

Future Directions: Toward Higher-Temperature Reactors

Dr. Charles Forsberg

Oak Ridge National Laboratory
P.O. Box 2008; Oak Ridge, TN37831
E-mail: forsbergcw@ornl.gov
Tel: (865) 574-6783

Workshop on Advanced Reactors With Innovative Fuels

Nuclear Energy Agency Nuclear Science Committee
Oak Ridge, Tennessee 37831
February 16-18, 2005

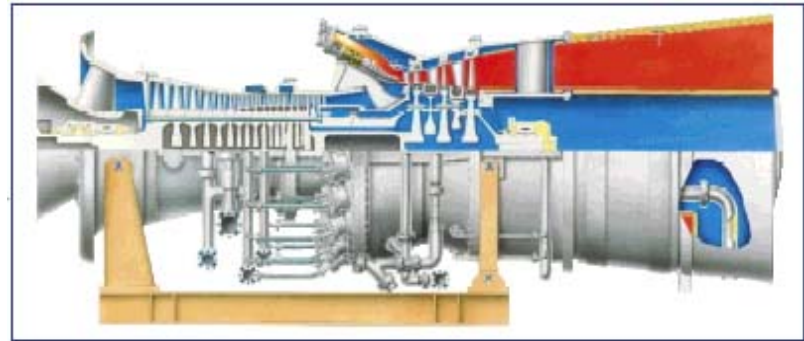
Thesis

New Technologies and New Needs Are Driving the Interest in Higher-Temperature Reactors

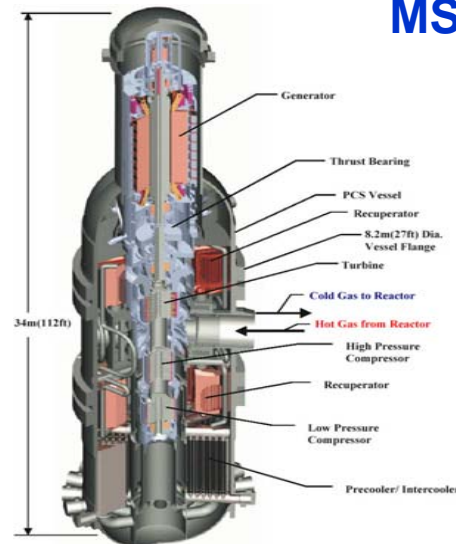
High-Temperature Reactors Drive the Need for Innovative Fuels

Brayton Cycles Enable Cost-Effective High-Temperature Reactors

- **Steam turbines (with a 550°C peak temperature) have been the only efficient, industrial method to convert heat to electricity**
- **High-temperature reactors have been non-competitive, partly because there was no efficient method to convert high-temperature heat to electricity**
- **Development of large efficient high-temperature Brayton cycles *in the last decade* makes possible economic higher-temperature reactors**

