GIF Risk and Safety Working Group (RSWG): Terms of reference, accomplishments, current activities and perspectives

Gian Luigi Fiorini (CEA) & Tim Leahy (INL)
RSWG Co-Chairs
Presented by R.Nakai, member of the RSWG

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Gen IV safety Goals

- ***Three specific safety goals "to be used to stimulate the search for innovative nuclear energy systems and to motivate and guide the R&D on Generation IV systems":***
  - **Generation IV nuclear energy systems operations will excel in safety and reliability.**
  - **Generation IV nuclear energy systems will have a very low likelihood and degree of reactor core damage.**
  - **Generation IV nuclear energy systems will eliminate the need for offsite emergency response.**
- ***The RSWG has focused on defining the attributes and identifying methodological advances that might be necessary to achieve or demonstrate achievement of these goals.***
- ***This has been done coherently with the work of IAEA.***

Purpose of the RSWG

- *"Promote a consistent approach on safety, risk, and regulatory issues between Generation IV systems"*
- *Advise and assist the Experts Group and the Policy Group particularly on matters of:*
  - *Generation IV safety goals and evaluation methodologies to be considered in the design*
  - *Interactions with the nuclear safety regulatory community, the IAEA, and relevant stakeholder*

RSWG's report:

Basis for the Safety Approach for the Design & Assessment of Generation IV Nuclear Systems

Delivered by the OECD/NEA on November 2008

- ***The first major work product of the RSWG,***
- ***It presents findings and recommendations:***
  - ***the objectives,***
  - ***principles,***
  - ***attributes,***
  - ***tools, and***
  - ***crosscut R&D***
- ***These are intended to provide designers with concepts and methods that can help designing and assessing on an agreed basis and guiding their R&D activities in a way that promotes the safety basis and efficient licensing of advanced nuclear technologies.***

RSWG's report: Findings and recommendations

Important findings and recommendations of the RSWG presented in the document include:

a. ***Generation IV Safety Philosophy***
b. ***Basis for the design and assessment of innovative systems***

a – Basis for the Generation IV Safety Philosophy

1. ***Opportunities exist to further improve safety records.***
2. ***Several elements have to be considered simultaneously to achieve the safety improvements.***
3. ***Need for a homogeneous strategy applicable for the design and the assessment of Gen IV systems.***
4. ***"Defence in depth" must be preserved in the design of Gen IV systems.***
5. ***The design process should be driven by a "risk-informed" approach.***
6. ***For Gen IV systems, in addition to prototyping and demonstration, modelling and simulation should play a large role in the design and the assessment.***

b- Basis for the design and assessment of innovative systems

I. The Design Basis should cover the full range of safety significant conditions.

II. Updated safety analysis methods have to be applied to examine the full range of safety-significant issues.

III. Ways for achieving the objectives and for implementing the practices for the design improvement.

IV. The safety demonstration's robustness.

V. Practical instruments & tools are suggested to be used by the designers to support the design activity as well as the assessment activities.

Current RSWG Activities

- ***Work during the past year has turned to focus primarily on development of an integrated framework for assessing risk and safety issues in Generation IV systems***
- ***Methodology is tentatively called the Generation IV Integrated Safety Assessment Method (ISAM)***

