SMR Regulators' Forum

Pilot Project Report:

Considering the Application of a Graded Approach, Defence-in-Depth and Emergency Planning Zone Size for Small Modular Reactors

January 2018

FOREWORD

There is a sustained global interest in small modular reactors (SMRs), which have the potential to play an important role in globally sustainable energy development as part of an optimal energy mix. Such reactors have the potential to enhance energy availability and security of supply in both countries expanding their nuclear energy programmes and those embarking on a nuclear energy programme for the first time.

The International Atomic Energy Agency (IAEA) has several dedicated projects and activities concerning SMRs intended to support future Member States needs regarding SMR development and deployment. Over the years, the IAEA has produced a number of major publications and has convened a series of international forums addressing a variety of SMR issues.

This report presents the findings and recommendations of the SMR Regulators' Forum Pilot Project that met regularly between March 2015 and May 2017. The purpose of the pilot project was to identify, understand and address key regulatory challenges that may emerge in future SMR regulatory discussions thanks to the work performed within three working groups (WG). This report contains valuable information for the development of future international guidance in the field.

The Steering committee of the Forum was chaired by D. Jackson of the United States of America and K. Herviou of France served as vice-chair. The IAEA is the Scientific Secretariat and the technical officer responsible for this report was S. Magruder of the Department of Nuclear Safety and Security.

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EXECUTIVE SUMMARY

The SMR Regulators' Forum was formed in 2015 as a two-year pilot project to understand each member's regulatory views on common issues to capture good practices and understand key challenges that are emerging in SMR regulatory discussions. The project would enable regulators to inform changes, if necessary, to their requirements and regulatory practices. The following countries are members: Canada, China, Finland, France, Korea, Russia, United Kingdom and United States.

In 2014, the IAEA facilitated consultancy meetings resulting in an agreement to organize a SMR Forum. Issues for the Forum were identified, security and safeguards issues were excluded taking note that security may need to be included in the future due to claims that SMRs may result in reduced security requirements compared to large NPPs. Within the two-year pilot project, the Forum addressed the following three issues for both light-water and non-light-water reactor designs:

- Graded approach: Regulators are being approached with SMR safety case proposals that are seeking to relax regulatory requirements for design and safety analysis. Therefore, there is a need to clarify the regulatory view of grading and what this means. One key conclusion of this report is that significant benefit could be gained if the IAEA was to lead activities to further clarify the concept of Graded Approach is, how it is used to ensure safety for Nuclear Power Plant (NPP) and how existing tools are used to develop high quality information to inform a decision making process.
- Defence-in-depth: A number of SMR designers are proposing alternate ways to address DiD in their designs. The Forum looked at these approaches and attempted to develop common positions around certain regulatory practices to ensure that the fundamental principles of DiD are maintained.
- Emergency Planning Zones (EPZs): On the basis of the alleged characteristics of SMRs, smaller EPZs are being proposed by some SMR vendors. The Forum examined existing practices and strategies for understanding how flexible (i.e., risk informed) EPZs are established in order to have a common position on this issue.

The Forum distinguishes itself from existing fora/organizations such as the Nuclear Energy Agency fora (e.g. Multinational Design Evaluation Programme - MDEP, Generation IV International Forum - GIF, Group on the Safety of Advanced Reactors - GSAR, Committee on Nuclear Regulatory Activities - CNRA) and World Nuclear Association, Coordination in Reactor Design Evaluation and Licensing working group (CODEL), whose focus lies more on specific technical issues or particular designs. The IAEA publications on SMR designs served as references for the discussions during the project. The Forum adopted the following SMR definition for consistency in discussions. Small Modular Reactors typically have several of these features:

- Nuclear reactors typically <300 MWe or <1000 MWt per reactor;
- Designed for commercial use, i.e., electricity, production, desalination, process heat (as opposed to research and test reactors);
- Designed to allow addition of multiple reactors in close proximity to the same infrastructure (modular reactors);
- May be light or non-light water cooled; and
- Use novel designs that have not been widely analysed or licensed by regulators;

The main limitation encountered by the Forum is the fact that development and deployment of SMRs around the world is at a very early stage in terms of maturity of technologies and varying degrees of activity occurring in Forum member countries. Another constraint was the lack of sufficient information from SMR design vendors on the implications of such things as new novel design principles and features (e.g., passive systems) and whether these challenged or complemented DiD principles.

In addition to the reports from the working groups on the issues noted above, the report provides recommendations for additional areas of interest for future work of the Forum. These include exploring where efficiencies can be gained by sharing of information and closer cooperation between regulators.

1 INTRODUCTION

In the last decade, there has been a significant, increasing interest in small modular reactors (SMR) from its Member States. Due to their smaller size, SMRs offer a viable alternative to larger reactors because they appear to require lower investments in both reactor and associated nuclear infrastructure due to their inherent safety characteristics and in terms of needed political and financial commitments. SMRs can be built in larger numbers, more quickly and in remote locations throughout the world. For these reasons, SMRs might represent a more attractive option to both embarking countries and countries expanding their existing nuclear power programmes. Forum's Regulators recognize that some SMR designs may offer a significant safety enhancement over existing nuclear power plants.

Forum Members States may struggle with the licensing of SMRs due to uncertainties regarding applicable safety requirements, which at present focus mainly on the reactor designs commercially deployed. National safety requirements need to take into account the specific features of SMRs, not only in terms of applying a Graded Approach to existing safety requirements (due to their smaller size and lower risk impact), but also in updating them when new features may represent a risk to safety (e.g. siting requirements for underground or underwater reactors).

1.1. BACKGROUND

The idea of establishing an international forum for regulators to discuss issues associated with licensing SMRs was first raised in mid-2012 after bilateral discussions between the U.S. and Canada. Initial considerations were that the Forum could be associated with NEA/MDEP. Four factors contributed to the decision to ask the IAEA to function as the Scientific Secretariat, (1) the MDEP Technical Steering Committee decided not to expand the scope of MDEP to include SMR issues, (2) the U.S. and Canadian regulators noted that IAEA/INPRO had sponsored several well-attended meetings on SMRs, (3) senior managers at the IAEA were supportive of the idea of an SMR Regulators' Forum, and (4) the membership of the IAEA is much larger than MDEP and would allow for discussions with a much more diverse group of countries.

At the INPRO Dialogue Forum on Licensing and Safety Issues for Small and Medium-sized Reactors, held in Vienna in July/August 2013, there was explicit interest expressed by a number of IAEA Member States to evaluate and discuss the benefits of forming a Regulators' Forum which would specifically address regulatory issues in safety and licensing of SMRs.

As a result, consultancy meetings, facilitated by the IAEA, were held in Vienna 18-20 February 2014, and 22-24 July 2014. The outcome of these consultancy meetings was an agreement to organize a Small Modular Reactor Regulators' Forum on a 2 year pilot basis. A draft Terms of Reference (ToR) and draft Pilot Project Plan were also produced.

