RIC 2006
Session W3BC
Risk-Informed Regulatory Structure for Future Reactors

# Safety Issues for Advanced Designs

**Mark R. Holbrook**

Advisory Engineer
Idaho National Laboratory

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Idaho National Laboratory

# Outline

- Introduction
  - Generation IV Nuclear Energy Systems
  - Global Nuclear Energy Partnership (GNEP)
- Designs
  - Very High Temperature Gas Reactor (VHTR)
  - Sodium Cooled Fast Reactor (SFR)
  - Other Sodium Cooled Designs
- Challenges for Advanced Licensing Framework

# Generation IV Energy Systems

- Identifies systems deployable by 2030 or earlier
- Specifies systems that offer significant advances towards:
  - Sustainability
  - Economics
  - Safety and reliability
  - Proliferation resistance and physical protection
- Identifies R&D activities and priorities for the systems

# Generation IV Energy Systems

**Very-High-Temperature Reactor System** **VHTR**

- Selected for Next Generation Nuclear Plant (NGNP)

**Sodium-Cooled Fast Reactor System** **SFR**

- Focus for Global Nuclear Energy Partnership (GNEP)

**Supercritical-Water-Cooled Reactor System** **SCWR**

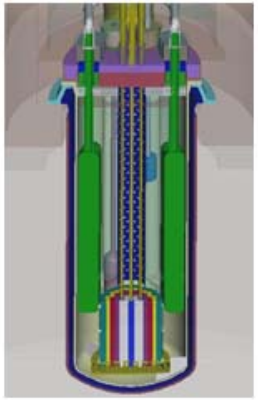
**Gas-Cooled Fast Reactor System** **GFR**

**Lead-Cooled Fast Reactor System** **LFR**

**Molten Salt Reactor System** **MSR**

# Global Nuclear Energy Partnership (GNEP)

- Developing countries are the next major electric power growth area; will look to developed countries for solutions; they will need:
  - Small increments of electric power (10-50 Mwe)
  - Simple controls and low maintenance power plants
  - Stability in the price of electricity over long time periods
- GNEP Policy
  - Increase US and global energy security
  - Encourage clean development and improve the environment
  - Reduce risk of nuclear proliferation
- GNEP will use fast reactors to recycle spend fuel and extend the life of spent fuel storage facilities



A Concept Diagram for an Advanced Burner Test Reactor

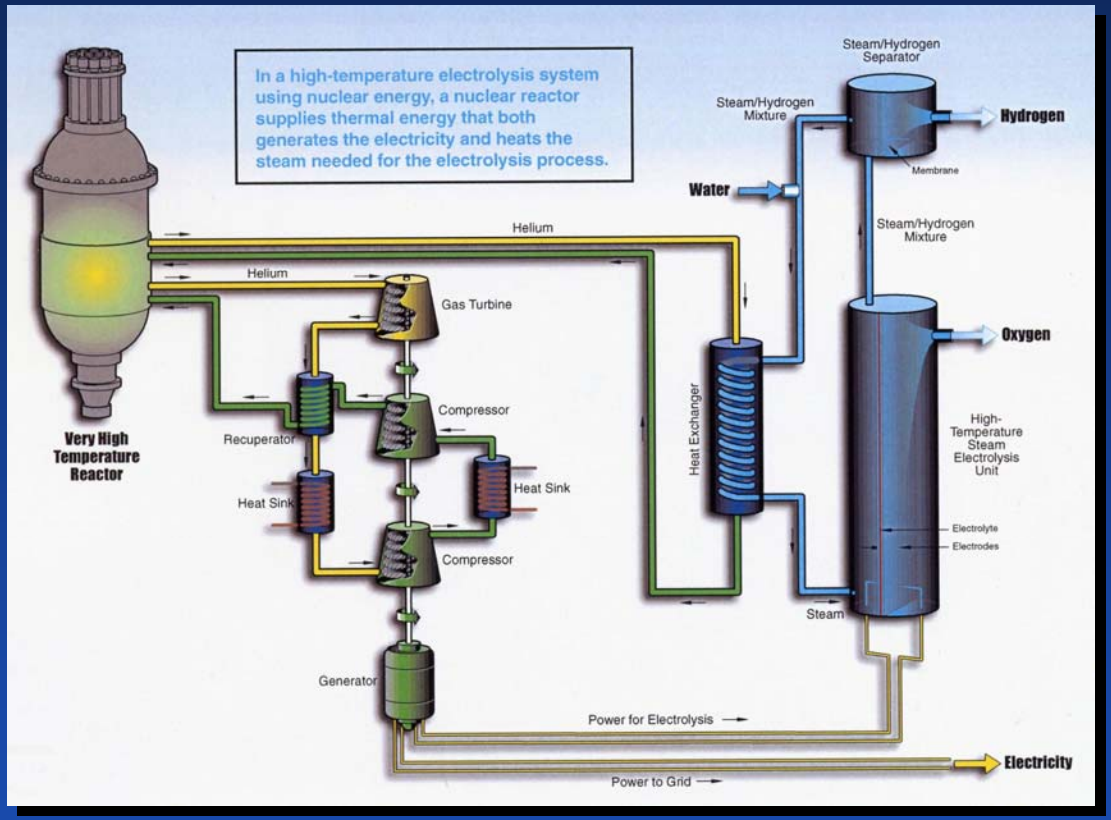
# Very-High-Temperature Gas Reactor (VHTR)

