The Generation-IV International Forum (GIF)

The Role of GIF International Cooperation in US Advanced Reactor R&D

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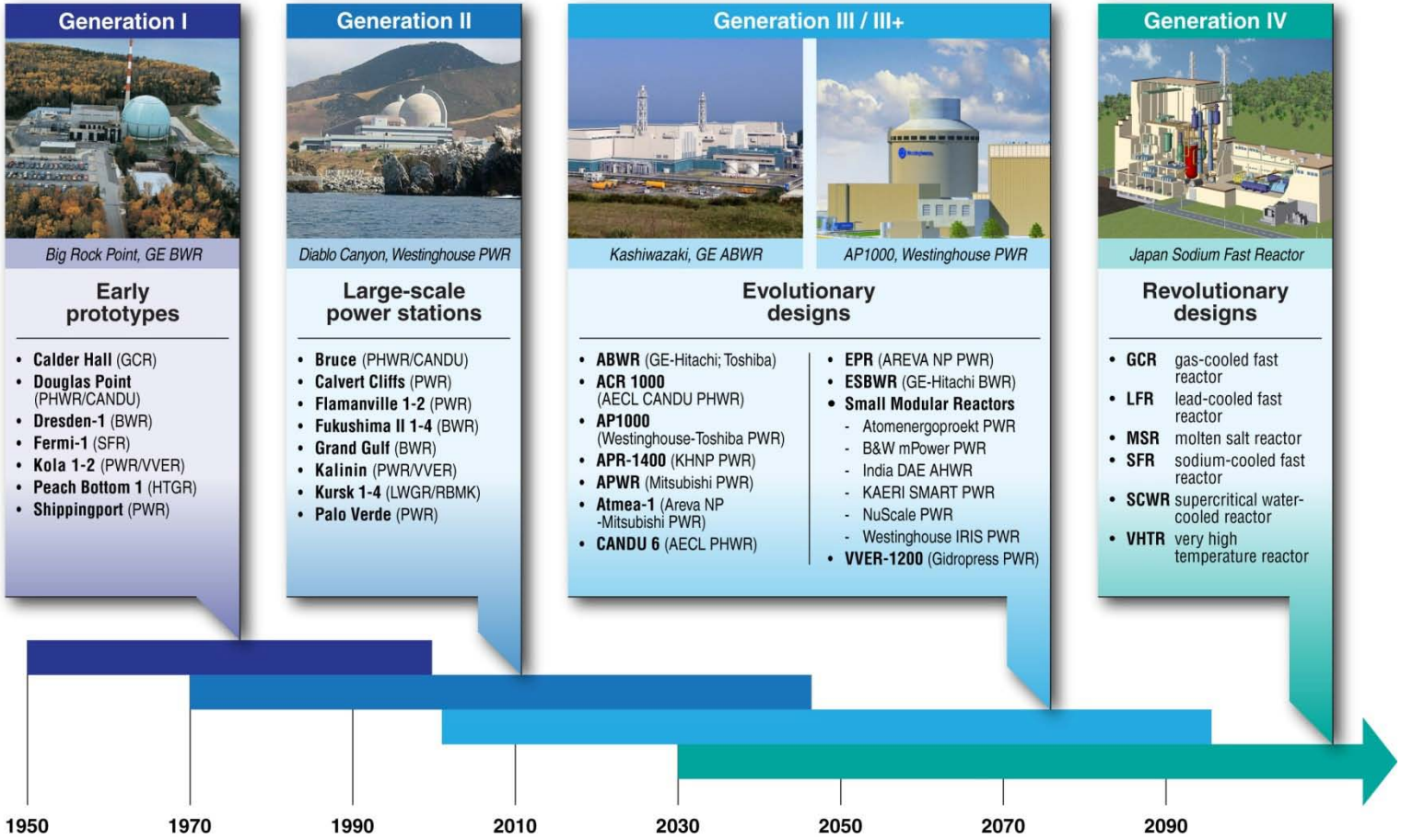
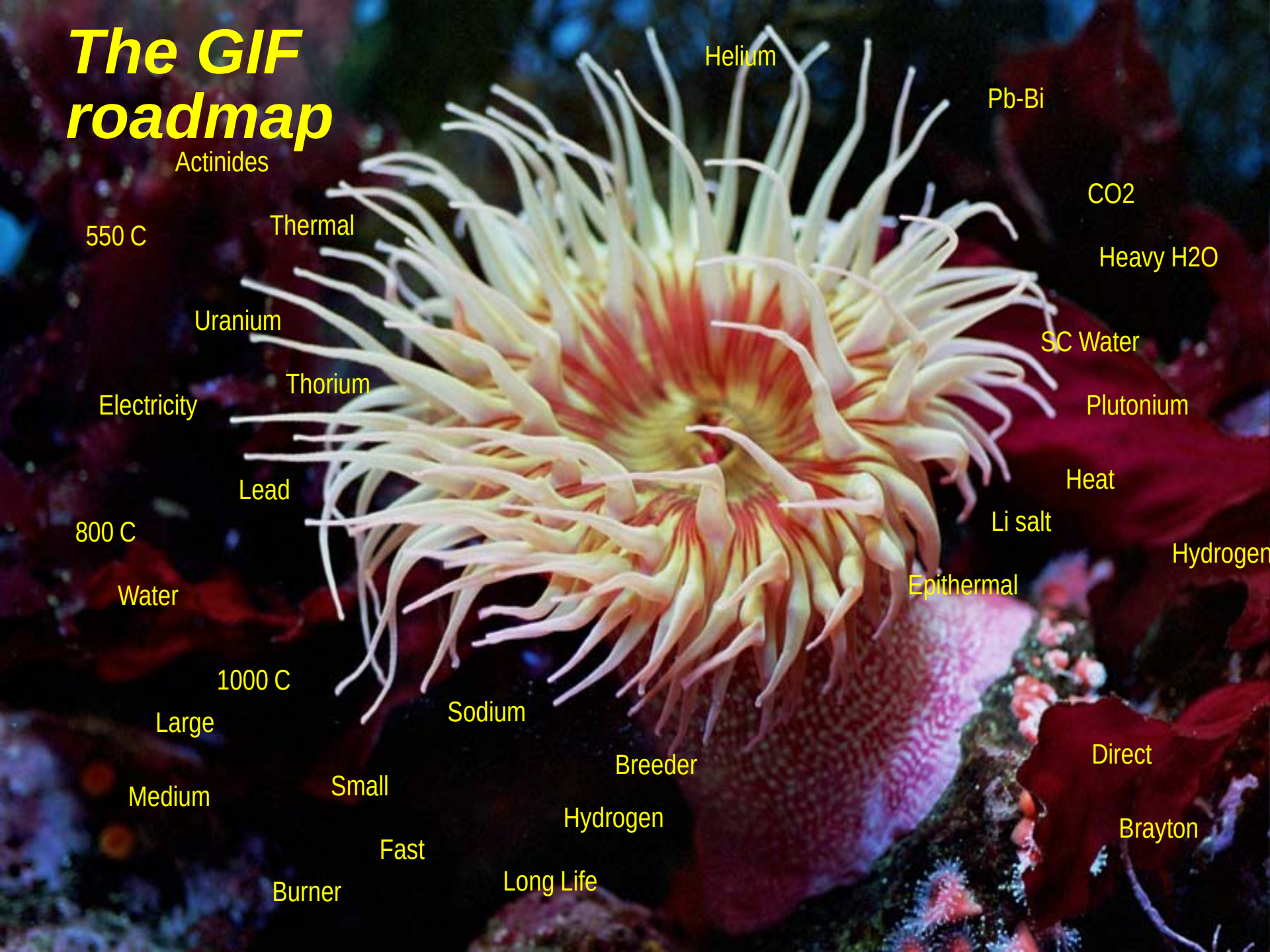
Generations of nuclear energy



