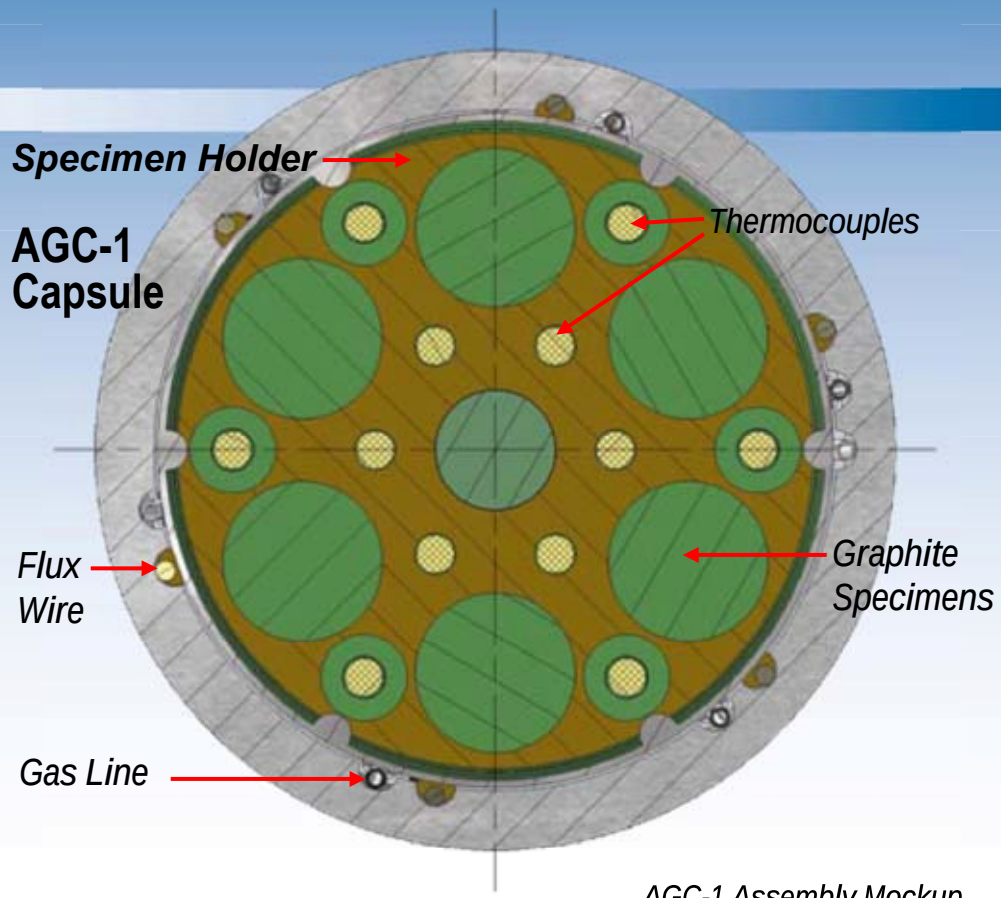
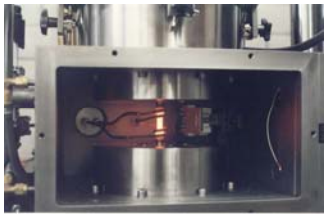
NGNP Graphite and High Temperature Materials Program

- Graphite:
  - Develop structural design data to validate current nuclear graphite types for use within NGNP
  - In service Inspection (ISI) capability
  - First graphite creep capsule (AGC-1) in final design
- High Temperature Materials:
  - Very high temperature testing of thermally stable nickel-based alloys: Creep, creep-fatigue, environmental performance in He
  - Development of database for ASME codification
  - ISI development



Creep Testing



Graphite Billet

AGC-1 Assembly Mockup

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NGNP Design & Safety Methods and Validation R&D

- Benchmark and validate models
- Resolve key safety, performance, and technical issues
- Modify, upgrade, and/or develop new analytical tools to reduce uncertainties and improve understanding the behavior and operating margins of the plant.
- Assist in definition of key experiments that will provide validation data for VHTR design and safety tools

INL's matched index of refraction (MIR) facility to study 3-D flow effects in plena

