ADVANCED REACTOR SAFEGUARDS & SECURITY

Gen-IV Proliferation Resistance & Physical Protection Working Group Activities

ARSS Spring Program Review (BNL)

PRESENTED BY

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PRPP Working Group Objectives

- Canada
- China
- Euratom
- France
- IAEA - Observer
- Japan
- NEA - Secretariat
- Republic of Korea
- South Africa
- UK
- USA

- Facilitate introduction of PRPP features into the design process at the earliest possible stage of concept development

→ PRPP by design

- Assure that PRPP results are an aid to informing decisions by policy makers in areas involving safety, economics, sustainability, and related institutional and legal issues

"Generation IV nuclear energy systems will increase the assurance that they are a very unattractive and the least desirable route for diversion or theft of weapons-usable materials, and provide increased physical protection against acts of terrorism."

PR&PP Resources

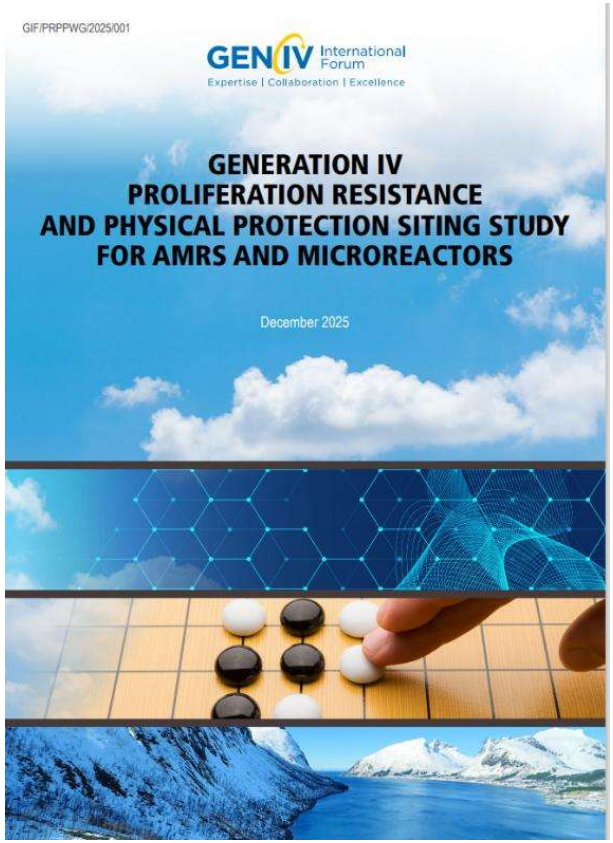
- PR&PP White Papers on each of the six reactor concepts can be found at:

https://www.gen-4.org/gif-activities/working-groups/gif-proliferation-resistance-and-physical-protection-working-group

- The PR&PP Evaluation Methodology and example applications can also be found on the website.
- Unique reference set of documents to foster PR&PP by Design into Gen-IV reactors.

Siting Study for AMRs and Microreactors

- The Siting Study was a response to a request at the 2022 GIF Industry Forum—vendors wanted to understand how various siting locations may affect PR&PP considerations.
- Focused on GEN-IV technologies small modular reactors, but findings also applicable for LWR SMRs
- Report was finalized in December, 2025



Siting Study for AMRs and Microreactors

- Siting in Remote Locations
  - Sealed cores increase difficulty of access which is a PR advantage but makes inspections more difficult.
  - Remote siting reduces access for potential adversaries but also increases response time for off-site response.
  - Key discussion point that remote siting should not in any way lead to reduced protection.
- Siting Near Population Centers:
  - Proximity to good infrastructure for effective data transmission, proximity to people improves transparency to improve PR
  - Proximity also introduces new PP threat vectors, considerations for petty crime and protests, and new sabotage pathways with proximity to airports, train lines, highways, or industrial complexes.
  - Public acceptance of security forces may be a consideration.

