

GEN IV Proliferation Resistance and Physical Protection (PR&PP) Working Group Activities

Presented by

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13th GEN IV-IAEA Interface Meeting, IAEA, Vienna, March 18-19, 2019

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's Major Accomplishments

- ***The Methodology: developed through a succession of revisions – currently in Revision 6 report***
- ***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***

The three reports can be downloaded from:

https://www.gen-4.org/gif/jcms/c_9365/prpp

PR&PP Methodology Paradigm



Threats

PR

- Diversion/misuse
- Breakout
- Clandestine facility

PP

- Theft
- Sabotage

PR & PP

Intrinsic

- Physical & technical design features

Extrinsic

- Institutional arrangements

Assessment

Measures and Metrics

The paradigm is consistent with standard approaches to safety assessment

PRPP Working Group: Terms of Reference

- **Advise** the PG and EG on PRPP issues related to Gen IV nuclear energy systems
- **Maintain capability** to perform or direct PRPP studies on request of GIF
- **Monitor** the integrity and quality of PRPP evaluations for GIF (peer review on request)
- **Maintain configuration control** over the PRPP methodology, its documentation and revisions
- **Strengthen the link** with GenIV system designers, in particular with GIF SSCs
- **Promote and facilitate** early consideration of PRPP in the development and design of GenIV systems
- **Maintain cognizance** of related GIF activities, e.g., safety, economics
- **Maintain cognizance** of and interactions with non-GIF activities such as IAEA initiatives and specific national initiatives
- **Promote** PRPP goals and broad acceptance of the PRPP methodology

Some Recent Activities

- ***PRPP-SSC workshop, OECD/NEA, Paris, April 2017***
- ***IAEA INPRO Technical Meeting on Proliferation Resistance and an Overview of the INPRO Methodology, IAEA, Vienna, October 10-12 2017***
- ***PR&PP for Training Programme to China on GIF methodologies, OECD/NEA, Paris, December 13-14 2017, and Beijing, July 2018***
- ***GIF R&D Outlook Drafting Workshop and contribution: OECD/NEA, Paris, February 20-21 2018***
- ***12th GIF-IAEA Interface meeting: IAEA Vienna, March 26-27 2018***

Other Recent PR&PP Activities

- ***PR&PP @ 2018 GIF Symposium, October 16-17 2018, Paris***
 - ***Paper in session “Safety and Security”, October 17***
- ***PRPPWG meeting: October 18-19 2018, Paris***
 - ***Included a session with SSCs on October 18***
- ***PR&PP @ 2018 IAEA Safeguards Symposium, 5-9 November 2018, Vienna***
 - ***Paper in session “The Safeguards Challenges of New and Advanced Reactors”***
- ***13th GIF-IAEA Interface meeting, March 2019 Vienna***

Outcomes of the April 2017 SSCs-PRPPWG Workshop

- ***Agreement with SSCs to move forward with enhanced interactions between PRPPWG and SSCs/pSSCs***
- ***Development of work plan for interactions***
 - ***Updating of joint SSC/PRPPWG white papers from 2011***
 - ***Possible specific PR&PP studies of GIF concepts***
- ***Formalization of PRPPWG-SIAP-SSC interactions***
 - ***All considered and developed further at PRPPWG meeting in Ispra in November 7-8 2017 (LFR & MSR pSSC attended)***

PRPPWG/SSC Interactions: 2011 Report

- **Abstract**
- **Executive Summary**
- **Part I: General Overview**
- **Introduction**
 - Objectives
 - Scope
- **How the report was produced**
 - Workshops
 - Production of White Papers
 - Drafting of the report
- **Crosscutting Topics**
 - **Fuel Type**
 - **Coolant, moderator**
 - **Refueling modes**
 - **Fuel cycle architectures**
 - **Safeguards topics**
 - **Other GIF crosscuts**
- **Conclusion**
 - Summary
 - Next steps
- **Part II: System White Papers**

System White Papers TOC:

1. **Overview of Technology;**
2. **Overview of Fuel Cycle;**
3. **PR&PP Relevant System Elements and Potential Adversary Targets;**
4. **Proliferation Resistance Features relevant for:**
 - a) **Concealed diversion or production of material;**
 - b) **Breakout;**
 - c) **Production in clandestine facilities.**
5. **Physical Protection Features relevant for:**
 - a) **Theft of material for nuclear explosives;**
 - b) **Radiological sabotage.**
6. **PR&PP Issues, Concerns and Benefits.**

