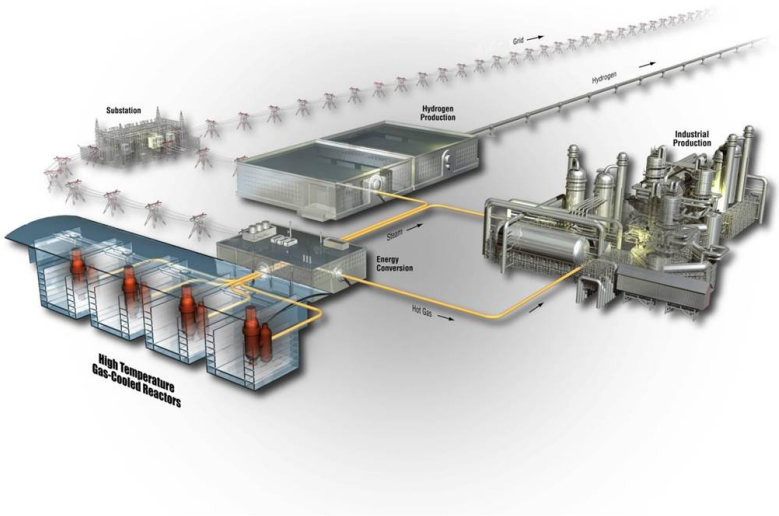
INL/EXT-20-59610
Revision 0

FY-20 GIF-RSWG and WGSAR Status Report

September 2020

James C. Kinsey



Changing the World's Energy Future

Idaho National Laboratory

INL/EXT-20-59610
Revision 0

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Prepared for the
U.S. Department of Energy
Office of Nuclear Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

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INL ART Program

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INL/EXT-20-59610
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September 2020

Approved by:

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SUMMARY

This report provides an end-of-year summary that reflects the progress and status of United States activities supporting the Global International Forum's Risk & Safety Working Group and the international regulators associated with the Working Group on the Safety of Advanced Reactors. This effort has commenced with the development of a technology-neutral, risk-informed approach for the selection of licensing basis events and the assessment of defense in depth for Gen-IV reactor technologies. These U.S. activities are being managed by Idaho National Laboratory on behalf of the U.S. Department of Energy.

CONTENTS

ACRONYMS

ACRS	Advisory Committee for Reactor Safeguards
BDBE	beyond design bases event
CRP	Cooperative Research Project
DEC	design extension condition
DID	defense in depth
Gen-IV	Generation IV
GIF	Global International Forum
HTGR	high-temperature gas-cooled reactor
IAEA	International Atomic Energy Agency
LBE	licensing basis events
LWR	light-water reactor
MHTGR	modular high-temperature gas-cooled reactor
MST	mechanistic source term
NEI	Nuclear Energy Institute
NGNP	Next Generation Nuclear Plant
NSRST	non-safety-related with special treatment
NRC	Nuclear Regulatory Commission
PES	practically eliminated situations
PRA	probabilistic risk assessment
RCM	Research Coordination Meeting
RIPB	risk-informed performance-based
RMRF	risk management regulatory framework
RSWG	Risk & Safety Working Group
SDC	safety design criteria
SR	safety related
SSC	structures, systems, and components
TECDOC	technical documents
TLRC	top-level regulatory criteria
WENRA	Western European Nuclear Regulators Association
WGSAR	Working Group on the Safety of Advanced Reactors

FY-20 GIF-RSWG and WGSAR Status Report

1. PURPOSE

This report provides an end-of-year summary that reflects the progress and status of United States activities related to its proposal for a joint effort engaging the Global International Forum's Risk & Safety Working Group (GIF-RSWG) and the international regulators associated with the Working Group on the Safety of Advanced Reactors (WGSAR). This effort has commenced with the development of a report that describes a technology-neutral, risk-informed approach for the selection of licensing basis events (LBE) and the assessment of defense in depth (DID) for Generation IV (Gen-IV) reactor technologies.