1.2. OBJECTIVES OF THE TWO-YEAR PILOT PROJECT

The pilot project was established to obtain an understanding of each member's regulatory views on common issues identified in the scope (Section 1.4) below to capture good practices and methods, enabling regulators to inform changes, if necessary, to their requirements and regulatory practices.

The objectives of the two-year pilot project were:

A. Share regulatory experience amongst Forum Members and strive to reach common understanding on discussed issues;

B. Document and disseminate the results of the discussions; and

C. Interact with key stakeholders, where possible, to effectively inform Forum activities.

1.3. STRUCTURE OF THE FORUM

The Forum structure defined for the two-year pilot project is provided in Figure 1 below. The structure includes a Chairperson, Vice-chairperson, Steering Committee and Issue specific Working Groups.

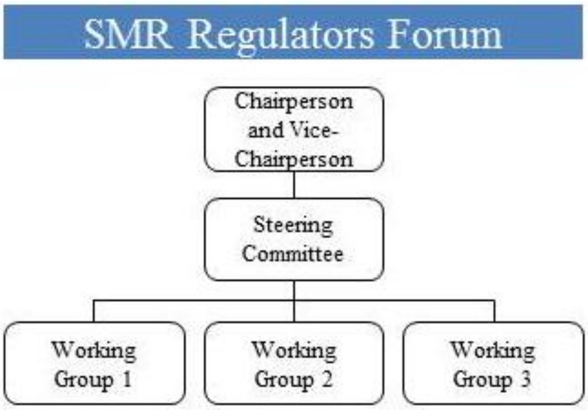

Figure 1. Forum Structure

Through Working Groups, the Forum addressed the following issues for both light-water and non-light-water reactor designs:

- Graded approach
- Defence-in-depth
- Emergency Planning Zone

For the pilot phase of this Forum, membership to the Forum is limited to the IAEA Member States who participated in the initial sessions of this Forum: Canada, China, Finland, France, Republic of Korea, Russian Federation and United States. The United Kingdom joined the Forum during the second year of the project.

At request of Forum members, the IAEA provided a Scientific Secretary made available through an extra budgetary contribution from Forum member(s) to facilitate and promote the Forum's activities. The IAEA provided general and professional support staff to facilitate the implementation of the Forum activities and develop and maintain a communication platform and provide advice on the IAEA Safety Standards.

1.4. SCOPE OF THE PROJECT

Within a two-year pilot project, the Forum addressed the following issues for both light-water and non-light-water reactor designs:

Graded Approach

Problem description: Regulators are being approached by SMR proponents who ask how to apply a Graded Approach for fulfilling regulatory requirements for design and safety analysis. Therefore, there is a need to clarify the regulatory view of grading and what this means.

The Forum members shared information about different methodologies used by regulators and licensees when addressing design and safety analysis requirements. They noted that there is a need to document the various regulatory approaches.

The below considerations stimulated discussions for the Graded Approach working group:

- Comparison between regulatory frameworks for research reactors and NPPs, how they are graded and what implications for SMRs might be;
- Understanding and documenting different methodologies;
- Grading, taking into account multi-module operation; and
- Informing emerging countries who are developing new regulatory frameworks.

Defence in Depth for SMRs

Problem description: A number of SMR designers are proposing alternate ways to address defence-in- depth (DiD) in their designs. The working group was tasked with looking at these approaches and attempting to develop common positions around certain regulatory practices to ensure that the fundamental principles of DiD are maintained.

The below considerations stimulated discussion for the DiD working group:

- Different regulatory approaches for DiD (WENRA);
- Structural and functional DiD (Safety injection accumulators, classification of passive systems);
  - Inherent core characteristics
  - Sole reliance on passive safety systems
- Flexibility in the implementation of DiD for SMRs;
- Shared control room for multi-module facilities (shared SSCs);
- Common cause failure considerations; and
- Different methods of applying single failure criteria.

<u>Emergency Planning Zones (EPZ)</u>

Problem description: Because of the characteristics of SMRs, smaller emergency planning zones (EPZs) are being proposed.

Referring to the following sub-topics, the group examined existing practices and strategies for understanding how flexible (i.e., risk informed) EPZs are established in Member States. The group also reviewed existing IAEA safety requirements and guidance to determine if any changes are needed.

The below considerations stimulated discussion for the working group:

- Siting;
- Source Term for water-cooled reactors (Sources Codes, Standards);
- Source Term for non-water-cooled reactors (Sources Codes, Standards); and
- Consequences from multiple module accidents.

1.5. SRUTCTURE OF THIS REPORT

This report presents the results of the Pilot Project of the SMR Regulators' Forum. It includes information on the background and structure of the Forum, as well as the objectives of the Pilot Project (Section 1.2), main findings of the Pilot Project (Section 2), conclusions, recommendations and common positions reached during the Pilot Project (Section 3) and recommendations for future work (Section 4)

The appendices to this report contain SMR project status and issues in Forum Member States (Appendix I), reports from each of the Forum working groups (Appendices II – IV), and the survey sent out by the Graded Approach and Defence-in-Depth working groups (Appendix V).

1.6. CONSTRAINTS AND LIMITATIONS

The working groups experienced a number of constraints and limitations. They established their scope of work accordingly and implemented other appropriate mitigation measures to address these constraints and limitations. The major constraints and limitations are discussed below.

Limited familiarity with SMR designs and availability of design information

The development and deployment of SMRs around the world is at a very early stage in terms of maturity of technologies and varying degrees of activity occurring in WG Member States. Many regulatory bodies of participating countries have exchanged limited information with SMR designers. Consequently, most WG members have limited personal knowledge and experience with SMR designs that could be brought to the Forum at the beginning of the project. Compounding this limitation is the fact that although IAEA has a number of initiatives to collect and disseminate information on SMR designs, most detailed design information is considered proprietary by SMR vendors and not available publicly. For example, limited design information was available on safety systems. Additionally, although one member had a significant amount of information on a design being developed in its country, it was unable to share such information.

To gain familiarity with many SMR designs, WG members identified a number of documents on SMR designs and safety issues. Members also researched their own files for publicly available information on SMR designs they had received from vendors. For studies like this in the future, it may be fruitful to pursue interactions with SMR designers and vendors to see if they would be willing to discuss design details with the Forum or through the IAEA.

Limited information about application of existing DiD requirements to SMRs

Another constraint was the lack of information from SMR design vendors on the implications of such things as new novel design principles and features (e.g., passive systems) and whether these challenged or complemented DiD principles. For example, to what extent does a multi-module facility design include coupling of modules and sharing of systems? Are designers concluding that provisions for DiD in levels 3 and 4 can be reduced in the presence of simple "inherently safe" design features normally associated with DiD level 1? The WGs could address this limitation only by drawing on information available to them from their limited interactions with designers and regulatory bodies.

