GIF PRPPWG Activities for GEN-IV PRPP Evaluation

Presented by
Lap-Yan Cheng on behalf of the PRPPWG
Brookhaven National Laboratory USA, GIF PR&PP Working Group Co-Chair

Prepared by
Lap-Yan Cheng, BNL, USA,
Giacomo G.M. Cojazzi, EC JRC, Italy
Guido Renda, EC JRC, Italy

14th GIF-IAEA Interface Tele Meeting, 8 July 2020
PRPP Working Group Objectives

• 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.”
PRPPWG Membership: Countries and Organizations

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

- Current Co-Chairs:
  - G.G.M. Cojazzi (EC-JRC), L. Cheng (BNL-US)
  - G. Renda (EC-JRC), Interim Co-Chair
- K. Hori (JAEA) retired
- UK: K. Hesket, C. Holmes, from NNL appointed
- Canada: B. van der Ende, from CNL appointed
- RoK: KIM, Bong Young (KAERI)
- Russia: ARTISYUK, Vladimir (ROSATOM)
- D. Zayani, from NEA new technical secretary PRPPWG

30th Meeting PRPPWG
06 - 08 November 2019, Upton, New York, USA
PRPPWG Major Accomplishments

• The Methodology: developed through a succession of revisions – currently in Revision 6 report (Japanese and Korean translations)

• The “Case Study” approach: an example (sodium-cooled) fast reactor system was chosen to develop and demonstrate the methodology – resulted in major report

• Joint Efforts with six GIF design areas (System Steering Committees or SSCs,) - resulted in major report including white papers on the six systems -> being updated

All three reports can be obtained at public WEB site:
https://www.gen-4.org/gif/jcms/c_9365/prpp

• GIF Updated PRPP Bibliography, January 2020
<table>
<thead>
<tr>
<th>Section</th>
<th>Type of Information Requested</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Overview of Technology</td>
<td>Description of the various design options in terms of their major reactor parameters, such as core configuration, fuel form and composition, operating scheme and refueling mode, fresh/spent fuel storage and shipment, safety approach and vital equipment, physical layout and segregation of components, etc.</td>
</tr>
<tr>
<td>2. Overview of Fuel Cycle(s)</td>
<td>High level description of the type, or types, of fuel cycles that are unique to this Gen IV system and its major design options. Information such as recycle approach, recycle technology, recycle efficiency, waste form(s)</td>
</tr>
<tr>
<td>3. PR&amp;PP Relevant System Elements and Potential Adversary Targets</td>
<td>For each design option, identification and description of the relevant System Elements and their potential Adversary Targets, Safeguards and Physical Security Approaches</td>
</tr>
<tr>
<td>4. Proliferation Resistance Features</td>
<td>High-level, qualitative overview, developed jointly by the SSC and the PR&amp;PP working group, to identify and discuss the features of the system reference designs that create potential benefits or issues for each of the representative proliferation threats. Ideally the section should highlight the response of the system to the concealed diversion or production of material, the use of the system in a breakout strategy, and the replication of the technology in clandestine facilities</td>
</tr>
<tr>
<td>5. Physical Protection Features</td>
<td>High-level, qualitative overview, developed jointly by the SSC and the PR&amp;PP working group, to discuss those elements of the system design that create potential benefits or issues for potential subnational threats, with specific discussion on the general categories of PP threats (theft of material for nuclear explosives and radiological sabotage)</td>
</tr>
<tr>
<td>6. PR&amp;PP Issues, Concerns and Benefits</td>
<td>Review of the outstanding issues related to PR&amp;PP for the concepts and their fuel cycles, the areas of known strength in the concept, and future plans for integration and assessment of PR&amp;PP for the concept. This section would ideally terminate with a bullet list of identified PR&amp;PP R&amp;D needs for the system concept</td>
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</tbody>
</table>
# System Designs Considered in the Update