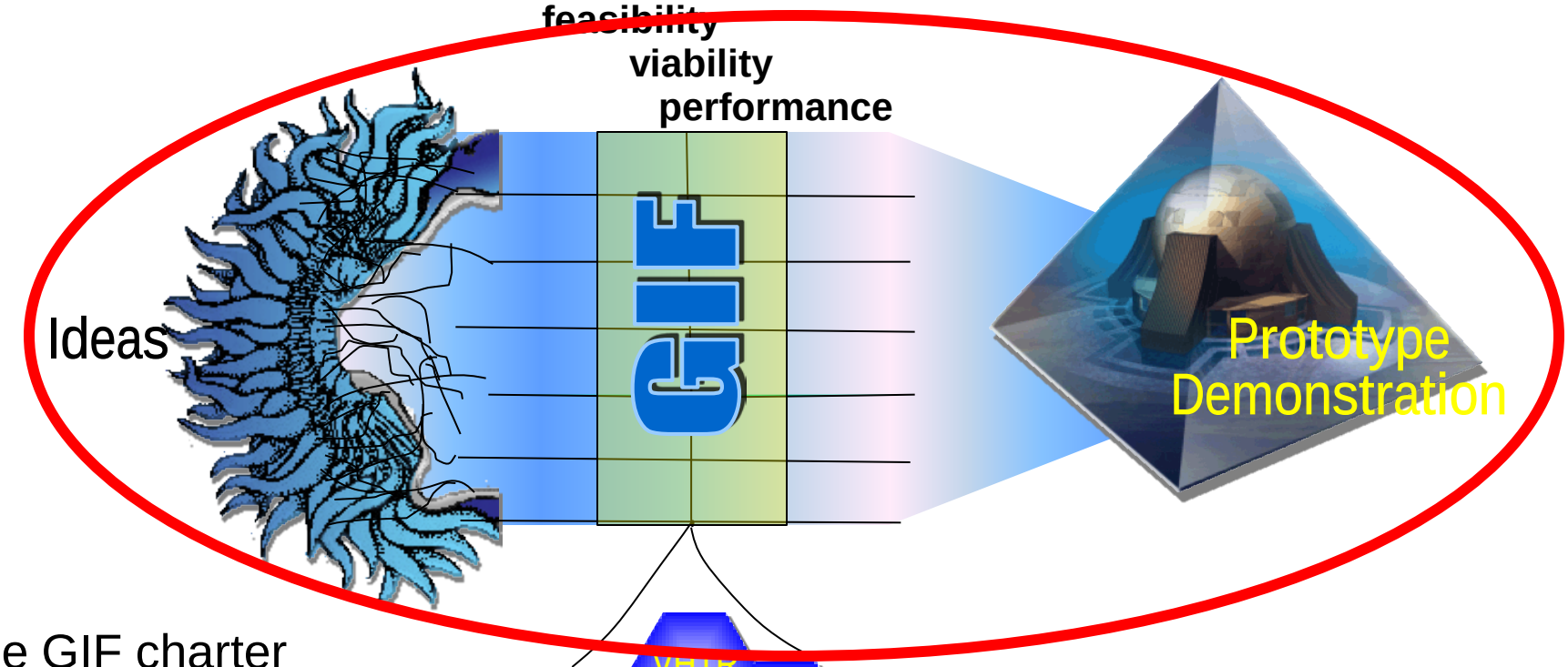
Generation-IV International Forum (GIF)