Systems in 2011 SSC-PRPPWG report

GIF System	System Options	Design Tracks	PR&PP Evaluation
SFR	Loop Configuration	JSFR	Used generic SFR system elements in the evaluation
	Pool Configuration	KALIMER	
	Small Modular	SMFR	
LFR	Large System	ELSY	Discussed special features of the two design tracks in the evaluation
	Small Transportable	SSTAR	
MSR	Liquid Fuel	MSFR	Only used the MSFR design based on the Th fuel cycle (breeder option) in the evaluation
		MOSART (only mentioned in footnote)	
	Solid Fuel	AHTR (only mentioned in footnote)	
GFR	Reference Concept	2400MWt GFR (UPuC or UPuN ceramic fuel)	Used reference GFR in the evaluation
VHTR	Prismatic Fuel Block	AREVA Modular HTR (ANTARES)	Used generic VHTR system elements in the evaluation
		General Atomics GT-MHR	
		Russian OKBM GT-MHR	
		JAEA GTHTR300C	
		KAERI NHDD	
	Pebble Bed	Westinghouse/South African PBMR	
		HTR-PM (China)	
SCWR	Pressure Vessel	Thermal core (HPLWR)	Used generic system elements based on BWR and fuel reprocessing facility in the evaluation
		Fast core (Super Fast Reactor)	
	Pressure Tube	Thermal core (CANDU)	

GIF SSCs-PRPPWG updated template

Section	Type of Information Requested
1. Overview of Technology	Description of the various design options in terms of their major reactor parameters (Fuel Form, Main Fertile Material, Fissile Material, Weight of Assembly, Dimensions of Fuel Assembly, Fuel Enrichment, Source of Fissile Material, Fuel Inventory, Presence and Type of Fertile Blanket, Presence and Type of Transmutation Targets, No. of Assemblies to make 1 Significant Quantity (SQ), Irradiation scheme, Composition and burnup of spent fuel elements, Composition of fresh fuel elements, Fuel storage and intra-site, transport methods, Safety approach and vital equipment, Physical arrangement - layout, segregation, etc. -)
2. Overview of Fuel Cycle(s)	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).
3. PR&PP Relevant System Elements and Potential Adversary Targets	For each design option, identification and description of the relevant System Elements and their potential Adversary Targets, Safeguards and Physical Security Approaches.
4. Proliferation Resistance Features	High-level, qualitative overview, developed jointly by the SSC and the PR&PPWG, 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 a) the concealed diversion or production of material, b) the use of the system in a breakout strategy, and c) the replication of the technology in clandestine facilities.
5. Physical Protection Features	High-level, qualitative overview, developed jointly by the SSC and the PRPPWG, 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).
6. PR&PP Issues, Concerns and Benefits	Review of the outstanding issues related to PR&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&PP for the concept. This section would ideally end/conclude with a bullet list of identified PR&PP R&D needs for the system concept.

SSC-&-pSSCs-PRPPWG milestones

- ***SSCs, update of system & fuel cycle sections (1-2) Feb. 2019***
- ***SSCs & PRPPWG, update PRPP sections (3-5), June 2019***
- ***2nd drafts, completion, review and finalization, Sep. 2019***
- ***Cross cutting issues 2019-2020***
- ***Progress report at GIF-EG/PG meetings***

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 12th on March 2018)*
 - *Updated interface Matrix*
- *Support PRPPWG in evolution (R&D 2018 Outlook)*

IAEA & GIF PRPPWG

Recent Interactions:

2017: SSC-PRPPWG WS, Paris & PRPPWG meeting Ispra

2018: Paris GIF week: Symposium, PRPPWG meeting & WS

- ***General and topical presentations***
- ***Included INPRO updates***
- ***Very positive feedback from SSCs***

Safeguardability, SbD & PRPP

- ***GIF, INPRO both addressed Safeguardability from different perspectives***
- ***IAEA Guidelines on SbD, referencing PRPP methodology***
 - ***General (IAEA STR-360) and facility specific documents***
 - ***Vols. relevant to PRPP (NP-T-2.9...)***
 - ***Refer to PRPP methodology and to FSA***
 - ***Support to designers***
- ***Safeguardability as proxy of DP...***
- ***Safeguardability & SbD Support PR&PP by design...***
- ***Anything similar existing for PP ?***