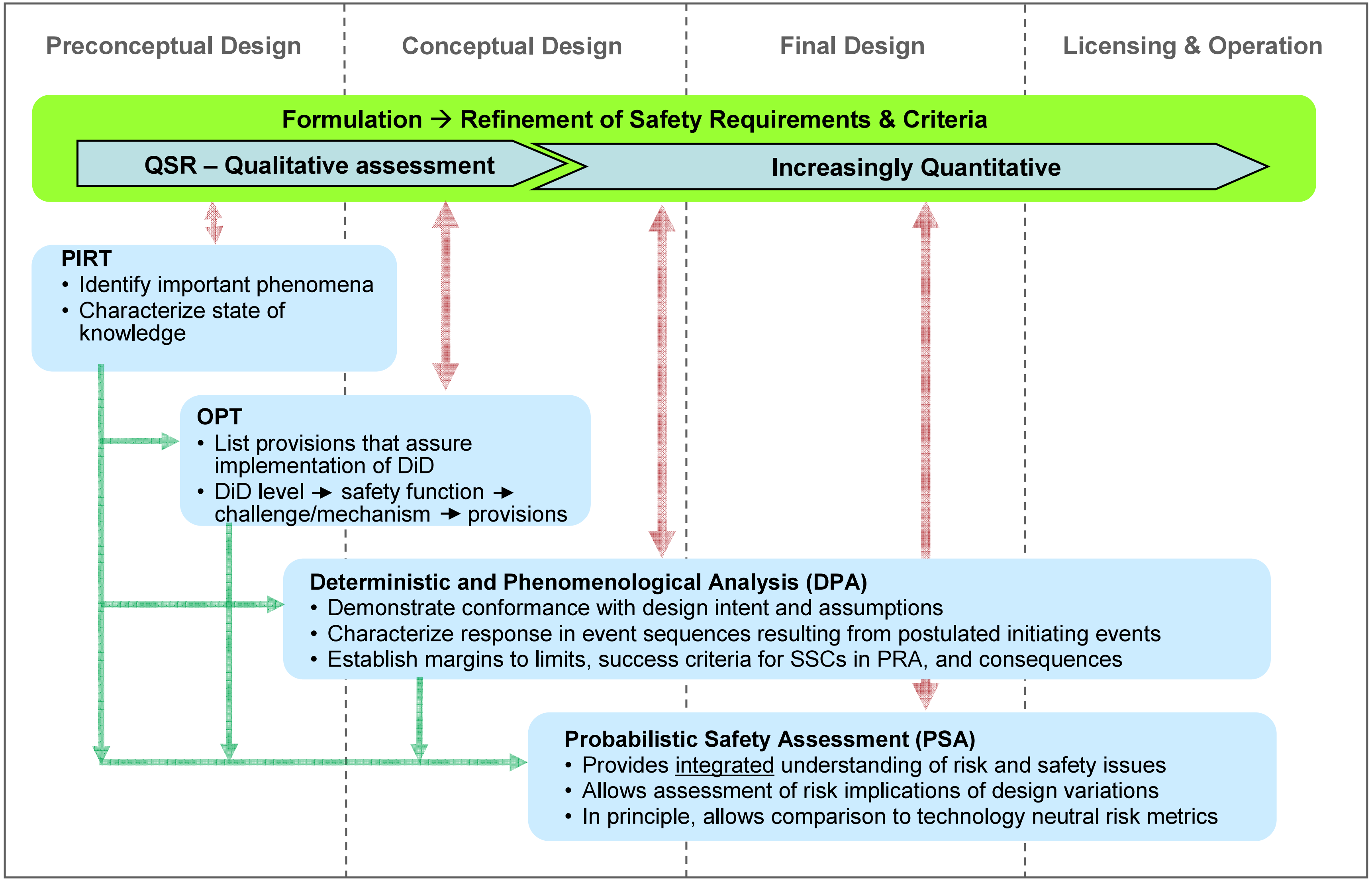
A Viable Assessment Methodology Must Fulfill Multiple Purposes

- ***Commensurate with design maturity, yields a complete and detailed understanding of relevant risk and safety issues***
- ***Within a given concept or design, guides the design process based on a detailed understanding of risk and safety***
- ***Promotes understanding of differences between concepts and designs based on risk and safety issues***
- ***Allow evaluation of a concept or design relative to various safety metrics or “figures of merit”***
- ***Support licensing and regulatory processes***

Desirable Characteristics of an Assessment Methodology

- *Consists of, or is largely based on, existing tools that are widely accepted for their validity. Minimizes need for development of new techniques.*
- *Practical and flexible - allows for graded approach to technical issues of varying complexity and importance. Offers analysis tools tailored to appropriate stage of design*
- *Identifies vulnerabilities and relative contributions to risk*
- *Allows for explicit consideration and characterization of uncertainty*
- *Helps identify areas for additional research, data collection, etc*
- *Supports integration of multidisciplinary inputs*
- *Combines probabilistic and deterministic perspectives*
- *Consistent with RSWG safety philosophy, PRPP methodology, and other relevant work (NUREG-1860, TECDOC-1570, etc)*

Proposed Generation IV Nuclear Systems Integrated Safety Assessment Methodology (ISAM)