The approach being considered recognizes that advanced reactor technologies provide an opportunity for design simplifications and improved safety through an emphasis on the utilization of inherent and passive safety features. The goal is to achieve safety that is built into the design, not added on, by relying on a combination of deterministic and risk-informed safety approach to implement the defense-in-depth principles.

The approach is being developed in coordination with GIF-RSWG and the WGSAR to establish a harmonized structure that would allow for both reactor developers and regulators to more consistently and effectively assess the passive and inherent safety attributes of those technologies. The U.S. activities summarized in this report are being managed by Idaho National Laboratory on behalf of the U.S. Department of Energy.

2. OBJECTIVES

Several current regulatory review processes are based primarily on light-water reactor (LWR) technology and focus on prescriptive, deterministic approaches, active systems, and associated defense-in-depth principles. Since some Gen-IV systems are pursuing demonstration/deployment within the next decade, a more efficient, systematic, and predictable process leading to an early resolution of fundamental technical issues is needed to support the efficient licensing and commercialization of Gen-IV technologies and to reduce regulatory uncertainties to developers, investors, regulators, and potential owner/operators.

The objectives and anticipated benefits of this planned two-year effort are expected to include:

- Establishing a process that allows for considerations and flexibilities regarding the improved safety margins and advanced design approaches associated with advanced non-light-water reactors while maintaining protection of the public
- Establishing an agreed upon, risk-informed approach to event selection, providing a foundation that technology developers can implement early in the design to avoid costly modifications late in the regulatory review and deployment process
- Providing a framework for a transparent and repeatable way to assess the adequacy of defense-in-depth measures, including the refinement of the concept of "practical elimination."

3. BACKGROUND

3.1 Risk & Safety Working Group RSWG

The RSWG was formed to promote a homogeneous and effective approach to assuring the safety of Gen-IV nuclear energy systems. The overall success of the Gen-IV program depends on, among other factors, the ability to develop, demonstrate, and deploy advanced system designs that exhibit excellent safety characteristics. While the RSWG recognizes the excellent safety record of nuclear power plants currently operating in most GIF member countries, it believes that progress in knowledge and technologies and a coherent safety approach hold the promise of making Gen-IV energy systems even safer and more transparent than the current generation of plants. The RSWG goal most closely aligned with this effort is to: *Promote a consistent approach on safety, risk, and regulatory issues between Generation IV systems.*

3.2 Working Group on the Safety of Advanced Reactors

WGSAR activities support the Nuclear Energy Agency in achieving its goals to "address safety issues associated with new technologies and reactor designs" and to "help maintain an adequate level of capability and competence in member countries necessary to ensure the safety of future nuclear facilities and activities." In this context, the mandate of the WGSAR is to exchange information and experience from licensing and oversight of past and current nuclear facilities.

The WGSAR provides regulatory perspectives through the issuance of technical reports discussing areas in which additional or revised regulatory framework and licensing approaches, including safety research, may be needed to facilitate the effective regulation of advanced reactors and to develop common understanding and approaches. Its involvement in this joint effort is most closely associated with its working method of sharing information and experience on the regulation of advanced reactors to facilitate a cooperative approach to identify key regulatory issues, promote a common resolution, and document commendable practices.

3.3 U.S. Contribution

A technology-neutral, risk-informed, performance-based approach for selection LBE and safety classification of structures, systems, and components is being developed to address the key GEN-IV reactor development and licensing issues. The proposed approach is based on the foundations and key attributes of the Licensing Modernization Project approach developed in the U.S. and endorsed by U.S. industry stakeholders. This approach has recently been approved by the Nuclear Regulatory Commission (NRC) for implementation in the U.S. via the issuance of NRC Regulatory Guide 1.233. Adoption of these key approach attributes on a more global scale would provide an expanded foundation on which the safety bases and design margins of GEN-IV technologies can be evaluated.

