



Generation IV Technology Roadmap

***NERAC Meeting: Washington, D.C.
September 30, 2002***

Generation IV Technology Roadmap

- *Identifies systems deployable by 2030 or earlier*
- *Specifies six systems that offer significant advances towards:*
 - *Sustainability*
 - *Economics*
 - *Safety and reliability*
 - *Proliferation resistance and physical protection*
- *Summarizes R&D activities and priorities for the systems*
- *Lays the foundation for Generation IV R&D program plans*

The Technical Roadmap Report

- ***Discusses the benefits, goals and challenges, and the importance of the fuel cycle***
- ***Describes evaluation and selection process***
- ***Introduces the six Generation IV systems chosen by the Generation IV International Forum***
- ***Surveys system-specific R&D needs for all six systems***
- ***Collects crosscutting R&D needs***
- ***Recognizes the need for and likelihood of nearer-term deployment, but specifies complete R&D activities***

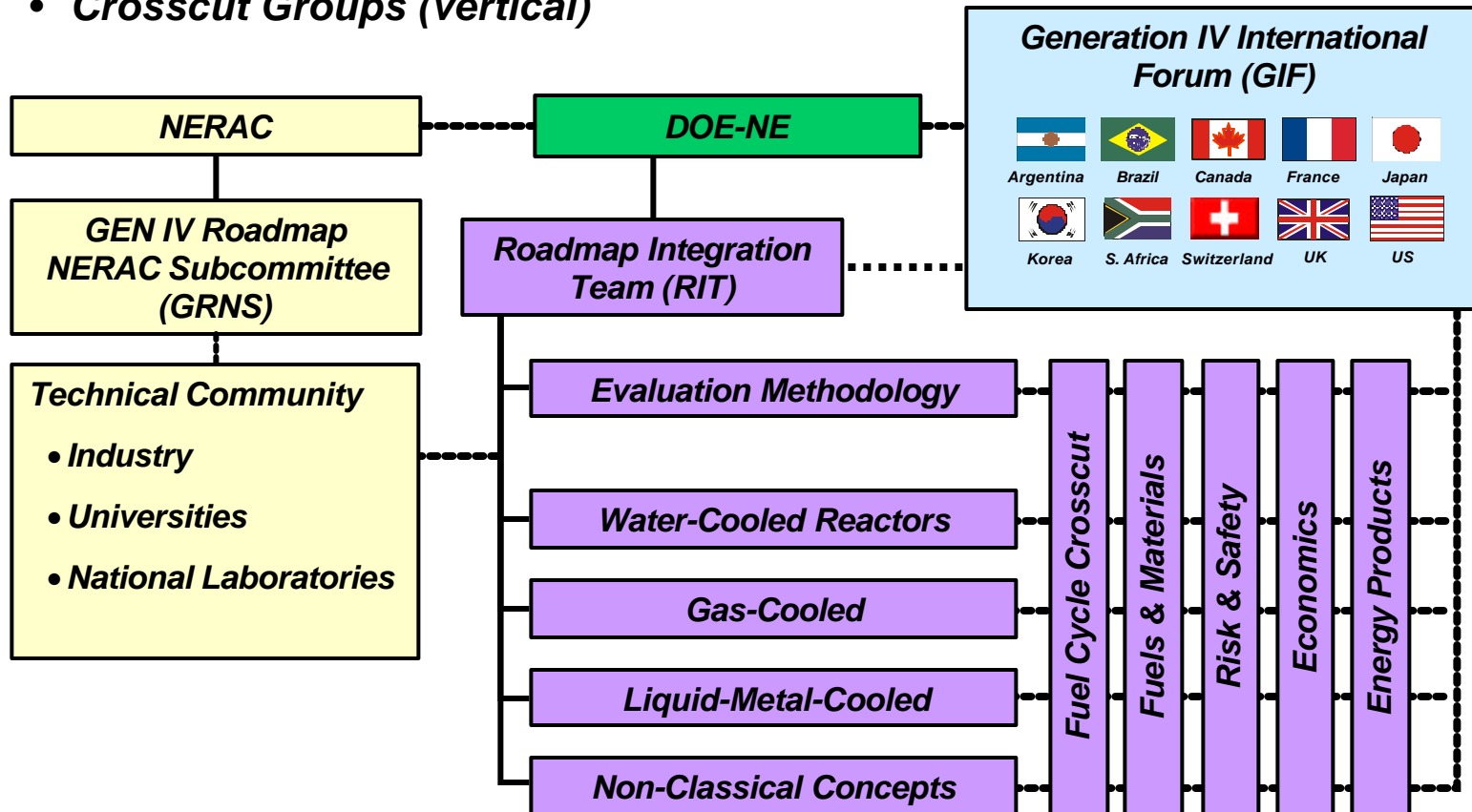
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- ***GIF countries will choose the systems they will work on***
 - ***Programs and projects will be founded on the R&D surveyed in the roadmap***