- ***Started January 2000 with a group of senior governmental officials from 9 countries.***
- ***Current member states:***
  - ***Argentina***
  - ***Brazil***
  - ***Canada***
  - ***China***
  - ***Euratom***
  - ***France***
  - ***Japan***
  - ***Republic of Korea***
  - ***Russian Federation***
  - ***Republic of South Africa***
  - ***United Kingdom***
  - ***United States***

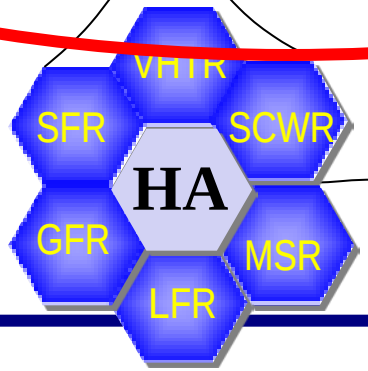
The GIF roadmap



From concept to demonstration

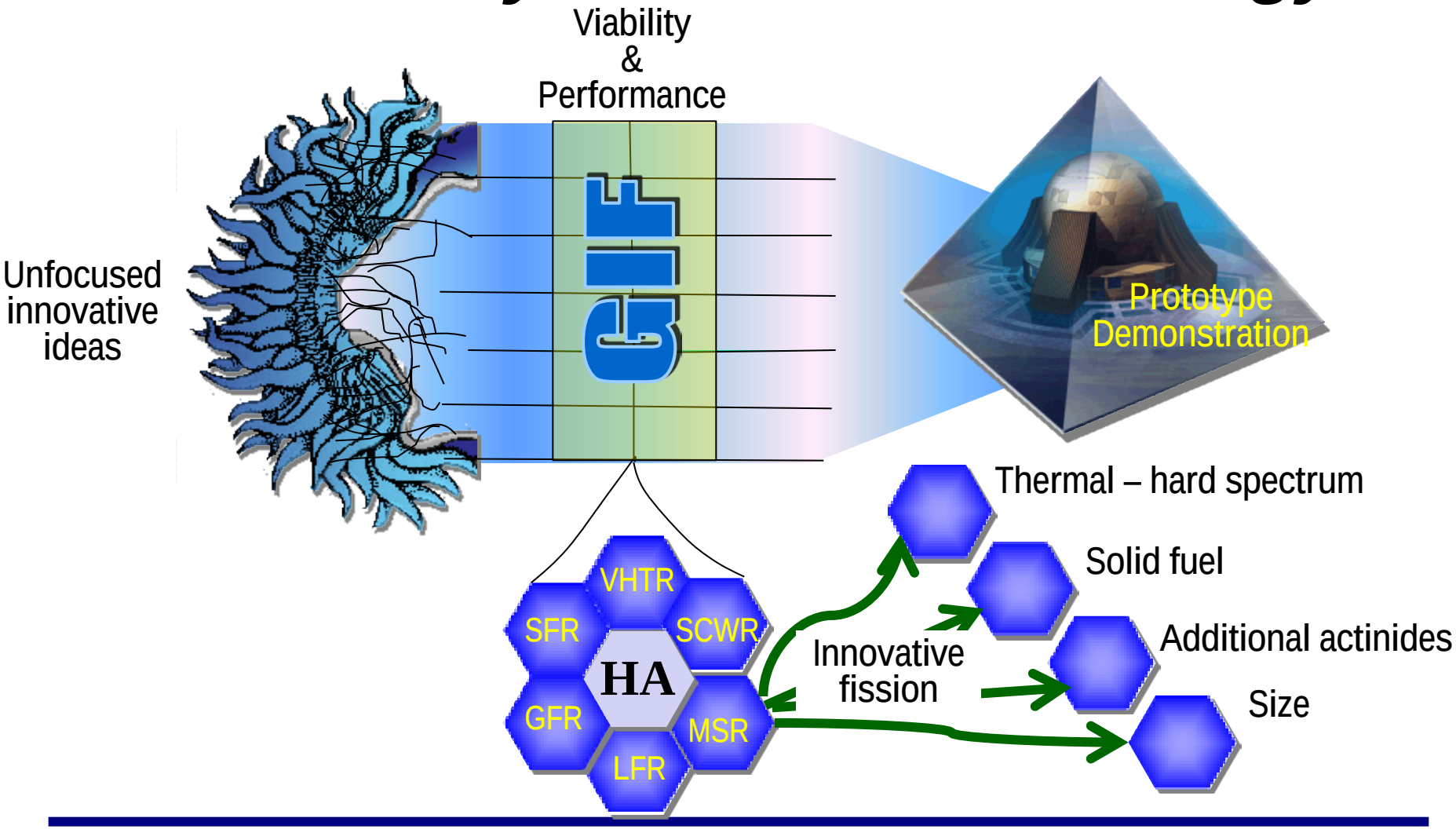


The GIF charter encompasses the complete development cycle and fuel cycle



Horizontal Activities
Economics
Safety
Proliferation

Focusing innovation to deliver commercially viable nuclear energy



Strategy

1. *Identify challenging goals*
2. *Create a multilateral framework for cooperation among leading nuclear development nations*
3. *Organize, grow, expand membership*