ANL facility to validate VHTR reactor cavity cooling system behavior

Graphite/air reaction rate testing

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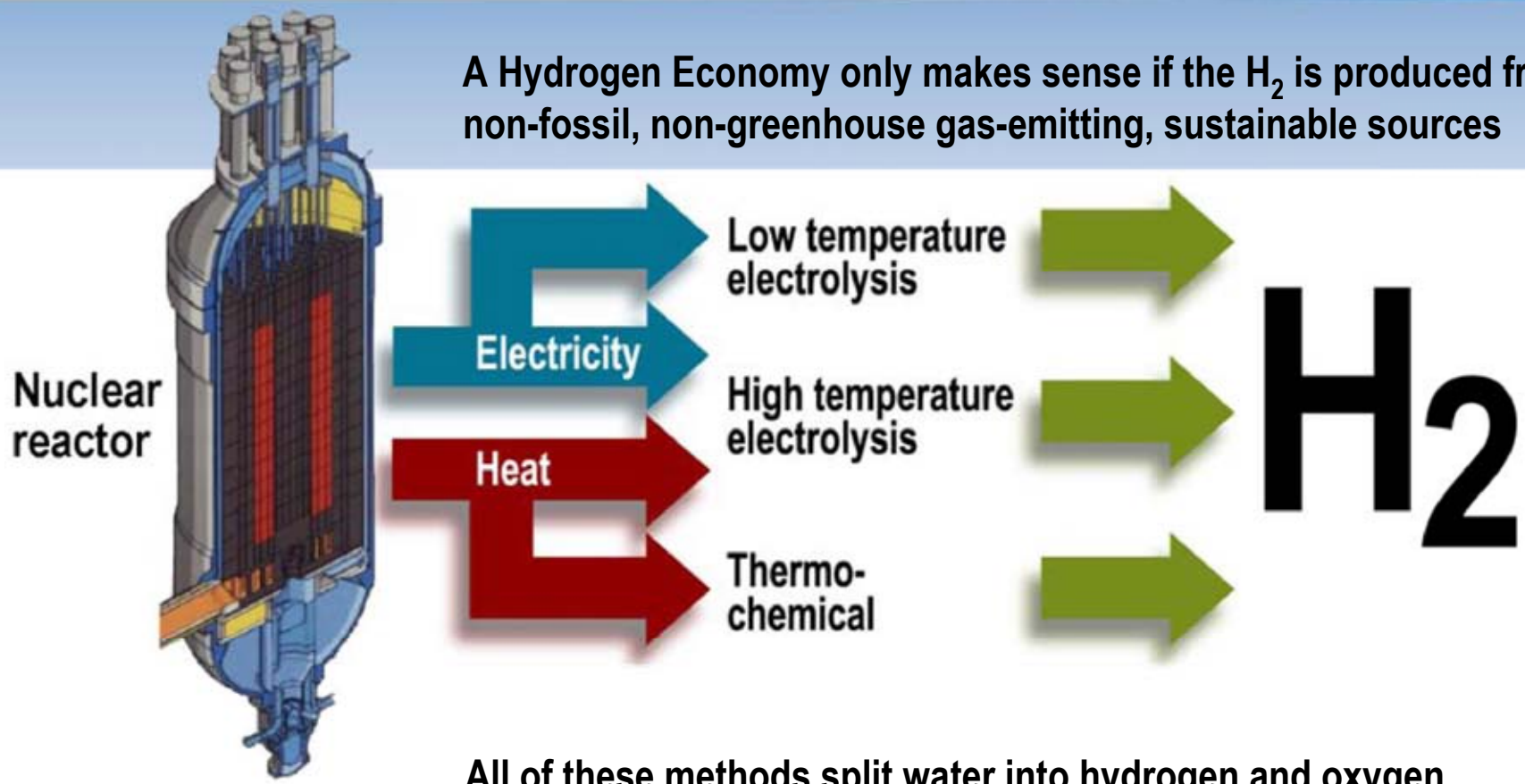
H_2 can be manufactured cleanly by using nuclear energy for water-splitting

A Hydrogen Economy only makes sense if the H_2 is produced from non-fossil, non-greenhouse gas-emitting, sustainable sources



All of these methods split water into hydrogen and oxygen

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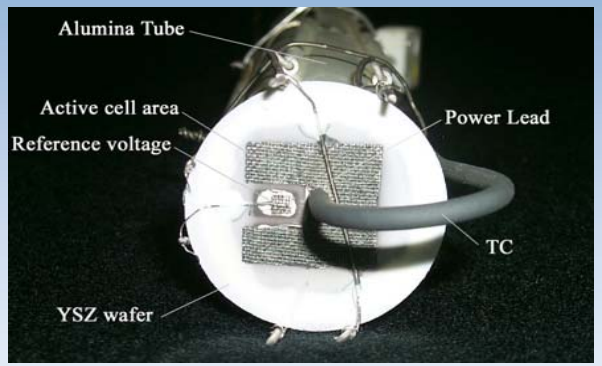
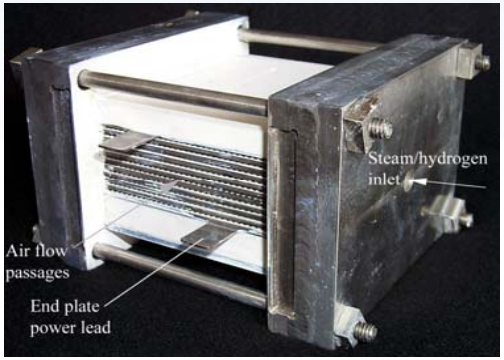
Nuclear hydrogen – from button cells to the integrated laboratory-scale experiment