Schedule for the Final Steps to Completion

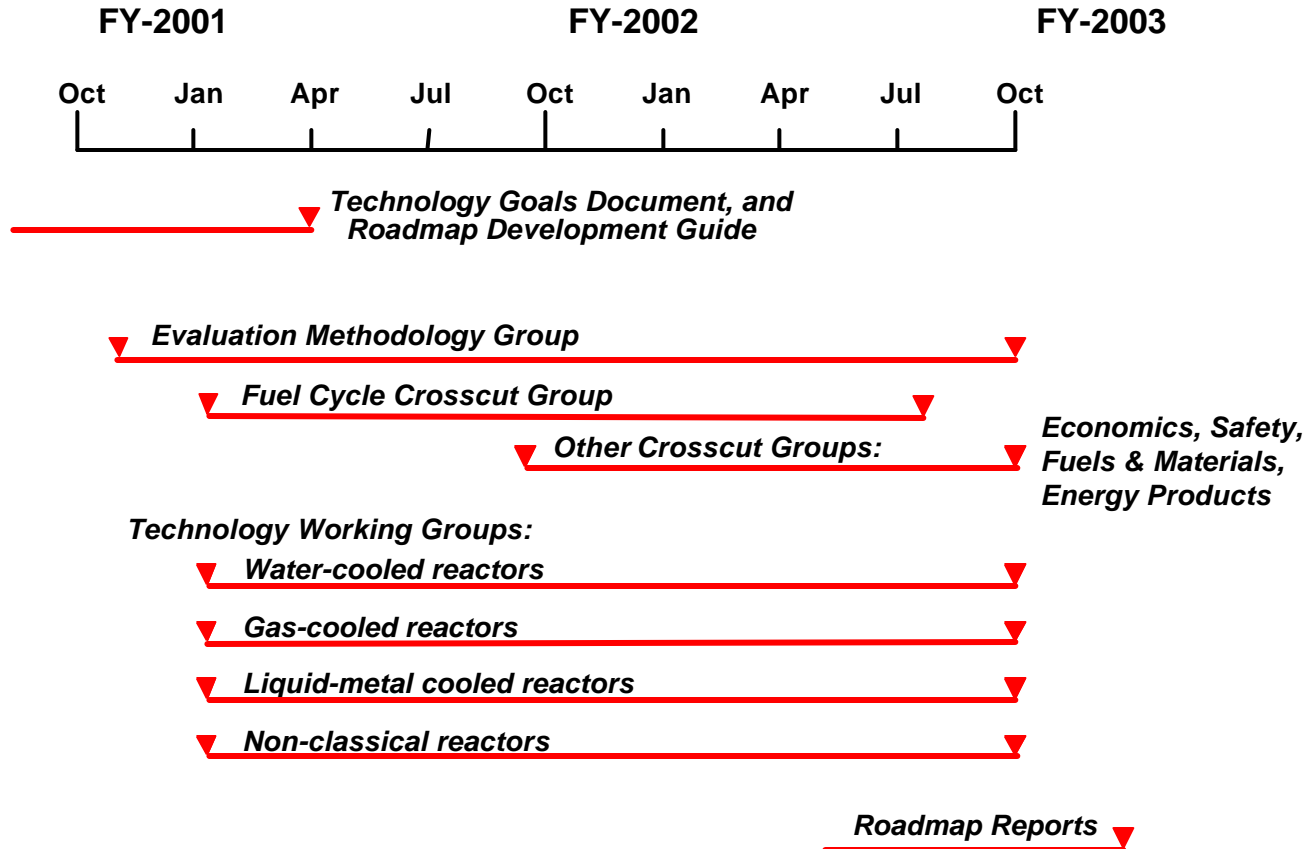
- **Most Recent Overview for NERAC** Apr 15
- **GIF Review in Paris** May 22
- **GIF Review in Rio** Jul 9
- **NERAC Subcommittee Review** Jul 31/Aug 1
- **DOE Review** Aug
- **Working Group Review** Aug 28-29
- **NERAC Subcommittee Review** Sep 13
- **Transmittal to NERAC** Sep 23