Limited time available for the WGs to work together

The limitation of time available for face-to-face discussion is common among international working groups. This limitation was especially constraining for this Forum. Working group members were faced with competing priorities within their sponsoring organizations resulting in limited attendance at Forum meetings from some Member States. There was also limited availability for the WG chairs to meet to understand the relationship between the three. Achieving the group's main objective and reaching agreement on complex issues in SMR designs required significant discussion.

Limited interaction with other conferences, organizations, etc.

Members of the Forum had limited interaction with other organizations during the two-year pilot project. The limitation resulted in the working groups having minimal interaction into activities performed by other regulatory Forums (e.g. IAEA, OECD-NEA) to ensure work was not duplicated and regulatory messaging remains consistent.

1.7. SMR DEFINITION

The SMR Regulators' Forum used the following SMR Definition: Small Modular Reactors typically have several of these features:

- Nuclear reactors typically <300 MWe or <1000 MWt per reactor;
- Designed for commercial use, i.e., electricity, production, desalination, process heat (as opposed to research and test reactors);
- Designed to allow addition of multiple reactors in close proximity to the same infrastructure (modular reactors);
- May be light or non-light water cooled; and
- Use novel designs that have not been widely analysed or licensed by regulators

It should be noted that the IAEA publications on SMR designs served as references for the discussion.

1.8. SMR-SPECIFIC FEATURES

The SMR-specific features that were considered by the WGs have been grouped into four categories: facility size, use of novel technologies, modular design and deployment. These categories are not mutually exclusive. They simply provide a useful framework for identifying important SMR specific features. The key SMR specific features are listed below:

Facility size:

- smaller plant footprint (as compared to a conventional NPP);
- small power of the core:
    - reduced decay heat load;

    - increased core stability;
    - smaller inventory of radionuclides;
    - passive safety.

Use of novel technologies:

- passive cooling mechanisms:
    - natural circulation;
    - gravity driven injection.
- integral design (incorporation of primary system components into single vessel);
- non-traditional or different number of barriers to fission product release;
- unique fuel designs (e.g., ceramic materials, molten salt fuel).

Modular design

- compact and simplified designs
    - practical elimination of some severe accidents
    - inherent safety features (e.g., longer grace periods)
    - fewer structures, systems and components (SSCs)
        - elimination of some traditional initiating events
    - introduction of new events
        - internal to single module
        - module to module interactions
        - new construction techniques
- production, assembly and testing in factory
- multi-module facilities
    - control room staffing
    - sharing of SSCs among modules
    - modules dependence/independence
    - multi-module failure in hazards conditions

Deployment (siting and transportation)

- siting:
    - on ground;
    - underground;
    - on sea;
    - under water;
    - movable;
    - in regions lacking in essential infrastructure (e.g., electrical grid, cooling water).
- module transportation:
    - during construction;
    - during the operation of other modules;
    - for refueling purposes in some designs.

As mentioned in Section 1.6, the WG members found it difficult to establish a definitive list of common SMR features due to the early stage of their development and limited publicly available detailed design information. Their judgment relies on a small set of available SMR documents, and is presented without feedback from SMR designers. For these reasons, the list of SMR features is non-exhaustive; their implications should be considered cautiously and will be considered for review in a latter phase of the Forum.

2. MAIN FINDINGS FROM THE PROJECT

2.1 USE OF A GRADED APPROACH FOR SMRs

The concept of Graded Approach1 is widely discussed in the IAEA safety framework including in documents applicable to nuclear power plants. The national regulatory frameworks for all SMR Regulators' Forum Member States were reviewed and in all cases, evidence of the use of a Graded Approach exists in one form or another. Essentially, the Graded Approach means that the level of analysis, verification, documentation, regulation, activities and procedures used to comply with a safety requirement should be commensurate with the potential hazard associated with the facility without adversely affecting safety. In some cases, analyses may result in the need for less protective measures, but the opposite is also true. Supporting information influences how the Graded Approach is applied in specific cases. In fact, a Graded Approach can also provide insights that lead to the need for more protective measures.

Use of the Graded Approach can enhance regulatory efficiency without compromising overall safety by focusing on specific issues that are important to safety.

Applying a Graded Approach in reviewing an application for a licence2 to perform a set of activities requires the regulatory staff to have a global understanding of a project, risks presented by activities and approaches to prevent and mitigate events following a defence in depth approach The use of grading by both an applicant for a licence and the regulator is heavily influenced by the information supporting the safety proposal. So-called 'proven' approaches and concepts are generally well supported and lend themselves to a more straightforward safety case assessment. In those cases, a regulator's technical assessment can then be focused on more innovative parts of the facility where uncertainties are higher and additional margins or even safety and control measures may be needed. Generally, the more proven the approaches and concepts are in a new reactor design, the more straightforward and efficient the regulatory review will be. This presents a significant conundrum for developers of new technologies such as Small Modular Reactors that utilize more advanced technologies with a goal to enhance both safety provisions and economic performance. In this case, the design may be composed of fewer systems, but these systems will seek to employ passive and inherent behaviours. The argument made by proponents is that this should lend itself to greater use of grading; however, in practice, these approaches are still developing the necessary evidence to demonstrate 'proven-ness'. Until the proven-ness has been established, it is difficult to claim credits for those features in a safety proposal because uncertainties need to be addressed and factored into the safety demonstration. In addition, regulatory attention in a technical assessment must factor in uncertainties from these proposals into licensing decisions. This is of particular importance for new SMR technologies, and particularly for demonstration projects and first-of-a-kind (FOAK) designs where uncertainties are greater. For example, a demonstration project generally integrates a number of novel features such a new fuels, passive and inherent features and compact arrangements of Structures, Systems and Components (SSCs). The intent is to demonstrate integrated performance and gather operating experience (OPEX) to further support safety claims and effectiveness of plant features. Lack of OPEX per novel feature increases uncertainties which are then individually reflected in safety analyses and affect the overall outcomes. The regulatory process would seek to understand how uncertainties are being addressed in the design and in operation until the OPEX has been generated and reviewed. In past practice, this has resulted in the need for supplemental measures in the demonstration plant such as greater safety margins, additional SSCs, restrictions on the operating envelope.

From a safety perspective, member regulators in the SMR Regulators Forum agree that SMRs should be treated as NPPs and that the starting point in use of the Graded Approach is the requirements established for NPPs. In general, IAEA and national regulations requirements and guidance can be applied to activities referencing SMRs. Nevertheless, there may be a need for regulators to define specific requirements in special cases such as marine based facilities where different requirements are justified. Then, the way the applicant demonstrates that their requirements are met may be graded.

This report articulates common views and recommendations from the following four Forum Members regulatory bodies about what "Graded Approach" means, how it is being used, common conditions and considerations concerning its use for application of technology neutral requirements to new technologies:

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[1] Alternate terminologies such as "proportionality" are used in some Member States but the intent of the term is essentially the same.