The implementation of the approach description established through RSWG and WGSAR interactions is intended to maintain an alignment of the GEN-IV concepts with the multiple levels of defense currently reflected in various international standards (International Atomic Energy Agency [IAEA], Western European Nuclear Regulators Association, Committee on Nuclear Regulatory Activities, etc.) while allowing flexibility for advanced reactor concepts to take full advantage of their passive and inherent safety attributes.

4. PLANNED OUTPUT DOCUMENT

A joint RSWG-WGSAR report describing the approach is being developed over the course of nominally two years, initially based on the U.S. contribution to this effort via the RSWG in close coordination with the WGSAR. A detailed summary of the progress in developing and issuing that report is provided in Section 5 below. Broader GIF system steering committee involvement for design-specific input to the process may be arranged through RSWG. Since both RSWG and WGSAR also include observers from IAEA, the consistency of the proposed approach with IAEA's safety standards and guidelines can be captured, including both the designer and regulatory perspectives.

A potential follow-up cooperative activity could be envisioned that would include specific application of the risk-informed, performance-based process to one or more Gen-IV systems.

5. SUMMARY OF FY 2020 ACTIVITIES

FY 2020 activities continued throughout the year, and includes the following four areas of most significant interaction:

5.1 Coordinated GIF-RSWF and WGSAR Meetings (October 2019)

The U.S. participated in two separate, but coordinated, GIF-RSWG and WGSAR meetings held at the Organisation for Economic Co-operation and Development facility in October 2019. Regarding this joint regulatory report development effort, the primary purpose of those meetings was for the U.S. to familiarize members with the key portions of the proposed risk-informed and performance-based approach and to identify the general set of issues and questions that the pending approach summary report should address. The slide material presented in those sessions is provided in Enclosure 1. That presentation also included a proposed timeline for completing this nominal two-year effort, which was agreed on by both GIF-RSWG and the WGSAR and was summarized as follows:

- Dec 2019: Based on feedback and inputs from the coordinated Oct. 2019 meetings, transmit draft report to GIF-RSWG summarizing the approach
- April 2020: Address/resolve GIF-RSWG inputs
- May 2020: Transmit updated and near-final draft report to GIF-RSWG and WGSAR for review/comment
- Oct 2020: Discuss and finalize report at coordinated GIF-RSWG and WGSAR meetings

5.2 Development of Draft Report with Distribution to GIF-RSWG Members (January 2020)

The draft report was developed in consideration of the inputs and insights provided by the GIF-RSWG members, IAEA observers attending the coordinated meetings, and the international regulators represented within the WGSAR. Additional GIF-RSWG member inputs were provided in the months following the October meetings. Based on the original charter of this joint initiative, and in consideration of these additional inputs, the initial draft report was distributed to GIF-RSWG members in January 2020 for their review and feedback. The report addressed the following primary objectives:

1. Establish the concept of high-level regulatory criteria within each country's existing structure for protecting public health and safety. Summarize the basic event-sequence types that must be addressed in design assessments and associated regulatory actions.

2. Establish event-sequence evaluation as the approach that allows for a facility evaluation against the high-level regulatory criteria, including the option for assessing multireactor and multiple radionuclide source risk.
3. Describe the structure of the frequency-consequence (F-C) target as the foundation of the proposed risk-informed and performance-based approach.
4. Establish a structured risk-informed approach that can be repeatedly applied while achieving consistent results when integrating the use of deterministic inputs and risk insights to identify and categorize events.
5. Establish a process for deriving required safety functions from the fundamental safety functions.
6. Establish a process to effectively classify structures, systems, and components (SSCs), with the goal of focusing attention and resources on those SSCs that are most risk significant.
7. Establish a process for the development of SSC performance requirements, including both capability and reliability.
8. Describe the conservative and deterministic assumptions applied to derive design-basis accidents.
9. Describe key constituents of DID, including plant capability and programmatic aspects.
10. Establish an approach for the use of expert judgment, combined with the use of risk insights, for assessing the adequacy of DID.

