ADVANCED REACTOR SAFEGUARDS

Gen-IV PR&PP

International Interfaces

PRESENTED BY

Lap Y. Cheng

Advanced Reactor Safeguards Spring Working Group Meeting
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Brookhaven National Laboratory | U.S. DEPARTMENT OF ENERGY

Leveraging International Interfaces to Support ARS

GEN IV International Forum℠

Expertise | Collaboration | Excellence

GIF is a framework for international co-operation in research and development for the next generation of nuclear energy systems

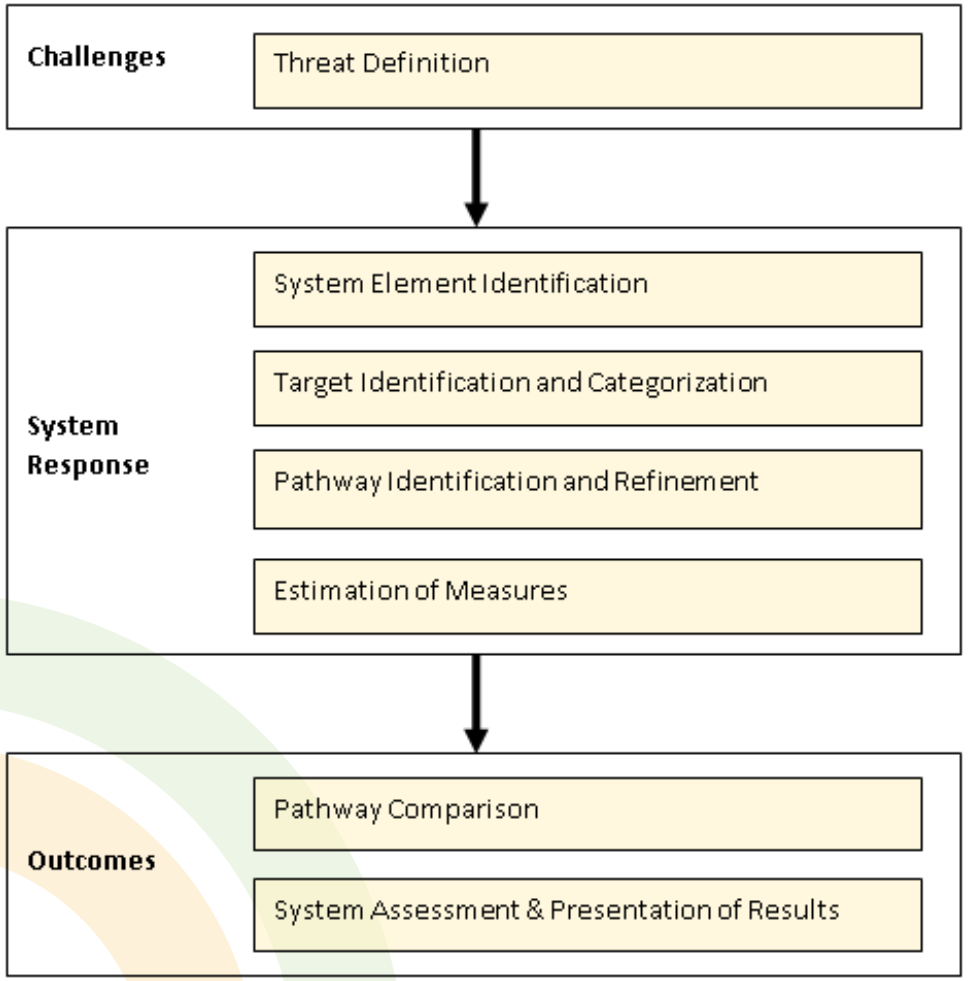
- GIF Proliferation Resistance and Physical Protection (PRPP) Working Group supports GIF technology goal for PR&PP – making GEN IV systems least desirable target for diversion, misuse, theft and sabotage.
- The working group is engaged with IAEA in safety, safeguards, and security (3S).
- ARS supports and leverages GIF PRPPWG activities to
  - Examine safeguards and security aspects of GEN IV systems
  - Evaluate intrinsic/extrinsic features of advanced reactors against proliferation and physical security threats
  - Inform designers and policy makes of research results
  - Facilitate the practice of safeguards and security by design (SSBD)
  - Share experience with vendors interested in international deployment