<table>
<thead>
<tr>
<th>GIF System</th>
<th>System Options considered in update</th>
<th>Design Tracks considered in update</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>GFR</td>
<td>Reference Concept</td>
<td>2400MWt GFR Mentions ALLEGRO as a GFR demonstrator</td>
<td>Other GEN IV designs include: EM2 (GA) ALLEGRO (V4G4) HEN MHR (High Energy Neutron Modular Helium Reactor) (CEA-ANL and GA-AREVA)</td>
</tr>
<tr>
<td>LFR</td>
<td>Large System</td>
<td>600 MWe (ELFR, EU)</td>
<td>These are the three reference design configurations discussed in the GIF LFR System Research Plan</td>
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<tr>
<td></td>
<td>Intermediate System</td>
<td>300 MWe (BREST-OD-300, Ru)</td>
<td></td>
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<tr>
<td></td>
<td>Small Transportable</td>
<td>20 MWe (SSTAR, US)</td>
<td></td>
</tr>
<tr>
<td>MSR</td>
<td>Liquid-Fueled with Integrated Salt Processing</td>
<td>MSFR, MOSART, MCFR, etc.</td>
<td>Dual Fluid Reactor</td>
</tr>
<tr>
<td></td>
<td>Solid Fueled with Salt Coolant</td>
<td>Mk1 PB-FHR, TMSR-SF1, Kairos</td>
<td>There is a wide variety of MSR technologies, encompassing thermal/fast spectrum reactors, solid/fluid fuel, burner/breeder modes, Th/Pu fuel cycles, and onsite/offsite fissile separation.</td>
</tr>
<tr>
<td></td>
<td>Liquid-Fueled without Integrated Salt Processing</td>
<td>MSDR, IMSR</td>
<td></td>
</tr>
</tbody>
</table>
### System Designs Considered in the Update

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</thead>
<tbody>
<tr>
<td>SCWR</td>
<td>Pressure Vessel</td>
<td>HPLWR (EU) (Thermal)</td>
<td>Most concepts are based on “familiar’ technology, such as, light-water coolant, solid fuel assemblies, and batch refuelling. Implementation of Th and Pu fuel cycles creates additional special nuclear materials of concern.</td>
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<tr>
<td></td>
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<td>Super FR (Japan)</td>
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<tr>
<td></td>
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<td>Super LWR (Japan) (Thermal)</td>
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<td></td>
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<td>CSR1000 (China) (Thermal)</td>
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<td></td>
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<td>Mixed spectrum (China)</td>
<td></td>
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<td></td>
<td></td>
<td>Fast core (RF)</td>
<td></td>
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<tr>
<td></td>
<td>Pressure Tube</td>
<td>Canadian SCWR (Canada) (Therm.)</td>
<td></td>
</tr>
<tr>
<td>SFR</td>
<td>Loop Configuration</td>
<td>JSFR (Japan)</td>
<td>Expect key PRPP issues to be tied to fuel handling, TRU inventory and physical protection.</td>
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<tr>
<td></td>
<td>Pool Configuration</td>
<td>KALIMER (RoK), ESFR (EU)</td>
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<td></td>
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<td>BN-1200 (Russia)</td>
<td></td>
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<tr>
<td></td>
<td>Small Modular</td>
<td>AFR-100 (US)</td>
<td></td>
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<tr>
<td>VHTR</td>
<td>Prismatic Fuel Block</td>
<td>Modular HTR, Framatome (ANTARES)</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>SC-HTGR, Framatome</td>
<td>SC-HTGR is a follow on of the ANTARES and the GA GT-MHR development.</td>
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<tr>
<td></td>
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<td>GT-MHR and GT-MHR, General Atomics</td>
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<tr>
<td></td>
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<td>GT-MHR, OKBM (Russia)</td>
<td>Expect some PR&amp;PP differences between the prismatic block and pebble bed design.</td>
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<td></td>
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<td>GTHTR300C, JAEA (Japan)</td>
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<td></td>
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<td>NHDD, KAERI (RoK)</td>
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<tr>
<td></td>
<td>Pebble Bed</td>
<td>X-Energy Xe-100</td>
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<td></td>
<td></td>
<td>HTR-PM (China)</td>
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</table>
Cross cutting topics

- Fuel type
- Coolant, moderator
- Refueling modes
- Fuel cycle architecture
- Flexibility
- Small modular and micro design options
- Safeguards
- Safety
- Security
- Economics, and
- Cybersecurity
PR&PP and IAEA

• IAEA observer status in GIF

• IAEA always represented at PRPPWG meeting, active and continuous participant since early steps

• PRPP & IAEA-INPRO, Info. exchange, PR Harmonization work

• PRPPWG meeting hosted at IAEA in 2013

• GIF-IAEA (Previous GIF-INPRO) Interface meetings, (last one, the 13th in March 2019)
  – Updated interface Matrix

• Support interactions with the GIF SSCs and the white paper updates
GIF-IAEA Cooperation on PR&PP (1/2)

• Support the ongoing process of updating the GIF SSCs-PRPPWG white papers on the six systems, by providing input and “resources” for identifying PR and PP strengths and weaknesses and by contributing to the review process.

• Address PR&PP crosscutting issues.

• Support the identification of potential safeguards challenges posed by the six GIF designs.