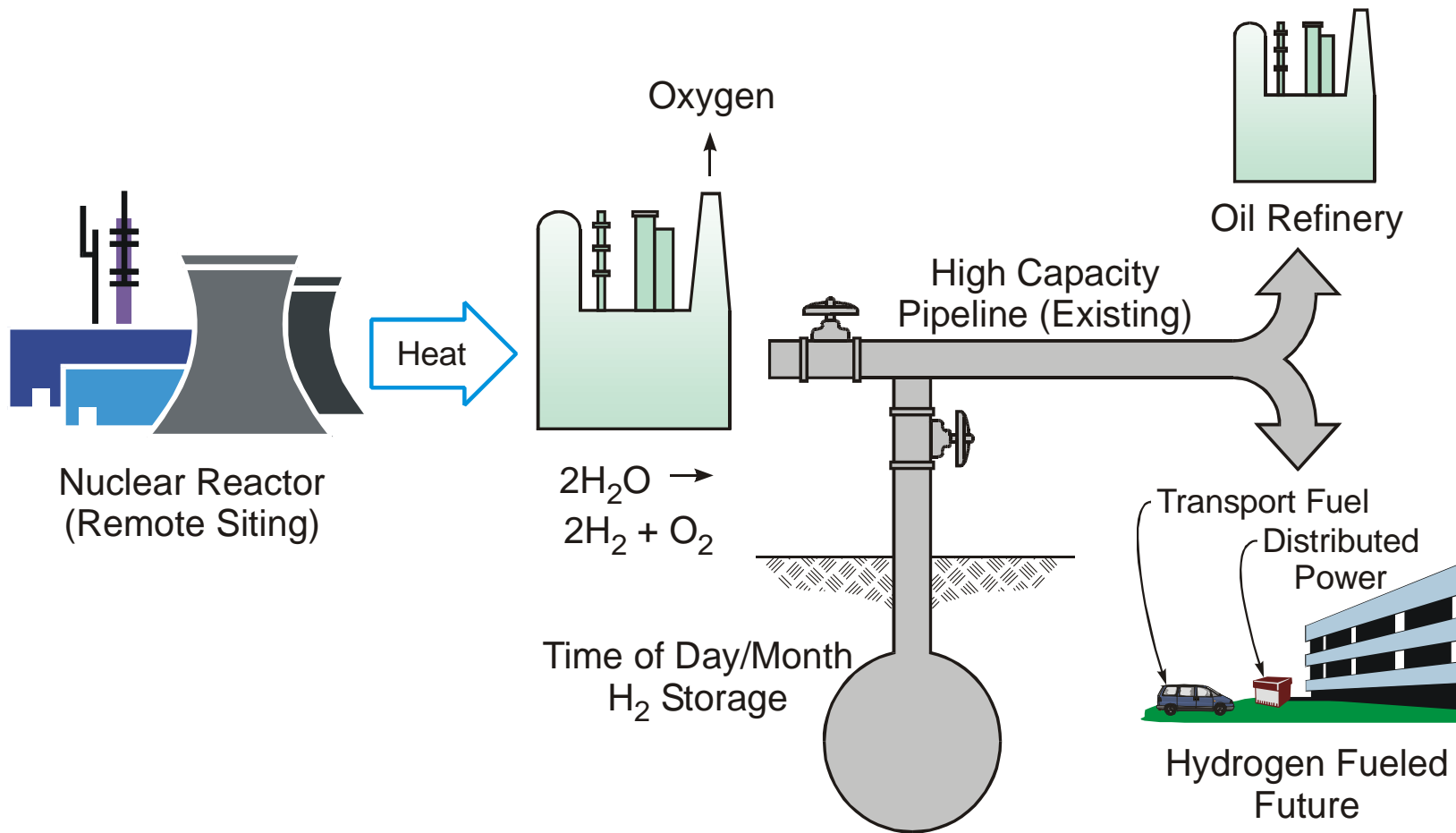


**GE Power Systems
MS7001FB**