Organization of Working Groups

- *Technical Working Groups (horizontal)*
- *Crosscut Groups (vertical)*



Two-year Gen IV Timeline



Key Steps Toward Generation IV Selections

- **Definition and evaluation of candidate systems
(Feb '01-'02)**
- **Review of evaluations and discussion of desired
missions for the systems
(Feb '02)**
- **Final review of evaluations and performance to
missions
(Mar and Apr '02)**
- **Final decision on selections to Generation IV
(May and Jul '02)**

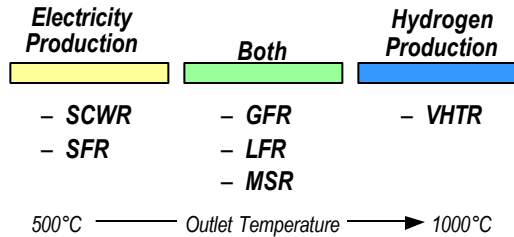
Generation IV Systems

<i>Gas-Cooled Fast Reactor System</i>	<i>GFR</i>
<i>Lead-Cooled Fast Reactor System</i>	<i>LFR</i>
<i>Molten Salt Reactor System</i>	<i>MSR</i>
<i>Sodium-Cooled Fast Reactor System</i>	<i>SFR</i>
<i>Supercritical-Water-Cooled Reactor System</i>	<i>SCWR</i>
<i>Very-High-Temperature Reactor System</i>	<i>VHTR</i>

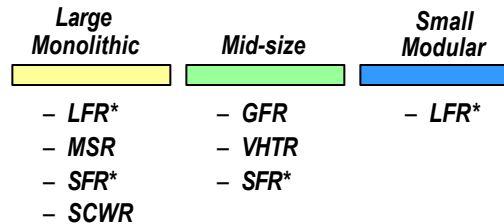
- ***Each system has R&D challenges ahead – none are certain of success***

Generation IV System 'Portfolio'