Siting Study for AMRs and Microreactors

- Floating or Underwater Power Stations
  - Smaller and compact designs may be harder to reconfigure for misuse, and many designs will not have equipment for refueling (expected to occur at a refueling site)
  - Similar remote siting tradeoffs
  - Potential legal challenges with multi-jurisdictional overlap
  - Physical protection needs to consider new attack paths and threats (approach by water, underwater, collisions, or theft of entire vessel. Physical limitations of the ship for delay and response should be taken into account
- Civilian Marine Propulsion:
  - Many similar tradeoffs as identified above
  - Potentially vastly different PR challenges for sealed cores versus on-line refueling (in the case of molten salt reactor designs)
  - Different challenges with PP due to the vessel traveling and going through different jurisdictions
  - Potentially a more attractive target and potential for technology theft

Siting Study for AMRs and Microreactors (Crosscutting)

- Single Reactor vs. Multi-modules
  - Single reactor sites will have less movement of equipment and fuel, so PR advantage. Multi-module sites will have more refueling activities so increase opportunities for diversions.
  - PP must consider protection during construction of new modules and how construction activities affect the protection strategy.
- Ultimate Heat Sink:
  - There is little impact to PR depending on air or water as the UHS.
  - The loss of decay heat removal systems, regardless of UHS, needs to be considered in sabotage scenarios.
- Autonomous and Remote Operation:
  - Unattended monitoring systems and remote data transmission will be important for international safeguards, and cybersecurity will play a key role.
  - Cyber threats are the key concern. Reactors need very robust delay features to prevent access (assuming no/few people on site). Autonomous operation can reduce potential for insider threats, but needs robust cybersecurity.

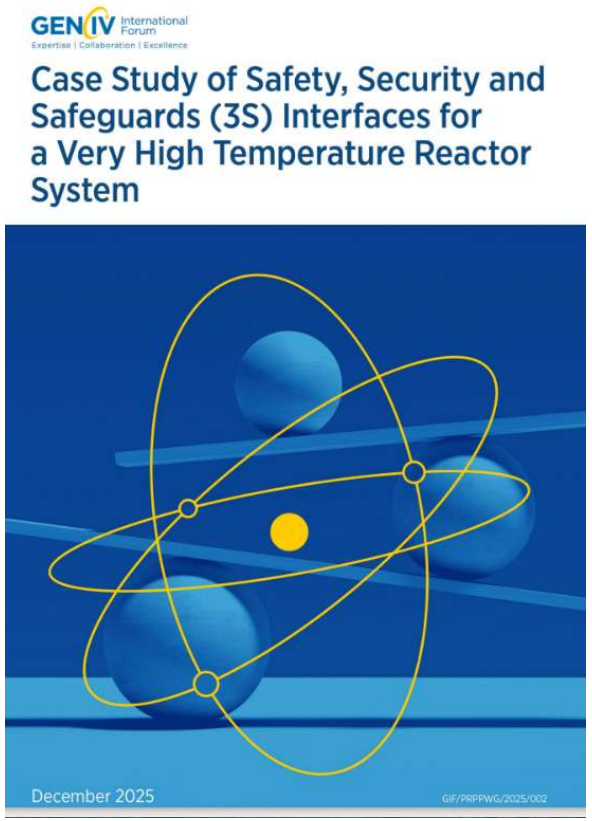
Siting Study for AMRs and Microreactors (Crosscutting)

- HALEU vs. LEU
  - Use of HALEU leads to less frequent refueling, which is a PR advantage. Tradeoff is that fresh HALEU is slightly more attractive (but PR depends on state's fuel cycle and related capabilities).
  - Some countries protect HALEU and LEU at different levels. The protection of the reactor will be the same, but differences for fuel cycle facilities.
- Transit of Reactors:
  - There are some PR tradeoffs in shipping reactors with or without fuel, but probably little overall difference.
  - Shipping a fueled reactor will likely be a more attractive target for theft, but ultimately the operator will probably make the decision based on economic reasons.