Qualitative Safety Features Review (QSR)

- ***The Qualitative Safety Features Review is a new tool that provides a systematic means of ensuring and documenting that the evolving Generation IV system's design incorporates the desirable safety-related attributes and characteristics that are identified and discussed in the RSWG's report***
- ***Using a structured template, the QSR provides a useful preparatory step to shape designers' approaches to their work to help ensure that safety truly is "built-in, not added-onto" since the early phases of the design of Generation IV systems.***

Phenomena Identification and Ranking Technique (PIRT)

- ***Applied initially in pre-conceptual design phase, and iteratively thereafter***

- ***PIRT can be used, e.g., to:***
  1) ***prioritize confirmatory research activities to address the safety-significant issues,***
  2) ***inform decisions regarding the development of independent and confirmatory analytical tools for safety analysis,***
  3) ***assist in defining test data needs for the validation and verification of analytical tools and codes, and***
  4) ***provide insights for the review of safety analysis and supporting data bases.***
  5) ***form input to PSA, and helps identify areas in which additional research is needed***

Objective Provision Tree (OPT)

- ***Applied iteratively from late pre-conceptual design stage through conceptual design***

- ***It can be useful :***
  - ***In helping to focus and structure the analyst's identification and understanding of possible initiators and mechanisms of abnormal conditions, accident phenomenology, success criteria, and related issues.***
  - ***To identify, motivate and document the right requirements for the design of the implemented "lines of protection" in response to safety-significant phenomena identified in PIRT***
  - ***To inform the design process and to help structure inputs that will eventually make their way into the PSA.***

Deterministic and Phenomenological Analyses (DPA)

- ***Classical deterministic and phenomenological analyses constitute a vital part of the overall Generation IV ISAM.***
- ***These analyses will be used as needed to understand safety issues that must guide concept and design development, and will form inputs into the PSA.***
- ***DPA will be used from the late portion of the pre-conceptual design phase through ultimate licensing and regulation of the Generation IV system.***

Probabilistic Safety Analysis (PSA)

- ***PSA serves as the focal point of the ISAM***
- ***While they have inherent value on their own, other elements of the ISAM serve largely to support the PSA***
- ***The PSA is a widely recognized methodology for assessing risk and safety issues***
- ***Worldwide, PSA is increasingly an expected part of the licensing and regulatory process***
- ***By integrating PSA into the earliest practical stages of the design process, designs can be more fully informed by insights and findings developed in the PSA***
- ***Although no element of the ISAM is "required," PSA is regarded as "essential." Other elements "recommended."***

ISAM is integrative

- ***ISAM provides means of developing a full understanding of risk and safety issues - both "whole picture" and detailed; it allows vulnerabilities and their magnitudes to be identified ;***
- ***The ISAM framework integrates multidisciplinary inputs, both qualitative and quantitative as well as probabilistic and deterministic; it can reflect a range of uncertainties inherent in complex technological systems;***
- ***ISAM is methodologically consistent with the notion that, in Gen IV systems, safety must be "built-in, not added-on"***
- ***ISAM should be developed, updated, and applied throughout the plant life cycle.***

Status of Methodology Development

- ***Analytical elements of integrated methodology are well defined***
- ***Roles and purposes of each element have been defined***
- ***Relationships and interfaces between elements are conceptually defined - more work needed***
- ***Limited scale “trial” of the methodological elements has been completed***
- ***Initial draft report describing the methodology has been completed***

RSWG : Future activities

- *The future work of the RSWG has to cover three different objectives:*
  - *To further develop and finalize the definition of the safety principles and the safety objectives introduced within the report;*
  - *To identify the crosscut R&D necessary for their adoption and application;*
  - *To help the System Steering Committees (SSC) in the identification and the implementation of the specific R&D effort needed for the development of the different systems .*
- *Moving forwards from here, the RSWG needs to widen the scope of its reflection to consider parts of the nuclear system other than the reactor (e.g. fuel cycle installations).*