Products

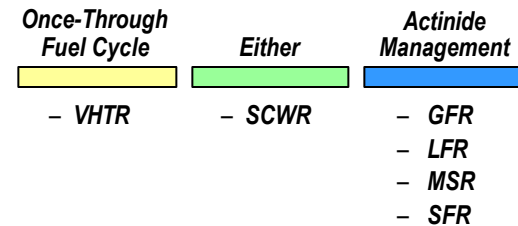


Plant Size

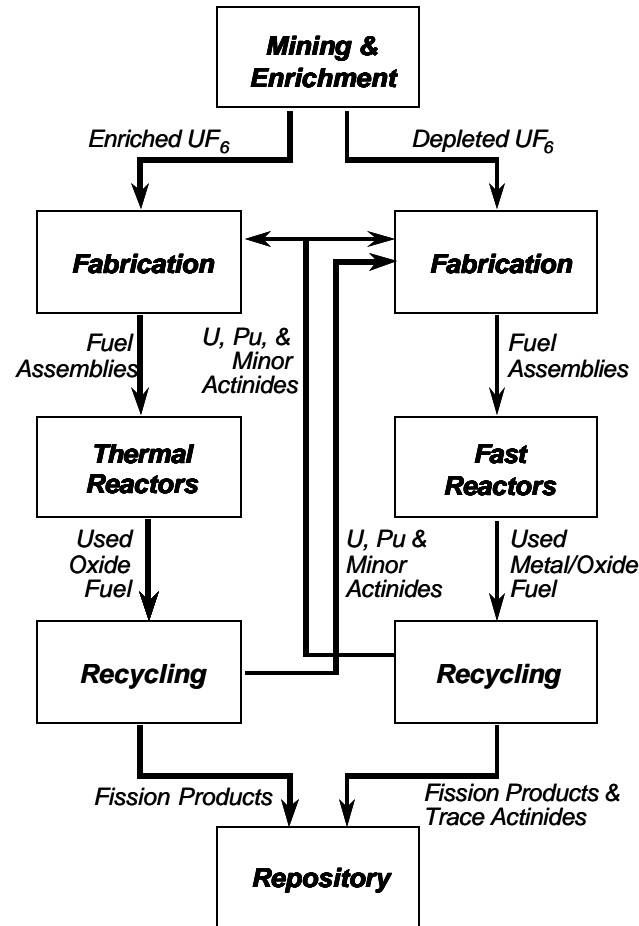


* Range of options

Fuel Cycle



The Portfolio Supports Symbiotic Fuel Cycles



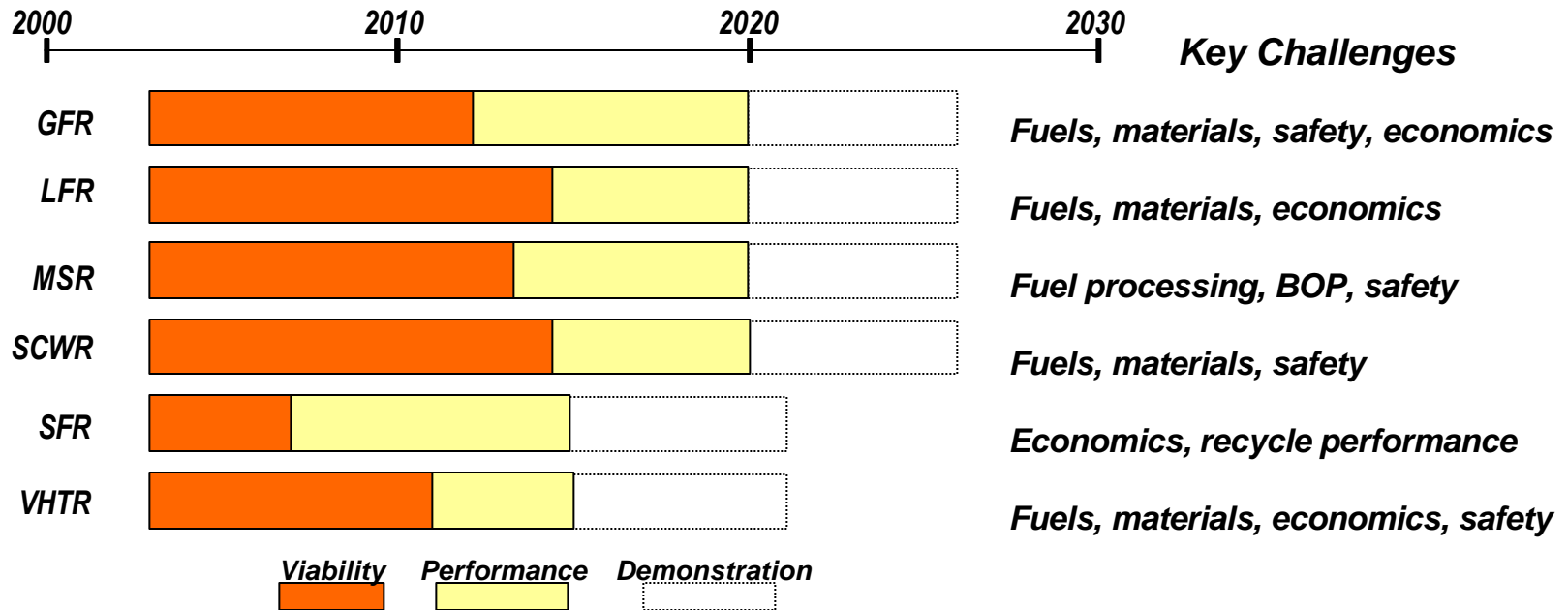
The Roadmap Addresses Viability and Performance R&D Phases

- ***Viability***
 - ***Key feasibility and proof-of-principle decisions***
 - ***Performance***
 - ***Engineering-scale development and optimization to desired levels of performance***
-
- ***Demonstration***
 - ***Mid- to large-scale system demonstration***
 - ***Commercialization***