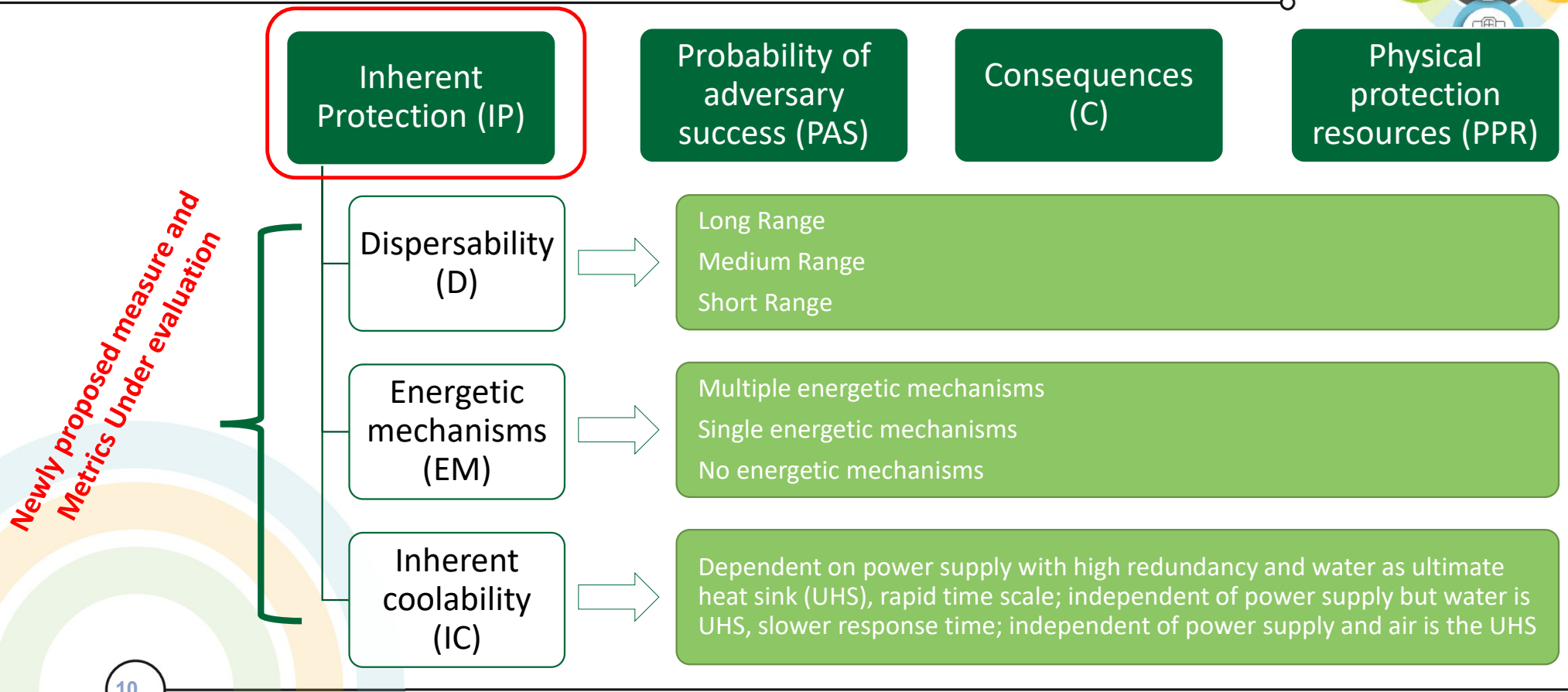
3S Study for VHTRs

The Gen-IV PR&PPWG, Risk and Safety Working Group (RSWG), and Very High Temperature Reactor (VHTR) System Steering Committee collaborated on a case study looking at 3S interfaces for a notional pebble bed reactors.

- *Designed by Idaho National Lab*
- *Pebble bed reactor (PBR)*
- *Power: 200 MWth*
- *Primary System Pressure: 6MPa*
- *Helium-cooled*
- *TRISO fuel pebbles, ca. 200k per core*
- *Enrichment (equilibrium): 15.5-wt%*
- *Core radius: 1.2m*
- *Core active height: 8.93m*



Physical Protection Measures and Metrics



PP Measures and Metrics: Consequence Analysis

- The group has held two virtual workshops to discuss the new metrics and work through a SFR and HTGR case study. Additionally, held a deep dive during the 2025 Annual Meeting.
- Working through differences in theft versus sabotage scenarios and how the metrics would play out for the different scenarios.
- Discussing the inclusion of consequence analysis to be more directly applicable to vendors leading to potentially a new report. This report would be designed for vendors to make it easier to use the methodology without going through a full analysis. This may be in collaboration with RSWG.
  - One benefit is to pull together work on consequence analysis from across the world to help build consensus
  - Also has relevance to EPZ sizing studies, a safety-security interface

Next Steps

- The PRPPWG is evaluating possible next steps with the 3S work, potentially another bottoms-up report based on a LFR design.
- Discussing potential follow-on work from the Siting Study which may include deeper dives on Data Centers, co-location with large LWRs, Maritime, and Remote Operations
- Plan out next steps for the PP Metrics/Consequence Analysis work including the goal of a report and targeted finalization date.

All current reports can be obtained at:

https://www.gen-4.org/gif-activities/working-groups/gif-proliferation-resistance-and-physical-protection-working-group