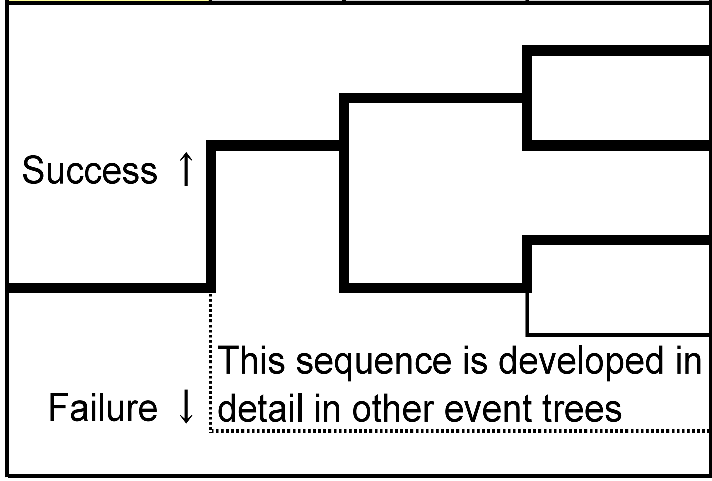
- ***Back up slides :***
  - ***Examples of preliminary ISAM applications***

Summary of PIRT preliminary application

- *Identified the key phenomena to be considered in evaluating the effectiveness of the SASS upon the ULOF accident.*
- *The comparison of PIRT application results between the two different time points showed that the knowledge level of the key phenomena has been improved through the various experimental studies for the SASS R&D.*
- *PIRT can be helpful to identify needs for a key experimental study if it is conducted before addressing a new R&D issue.*

Identification of the scenarios to be analyzed, which result in success or PLOHS within 24hr based on the event tree model in the JSFR Level-1 PSA

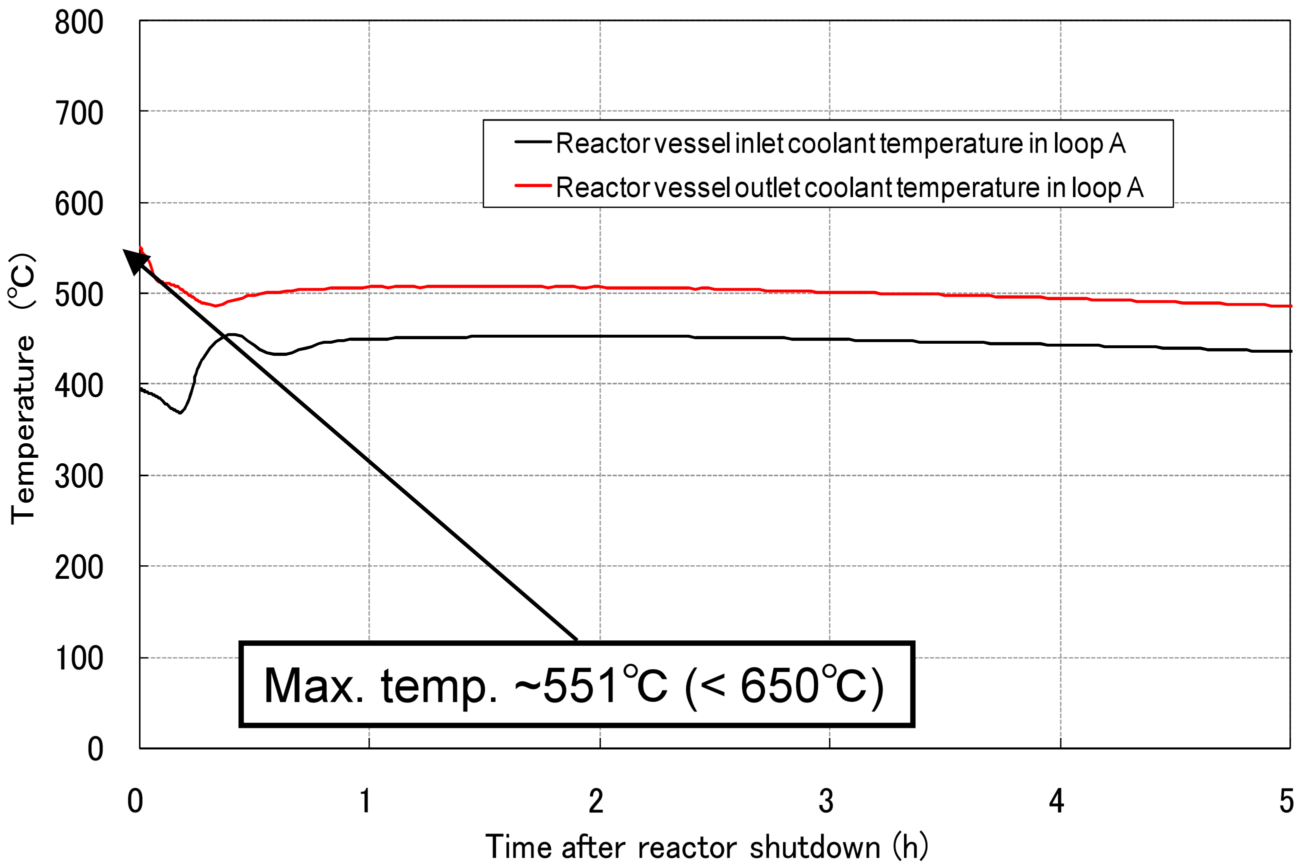
Loss of circulation capability in PRACS-B	Reactor SCRAM	Passive cooling by using PRACS-A *	Passive cooling by using DRACS *	Seq. No.	Accident sequence	Core integrity
IC07-B	RS	ANC	DNC			
				1	/RS*/ANC*/DNC (Successful DBA scenario)	**Should be OK** (1)
				2	/RS*/ANC*DNC (Passive cooling by using PRACS-A alone)	**Unknown** (1)
				3	/RS*ANC*/DNC (Passive cooling by using DRACS alone)	**Unknown** (1)
				4	/RS*ANC*DNC (Loss of all heat sink)	Damage
				5	-	-