- Develop efficient solid-oxide electrolysis cells, building on solid-oxide fuel cell research
- Decrease cost, increase durability
- Determine reasons for long-term cell degradation
- Optimize plant designs
- Co-electrolyze CO_2 and steam to CO and H_2
- Develop designs to apply nuclear heat and H_2 to heavy petroleum and oil sand upgrading
- Integrate nuclear energy sources and fossil/biomass carbon sources for hydrocarbon synthesis

120-cell half-module (2006) 7,680 cm^2



Button cell (2003) 3.2 cm^2



10-cell stack (2004) 640 cm^2

Integrated Laboratory Scale (operational 8-22-07)
720 cells, 3 modules (2008) 46,080 cm^2

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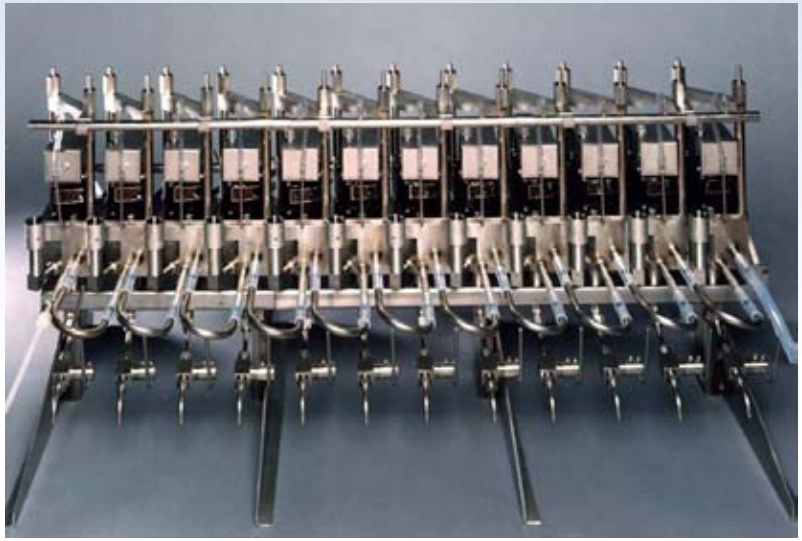
Advanced Fuel Cycle Initiative – Considering a closed nuclear fuel cycle

- Expansion of nuclear energy will necessitate moving to a closed nuclear fuel cycle
  - Better use of energy resources
  - Integrated and effective management of waste
- Advanced separations and processing of used fuel in combination with fast reactor systems, would result in geological disposal of waste much less hazardous, creating options for use of geologic repository space
- Research and development conducted by 11 national labs, involving universities, international organizations, and industry
  - Advanced Separations
  - Transmutation fuels development/qualification
  - Sodium fast reactor
- Research integrated across campaigns and cross cutting activities by Technical Integration Office at Idaho National Laboratory