It is noted that the key attributes of the approach described in this draft report were closely aligned with the approach developed by U.S. industry stakeholders and reviewed/endorsed by the NRC as an approved method for use in the designing and licensing of advanced reactor technologies in the U.S.[1]

5.3 GIF-RSWG Comments Received and Incorporated into Draft Report (June 2020)

GIF-RSWG members provided feedback and comments on the January report draft (from Section 5.2 above) in the March 2020–May 2020 timeframe. Those inputs were incorporated, and an updated draft report was redistributed to GIF-RSWG members in early June 2020. That updated and current version of the draft report is provided in Enclosure 2.

Consideration of GIF-RSWG member inputs during the development of this updated draft identified five generic or common member comments/concerns that will likely need to be resolved to facilitate the joint GIF-RSWG and WGSAR endorsement of the report. A summary of each of those five comments, with suggested resolution approach, is provided in the sections below.

5.3.1 Terminology and definitions are not directly consistent.

Members indicated that the terminology and associated definitions that are used in the proposed approach are not directly consistent with various and existing international standards and guidance documents (IAEA, GIF, Western European Nuclear Regulators Association [WENRA], etc.), particularly those that are very LWR focused. There are foundational differences in the proposed approach that may make the continued or adapted use of existing terms problematic and potentially confusing. Those differences include items such as:

- Existing international approaches tend to establish terminology based on categorizing initiating event types (abnormal operation or abnormal plant state). In contrast, the categorization of LBEs within the proposed approach is based on the evaluation of plant event sequences from initiating event through

the associated end-state for the sequence. Therefore, an "Anticipated Operational Occurrence" is an expected plant transient event sequence in the proposed approach.

- The existing concept of the "Practically Eliminated Situation" indicates that the term can apply to an initiating event, an event sequence, or a situation.
- In the proposed approach, event-sequence frequencies are evaluated on a "per plant-year" basis where the "plant" refers to all reactor units and radionuclide sources at the plant facility. This is different from the single reactor "per reactor-year" approach reflected in existing approaches and references.

To address this topic, the proposed approach summarized in the report includes a glossary that is intended to clearly define the key terms used in describing the approach. Rather than working to address and resolve all terminology differences at this stage of the report review, it is recommended that the group first work toward establishing an agreement or consensus on the key parts of the proposed approach. Terminology can then be revisited to determine whether it should be revised or updated to allow for clear and consistent understanding and implementation going forward.

5.3.2 There are challenges in identifying initiating events.

Commenters observed that it's not clear how an initial set of postulated initiating events could be identified for advanced technologies when considering the limited design and operating information available.

In response to this question/comment, it is noted that there are various methods available for an initial and the systematic search for initiating events. Those methods include:

- Plant-Level Failure Modes and Effects Assessment where the faults are postulated at the system and system train level and the effects are evaluated on the overall plant response, including an initiating event with potential adverse impacts on mitigating systems.
- Master Logic Diagram in which a logic tree is developed in a top-down fashion to identify the causes of an adverse plant state in terms of the sources of radionuclides affected, the safety functions impacted, and the initiating events that could trigger an adverse end-state.
- Heat Balance Fault Tree in which a logic tree is developed to identify disturbances in the plant heat balance that could initiate a plant transient and resulting initiating event.
- Process hazards analysis such as a Hazard and Operability study in which deviations in plant process parameters are postulated, and their causes, effects, and corrective actions are evaluated.
- Reviews of initiating events from reactor operating experience, regulator data and reports, and results of published probabilistic risk assessment (PRAs) for associated technologies.

5.3.3 A lack of operating experience is a challenge for the application of PRA.

The proposed risk-informed approach relies on insights gained from the PRA, including uncertainty analyses. RSWG members questioned how adequate knowledge and quantification of uncertainties could be achieved for new reactor technologies with limited or no operating experience and potentially incomplete technical support data.

In response to this input and consistent with how this topic has been addressed in the U.S., it was noted to GIF-RSWG members that, if the PRA is introduced at an early stage of design, it is expected that there will be a number of iterations involving changes to plant design, PRA upgrades and revisiting of the tasks in the proposed approach involving LBE selection and evaluation, SSC safety classification, and

selection of special treatment requirements. The impact of changes made through these iterations can be minimized if the guidance below is followed.