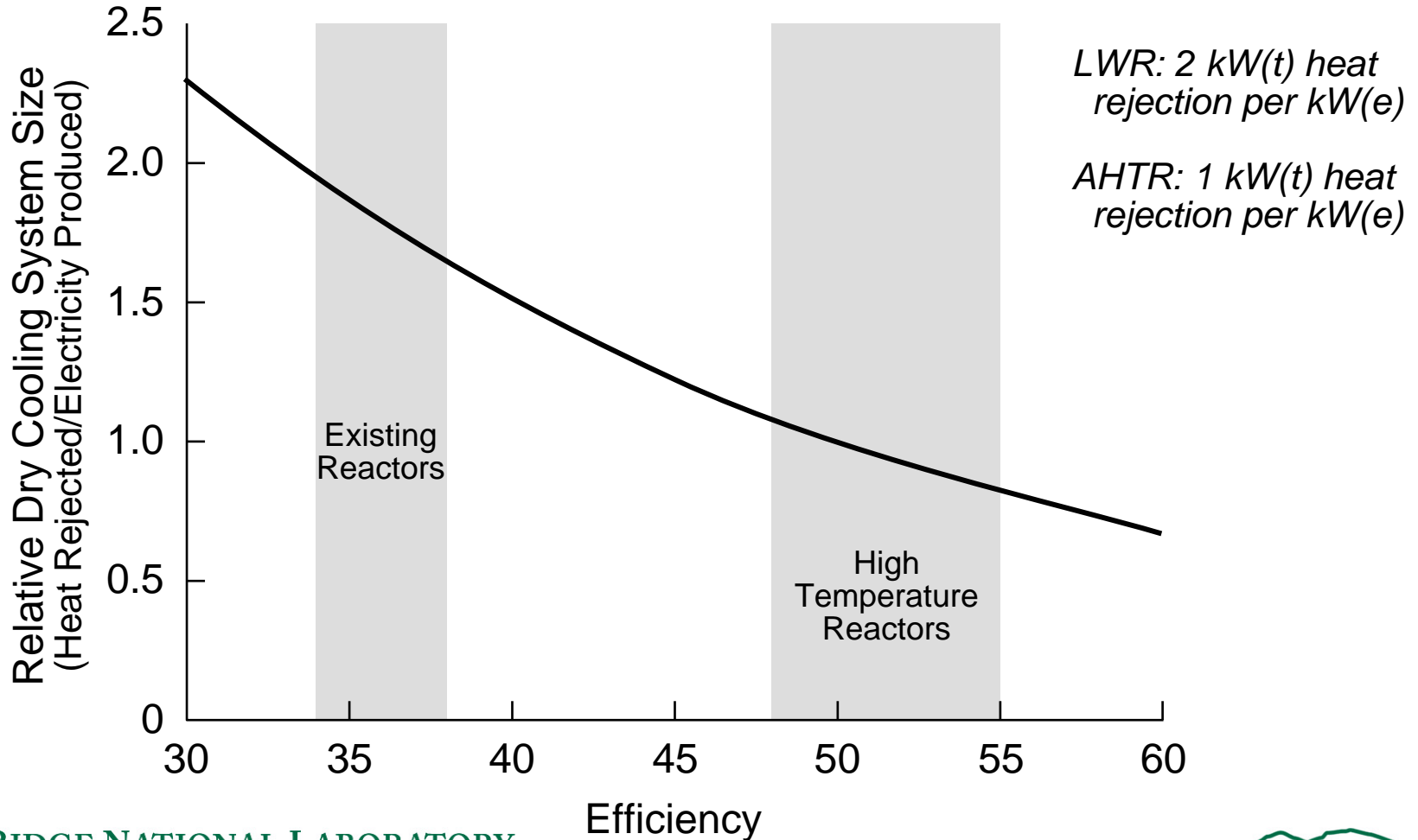
**General Atomics
GT-MHR Power
Conversion Unit
(Russian Design)**