• Provide guidance to designers of NPP on “PR&PP by design”, building on existing and planned activities. Extend collaboration to security area.
GIF-IAEA Cooperation on PR&PP (2/2)

• Revision of INPRO methodology on PR
  – Harmonize the characterization of PR features and the formulation of measures and metrics for comparing the robustness of nuclear systems against proliferation.

• Identify special PR&PP features of small modular reactors (SMR) and micro-reactors.

• Collaborate with the IAEA and GIF RSWG on advancing the concepts of safety, security and safeguards by design.
Back-up Slides
PR&PP Methodology Paradigm

<table>
<thead>
<tr>
<th>CHALLENGES</th>
<th>SYSTEM RESPONSE</th>
<th>OUTCOMES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threats</td>
<td>PR &amp; PP</td>
<td>Assessment</td>
</tr>
<tr>
<td>PR</td>
<td>Intrinsic</td>
<td>Measures and Metrics</td>
</tr>
<tr>
<td>- Diversion/misuse</td>
<td>- Physical &amp; technical design features</td>
<td></td>
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<tr>
<td>- Breakout</td>
<td>- Extrinsic</td>
<td></td>
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<tr>
<td>- Clandestine facility</td>
<td>- Institutional arrangements</td>
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<tr>
<td>PP</td>
<td>- Theft</td>
<td></td>
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<tr>
<td>- Theft</td>
<td>- Sabotage</td>
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</tr>
</tbody>
</table>

The paradigm is consistent with standard approaches to safety assessment
Proliferation Resistance and Physical Protection Working Group (PRPPWG)

Bibliography
Compiled by the PRPPWG

Revision 07
December, 2019

PRPPWG Bibliography

Table of Contents

Section 1 Official GIF PRPPWG reports and deliverables (and their translation in non-English languages) ...................... 3
Section 2 Official/collective GIF PRPPWG articles and papers on the PRPP Methodology and its applications .................. 5
Section 3 Papers and articles authored by GIF PRPPWG members (from one institution) and non-members on the PRPP Methodology and its applications ........................................ 10
Section 4 Papers and articles authored by individual GIF PRPPWG members and non-members on PRPP related topics .......... 16
Appendix A Selected IAEA and IAEA-INFRO publications referencing the PRPP Methodology ...................................... 20
Some Other Recent GIF Activities

- 4th GIF Symposium, Paris, 16-18 October 2018 (Paper)
- EG-Meeting, Paris, 15 October 2018
- 29th GIF PR&PP Working Group Meeting, Paris, 18-19 October 2018; joint session with the SSC/pSSC, Report.
- IAEA Safeguards Symposium, Vienna, 5-9 November 2018 (Paper)
- 13th GIF-IAEA Interface meeting, Vienna, 18-19 March 2019
- 29th GIF RSWG meeting, ANL, 11-12 April 2019
- EG-Meeting, Vancouver, 28-29 May 2019
- ESARDA Symposium 2019, Stresa, 14-16 May 2019 (Paper)
- ESARDA-INMM, Tokyo, 7-10 October 2019 (Contribution)
- EG-PG Meeting, Weihai, 17-18 October 2019
- 30th GIF PR&PP Working Group Meeting, BNL, 6-8 November 2019; Review session.
- Issue of Bibliography, January 2020
Timeline SSCs-PRPPWG Interaction

• 2016 Preparation of the Questionnaire

• 2017, April, Workshop with SSCs and PRPPWG, OECD-NEA, Paris. (Internal report with replies to the questionnaire)

• 2017, October, PRPPWG meeting in ISPRA with session LFR & MSR (meeting report, with records of the session)

• 2018, October PRPPWG meeting in Paris with session with SSCs and pSSC (meeting report, with records of the session)

• 2019 Work in progress

• 2019 November Drafting and reviewing meeting, BNL, NY.

• 2020 Finalization
GIF & INPRO PR harmonization efforts

- Investigated type of users
  - Technology users vs. technology holders
- Presentation of results
- Possible interactions on PR
IAEA-INPRO PR vs GIF PR&PP

• IAEA/INPRO methodology for nonproliferation provides “rules of good practice” for design concepts. A useful check-list → how to do things right

• GIF/PRPP methodology is a systematic approach to evaluating vulnerabilities in design concepts → to make sure that you did not do things wrong

• Methodologies both complement and supplement

• IAEA/INPRO is more broadly known to IAEA community; GIF/PRPP provides a powerful analytical tool for evaluating strong and weak spots and therefore enhancing nonproliferation characteristics in a design

• Together both are potentially useful in national programs