- In the initial performance of the PRA, prior to the first attempt at safety classification, the PRA should be performed based on a conservative assumption that all modeled SSCs are commercial grade.
- As the plant design evolves and the PRA is upgraded, conservative assumptions, such as assuming commercial-grade SSCs, will be replaced with a more realistic assumption that will tend to reduce the frequencies of LBE as well as reduce uncertainties.
- As the DID aspects of the proposed approach are applied, special treatments will be specified for safety-related (SR) and non-safety-related with special treatment (NSRST) SSCs that, at a minimum, will involve the selection of performance targets for the reliability and capability and specification of a performance monitoring program.
- As the overall process progresses, the PRA results will become progressively more realistic, reducing the magnitude of uncertainties, which in turn will reduce the mean frequencies and consequences. This should greatly reduce the potential for changes later in the design process that would increase the classification and special treatments of SSCs classified as NSRST. The determination of required safety functions and the selection of SR SSCs are expected to be highly stable through these iterations.

5.3.4 The concept of design extension condition (DEC) does not appear to be addressed by the proposed approach.

Commenters identified that the topic of DEC is not directly called out in the draft report, so it doesn't appear to have been addressed. DEC is a key consideration of both international designers and regulators.

In response, it is noted that Requirement 20 in IAEA SSR-2/1 (Rev. 1)[2]describes DEC as follows:

A set of design extension conditions shall be derived on the basis of engineering judgement, deterministic assessments and probabilistic assessments for the purpose of further improving the safety of the nuclear power plant by enhancing the plant's capabilities to withstand, without unacceptable radiological consequences, accidents that are either more severe than design basis accidents or that involve additional failures. These design extension conditions shall be used to identify the additional accident scenarios to be addressed in the design and to plan practicable provisions for the prevention of such accidents or mitigation of their consequences. (The analysis of design extension conditions for the plant could be performed by means of a best estimate approach (more stringent approaches may be used according to States' requirements).

As described in Section 5.3.2 above, the proposed approach summarized in the draft report includes the consideration of a combination of insights that may be based on engineering judgment, deterministic insights, and probabilistic assessments at the outset of the design process to determine a broad range of potential initiating events. The event sequences resulting from this range of identified initiating events, which include both internal and external events, are then evaluated and categorized according to their risk, in association with the F-C target. The resulting event-sequence categories include beyond design bases event (BDBE) sequences that are more severe than design-basis accidents. BDBEs are assessed on a realistic basis using best estimate analyses, including the use of all available plant equipment (full plant responding). Therefore, it appears that the proposed approach and its associated BDBE category generally address the types of events of interest within DEC.

However, it is also noted that the proposed approach does not generally provide for the identification or classification of additional BDBEs at the end of the application of the process based solely on

deterministic inputs or engineering judgment. Individual member states that have a requirement to include these kinds of judgment-based events within the DEC category may therefore need to supplement the results of the proposed approach with those additional requirements.

5.3.5 The concept of practically eliminated situations (PESs) does not appear to be addressed by the proposed approach.

GIF/RSWG/2007/002, Rev. 1[3] describes that: … *the underlying principle of the "practical elimination" concept is that plausible plant conditions (single initiating events and a selected number of postulated accident sequences) that could lead to large releases and that cannot be reasonably mitigated must be practically eliminated. Practical elimination means that they are physically impossible or proved with high confidence to be very unlikely to arise.*

GIF-RSWG reviewers questioned how the proposed approach addresses PES, since that term was not included in the draft document provided for comment. In response to this feedback, the proposed approach document was updated to more clearly describe how it can be applied to address key attributes of the PES category and now includes the proposed expanded text below on the topic of defense-in-depth assessment.