Goals

Sustainability: resources and waste management

Economics: Competitive cost and financial risk

Safety: Reliable, low risk of core damage, no EPZ

Proliferation: Not a weapons path; secure against terrorism

System Partners

VHTR	◆	◆	◆	◆	◆	◆	◆	◆	◆ Footnote	
GFR		◆	◆	◆		◆				
SFR		◆	◆	◆	◆		◆	◆		◆
SCWR	◆	◆		◆						
LFR		MOU 10/2010		MOU 10/2010						
MSR		MOU 10/2010	MOU 10/2010							
Partners	**NRCan**	**JRC**	**CEA**	**ANRE/JAEA**	**MEST/KOSEF**	**PSI**	**DOE**	**CAEA/MOST**	**DME**	**ROSATOM**

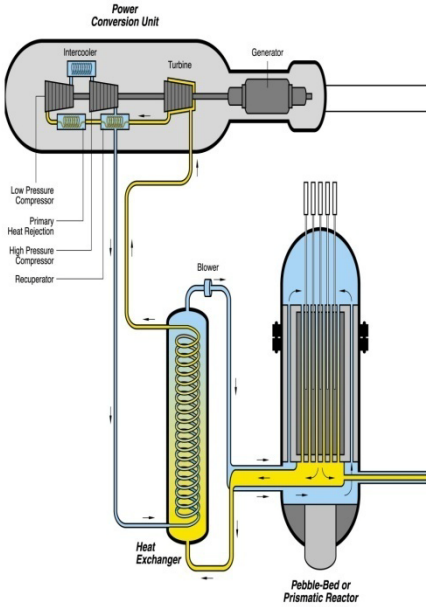
ANRE *– Agency for Natural Resources and Energy (JP)*
CAEA *-- China Atomic Energy Authority (CN)*
CEA *– Commissariat à l'Énergie Atomique (FR)*
DME *– Department of Minerals and Energy (ZA)*
DOE *– Department of Energy (US)*
JAEA *– Japan Atomic Energy Agency (JP)*
JRC *– Joint Research Centre (EU)*
KOSEF *– Korean Science and Engineering Foundation (KR)*
MEST *– Ministry of Education, Science and Technology (KR)*
MOST *– Ministry of Science and Technology (CN)*
NRCan *– Natural Resources Canada (CA)*
PSI *– Paul Scherrer Institute (CH)*

VHTR *– Very-High-Temperature Reactor*
GFR *– Gas-Cooled Fast Reactor*
SFR *– Sodium-Cooled Fast Reactor*
SCWR *– Supercritical Water-Cooled Reactor*
LFR *– Lead-Cooled Fast Reactor*
MSR *– Molten Salt Reactor*

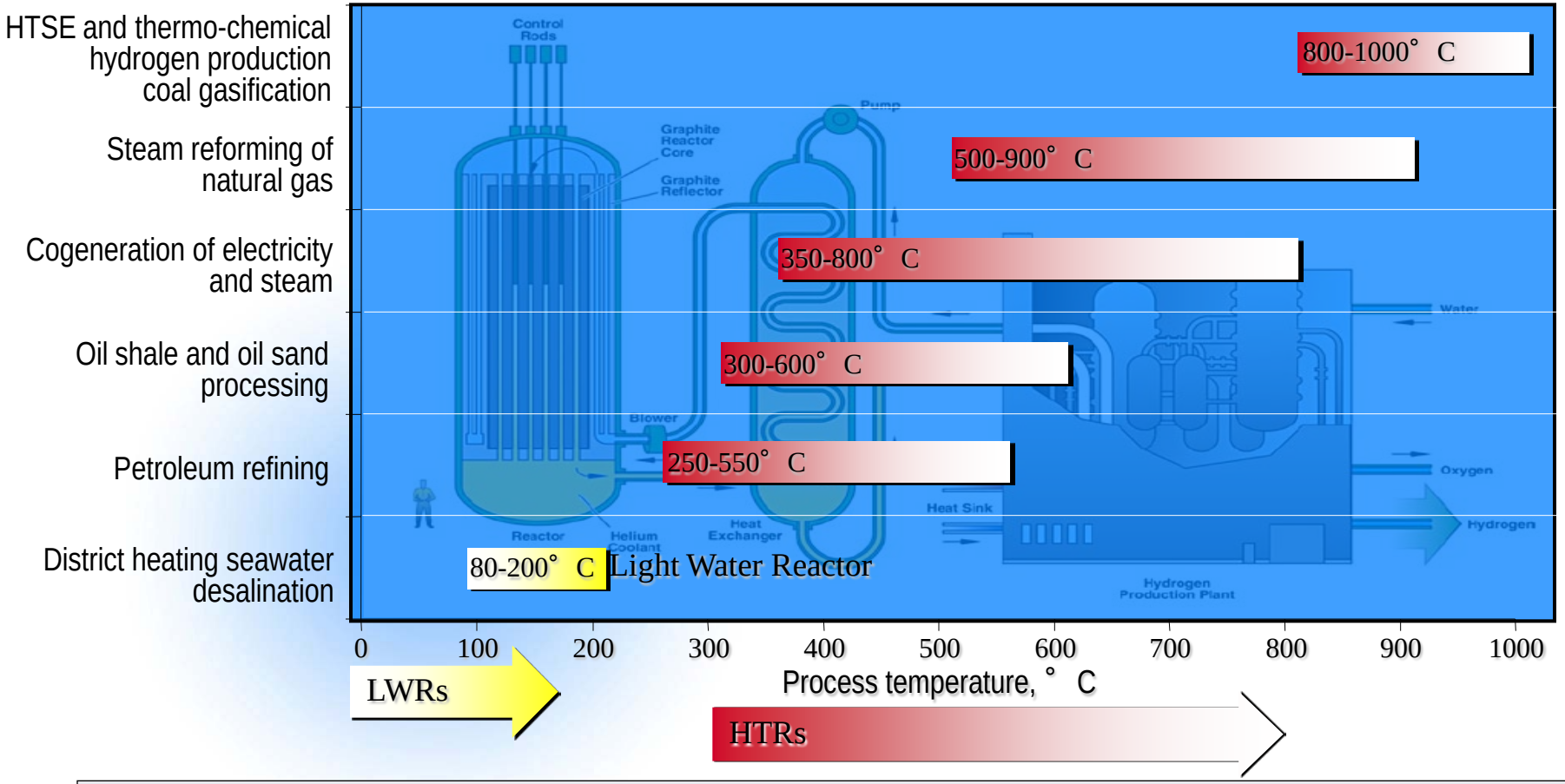
Footnote: South Africa is member of VHTR Materials & Components Project but is not a signatory to the SA