**Characteristics:**

- Helium coolant
- 1000°C outlet temperature
- 600 MWth
- Graphite moderated with prismatic or pebble-bed core
- Thermal neutron spectrum

**Benefits:**

- Co-generation of hydrogen and electricity
- Efficiency over 50% with excellent economics

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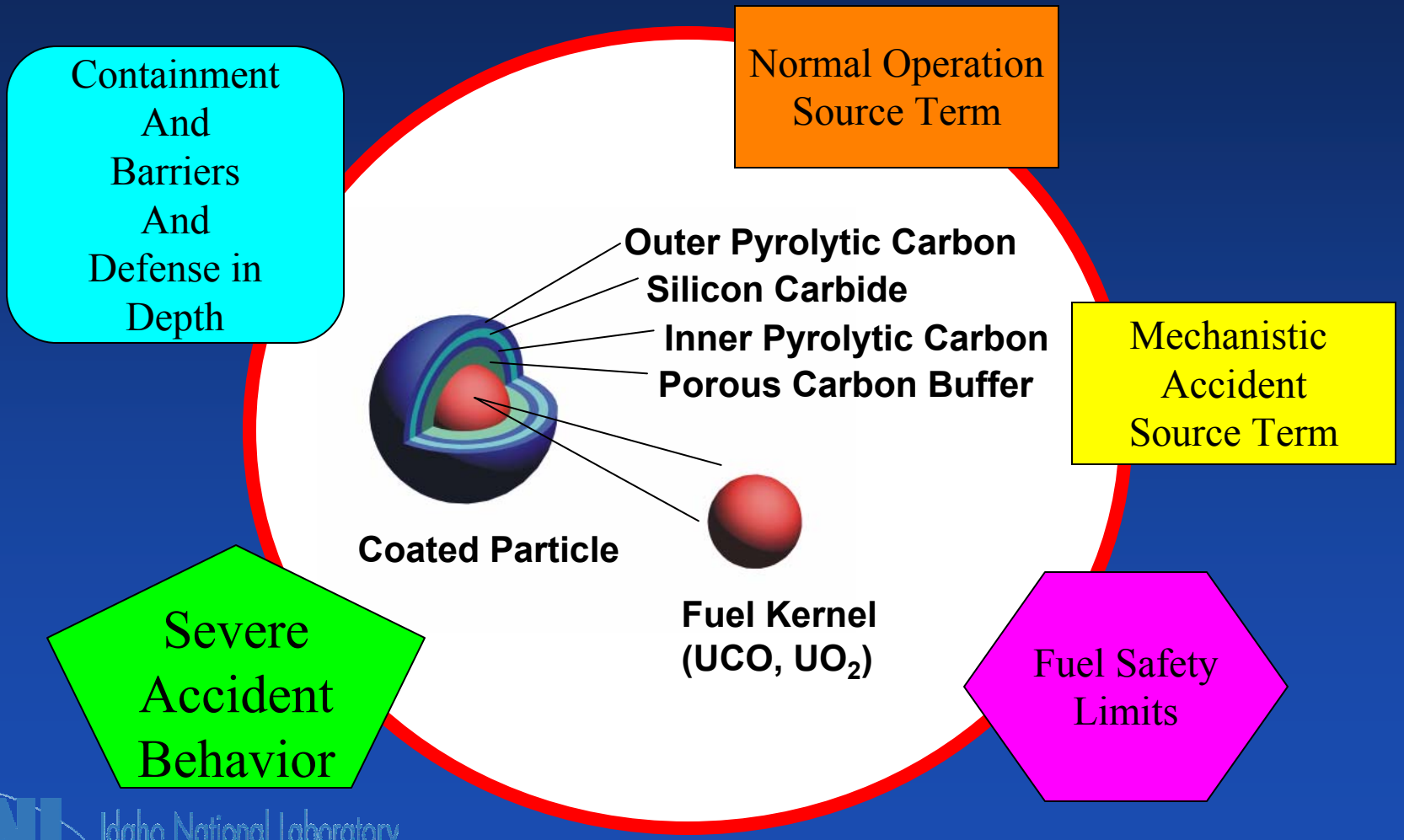
# Coated particle fuel performance is at the heart of the VHTR safety case