Hydrogen Production Requires High-Temperature Heat (700-850°C)

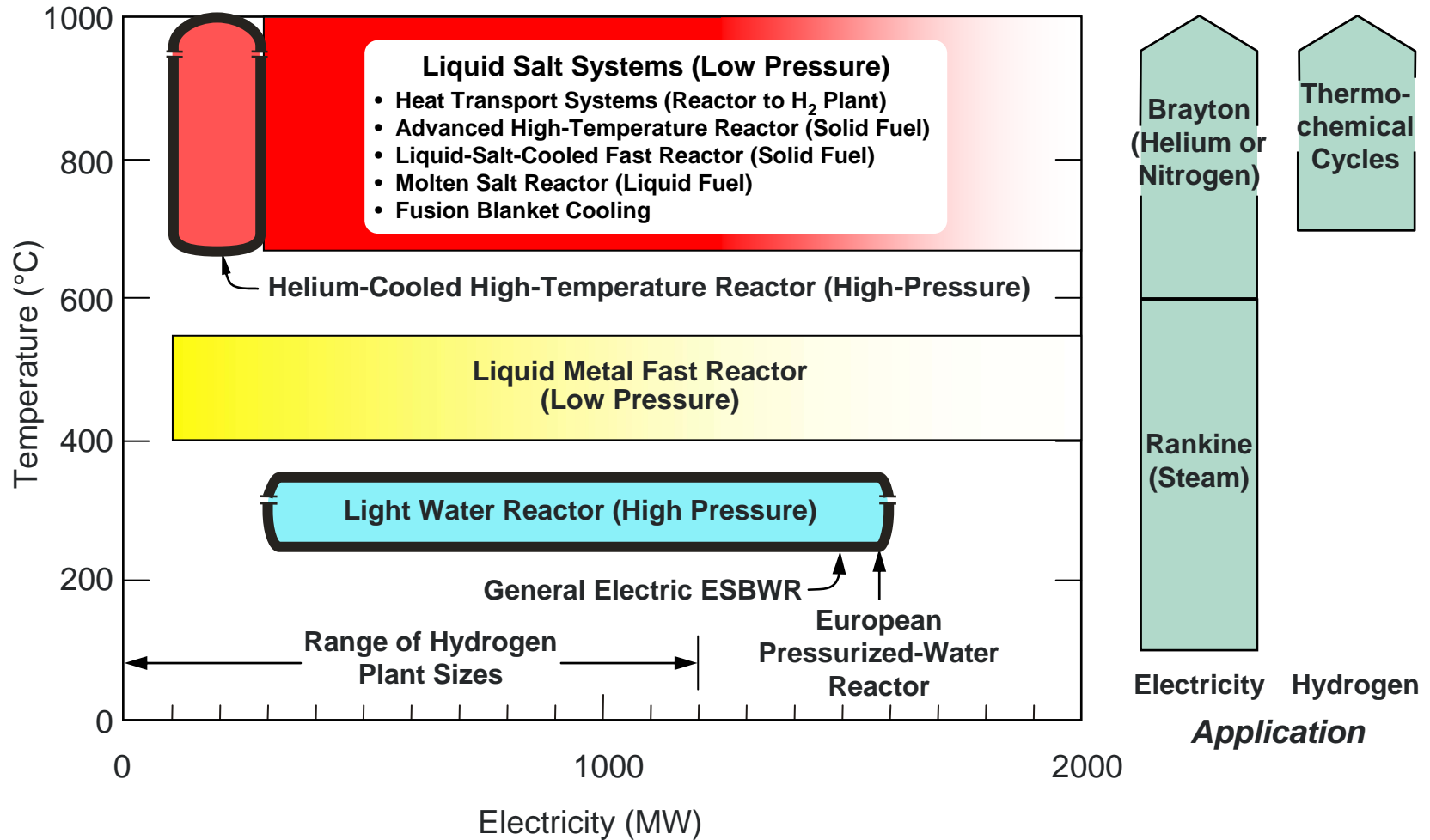


Water and Energy Conflicts Abound

Higher-Temperature Reactors Enable Dry Cooling and Open Up Power Plant Siting

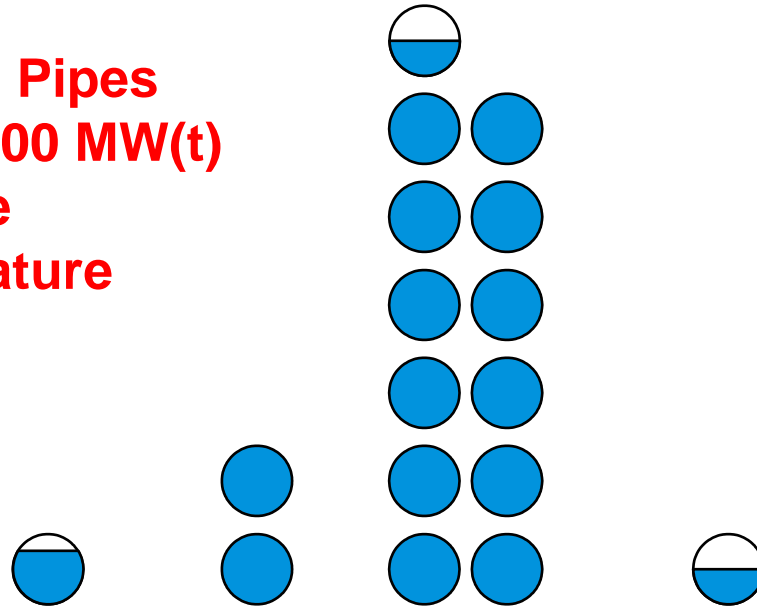


Schematic of Reactor Options By Coolant Temperatures and Reactor Size



Properties of Gases Support Use in Smaller Modular Reactors; Properties of Liquids Support Use in Large Reactors

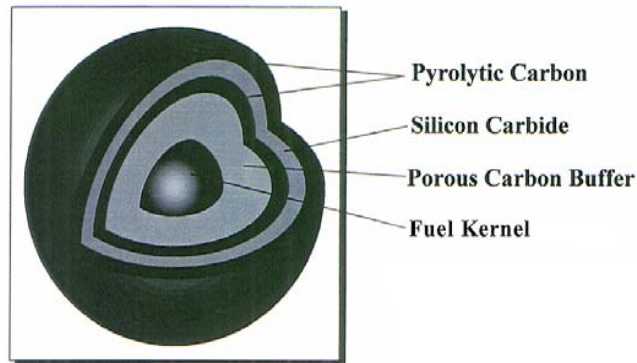
**Number of 1-m-diam. Pipes
Needed to Transport 1000 MW(t)
with 100°C Rise
in Coolant Temperature**