Uncertainties

- **Uncertainties in evaluations were captured as simple probability distributions by expert judgment**
- **Uncertainties in Economics evaluations were very large, and underscore the need for an emphasis on system economics in the R&D**
 - **Evaluation methodology R&D is needed, especially to address and quantify uncertainties**
- **R&D costs and schedules are conceptual**
- **R&D schedules assume steady progress and ample funding**
- **R&D costs do not include demonstration, infrastructure or contingency for setbacks**
 - **Programs founded on the roadmap will need additional detail and review**

High-Level Generation IV Timelines



Surveys of R&D Needs

- **System-specific R&D**
- **Crosscutting R&D (common to several or all)**

Notes on Organization:

- **Two major fuel cycle options (advanced aqueous and pyroprocessing) are crosscutting**
- **Much of the safety R&D is system-specific**
- **Fuels and materials more crosscutting at the start, becoming more system-specific later**
- **Any system needs to undertake an appropriate share of the crosscutting R&D**

System-Specific R&D Areas

- ***Fuels and Materials***
- ***Reactor Systems***
- ***Balance-of-Plant***
- ***Safety***
- ***Design and Evaluation***
- ***Fuel Cycle***
- ***R&D Schedule and Costs***

Crosscutting Fuel Cycle R&D Needs

Generation IV System	Fuel				Recycle	
	Oxide	Metal	Nitride	Carbide	Advanced Aqueous	Pyroprocess
GFR ¹			S	P	P	P
MSR ²						
SFR ³	P	P			P	P
LFR		S	P		P	P
SCWR	P				P	
VHTR ⁴	P				S	S

P: Primary option S: Secondary option

¹ The GFR proposes (U,Pu)C in ceramic-ceramic (cercer), coated particles or ceramic-metallic (cermet).

² The MSR employs a molten fluoride salt fuel and coolant, and fluoride-based processes for recycle.

³ The SFR has two options: oxide fuel with advanced aqueous, and metal fuel with pyroprocess.

⁴ The VHTR uses a once-through fuel cycle with coated (UCO) fuel kernels, and no need for fuel treatment, as the primary option.

Crosscutting Fuels & Materials R&D Needs

System	Fuel Materials					Structural Materials						
	Oxide	Metal	Nitride	Carbide	Fluoride (liquid)	Ferritic-martensitic Stainless Steel Alloys	Austenitic Stainless Steel Alloys	Oxide Dispersion Strengthened	Ni-based Alloys	Graphite	Refractory Alloys	Ceramics
GFR			S	P		P	P	P	P		P	P
MSR					P				P	P	S	S
SFR	P	P				P	P	P				
LFR		S	P			P	P	S			S	S
SCWR-Thermal	P					P	P	S	S			
SCWR-Fast	P	S				P	P	S	S			
VHTR	P					S			P	P	S	P
P: Primary Option S: Secondary Option												

Crosscutting Energy Products R&D Needs

Generation IV System (T _{outlet})	Hydrogen Production		Heat Delivery		Advanced Cycles for Electricity Production		
	I-S Process	Ca-Br Process	Process Heat	Desalination	Supercritical CO ₂ , Brayton	Supercritical Water Rankine	Helium Brayton
GFR (850°C)	P	S	S	O			P
MSR (700-850°C)	P	S	S	O			P
SFR (550°C)				O	S		
LFR (550°C)				O	P	S	
(800°C)		P	S	O	S ¹	S ¹	
SCWR (550°C)				O		P	
VHTR (1000°C)	P		S	O			P

P: Primary option
S: Secondary option
O: Option for all systems

¹ Bottoming cycle using heat at lower temperatures available after higher temperature heat has been used for hydrogen production.

Issues and Opportunities

- ***Communications and Stakeholder Feedback***
- ***Infrastructure Development and Use***
- ***Coordinated Licensing Approaches***
- ***Institutional Barriers and Development***
- ***Interactions with Nearer-Term Systems***
- ***R&D Pathways***

Summary

- ***Six systems were selected, based on evaluations to the Generation IV goals and other considerations***
- ***R&D activities were developed and prioritized, with proposed schedules and costs***
- ***Viability phase R&D focuses on key decision points to decide feasibility and proof-of-principle***
- ***Performance phase R&D focuses on priority issues for the systems to attract demonstration and deployment***

- ***The roadmap is a foundation for formulating national and international program plans***