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# VHTR Safety Focus

- TRISO fuel coating forms first barrier to fission product release
- Coated fuel withstands accident temperatures up to 1600°C
- Large thermal inertia of graphite core results in long time constants for transients
- Power density is balanced with passive heat removal capability to ensure fuel does not exceed 1600°C
- Passive decay heat removal system with multiple heat removal paths

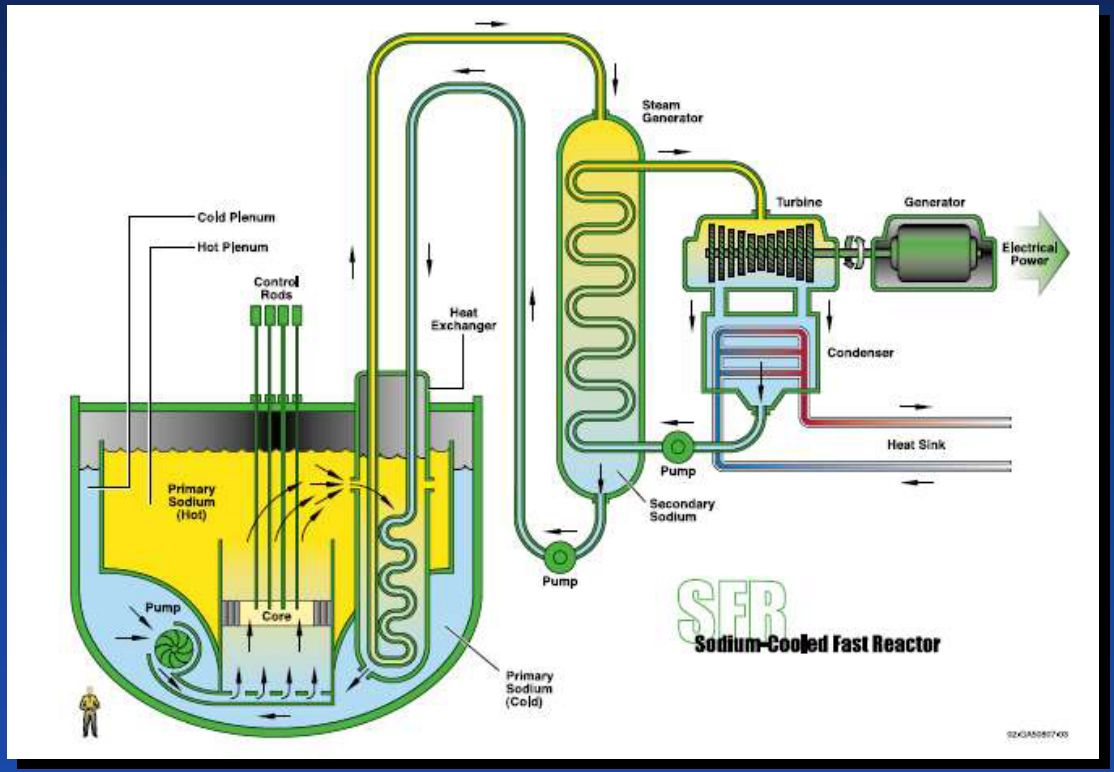
# Gen IV Sodium-Cooled Fast Reactor (SFR)

**Characteristics:**

- Sodium coolant
- 530°C to 550°C outlet temperature
- 200–1500 MWe
- Uses a secondary loop to isolate radioactive sodium

**Benefits:**

- Management of high-level waste (Pu and actinides)
- Passive safety characteristics

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# Other Sodium-Cooled Designs

- Toshiba 4S Reactor
  - Battery heat source design (10-50 Mwe)
  - Long (20-30 year) whole core refueling interval
  - All reactivity feedback coefficients including coolant void reactivity are negative
  - Fully passive decay heat removal system
  - Factory fabrication/barge or rail shippable

# Challenges for Advanced Licensing Framework

# VHTR Challenges

- Fuel Qualification
  - More aggressive service conditions relative to older designs
  - Previous U.S. experience with fuel fabrication
  - Desire to extend max. accident fuel temperatures to 1800°C
- Containment Design
  - Vented low-pressure containment
- Emergency Planning Zone
  - Desire to limit to site boundary
- Materials Qualification
  - 1000°C outlet temperature exceeds code allowables
  - Need better understanding of material response to neutron dose over plant lifetime

# SFR Challenges

- Spent Fuel Reprocessing
  - The licensing requirements will need to accommodate a reactor plant that is part of spent fuel reprocessing facility
  - Reprocessing will create a new set of security challenges
- Passive Safety
  - Ensuring validity of passive characteristics for a non-light water design (e.g., response to licensing-basis transients and anticipated transients without scram)
- Beyond Licensing-Basis Events
  - Ensure that bounding events considered in licensing can be sustained without loss of cooling of fuel or loss of containment function