Recent Accomplishments

- Elected Ben Cipiti to be the 3rd international co-chair of the PRPP Working Group
- Published first two of the PRPP White Papers - LFR & SFR
- Published 2022 edition of the Bibliography
- The SCWR and the GFR white papers will be available soon.

https://www.gen-4.org/gif/jcms/c_9373/publications

PR&PP Evaluation Methodology

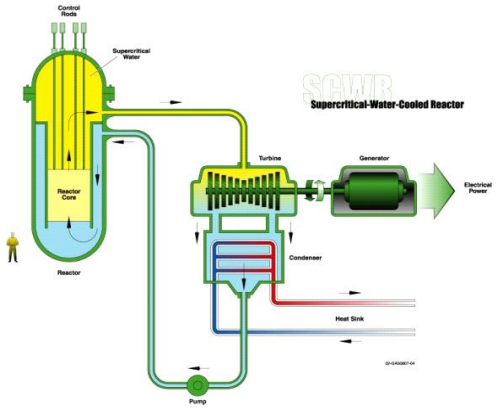


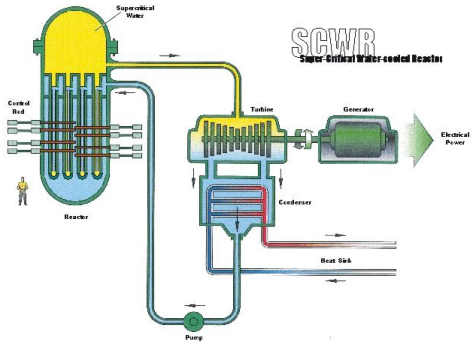
In each White Paper an appendix was added to summarize PR relevant intrinsic design features based on IAEA STR-332*:

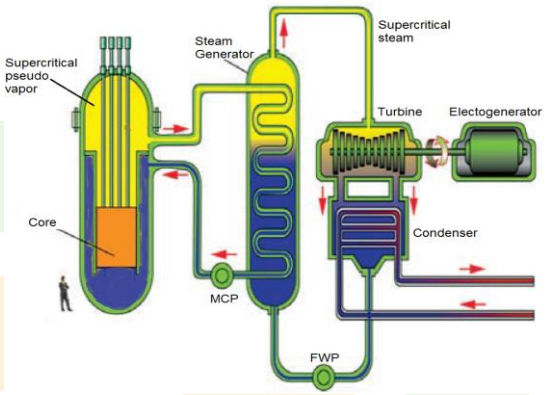
- Features reducing the attractiveness of the technology for nuclear weapons programs
- Features preventing or inhibiting diversion of nuclear material
- Features preventing or inhibiting undeclared production of direct-use material
- Features facilitating verification, including continuity of knowledge

*INTERNATIONAL ATOMIC ENERGY AGENCY, Proliferation Resistance Fundamentals for Future Nuclear Energy Systems, IAEA STR-332, IAEA Department of Safeguards, IAEA, Vienna (2002).

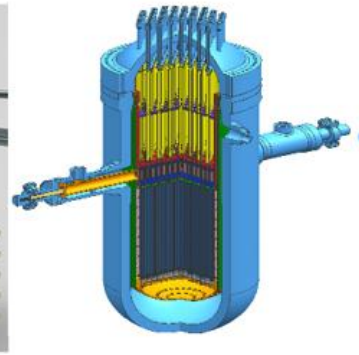
Super-Critical Water Reactor (SCWR) Design Concepts