[2] Some Member States may refer to these as authorizations, or permission.

- Canada – CNSC;
- France – IRSN on behalf of ASN;
- Russian Federation – Rostechnadzor; and
- United States – U.S. NRC.

One of the key findings of this Working Group is that although grading has been used since the beginning of the nuclear power industry, questions remain within the regulated community about appropriate ways to perform grading in design and safety analysis work. There are numerous tools that one can use to implement the Graded Approach and document decision making around how to meet regulatory requirements; however, there is no consensus on appropriate application in specific cases. At the centre of this discussion remains the scope and depth of technical information needed to support a safety proposal: That is, the industry is asking 'what is necessary to demonstrate proven-ness'? Conversely, SMR proponents are looking for more objective-based regulatory approaches with less prescriptive requirements that also recognize new safety approaches. This has resulted in a dilemma for regulators who are seeking to develop a balanced regulatory framework adaptable for a wide range of technologies.

Forum Members' regulatory bodies have the responsibility (e.g. per the IAEA Safety Fundamentals) to ensure that the national regulatory framework for safety is established and implemented to regulate the use of nuclear power. The regulatory framework in each country is developed using the national legal framework and considers both the IAEA safety framework and inputs from stakeholders such as industry, scientific bodies, government and the public. As a result, differences between national frameworks can and likely will always exist. However, regulators also have a history of collaborating in the development of requirements and guidance and are continuing to develop common approaches even if they are not identical. In many cases, similar requirements and guidance exist. The question is raised on the possibility to go further, by sharing views on a given concept, taking into account vendor's constraints in terms of design, manufacturing and operation to develop economically viable concepts, e.g., deploying an identical design in several countries.

One key conclusion of this report is that significant benefit could be gained if the IAEA were to lead the development of a technical document that further explains what the Graded Approach is, how it is used to ensure safety for NPP and how existing tools are used to develop high quality information to inform a decision making process. As a result, the SMR Regulators' Forum should promote and participate in the development of this document. This document should also speak to specific case studies that explore the implications of measures such as passive safety, inherent safety and use of conservatism in addressing regulatory requirements taking into account the use of tools such as:

- Results from R&D activities;
- Safety analysis tools (e.g. hazard analysis, deterministic safety analysis, probabilistic safety assessment); and
- Quality-assured use of Professional Judgement (management system considerations).

The aim of this document is to inform both embarking countries and experienced countries exploring new technologies how regulatory frameworks can articulate the use of the Graded Approach in regulatory requirements and guidance.

2.2 APPLICATION OF THE DEFENCE-IN-DEPTH CONCEPT

SMR designers purport to have enhanced safety performance through inherent, passive and novel safety design features. There are design options for remote regions with less developed infrastructures, factory-builds, multiple-modules, transportable floating and seabed-based units. Any of these SMR features could challenge traditional licensing processes including legal and regulatory frameworks. Some SMR specific features have raised questions about how the principles of DiD are being incorporated into SMR designs.

The SMR Regulators' Forum Defence-in-Depth Working Group was established to identify, understand and address key regulatory challenges with respect to DiD that may emerge in regulatory activities relating to small modular reactors (SMRs). This group's work will help enhance safety and efficiency in licensing, and enable regulators to inform changes to their requirements and regulatory practices. This report articulates common views and recommendations about Defence-in-Depth from the following Forum Members' regulatory bodies:

- Canada – CNSC;
- Finland – STUK;
- France – IRSN on behalf of ASN;
- Republic of Korea –Korea Institute of Nuclear Safety;
- Russian Federation – Rostechnadzor; and
- United States – U.S. NRC.

The DiD WG agreed that, as a fundamental principle for ensuring nuclear safety, the DiD concept is valid for SMRs and should be a fundamental basis of the design and safety demonstration of SMRs. However, since it is recognized that the DiD principles were developed for and applied mainly to large NPPs, the WG discussed their application to SMRs considering the SMR design specifics.

The working group members issued several findings that were divided into three groups: WG common positions, WG recommendations and WG observations. Opportunities to further develop safety guidance to help with the safety assessment of DiD as applied to SMRs were identified and include:

- Demonstration of reinforcement of DiD levels 1 and 2;
- Development of safety criteria and requirements for passive safety systems and inherent safety features;
- Application of failure criteria for safety functions involving passive systems;
- Criteria for exclusion of events;
- New guidance for procedures may need to be developed for inspections of the manufacturer/producer of the module;
- Development of principles and requirements for the safety assessment of "multi-module" SMRs;
- Investigation or enhancement of methods to deal with passive features and with multi-module issues in PSAs; and
- Requirements and guidance for qualifying new materials and features applicable to SMRs designs, including the extent and scale of the testing, verification and validation of models, and fabrication processes.

It should be noted that the WG members found it difficult to establish a definitive list of common SMR features due to the early stage of their development and limited publicly available detailed design information. Subsequently, the group members identified potential opportunities and challenges related to the features and the application of DiD in a general way.

2.3 EMERGENCY PLANNING ZONE

The SMR Regulators' Forum Emergency Planning Zone Working Group was established to identify, understand and address key regulatory challenges with respect to EPZ sizes that may emerge in future SMRs regulatory activities. This will help enhance safety, efficiency in licensing, and enable regulators to inform changes, if necessary, to their requirements and regulatory practices.

Regarding the application of the concept of EPZ size to SMRs, this report:

- Shares regulatory experience and views amongst Forum members;
- Captures good practices and methods and strives to reach a common understanding; and
- Communicate the results of these discussions to the Forum Members.

The WG consensus positions are:

- SMRs encompass a variety of nuclear reactor designs;
- There is a need to consider that the EPZ size for SMRs can be scaled based on the technology, novel features and specific design characteristics; and
- The existing IAEA safety requirements and methodology, in general, for determining the EPZ size are effective in establishing emergency planning zones and distances. Specifically, IAEA Safety Standard Series No. GSR Part 7 and associated lower level publications.

3 CONCLUSIONS AND COMMON POSITIONS

3.1 ENHANCEMENT TO THE CURRENT DEFINITION OF A GRADED APPROACH

Rationale: Despite the existing IAEA definition of Graded Approach, there remain different interpretations as to what it means, who applies it and how it is applied. There is a need to enhance the overall understanding of this term by further describing how it is used for NPPs (including SMRs) and that it does not represent a reduction in overall safety. In fact a document that goes into more depth on the application of the Graded Approach (similar to that which already exists for research reactors) including sample case studies would be useful for all stakeholders. The report of the WG on GA (Appendix II, Section 3.1) presents additional information the GA-WG feels needs to be articulated in the IAEA safety framework for Nuclear Power Plants.

The GA-WG recommends that the IAEA champion such a document for NPPs that encompasses SMRs and that the GA-WG actively participates in the drafting of this document.