Very High Temperature Reactor outlook

- ***Strong national programs and GIF arrangements***
- ***Benefits from large national programs with plans for near-term prototype construction of GCRs with outlet temperatures of 750-850 C.***
- ***Goal: Complete viability phase in 2010***
- ***Technical focus***
  - ***TRISO fuel (oxide and oxicarbide)***
  - ***Hydrogen production processes***
  - ***Core and cooling system materials***
  - ***Computational modeling and validation***
- ***Requirements for R&D: set power and temperature requirements, move into performance and design optimization phase.***

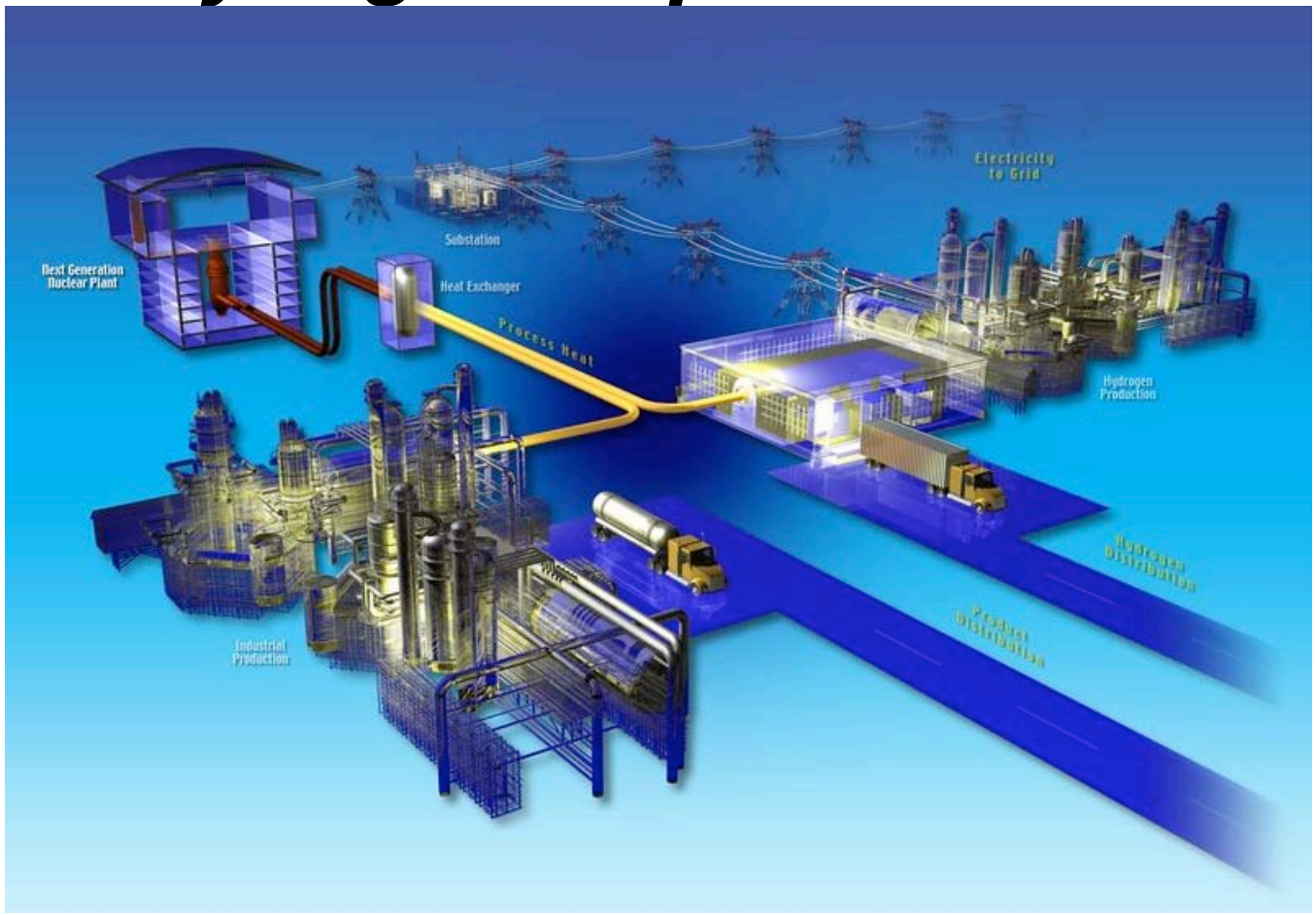


Higher temperature expands the range of applications



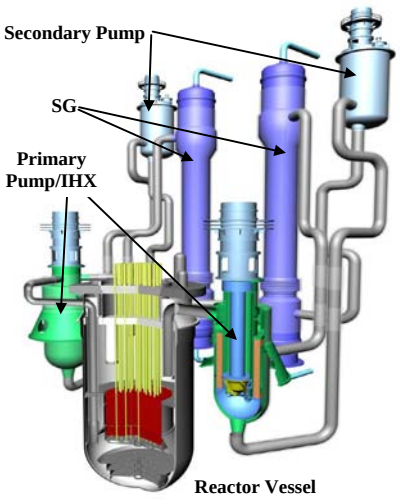