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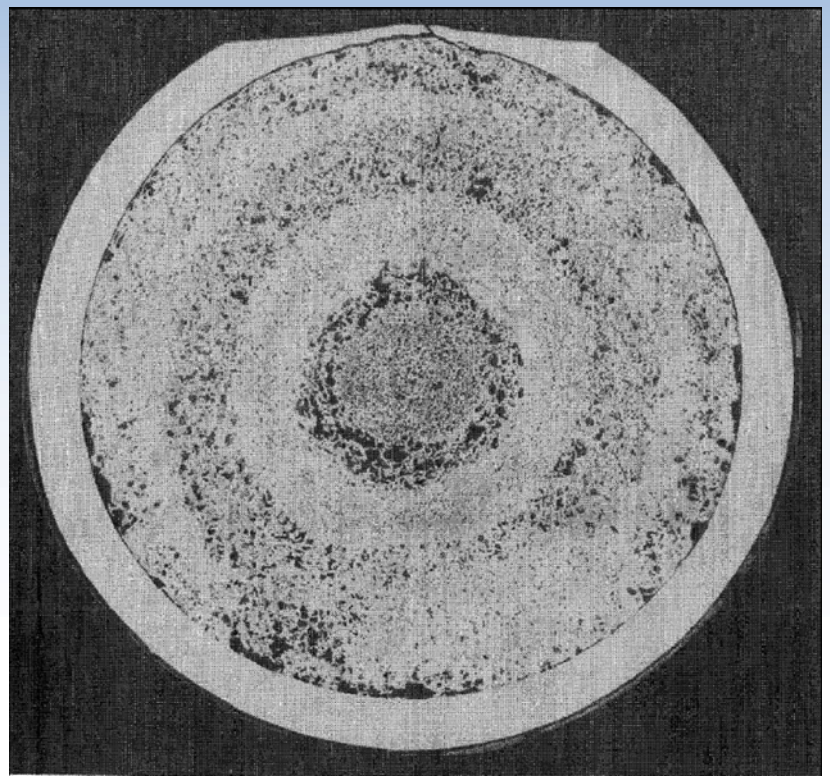
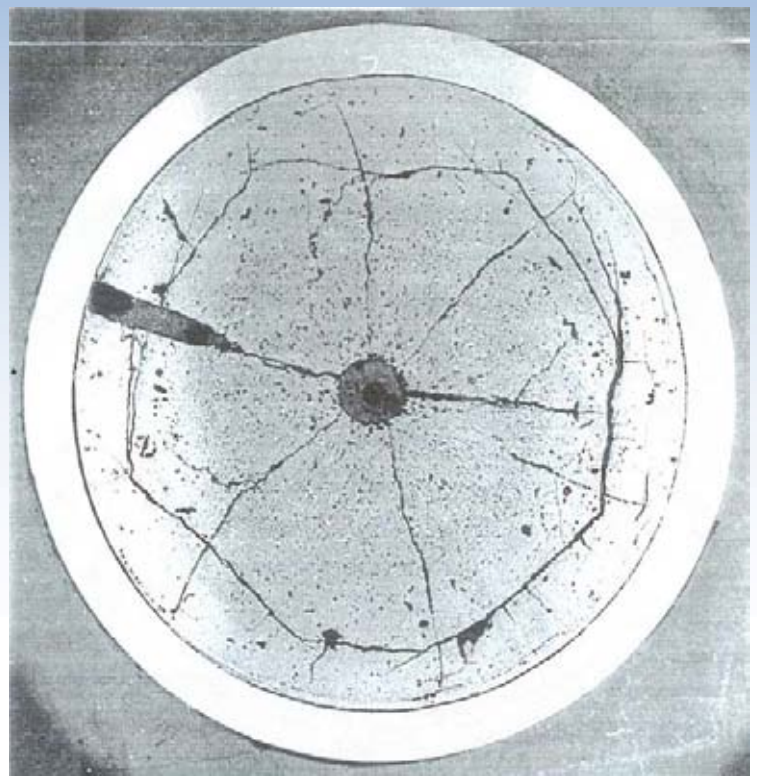
Conventional fast reactor fuels

qualified to ~10 at % burn-up and demonstrated to ~19.8 at % burn-up

Conventional (U-Pu-Zr) Microstructure (12 at%)



Conventional MOX Microstructure (6.5 at%)



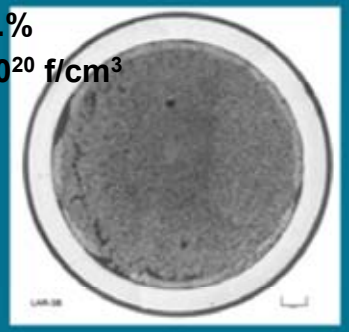
TRU bearing metal and oxide fuels

have demonstrated performance and feasibility to ~6 at % and current testing will extend this to ~15 to 20 at %

Metals

Performance similar to (U, Pu, Zr) and the onset of swelling at higher burnup than conventional (U, Pu, Zr)

6.0 at.%
6.8×10^{20} f/cm^3

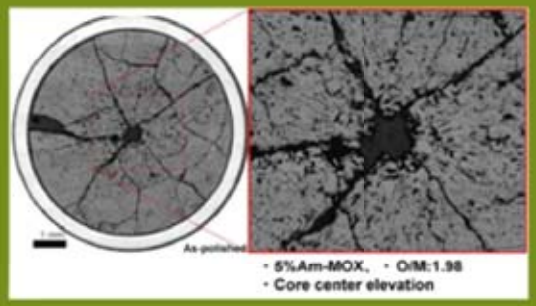


Nitrides

Have had difficulty with consistent fabrication but have performed as expected under irradiation.

Oxides

Performance and micro-structure develops similar to conventional MOX.