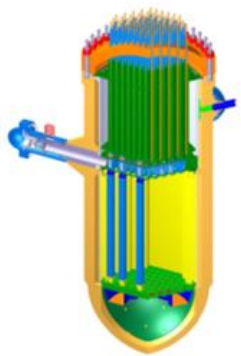




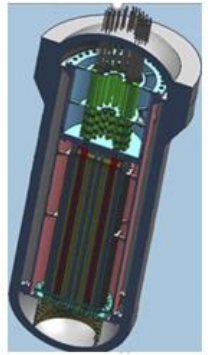
Canada's Pressure-Tube Type SCWR Core Concept



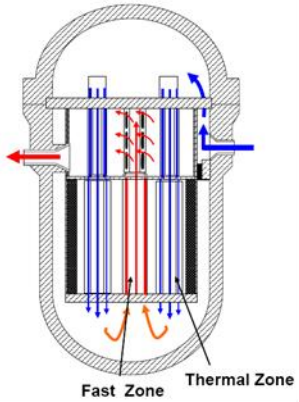
China's Pressure-Vessel Type SCWR Core Concept



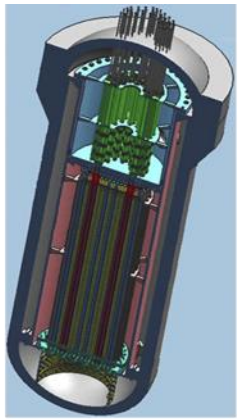
EU's Pressure-Vessel Type SCWR Core Concept



Japan's Pressure-Vessel Type SCWR Core Concept



China's Mixed-Spectrum SCWR Core Concept



Japan's Fast-Spectrum SCWR Core Concept

Russian Federation's Mixed-Spectrum SCWR Core Concept (VVER-SKD)

Russian Federation's Fast-Resonant Spectrum SCWR Core Concept (VVER-SCP-600)

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Some Observations of SCWR PR&PP Characteristics

- PR and PP characteristics of SCWRs are closer to the current fleet of light-water reactors (LWRs) than any of the other GEN IV systems.
- There is little distinction between the operation of the vessel and pressure-tube designs; both rely on batch refueling.
- Use of HALEU (High Assay Low Enriched Uranium) and MOX fuel in some designs may require more effort for protection and surveillance.
- Existence of breeding assemblies in some of the fast and mixed-spectrum reactors might need some modification, such as blending them with minor actinides to make them less attractive for diversion.
- For reactors with a thorium fuel cycle, pure U-233 stream available by diverting Pa-233 is not considered a serious vulnerability in the SCWR solid-fuel cores as the fuel removal and reprocessing time would have to be on a very frequent timescale due to the short, 27 day, half-life of Pa-233.
- The separation of the coolant and moderator may have some PP benefit against sabotage in the pressure tube design.

Crosscutting Topics – Compendium Volume

- Fuel Type – Impact of different fuel types and configurations.
- Coolant/Moderator – Impact of different materials in the reactor design.
- Refueling Modes – Impact of refueling differences.
- Small Modular and Microreactor Options – Impact of moving toward smaller designs.
- Fuel Cycle Architecture – Discusses the types of fuel cycles that may be considered.
- Life Cycle – Discusses cradle to grave impacts.
- Flexibility – Discusses differing energy production, load following, and flexible operations.
- Safeguards Topics – Focuses on IAEA safeguards.
- Cyber Threat – Discusses increasing focus on cybersecurity.
- Operational Transparency – Discusses verification of reactor operations.
- Safety – Synergies between safety, security and safeguards.
- Economics – Impact of PR&PP on plant economics.

Next Steps

- Finalize and issue the remaining PR&PP white papers: SCWR, GFR, MSR, VHTR.
- Complete and finalize companion white paper on crosscutting topics, end 2021/beginning 2022.
- Continue collaborate with IAEA, and other GIF working groups with a focus on the 3S integration and special issues related to deployment of SMRs and micro-reactors.
  - Joint project with the GIF Risk & Safety Working Group to explore the interfaces between safety, security and possibly safeguards.
  - Work with the GIF VHTR System Steering Committee to select a system for analysis.
- Outreach to vendors and share results of working group activities.