There is a role for existing LWRs, advanced LWRs, and small reactors…

NGNP: The US Project
Very high temperature nuclear heat



- Transportation
- Manufacturing
- Refining
- Mining
- Water

Sodium Fast Reactor outlook

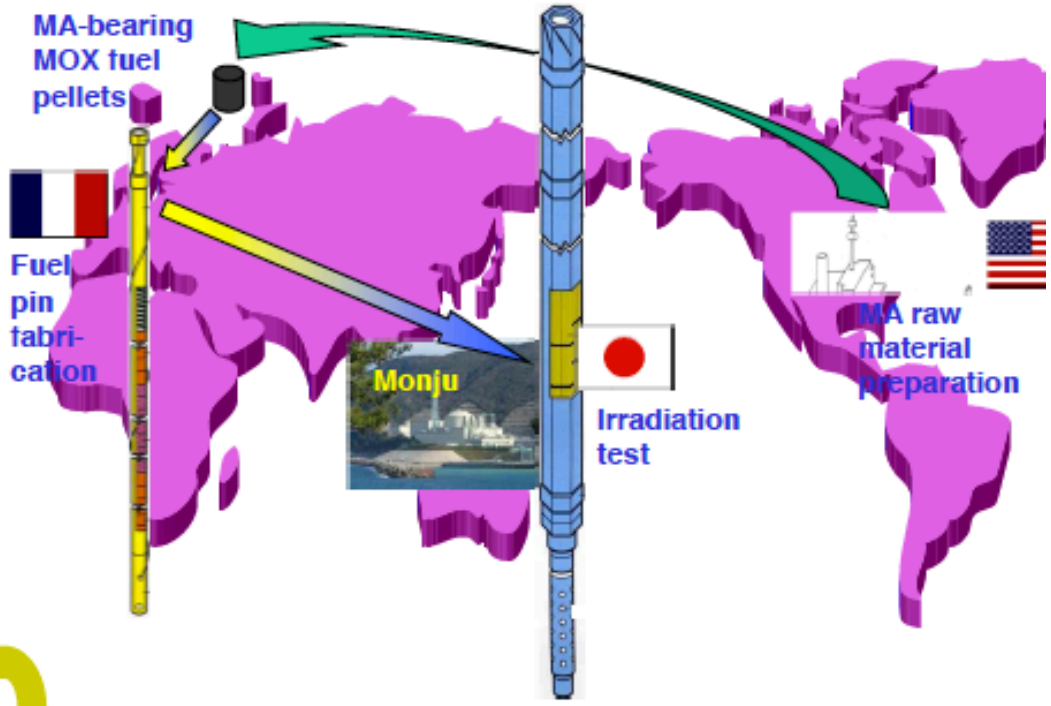


- *Strong national programs and experience*
- *Goal: Complete performance phase by 2015*
- *Gather fresh operating experience from existing, new and restarting reactors*
- *Key technical focus*
  - *Advanced fuels including actinide recycling—GACID project*
  - *Converge safety approach*
  - *Resolve feasibility issues regarding in-service inspection and repair*
  - *Energy conversion systems*
  - *Codes and standards for high temperature application*
  - *System integration*