(1) Need to be confirmed by DPA

PLOHS: Protected Loss Of Heat Sink, which includes insufficient heat removal capacity.

Example of DPA results: Passive cooling scenario by using DRACS & PRACS-A with a single damper failure (Seq. No. 1)



This accident sequence results in maintaining the reactor coolant boundary integrity.

Summary of DPA results and interpretation to PSA input

Seq. No.	Accident sequence	Core integrity assigned by considering DPA results
1	/RS*/ANC*/DNC (Successful DBA scenario)	OK(1)
2	/RS*/ANC*DNC (Passive cooling by using PRACS-A alone)	Damage(2)
3	/RS*ANC*/DNC (Passive cooling by using DRACS alone)	Damage(2)
4	/RS*ANC*DNC (Loss of all heat sink)	Damage

(1) Confirmed the accident consequences of Seq. 1 based on the DPA results.

(2) Regarded conservatively the accident consequences of Seq. 2 and 3 as damage by considering uncertainty.

- *It is a future work to implement sensitivity analyses to establish margins to limits and to cover imprecision in actual parameters at the design stage.*

PSA application to JSFR DHRS

- *Scope: Level-1 PSA related to internal initiators, focused on decay heat removal after successful reactor shutdown.*
- *PSA was conducted following the steps below*
  - *Identified initiating events based on the plant design information and using master logic diagram method.*
  - *Defined mitigation systems and developed event trees (ET) based on the plant design information and DPA results.*
  - *Developed fault trees (FT) based on the system design information with some assumptions related to support systems.*
  - *Considered common cause failures of major active failure modes of redundant components: e.g., damper failure to open, battery failure to supply electricity to damper drivers.*
  - *Considered human error in operator's recovery action.*
  - *Estimated component failure rate based on the CORDS for sodium-fluid components and domestic LWR reliability data.*
  - *Assigned CCF parameters and HEP based on the methodology used in LWR PSA.*
  - *Quantified accident sequences with combining ET and FT.*

Summary

- ***Following the method described in the draft RSWG/ISAM report, applicability of PIRT, OPT, DPA and PSA to the JSFR system was preliminarily examined.***
- ***It is useful to show the adequacy of safety-related design/R&D activities of JSFR.***
  - ***PIRT: confirmed the appropriateness for key R&D studies***
  - ***OPT: organized structure of safety-related provisions based on the DiD philosophy***
  - ***DPA: provided key information for the success criteria to be defined in the PSA model***
  - ***PSA: assessed the level of safety quantitatively and provide useful information for the system design improvement***