3.2 ADDRESSING OPERATING LICENCE JURISDICTIONAL ISSUES FOR FACTORY FUELLED TRANSPORTABLE REACTORS

Factory fuelled and sealed transportable reactor modules represent a unique issue to regulation that will require further discussion about the role of the 'factory' licensee versus the 'site' licensee during the manufacturing, testing, delivery/installation and commissioning phase. Some questions to be addressed include:

- When the module is being assembled (and possibly tested) at the factory, what is the role of the deployment site licensee?
- The factory requires an operating licence to load fuel into each reactor module, perform any testing and store the module prior to deployment in a guaranteed shutdown state. The operating licence for such activities would likely begin with the requirement applicable to NPP (and a safety case) but the Graded Approach will be applied commensurate with the scope of activities. When constructions of site structures are in progress under a construction licence, it is for the purpose of future installation and operation of the reactor module. What is the role of the site licensee in the reactor factory's activities? Is any factory testing part of commissioning? How much commissioning can be credited given transport may introduce stresses to the reactor module?

3.3 COMMON POSITION ON TREATMENT OF SMRS WHEN APPLYING REGULATORY REQUIREMENTS AND GUIDANCE

From a safety perspective, all regulators agree that SMRs should be treated as NPPs and that the starting point in use of the Graded Approach is the requirements established for NPPs. The reason for this is:

- There is clear recognition that although SMRs are smaller in size than NPP, the hazards from the inventory and energy contained in an SMR core are significant enough to require a disciplined application of a set of safety and control measures to ensure the risk from activities involving these reactors remains acceptably low;
- NPP requirements encompass all of the safety and control measures pertinent to activities that will be conducted using SMRs including generation of electricity and secondary uses of the reactor heat; and
- There is a need to send a clear message to the greater public that all power reactor technologies are regulated within one set of safety requirements. At the same time, there is a need to recognize and encourage new technologies to offer significant improvements in performance such as lower potential consequences to persons during all operational states. For example, it is realistic to expect new technologies to be able to offer solutions that significantly reduce off-site radiological consequences from accidents.

With this in mind, regulators may define specific requirements and/or guidance in special cases such as marine based facilities where justified.

The Forum considers that the existing IAEA safety framework for NPPs, as currently articulated, can be applied to activities referencing the use of SMR facilities (either single plant or multiple unit/module facilities). Although many documents have expressed that they are applicable to water cooled reactor concepts, the SMR Regulators Forum agrees that the fundamental principles in the majority of the requirements and guidance can and should be addressed for SMRs including non-water cooled facilities taking into account the Graded Approach. In some cases, guidance does not yet exist or be applicable to certain SMR applications (e.g. factory fuelled transportable reactors). The IAEA safety framework allows for the alternative proposals to be made. Any alternative approach is expected to demonstrate equivalence to the outcomes associated with the use of safety requirements. Paragraph 1.6 of Specific Safety Requirement (SSR) 2/1 (Rev.1) Safety of Nuclear Power Plants: Design, supports this point.

3.4 COMMON POSITION ON GLOBAL HARMONIZATION OF REGULATORY REQUIREMENTS

Member State regulatory bodies have the responsibility (per the IAEA Safety Fundamentals) to ensure that the national regulatory framework for safety is established and implemented to regulate the use of nuclear power. The regulatory framework in each country is developed using the national legal framework and considers both the IAEA safety framework and inputs from stakeholders such as industry, scientific bodies, government and the public. As a result, differences between national frameworks can and likely will always exist. For this reason, harmonization of most requirements and guidance globally will remain a significant long term and complex challenge that will require significant cooperative investments by Member State governments. The regulatory bodies play a partial, but important, role in this discussion. However, there are two points that can be made based on GA-WG lessons learned:

1. There are specific areas where a certain amount of harmonization/agreement can be achieved following approaches developed by the NEA MDEP Codes and Standards Working Group. For example:

    a) common regulatory acceptance criteria for fuel qualification programs;

    b) agreement on factors used to establish emergency planning zones; and

    c) common regulatory acceptance criteria for human factors engineering programs.

    The Graded Approach Working Group recommends that the next phase of work identify a list of such areas and prioritize them for discussion between regulators within the Forum.

2. Regulators have a history of collaborating in the development of requirements and guidance and are continuing to develop common approaches even if they are not identical. In many cases, similar requirements and guidance exist. Work in this area should continue.

3.5 COMMON POSITION: APPLICATION OF THE GRADED APPROACH TO THE LICENSING PROCESS FOR ACTIVITIES REFERENCING SMRs.

A number of proponents (such as industry or energy policy decision makers) of SMR technologies are requesting that licensing processes be modified/adapted or even simplified to address unique features presented by SMRs such as smaller size, difference in design and alternative approaches for construction (e.g. modularity).

Members of the SMRs' Regulators Forum agree that, in many cases, it is not necessary to develop new licensing processes for SMRs as the existing processes are sufficient but efficiencies can be gained in existing processes.

Certification of reactor or module designs is an acceptable approach to use in a licensing process; however, it is not necessary to have it in place to have an efficient licensing process. The decision to adopt a certification regime is a national decision.

IAEA Specific Safety Guide SSG-12, Licensing Process for Nuclear Installations, (which includes NPPs, fuel cycle facilities and research reactors and is applicable to SMR facilities) establishes the following fundamental principles that should be addressed in national licensing processes including:

1. Assessment of the license application against published regulatory requirements (including regulations) and guidance;
2. Documenting the bases for licensing;
3. Transparency of the decision making process including sufficient stakeholder involvement; and

4. Consistent and fair treatment of applicants for licenses.

The licensing process generally involves the following key phases:

1. Submission of an application (including all information supporting safe conduct of the proposed activities);
2. A sufficiency review of the application and time for resolution of requests for additional information;
3. Detailed technical assessment of the application which may include submission of additional supporting information as justified by the regulatory body;
4. Licensing basis development and recommendations to the decision maker;
5. Public hearings or other decision-making forums that include sufficient time for review of the application, interventions and recommendations;
6. Development of the final decision including the rationale for the decision and any additional conditions the license should contain; and
7. Issuance of the licence/authorization.

Items 5 and 6 can form the largest part of the licensing timeline, and is generally independent of facility size and cannot be shortened without reducing the credibility of the licensing process.

Items 1 to 4 are highly dependent on the nature of the activities being proposed, and the completeness and quality of the application, which includes all of the supporting technical information. Although a SMR design can be purported to be 'simpler and safer' the nature of the supporting information determines the duration of Steps 1-4. It is not obvious that a smaller reactor design means a shorter duration for technical assessment. Where multiple levels of novel features are being proposed, the time to complete the review is influenced by the time needed to confirm the proposed safety and control measures meet regulatory requirements. In the Safety Guide SSG-12, the use of the Graded Approach is discussed from Clause 2.46 to 2.50 and reinforces that technical assessment of a licensee's safety case must be conducted under a continual awareness of changing risk based on the information provided. That is, an assessment should evolve based on what is reviewed allowing for changes in focus as needed to provide additional emphasis based on discovery. All Forum Member States use this approach.