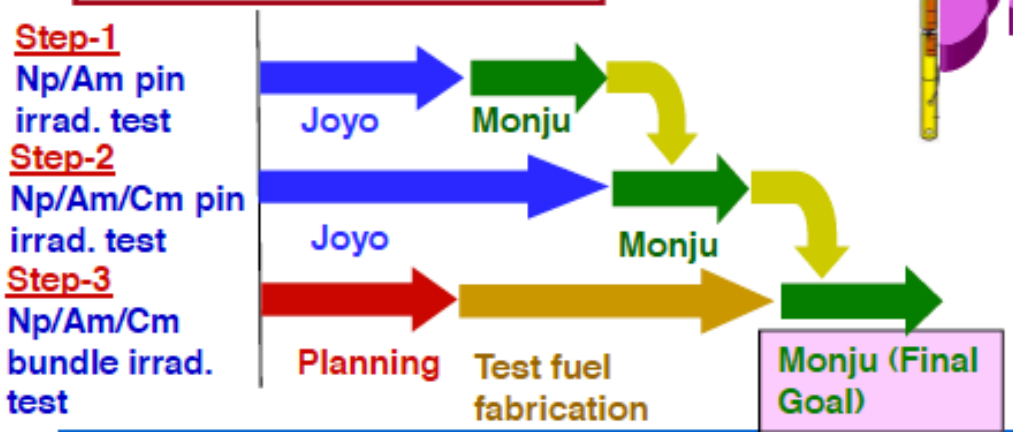
SFR/GACID Project

- *Objective: to demonstrate, using Joyo and Monju, that FR's can transmute MA's (Np/Am/Cm) and thereby reduce the concerns of HL radioactive wastes and proliferation risks.*
- *A phased approach in three steps.*
- *Material properties and irradiation behavior are also studied and investigated.*

Tri-lateral collaboration in GACID pin-scale tests.



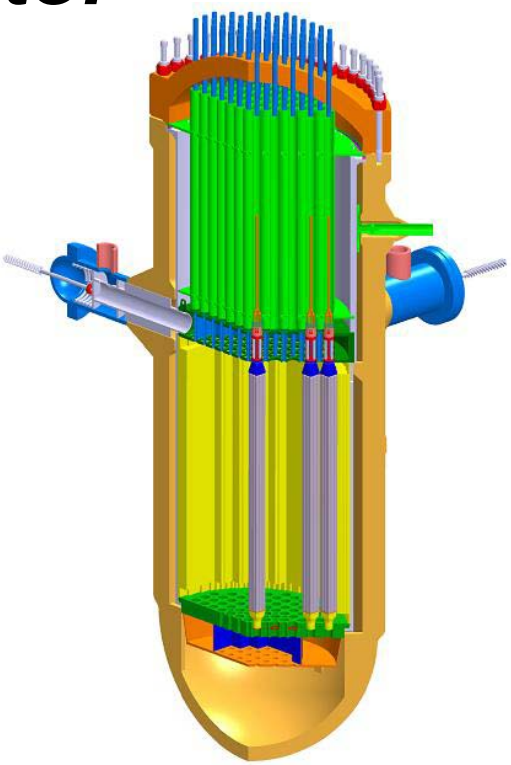
GACID overall schedule



- *The Project is being conducted by CEA, USDOE and JAEA as a GIF/SFR Project, covering the initial 5 years.*

510-625 C

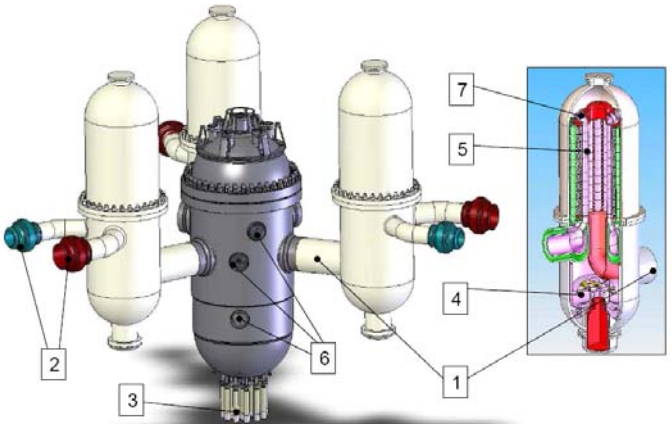
Supercritical Water-Cooled Reactor outlook



- Merges GEN-III+ reactor technology with advanced supercritical fossil plant technology
- operates above the thermodynamic critical point (374° C, 22.1 MPa) of water
- Pressure vessel and pressure tube options; fast and thermal spectrum options
- Goal: Improve knowledge base to optimize designs
- Key technology focus:
  - Materials, water chemistry, radiolysis
  - Thermal hydraulics and property changes around the critical point
  - System integration
  - Fuel qualification

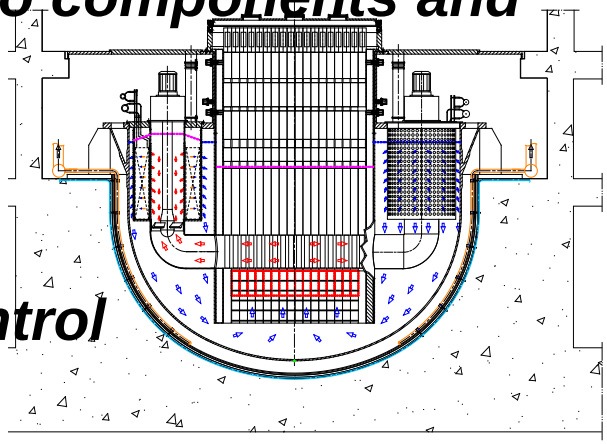
Gas-cooled Fast Reactor outlook

- *Limited experience; some benefit from VHTR*
- *Goal: Complete viability experiments by 2012*
- *Key technical focus:*
  - *SiC clad carbide fuel*
  - *Conceptual design and safety*
  - *Components and materials*