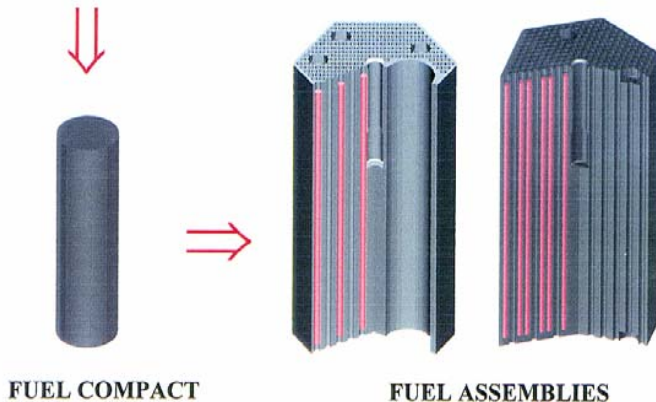
	Water (PWR)	Sodium (LMR)	Helium	Liquid Salt
Pressure (MPa)	15.5	0.69	7.07	0.69
Outlet Temp (°C)	320	540	1000	1000
Coolant Velocity (m/s)	6	6	75	6

Very High-Temperature Reactors

One Fuel Option



FUEL PARTICLE



Two Coolant Options



Helium

High-Pressure
Transparent



Liquid Fluoride Salts

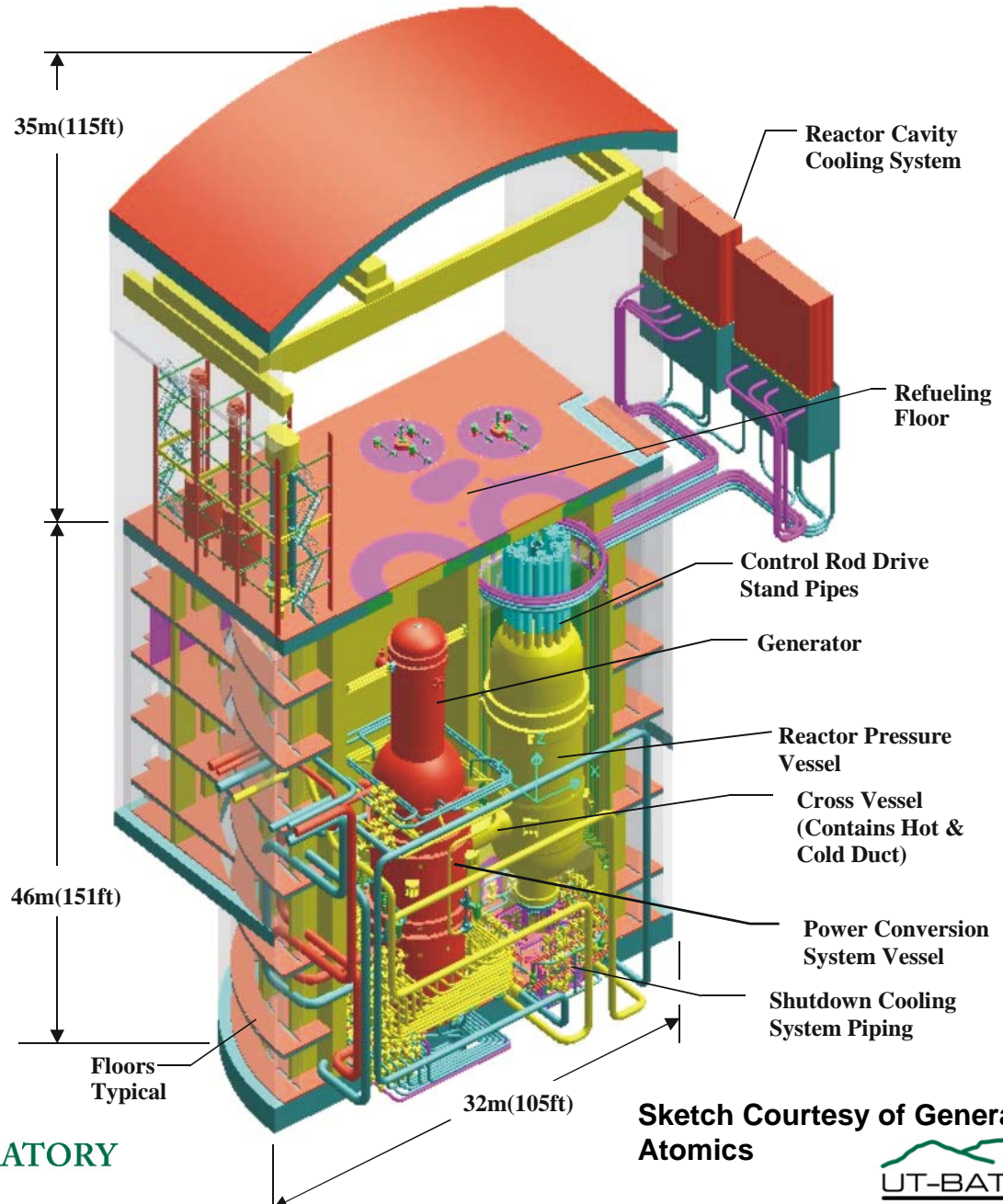
Low Pressure,
Transparent

Gas-Turbine Modular Helium Reactor

Graphite-Matrix
Fuel

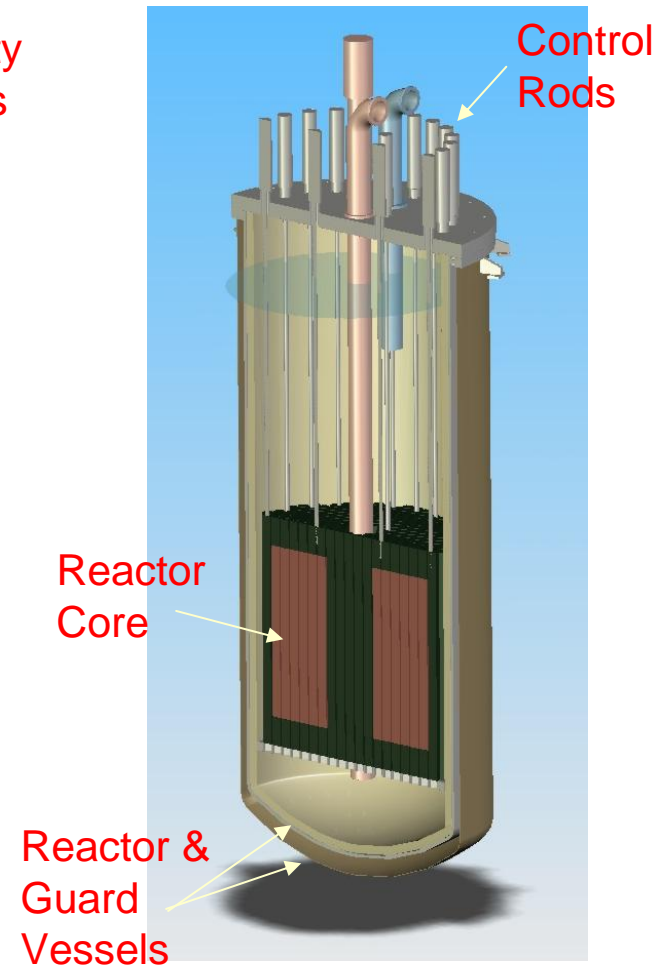
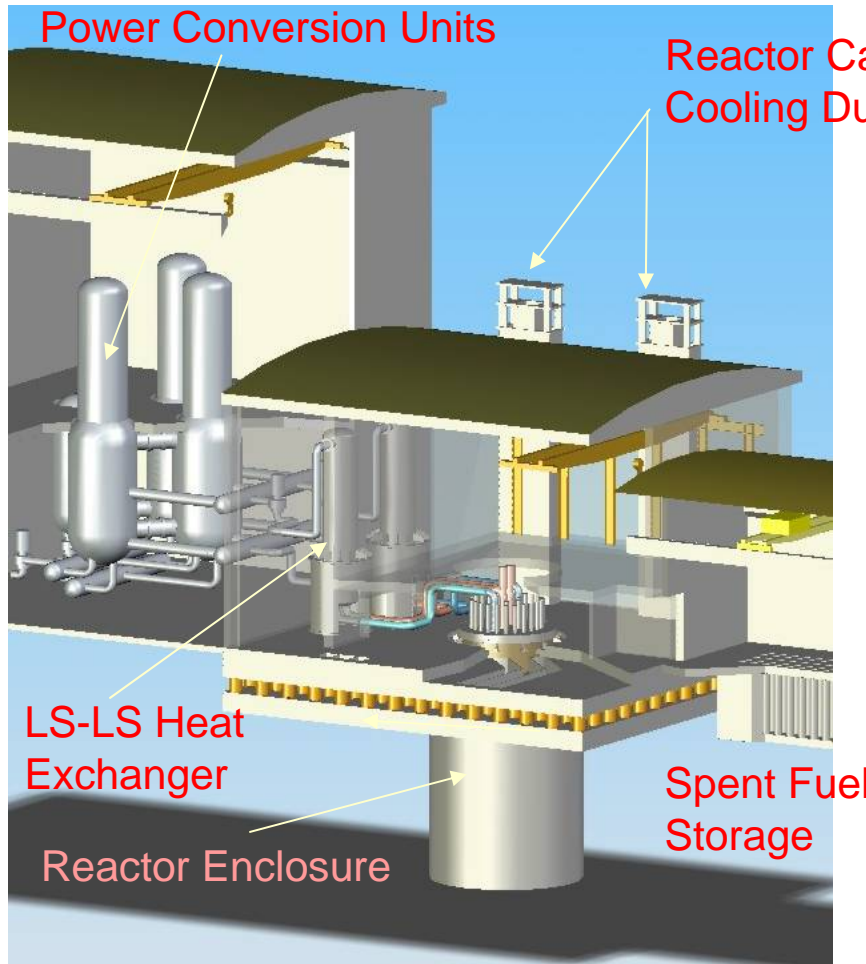
Helium Coolant