3.6 COMMON POSITION ON ISSUES REQUIRING MORE DEVELOPMENT UNDER THE NEXT PROGRAMME OF WORK:

Issue #1: Application of the Graded Approach to Demonstration Facilities, First of a Kind Plants and Nth of a Kind Plants

The levels of uncertainties as well as the level of completeness of technical information supporting safe conduct of activities strongly influences the time needed to conduct technical assessment for licensing or other assessment and compliance activities that occur as the licensee conducts their activities under their licence. Examples would include:

1. Assess cases for exceptions to codes and standards;
2. Regulatory concurrence for key as-built modifications;
3. Construction inspections;
4. Analysis of impacts from non-conformances (with working level codes or technical specifications); and
5. Regulatory witnessing and technical assessment of commissioning activities.

Demonstration facilities and FOAK Plants may and often do present additional levels of uncertainties that may require additional regulatory effort to resolve. This impacts all regulatory licensing and compliance activities and this means that timelines for placing a plant into service will be longer than for subsequent projects. This applies whether building discrete separate plants or adding modules to an existing facility.

However, once precedent has been set through deployment of the first facility, efficiencies are realized when a technical assessment can focus on:

1. Site characteristics;
2. Potential design evolution;
3. The applicant's qualifications and ability to conduct the licensed activities; and
4. Experience gained by both the regulator and the licensee.

3.7 COMMON POSITION REGARDING DEFENCE-IN-DEPTH FOR SMRs

As a fundamental principle for ensuring nuclear safety, the DiD concept is valid for SMRs and should be a fundamental basis of the design and safety demonstration of SMRs.

However, it was recognized that the DiD principles were developed for and applied mainly to large NPPs. Consequently, the design specifics and safety claims associated with SMRs as compared to large NPPs raise some questions for discussion regarding the application of DiD principles to SMRs. These SMR design specifics notably include facility size, modular design, the use of novel technologies, and SMRs applications.

It is not possible to express detailed requirements at this stage because the spectrum of SMRs is very large and because of the lack of information about SMR designs and designer intentions.

At this stage, the DiD WG identified some important issues for consideration in the evaluation of DiD for SMRs. The conclusions of the WG about the application of these issues to SMRs are presented in Section 7.1 of the Report from the WG on DiD (Appendix III).

Among these issues, the DiD WG identified safety areas for which the opportunity to further develop safety guidance to help the safety assessment of DiD applied to SMRs may be investigated. This is presented in Section 7.2 of the Report from the WG on DiD (Appendix III).

It could be desirable for future SMR Regulators' Forum activities to organize exchanges on safety information among SMR designers, regulatory bodies and their technical support organizations (TSOs) to better understand and frame SMR characteristics as mentioned in Section 7.2 of the Report from the WG on DiD (Appendix III).

3.8 CONCLUSIONS ABOUT THE APPLICATION OF DEFENCE IN DEPTH TO SMRs

3.8.1 Application of Defence-In-Depth levels

In general, all five DiD levels as defined for typical large Generation III NPPs and taking into account lessons learned from the Fukushima Daiichi Nuclear Power Plant accident are also applicable to SMRs. Appropriate features should be included in the SMRs design at each level.

In order to ensure the successive levels of DiD, and despite the efforts of SMR designers on DiD levels 1 and 2 reinforcement, it is important to get a clear demonstration of the effectiveness of the design safety features to mitigate PIE (level 3) and of the features to mitigate severe accidents (level 4) for all operating modes.

For DiD level 5, the DiD WG is in agreement with the NEA statement that, no matter how much other levels may be strengthened, effective emergency arrangements and other responses are essential to cover the unexpected.

3.8.2 Independence of the DiD levels

The independence among DiD levels, as far as practicable, is considered to be an important requirement to enhance the effectiveness of defence in depth in international and national standards and documents. The Fukushima Daiichi NPP accident has confirmed and reinforced this requirement. Therefore it should apply to SMRs as well. In the case of SMRs, it could be investigated whether the SMR specific features, in particular the compact design of the modules and the multi modules design, may particularly challenge the independence of DiD levels.

Some questions raised by the application of the independence concept in SMR design could be discussed. These include in particular the interpretation of "as far as practicable" and the acceptability of potential non-independent features that may be implemented by the designers.

3.8.3 Siting issues

Taking into account SMR specific features, selected site characteristics could be an important challenge for DiD reinforcement.

The design shall take due account of site-specific conditions to determine the maximum delay time by which offsite services need to be available.

Siting aspects may have important influence on SMR safety design and different DiD levels due to applicable range of suitable site for SMR installations, including underground, underwater or floating on water.

New site configurations may require the evaluation of additional specific external hazards and environmental phenomena. For multi-unit/module plant sites, designs shall take due account of the potential for specific hazards giving rise to simultaneous impacts on several units/modules on the site.

3.8.4 Design issues

Design activities

The DiD WG identified that the tendency of global standardization and certification of SMR designs desired by some designers and proposed by World Nuclear Association (WNA) may be challenging for current licensees and regulators. It may require significant changes in the national licensing process.

Inherent safety and passive systems

An important challenge for DiD in SMR designs is to achieve a well-balanced safety concept based on the use of optimal combination of active, passive and inherent safety features.

All inherent safety characteristics that are provided by the design and credited in the safety demonstration should be duly substantiated by SMR designers. The requirements and criteria for this demonstration should be defined beforehand and developed, which may need particular guidance. As many safety requirements are mostly oriented to DiD levels 3 and 4, it could be useful to further develop guidance and requirements for safety assessment of DiD levels 1 and 2. (See Section 7.2 of the Report for the WG on DiD, Appendix III).

SMR design with enhanced use of passive systems is required to develop safety criteria and requirements on the level of IAEA safety standards and safety guides, WENRA recommendations and national regulations. (See Section 7.2 of the Report for the WG on DiD, Appendix III).

The use of passive systems may induce new challenges: new innovative technologies without sufficient operational experiences, uncertainties related to qualification and reliability assessments, operational aspects as periodic testing, maintenance and in-service inspections. Particular attention should be paid to these issues at each of the design, construction and operation stages of SMRs. Further development of safety criteria and requirements may be necessary. This includes the application of failure criteria for safety functions involving passive systems. (See Section 7.2 of the Report for the WG on DiD, Appendix III.)

In case of uncertainties in passive features reliability or common cause failure mechanisms in active systems, a combination of active and passive safety systems may be desirable. Such a combination could even strengthen safety function performances at DiD levels 3 and 4 and improve the independence between those two levels.

Excluded events versus postulated initiating events

The designers should demonstrate that they have developed and applied a systematic approach for identifying postulated initiating events that may occur considering the design specifics of their SMRs and taking into account all plant states.