GIF-IAEA-Matrix-Cooperation on the evaluation methodologies, March 2018

<p>Upcoming activities:</p> <ul style="list-style-type: none"> - Reporting to EG/PG - Contribution of PRPPWG to GIF symposium - Planned PRPPWG contribution to the IAEA Safeguards Symposium (Nov 2018) 	<ul style="list-style-type: none"> - IAEA is continuing development of the NE-series documents on Safeguards by design (SG). - An activity to revise the INPRO manual on PR is beginning (TM majority advised revision of the PR Manual, INPRO SCM confirmed that finding in Nov 2017) - Questionnaire sent to the 6 SSC – designers will benefit from a sustained interaction with the PR&PP WG - Regular PRPPWG meeting in conjunction with GIF symposium Oct 2018 with joint section with SSCs for project on updating the PRPP white papers (6 systems) - Possible collaboration in the area to give guidance to designers of NPP on “PRPP by design” (should discuss whether it makes more sense for GIF PRPP to engage NS to start a separate “Physical Protection by Design (PPBD) activity” under Security Series publications as a complement of the “Safeguards by Design (SBD)” publications under NE-Series) 	<p>B.Boyer (SG) J Phillips (NE)</p>	<p>G. Cojazzi (PRPPWG Co-chair) P. Peterson (PRPPWG Co-chair)</p>
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GIF PRPPWG for GIF 2018 R&D Outlook

R&D Line	Brief Description
<p>To capture the salient features of the design concepts that impacts their PR&PP performance</p>	<p>A more mature design will mean less room for design modifications.</p> <p>The analysis will likely focus more on the identification of potential safeguards challenges posed by the designs.</p>
<p>To facilitate PR&PP crosscutting studies of relevance for several of the Generation IV systems</p>	<p>Despite the differences among the six design concepts, aspects such as the systems' fuel, fuel cycle front ends and back ends might share a lot of commonalities among the concepts. These aspects will have to be addressed in a consistent and efficient way.</p>
<p>To identify insights for enhancing PR&PP characteristics of future nuclear energy systems</p>	<p>It is expected to be able to perform a full PR&PP analysis of at least one design concept in the next years.</p> <p>In addition, the possibility to conceive PR&PP guidelines for the benefit of GIF designers is under consideration.</p>
<p>To foster the implementation of a PR&PP culture into the earliest phases of design</p>	<p>To ensure that PR&PP is considered in the most effective and efficient way, there might be the need a) to focus on identifying the PR&PP aspects that need to be specifically targeted at each design stage and b) how to do it in synergy with all the other design tasks and requirements, such as risk and safety.</p>
<p>To keep cognizance of and to benefit from PR&PP activities outside GIF</p>	<p>The PRPPWG will continue to monitor international activities in the PR&PP domain, to cross-fertilize the GIF PR&PP approach and better support GIF designers.</p>

GIF-IAEA: PR&PP

- ***Continuous support of IAEA to the activities of the PRPPWG.***
- ***Observers from IAEA have been always present at the meetings of the PRPPWG and have actively contributed to the working group activities.***
- ***This collaboration is expected to continue and to increase as the GIF designs will mature.***
- ***Priority is to ensure and support ongoing & planned work.***
- ***Engagement need to be matched with available level of resources.***

PRPPWG Path Ahead

- ***Work with GIF system designers and SIAP as designs mature.***
- ***Get updates from member organizations on their PR&PP activities***
- ***Interact with other GIF cross-cutting working groups***
- ***Encourage Safeguards by Design***
- ***Maintain (and strengthen) interactions with IAEA as appropriate***

PRPP Bibliography



Proliferation Resistance and Physical Protection Working Group (PRPPWG)

Bibliography

Compiled by the PRPPWG

Revision 06
20 July, 2018

PRPPWG Bibliography

PROLIFERATION RESISTANCE AND PHYSICAL PROTECTION WORKING GROUP (PRPPWG) BIBLIOGRAPHY

This bibliographic list compiles publications, including articles of scientific journals and papers presented in proceedings of conferences, symposia and workshops, related to the PR&PP Methodology developed by the GIF PRPPWG and its applications. It is intended as a source of information for interested experts and researchers within and outside the GIF community.

Sections 1 to 3 are devoted to reports, articles and papers on the PR&PP Methodology and on its applications.

Section 4 deals with articles and papers authored by PRPPWG members and/or non-members on topics related to the PR&PP Methodology.

Relevant IAEA and IAEA-INFRO documents making reference to the PR&PP Methodology are listed in Appendix A.

For the purpose of the present document "members of the PRPPWG" is defined as colleagues who are or were members or observers in the Group or contributed to its work on an ad hoc basis and, therefore, co-signed some of its outcomes.

In each section/subsection papers are presented by member country/organization in alphabetical order and, for each country/organization, chronologically.

Only references of openly available written reports, articles and papers are included; oral presentations are not considered.