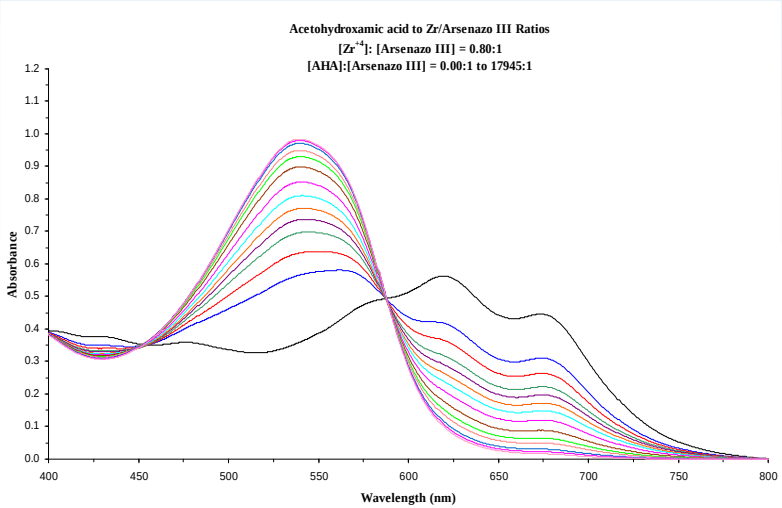


Feasibility of aqueous and electrochemical separations has been demonstrated

- Small-scale aqueous flowsheet tests with actual LWR met separation criteria (>99% recovery). ANL tests of UREX; future ORNL coupled tests (CETE)
- Fast reactor spent fuel processing demonstrated for uranium recovery (97.6% recovery)
- Recovery of uranium and transuranic elements at engineering scale using electrochemical methods
- Initial oxide reduction capability developed at kg scale (surrogates) and 50 g scale (>99% efficiency with actual fuel)

Separations Technology Development Strategy

- **Further develop and validate process models and utilize for process optimization and waste minimization**
- **Understand balance-of-plant issues (acid recycle, solvent losses, solvent wash, noble gas capture, etc)**
- **Perform integrated testing of separation processes to demonstrate controllability, understand interactions between processes, determine long-term solvent stability, and establish overall process reliability**
  - Engineering-scale testing with surrogates and uranium
  - Verification testing with small-scale equipment and spent nuclear fuel to confirm engineering-scale results



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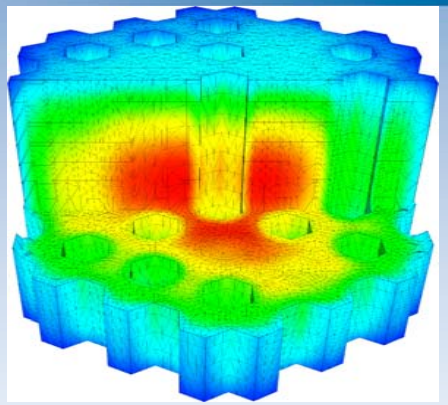
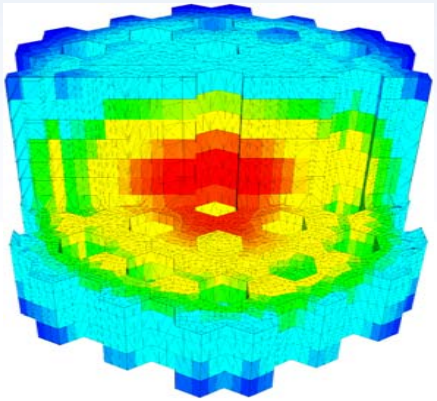
Modeling and Simulation

- Goal: an advanced, fully integrated multi-physics code
  - Coupled neutronics, thermal-hydraulics and structural mechanics calculations for design, operations, and safety
- Enable accurate predictions of system performance
  - Define service conditions for fuels, materials, and components
  - Quantify performance advances and increase assurance of performance gains
    - prior to system operation
- Reliably characterize and reduce modeling uncertainties, which necessitate over-conservatism in design
- M&S is the key area for US International Leadership



Group 1 Flux



Power Distribution

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The New NE University Initiative

Investing in a Clean, Safe, and Secure Energy Future through Education and Research

- NE expects to commit 20% of program funds to university R&D
- Efforts aimed at increasing integration of R&D in DOE's research
- Includes support for infrastructure and fellowships/scholarships
- Faculty grants relative to NE's R&D
- Administered by the Idaho Center for Advanced Energy Studies
- Workshop planned for August 19-20 in Bethesda, Maryland
- FY2009 award process to be launched this fall

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