600 MW(t)



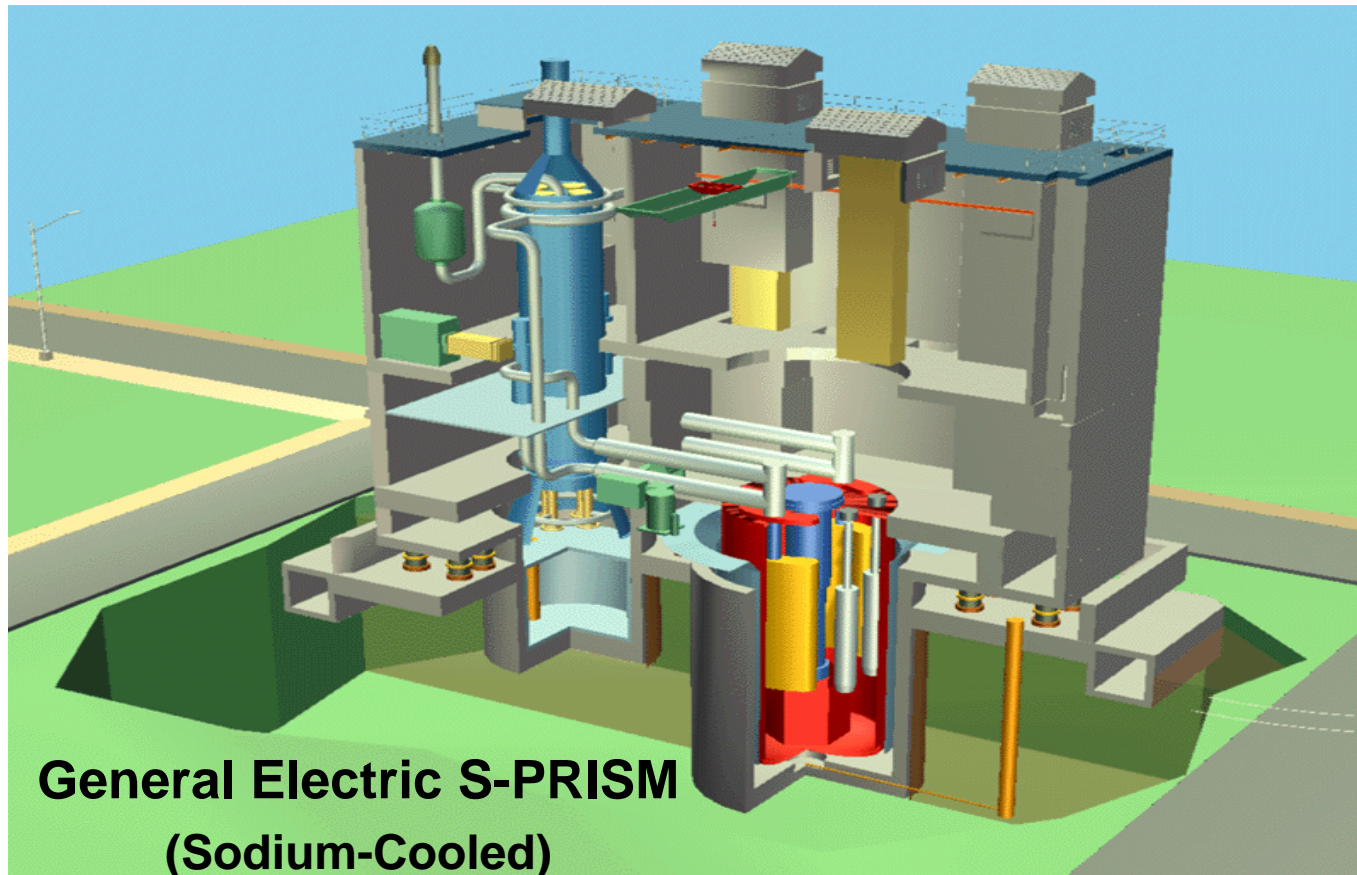
Advanced High Temperature Reactor

Graphite-Matrix Fuel, Liquid Salt Coolant



High-Temperature Fast Reactor Options

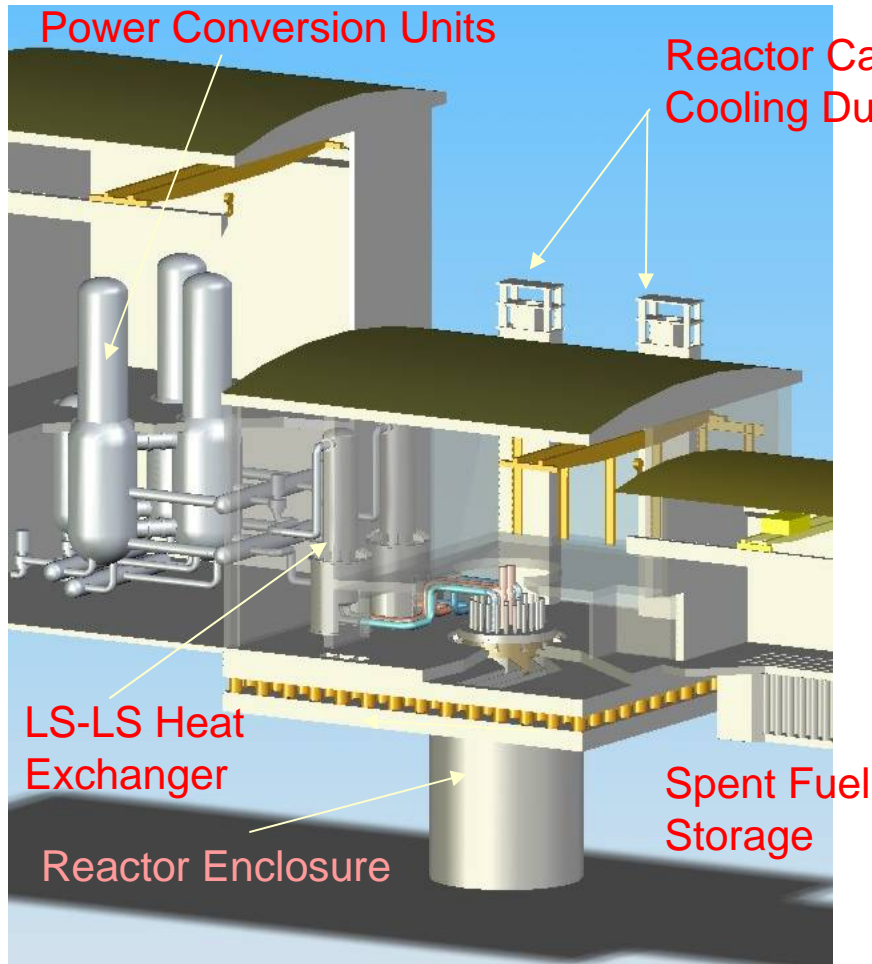
Liquid-Salt-Cooled and Lead-Cooled
(Boiling point must exceed 1000°C)



Observations I

- **Strong drivers for higher-temperature reactors**
 - Recent development of efficient Brayton cycles to convert heat to electricity
 - Need for hydrogen production
 - Need for dry cooling to avoid water shortages and siting constraints
- **Options**
 - Helium-cooled high-temperature reactor
 - Advanced High-temperature reactor
 - Lead-cooled fast reactor
 - Liquid-salt-cooled fast reactor
 - Fast-gas-cooled reactor
- **Need for advanced reactors with innovative fuels**

Observations II: Strong Incentives for International Cooperation



- **Development of advanced reactors is a major undertaking**
 - Time
 - Resources
 - Facilities
- **Commercial reactor development is an international effort**
- **Similar approach applicable for pre-commercial development of new reactor concepts (through first test reactor)**