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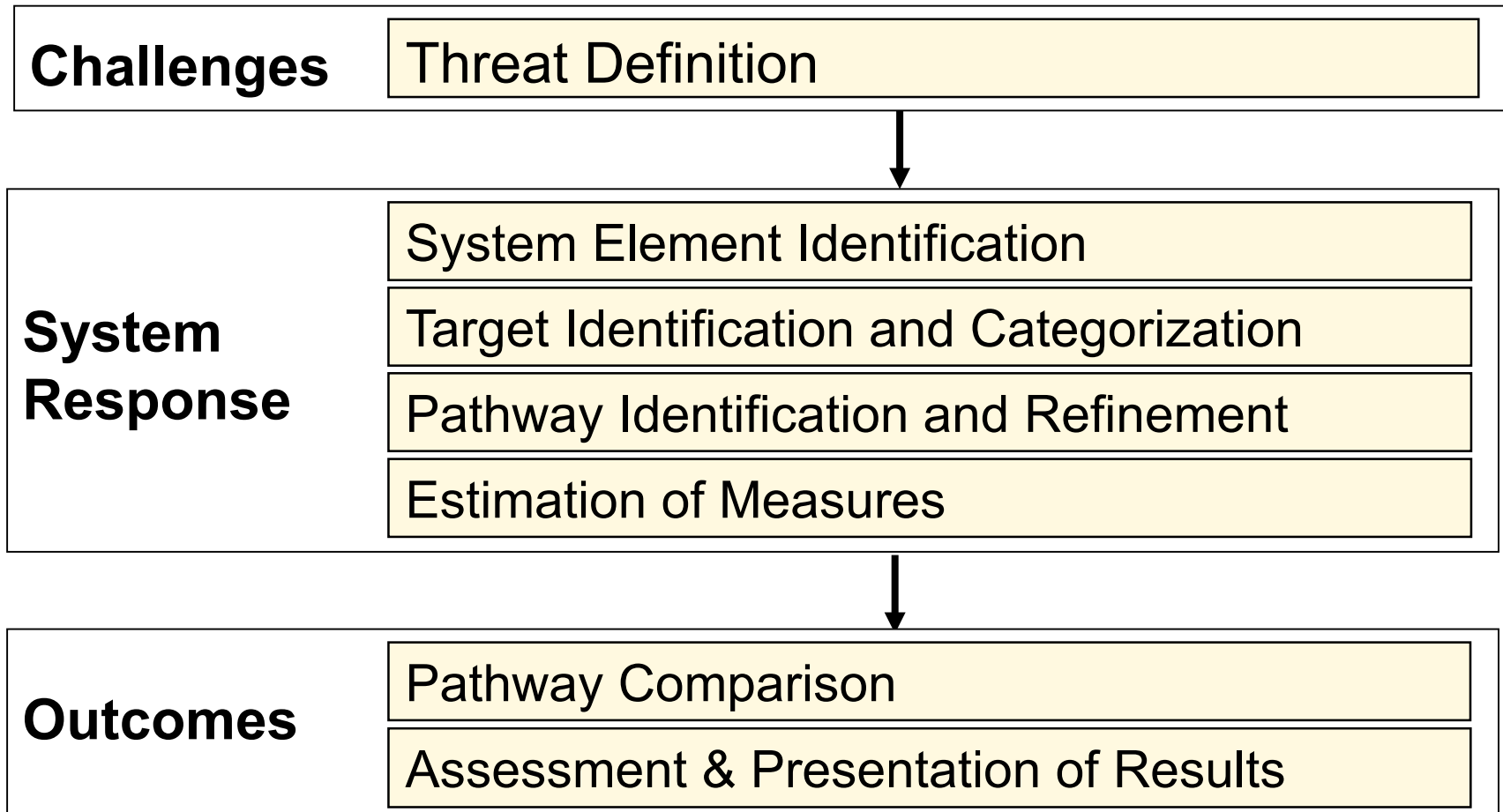
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PRPPWG Membership: Countries and Organizations

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

Back-up Slides

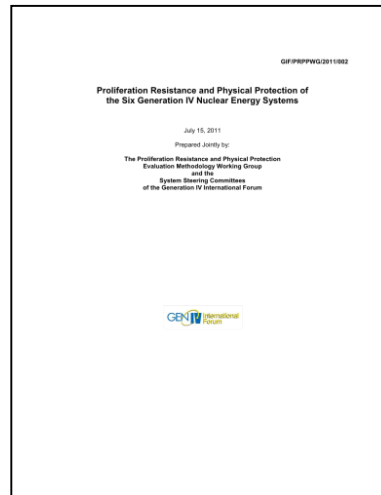
Evaluation Framework



PR&PP Measures

Proliferation Resistance

- **Technical Difficulty**
- **Detection Probability**
- **Material Type**
- **Proliferation Cost**
- **Proliferation Time**
- **Safeguards Cost**