If some initiating events are considered to be "excluded" by SMR designers, without any safety features to mitigate their consequences, sufficient provisions (e.g., design, fabrication and operation) shall be implemented and duly justified.

Criteria for exclusion of events should be established. (See Section 7.2 of the Report for the WG on DiD, Appendix III).

Internal and external hazards

Common mode events due to internal hazards and their influence on DiD levels independence should be considered, taking into account SMR design specifics (e.g., modules, compact design and multi units/modules aspects).

Regarding the external hazards, because SMRs may be located remotely or in many different environments, a detailed analysis of all possible hazards and associated risks for SMRs should be performed for each specific SMR application. The IAEA, OECD NEA and WENRA international experiences and the lessons learned after the Fukushima Daiichi NPP accident should also be extensively used in the design of SMRs regarding the risks of external hazards.

Moreover, multi modules/units aspect should be considered in the safety assessment of internal and external hazards.

Practical elimination

The practical elimination concept should not be used to justify omission of a complete DiD level. For example, it should not be used to justify absence of severe accident management arrangements and capabilities that are expected at DiD level 4 or in the absence of offsite emergency response at level 5.

Multi-modules issues

As the concept of SMR "module" is not equivalent to the "unit" or "plant" concept for large reactors, the safety principles developed for the "multi-units" issue cannot be transposed to "multi-modules" in SMR facilities. Therefore, principles and requirements for the safety assessment of a "multi-module" SMR should be developed. (See Section 7.2. of the Report from the WG on DiD, Appendix III).

It is necessary to demonstrate that for "multi-modules" facilities, connections, shared features and dependencies among modules are not detrimental to DiD. A "multi-modules safety assessment" could contribute to verifying that all common features and dependencies don't induce unacceptable effects.

Even if the SMR concept is based on modular design with small unique power on multi modules/units sites, the SMR design should take due account of the potential consequences of several – or even all – units failing simultaneously due to external hazards. It may affect the methodology for EPZ assessment.

Role of PSAs

As for large reactors, PSAs should be used for SMRs to complement the deterministic approach on which the design relies first.

PSAs could be used to check that DiD principles have been properly applied. PSA results could reflect the reliability of the features implemented at each DiD level and the sufficient independence of the levels. PSAs could also be used for the identification of so-called complex DEC sequences and for the assessment of the risks induced by multi-modules.

Methods to deal with passive features and with multi-module issues in PSAs should be investigated or enhanced. (See Appendix III, Section 7.2.)

3.8.5 Post-design issues

After the design phase, safety should be guaranteed during fabrication, construction, transportation, commissioning, operation and decommissioning of the installation.

The DiD WG focused the discussions on DiD application in siting and design activities. Post-design activities were not discussed in detail. However, the DiD WG has identified fabrication and transportation as specific aspects to focus on for many SMRs.

Since there is an increasing role of the manufacturer/producer of the main equipment of the module in the factory conditions, inspections performed in the factory are particularly important and new guidance for procedures for such inspections may need to be developed. (See Appendix III, Section 7.2.) A well planned and properly documented site acceptance testing and commissioning program should be prepared and carried out.

3.8.6 Novel technologies

Detailed assessments should be applied to innovative technologies of SMR designs that are without operational experiences. The new features and practices shall be adequately qualified through verifications, validations and testing before being brought into service to the extent practicable, and shall be monitored in service to verify that the behavior of the plant is as expected. Requirements and guidance are necessary for qualification programs of new materials and features applicable to SMR designs including the extent and scale of the testing, verification and validation of models, and fabrication processes. (See Appendix III, Section 7.2.)

3.9 CONCLUSIONS FOR EMERGENCY PLANNING ZONE FOR SMRs

The EPZ WG developed conclusions as listed below:

- SMRs encompass a variety of nuclear power plant designs. Managing SMR events involving the potential for releases of radioactive material that challenge public safety and the environment requires a coordinated response;
- There is a need to consider that the EPZ for SMRs is scalable depending on the results of a hazard assessment, the technology, novel features and specific design criteria, as well as for some, policy factors. The IAEA safety requirements and methodology for determining the EPZ size are effective in establishing an emergency preparedness and planning program, such that if a release does occur, protective actions will be implemented to protect the public and environment;
- A pre-application process may be considered to discuss the requirements and standards for siting and determining EPZs with potential applicants;
- For SMRs without on-site refueling capability, there is a need to consider the establishment of an EPZ at any intermediate stop and land-based maintenance facility used for the handling and the storage of the fuel assemblies;
- There is a need to consider some level of community emergency preparedness, for example, to receive public information and perform response drills, specifically when the size of the EPZs for SMRs are reduced to be in close proximity to densely populated centers;
- For SMR designs employing novel features and technology, there is a need to consider a mechanistic methods for determining relevant source terms, which may be considered in the determination of the size of the EPZ&Ds; and
- The same design of SMR implemented in different countries may result in different EPZ sizes depending on the regulation, protection strategy, dose criteria, policy factors, and public acceptance.

The IAEA Secretariat highlighted that:

- Existing IAEA Safety Standards already address EPZ&Ds and are applicable to new reactor designs (including SMRs);
- According to existing IAEA Safety Standards, it would not be appropriate to consider EPZ&D as a design issue (i.e. as being related/influenced by the design safety);
- EPR arrangements, including EPZ&D, need to be developed based on results of hazard assessment, accounting for events of very low probability and events not considered in the design;
- High uncertainties and the need for urgent response actions may persist for SMRs, hence the need for an emergency classification system and pre-established response plans;
- The timing may be positively affected by new reactor designs. The possible failure of additional safety functions needs to be considered nonetheless;
- The duration of the release may be impacted by new reactor designs, but response actions may still be required in all directions; and
- The size of the release may be affected by new reactor designs, having an effect on the size of the EPZ&D. The impact may not be the same for all EPZ&D.

4 RECOMMENDATIONS FOR FUTURE FORUM ACTIVITIES

Project participants made several recommendations with regard to the follow-up of the project. These are presented below:

4.1 RECOMMENDATIONS FOR FUTURE ACTIVITIES FROM GRADED APPROACH WORKING GROUP

From a safety perspective, member regulators in the SMR Regulators Forum agree that SMRs should be treated as NPPs and that the starting point in the use of the Graded Approach is the requirements established for NPPs. In general, IAEA and national regulations requirements and guidance can be applied to activities referencing SMRs. Nevertheless, there may be a need for regulators to define specific requirements in special cases such as marine based facilities where different requirements are justified. Then, the way the applicant demonstrates that their requirements are met may be graded.

The concept of Graded Approach is widely discussed in the IAEA safety framework and is mentioned in documents applicable to nuclear power plants. Appendix 1 provides a high level sampling of some of the IAEA documents by the GA-WG. The review indicated that, as expected, the IAEA does not prescribe any specific methodologies, but does present enough guidance to allow Member States to develop appropriate acceptance criteria under their regulatory framework.