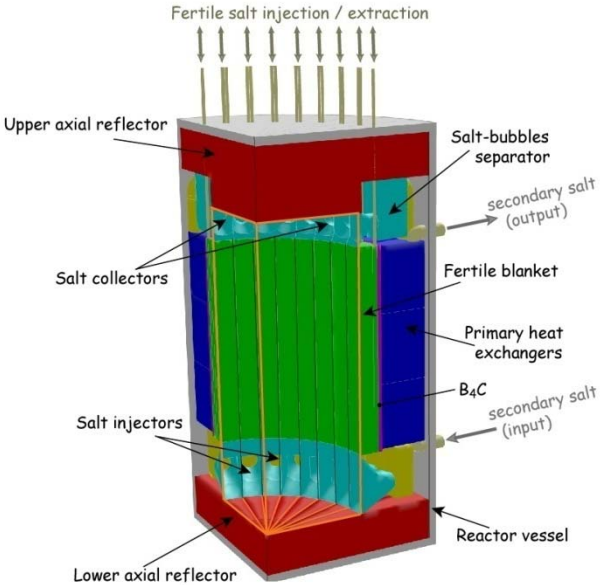
Lead Fast Reactor outlook

- *No formal GIF arrangement; provisional participation*
- *Goal: Resolve feasibility with respect to components and corrosion control*
- *SSTAR (US) and ELSY (Euratom)*
- *Key technical focus:*
  - *Fuels, Materials, and corrosion control*
  - *Design features*
  - *Operating parameters*
    - » *2-step approach*
    - » *Develop low-temperature approach first*



Molten Salt Reactor outlook

- *No formal GIF arrangement; provisional participation*
- *Goal: Develop design features, processing systems and operating parameters within 5 years*
- *Divergent paths: solid fuel with molten salt coolant; dissolved fuel in molten salt coolant*
- *Key technical focus*
  - *System integration and assessment*
  - *System design and operation*
  - *Materials and components*
  - *Safety and safety systems*
  - *Liquid salt chemistry and properties*
  - *Fuel and fuel cycle (thorium)*



Crosscutting activities

- *Economics Methodology Working Group*
  - *Tool set tested on several systems*
  - *Available through the NEA*
  - *Effort is "mature"*
- *Risk and Safety Working Group*
  - *Goal is to produce an integrated framework based on PRA*
  - *Effort is well established; perhaps ripe for re-assessment*
- *Proliferation Resistance and Physical Protection WG*
  - *Developing methodology that has been tested on example systems*
  - *Next steps would benefit from more feedback from GIF community*
- *New initiatives*
  - *Modeling and simulation*
  - *Education*
  - *Coordination and integration with INPRO and OECD/NEA*
  - *Other (thorium, materials, power generation, SMRs, …)*

GIF Summary

- ***The GIF provides a unique framework for sharing the R&D burden of developing promising nuclear systems through the feasibility, viability and performance phases.***
- ***The systems have some common challenges***
  - ***Higher temperatures for greater efficiency and in some cases additional applications beyond electricity***
  - ***Materials required for the higher temperature and in some cases corrosive environment***
  - ***Advanced components including power conversion***
  - ***Robust, reliable fuel***
- ***A constant pressure to old/new ideas (thorium, small reactors, etc.) in the light of new developments***

What are the challenges?

- ***Huge variation in laws and tradition of participating countries for protecting intellectual property***
- ***Shrinkage of R&D scope vs. GIF charter***
- ***Competing international arrangements***
- ***Bureaucracy emergence***
- ***Accountability***
- ***Flexibility vs. focus***
- ***Internal importance to national programs***

Generation-IV distractions

AFCI

NERI

ARC

LWRS

MIT Report

NE Roadmap

NGNP

ARPA-E

CASL

SMR

GNEP

Nuclear innovation is hard

- ***Very conservative enterprise***
- ***Cost of designing and certifying a new reactor concept is approximately $1B; perhaps $3-4B for 1st unit***
  - ***Standardization vs. innovation***
- ***Advanced nuclear technology is not the only need***
  - ***Communication tools***
  - ***Regulatory tools for adapting to innovation***
  - ***Construction techniques***
  - ***Lessons from construction and operational experience***
  - ***Experimental and analytical tools***
- ***How can a Gen-IV reactor economically compete against Gen-III?***

Trends in nuclear innovation

- ***Technology transfer from another field***
  - ***Exascale computing***
  - ***Nanomaterials***
  - ***Instrumentation and control***
  - ***Power generation***
- ***"Frankenstein" approach—combining the best parts to produce something powerful, some refinement needed***
  - ***VHTR+MSR-He-UF4=AHTR***
  - ***VHTR+SFR-Na=GFR***
- ***Technology focused on policy goals***
  - ***Safety***
  - ***Nonproliferation***
- ***Cost-effective modernization of existing plants***

To paraphrase Admiral Rickover:

An academic reactor is simple, small, cheap, light, flexible of purpose, requires little development, and can be built quickly. A practical reactor is large, heavy, complicated, expensive, is being built now, is behind schedule, and is requiring an immense amount of engineering development on seemingly trivial items.

Other Recent Developments

- ***Germany to phase out all nuclear power by 2022***
- ***Switzerland, Italy "on hold"***
- ***Japan "Needs to start from scratch" (Prime Minister Kan)***
- ***US Nuclear Renaissance slowed by economic issues, lack of definitive waste solution, and post-Fukushima fears***
- ***Many other countries proceeding with aggressive nuclear development programs (India, China, UAE, Britain, France, etc.)***
- ***IAEA providing assistance to >30 countries that seek to develop nuclear energy programs***

In summary,

At the dawn of the nuclear age, nuclear energy was a major driver for developments in science and technology.

Today we are technology adapters…

…and that has some advantages