Physical Protection

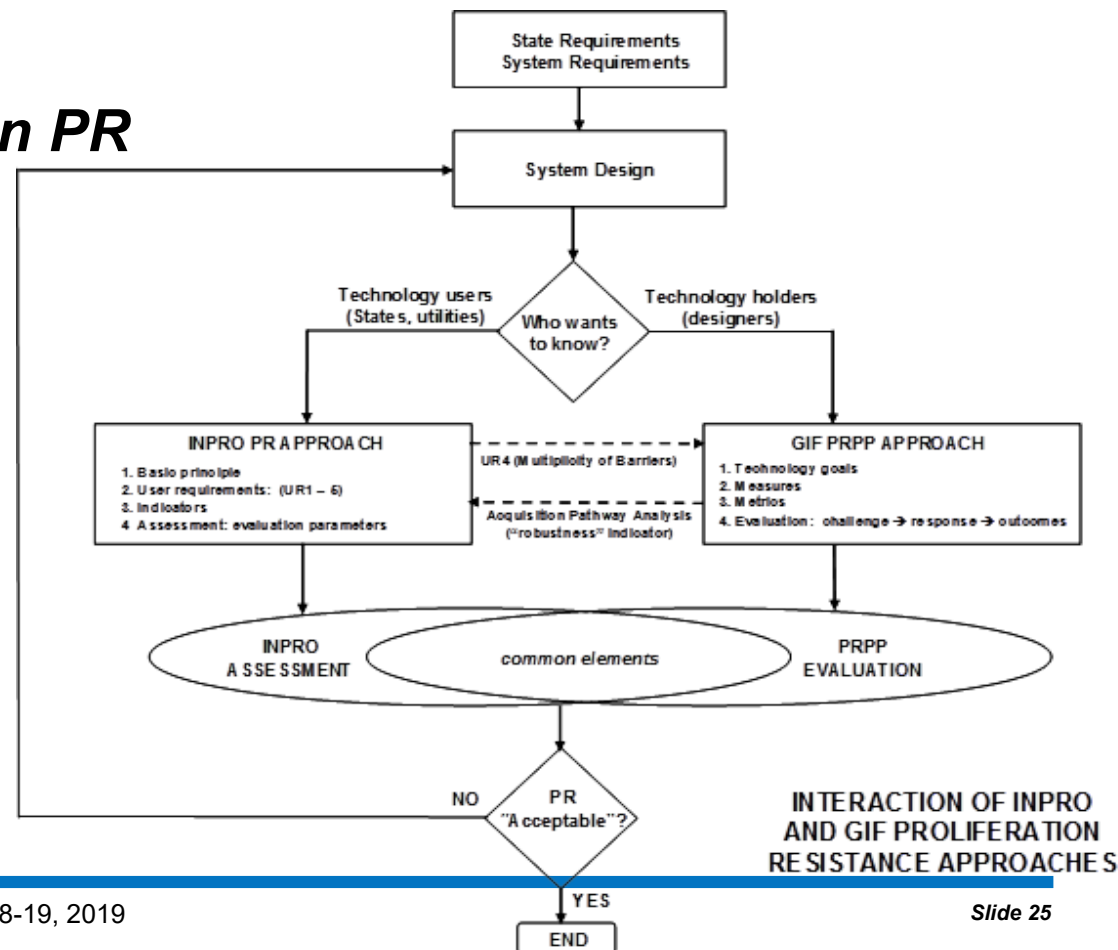
- **Adversary Success Probability**
- **Consequence**
- **Cost of Protection**

GIF & INPRO PR harmonization efforts

- Investigated type of users
 - Technology users vs. technology holders
- Presentation of results
- Possible interactions on PR

IAEA-TECDOC-1684

INPRO Collaborative Project:
Proliferation Resistance:
Acquisition/Diversion
Pathway Analysis (PRADA)



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*

Related Activities of Current Interest

- ***IAEA-INPRO PRADA & PROSA study in final review***
- ***Safeguards by Design ongoing at IAEA and in various countries (See also IAEA Guidelines, referencing PRPP)***
- ***Small Modular Reactors ongoing in several countries***
- ***Several applications of PR&PP methodology, outside GIF, i.a.:***
 - ***Safeguards for Advanced CANDU, AECL***
 - ***Small Modular Reactors, Princeton U.***
 - ***Japanese Sodium Fast Reactor, JAEA & Bologna U.***
 - ***Accelerator-driven research reactor, MYRRHA, SCK-CEN***
 - ***CP European Sodium Fast Reactor, JRC et al.***