One of the key findings of this Graded Approach Working Group is that although grading has been used since the beginning of the nuclear power industry, questions remain within the regulated community about appropriate ways to perform grading in design and safety analysis work. In the past, when the technologies were still in the early stages of development, the decisions to implement certain safety approaches were based on a mix of engineering judgment and scientific investigation with minimal public engagement. In modern transparent regulatory frameworks the same approaches remain valid and are, in fact, well supported by operating experience gained over decades; however, the public is seeking more information showing the rationale behind conclusions made by regulators and proponents of projects. In other words, the proponents and the regulators are being asked to show how they have applied a Graded Approach in making risk-informed decisions.

In the past two years of work within the GA-WG, the national regulatory frameworks for all SMR Regulators' Forum Member States were reviewed and in all cases, evidence of the use of a Graded Approach exists in one form or another. However it is recognized that more could be done to document how the methodologies used to perform grading are appropriate in each case.

One key conclusion of this report is that significant benefit could be gained if the IAEA were to lead the development of a technical document that further explains what the Graded Approach is, how it is used to ensure safety for Nuclear Power Plants and how existing tools are used to develop high quality information to inform a decision making process. As a result, the SMR Regulators' Forum should promote and participate in the development of this document. This document should also speak to specific case studies that explore the implications of measures such as passive safety, inherent safety and use of conservatism in addressing regulatory requirements taking into account the use of tools such as:

- Results from R&D activities;
- Safety analysis tools (e.g. hazard analysis, deterministic safety assessment, probabilistic safety assessment); and
- Quality-assured use of Professional Judgement (management system considerations).

One of the main advantages of such an effort would be to establish common ground between regulators on which grading approaches might be acceptable from one Member State to the next under different circumstances. Even if requirements cannot be harmonized between Member States due to legal structure differences, acceptance of common methodologies can facilitate the use of one regulator's conclusions to inform another's technical assessment work. Such work would also inform both embarking countries who are developing their regulatory frameworks in light of new technologies.

In the next phase of work for the SMR Regulator's Forum, the GA-WG should complete a review of IAEA Safety Standards and Guides and present recommendations to the IAEA for future consideration.

In the next phase of work for the SMR Regulator's Forum, the GA-WG should collaborate with the other SMR Regulators' Forum working groups to provide greater clarity to the IAEA of the concept of "proven" when applied to technologies or methodologies. The rationale for this is that the level of proven-ness is directly tied back to the methods used to perform grading or to assess the adequacy of grading. For example, a low degree of proven-ness of a technology increases the uncertainties in prediction of safety performance in Probabilistic Safety Assessments. Therefore other methods of grading may be more appropriate. This is particularly important where SMR developers are planning first of a kind (FOAK)/demonstration facilities to gather operational experience and information needed to support safety cases for a future fleet of reactor facilities referencing that design3. A few areas for SMRs that merit a discussion of the meaning of "proven" could be:

- The state of qualification of fuel and impacts on the safety case for a FOAK versus an nth of a kind. A TRISO HTGR would be a good example given that the DiD approach of a typical design relies heavily on fuel and physics performance;
- Identifying and demonstrating resilience to Design Extension Conditions with Passive and Inherent safety features; and
- Single operator, multiple reactor interface architectures.

4.2. RECOMMENDATIONS FOR FUTURE ACTIVITIES FROM DEFENSE-IN-DEPTH WORKING GROUP

The DiD WG identified safety areas for which the opportunity to further develop safety guidance to help the safety assessment of DiD applied to SMRs may be investigated. These include:

- Demonstration of reinforcement of DiD levels 1 and 2;
- Development of safety criteria and requirements for passive safety systems and inherent safety features;
- Application of single failure criteria for safety functions involving passive systems;
- Criteria for exclusion of identified initiating events from the design;
- New guidance for procedures may need to be developed for inspections of the manufacturer/producer of the module;
- Development of principles and requirements for the safety assessment of "multi-module" SMRs;
- Investigation or enhancement of methods to deal with passive features and with multi-module issues in PSAs; and
- Requirements and guidance for qualifying new materials and features applicable to SMRs designs, including the extent and scale of the testing, verification and validation of models, and fabrication processes.

The following activities are recommendations for possible future Forum activities:

- Organize exchanges on safety information among designers, regulators and their TSOs to better understand and frame the SMR characteristics; and
- Exchange information and share common positions on DiD with Member States in an effort to enhance harmonization on national and international levels of the licensing process.

4.3 RECOMMENDATIONS FOR FUTURE ACTIVITIES FROM EMERGENCY PLANNING ZONE WORKING GROUP

The WG members had a variety of discussions and insights while writing this document. Many of the discussions pertained to the following topics, which were determined to beyond the scope of the WG's purpose. Therefore, the WG makes the following suggestions for the future work of the SMR Regulators Forum:

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[3] By their very nature, the lack of operating experience means that the safety case will have greater uncertainties that will need to be addressed by use of conservatism or additional safety and control measures.

- Explore further the necessity to develop publications addressing in further detail the technical basis for developing EPZ&Ds based on existing IAEA Safety Standards;
- Examine the safety culture with respect to SMR industry. This topic arises from new designers and operators entering the industry, as well as, creating a culture from the beginning to not become complacent by “safety by design”;
- Examine the physical security requirements for SMRs. Do SMRs adopt a “security by design” philosophy?
- Examine the elements for community emergency preparedness or off-site response planning;
- Examine the licensing of materials, reactors and irradiated fuel while in transit and among transit state;
- Explore further the “One design, one review” concept;
- Define a “Prudent proven” technology; and
- Examine the advances in “human factors engineering” and how novel features of SMRs expand leverage HFE.

ACRONYMS

DiD	Defence-in-Depth
EPD	Extended Planning Distance
EPR	Emergency Preparedness and Response
EPZ	Emergency Planning Zone
FOAK	First of a Kind
GA	Graded Approach
HFE	Human Factors Engineering
HTGR	High Temperature Gas Reactor
ICPD	Ingestion and Commodities Planning Distance
INPRO	International Project on Innovative Nuclear Reactors and Fuel Cycles
MDEP	Multinational Design Evaluation Program
NPP	Nuclear Power Plant
NSCA	Nuclear Safety and Control Act
OECD	Organisation for Economic Co-operation and Development
OPEX	Operational Experience
PAZ	Precautionary Action Zone
PEPZ	Plume Emergency Planning Zone
PIE	Postulated Initiating Event
PSA	Probabilistic Safety Assessment
PSAR	Preliminary Safety Analysis Report
SC	Steering Committee
SSC	Structures, Systems and Components
SMR	Small Modular Reactor
TRISO	Tristructural-isotropic
TSO	Technical Support Organization
UPZ	Urgent Protective Action Planning Zone
WENRA	Western European Nuclear Regulators Association
WG	Working Group
WNA	World Nuclear Association