Note: It is recognized that member countries may have requirements for identifying and addressing "practically eliminated situations" (PES). The PES are addressed by the designer by first identifying all plausible single initiating events, as well as a limited number of postulated sequences which might lead to severe plant conditions and/or specific situations which would lead to large early releases. Within this proposed approach, the resulting LBEs (event sequences) are evaluated through the following set of tasks to assure that they are appropriately categorized and "dealt with" in a manner that is consistent with the frequency-consequence target. A portion of these event sequences may be shown to have been "practically eliminated" if the assessment of their frequency and consequence places them in the "residual risk" portion of the frequency-consequence figure above. These practically impossible "residual risk" sequences will not be addressed by the design, but will be a consideration when establishing Level 5 of the defense in depth approach.

It is further noted that this proposed update to the approach may not fully address various international guidance (such as WENRA) that practical elimination cannot be proved only on probabilistic grounds. Countries requiring a more prescriptive method for identifying very low frequency events that are still considered to be plausible may need to supplement the outcomes of this proposed approach to address these individual member country requirements.

5.4 Draft Report Addressed at GIF—RSWG Meeting (June 2020)

The 31st meeting of the GIF-RSWG was originally scheduled for early April 2020 as an in-person meeting of members at an individual member's facility in Japan. That meeting was initially postponed to early June due to COVID-19 travel restrictions. With the continuation of those restrictions, the meeting was then held June 30–July 1, 2020 by teleconferencing. A June 30th agenda item was dedicated to the review and discussion of member comments on the draft of the technical report (Enclosure 2) on the risk-informed approach for event selection and component classification.

The U.S. presentation of the draft report focused on the five generic comments topics and suggested path forward summarized in Section 5.3 above. There were significant group discussions on these topics, both in the meeting and in a focused follow-up meeting with selected members held via teleconference on July 15, 2020. The result of these interactions is that these generic topics remain largely unresolved. This

appears to be primarily due to member focus and familiarity with IAEA, GIF, and other international standards and approaches that are more deterministic and prescriptive in nature. It is noted that this general difference was recognized during the development of the original U.S. proposal for this joint GIF-RSWG and WGSAR initiative, and establishing an alternate and acceptable risk-informed approach is its primary objective, as summarized in Section 5.2 above.

At the conclusion of these interactions, GIF-RSWG members agreed to further review the existing version of the draft report (Enclosure 2) with a goal of providing additional comments or insights that may support generic issue resolution (Section 5.3) in advance of future meetings. Members also generally concluded that the draft report should not be shared with the international regulators represented in the WGSAR until GIF-RSWG members have reached full consensus on its content.

5.5 Next Steps

The next set of annual coordinated GIF-RSWG and WGSAR meetings is scheduled for October 2020. As summarized in the overall timeline in Section 5.1 above, it was originally intended that the draft report would be finalized through interactions with both groups in these meetings. However, the delays in achieving GIF-RSWG consensus will likely mean that WGSAR members will not be able to receive and review the draft report in advance of the October interactions. This challenge has been raised to the chairpersons of both groups for their recommendations on the most effective path forward, including the establishment of an updated timeline. In the interim, U.S. resources will continue to be applied to GIF-RSWG comment resolution as new or updated feedback is provided.

6. References

[1] U.S. Nuclear Regulatory Commission Regulatory Guide 1.233, Revision 0, *Guidance for a Technology-Inclusive, Risk-Informed, and Performance-based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-water Reactors* (June 2020), ADAMS Accession No. Ml200911698.

[2] IAEA Safety Standards, Specific Safety Requirements SSR 2/1 (Rev. 1), *Safety of Nuclear Power Plants: Design*.

[3] GIF/RSWG/2007/002, Rev. 1 *Basis for the Safety Approach for Design & Assessment of Generation IV Nuclear Systems*, Revision 1 (November 24, 2008)

Enclosure 1

Risk Informed Approach for Event Selection and Evaluation

(Oct. 2019 Presentation)

Enclosure 1

Enclosure 2

Proposal to Establish a Risk-Informed and Performance-Based Approach for Event Selection and Component Safety Classification

(Current Draft Report)

Enclosure 2