Small Modular Reactors Regulators' Forum

Manufacturing, Construction, Commissioning and Operations Working Group.

Report on manufacturability, supply chain management and commissioning of Small Modular Reactors.

INTERIM REPORT

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Common regulatory position on manufacturability, supply chain management and commissioning of SMRS.

Context

Advocates for small modular reactors (SMRs) say that SMRs could play an important role in globally sustainable energy development as part of an optimal energy mix for countries expanding their nuclear energy programs and in countries embarking on nuclear energy for the first time.

The SMR Regulators' Forum was formed in 2014 to identify, improve understanding of and address key regulatory challenges that may emerge in future SMR regulatory discussions. This will help enhance safety, improve efficiency in SMR regulation, including licensing, and enable regulators to make informed changes, if necessary, to their requirements and regulatory practices.

The Forum entered its second phase in 2017, following up on the work carried out in the previous years. The three topics covered in the second phase are:

- licensing issues
- design and safety analysis
- manufacturing, construction, commissioning and operations

This document is the outcome of the third topic covered by the Manufacturing (and Construction), Commissioning and Operations Working Group (MCCO-WG). Appendix 1 gives details about the MCCO-WG.

Purpose of this document

This report was developed based on information, insights, and experience gained from the regulatory activities of the SMR Regulators' Forum members. It is considered to be generally consistent with existing IAEA documents but may deviate in some cases. This report is intended to provide useful information to regulators and industry in the development, deployment and oversight of SMRs.

This document presents the common regulatory position on manufacturing, construction, and first-of-a-kind commissioning for SMRs**.** Subsequent documents are proposed to cover the topics of operations and decommissioning.

Executive summary.

SMRs are likely to use familiar approaches to building new reactors, but emphasize certain aspects more, such as:

- greater use of modularization,
- more construction and testing in factories and
- designs that may be replicated and supplied to a number of different operators in different countries.

The common regulatory position is that the existing arrangements[1] to regulate activities involving large nuclear power plants are also suitable arrangements to regulate activities involving SMRs[2], with some adjustments and balancing to take into account novel deployment approaches under the SMR business model.

Consequently, a single organization should be responsible (the Licensee). The Licensee needs to be resourced and capable of establishing adequate oversight of the supply chain. The Licensee should have influence over the design and procurement so as to secure nuclear safety, including those aspects of nuclear safety secured by design and quality standards in the period of first supply and assembly.

The common positions that apply to SMRs are as follows:

Chapter 1: Modularity

- *The terms "module" and "modularity" may mean something different depending on the design and business model for the SMR in question. All parties need to be attentive to what is included in the terms for the particular SMR being considered.*
- *There are safety implications that arise from the use of modularity in building and operating SMRs, and the end-user (Licensee) needs to have the ability to address those implications to secure nuclear safety.*

Chapter 2: Manufacturability

- *Manufacturability has implications for demonstrating compliance with requirements, long-term maintainability and operability of structures, systems and components. There are safety implications that arise from these facts. The Licensee is responsible for addressing these aspects.*
- *The Licensee needs to mobilize adequate competence skills early in the design stage to verify that the SMR design will fulfill safety requirements. Suppliers need to be involved at an early stage in the manufacturability, inspectability, operability, and maintainability assessments of modules for the purpose of specification.*
- *When assessing alternative or novel configurations of structures systems and components (SSCs), such as compact modular assemblies, licensees should work directly with the SMR designers and their vendor to evaluate and address appropriate provisions to enable access for required inspections, operations, and maintenance of SSCs. These provisions should also enable licensee to conduct specific oversight activities during manufacturing and construction such as witnessing key quality assurance activities during manufacturing or conducting receipt inspections at the site.*
- *As standard practice, industry stakeholders and, where applicable, regulators, should work with the standard development organizations to address potential gaps in existing standards related to manufacturing and construction issues.*

[1] Existing good practice is set out in relevant IAEA publications on NPP safety.

[2] From this point forward in this report, the term "regulating SMRs" refers to regulation of safe conduct of activities concerned with SMR projects, including manufacturing, construction and commissioning.

- *If there are aspects of SMR manufacture that are not covered by an appropriate existing standard, then the SMR intelligent customer should set a tailored standard for that aspect with appropriate surveillance, third party oversight and witnessing, proportionate to the risk to nuclear safety. Good engineering practices should be used in the derivation of tailored standards, consistent with the regulatory requirements.*
- *Manufacturing processes, if not implemented correctly for safety significant modules, could result in potential latent issues. Hence, the development and implementation of manufacturing processes need to contain sufficient control measures to prevent latent issues.*
- *Configuration management and stability needs to be verified from the first-of-a-kind (FOAK) manufactured SMR to the Nth-of-a-kind (NOAK) SMR (including situations that involve changes in manufacturing facilities or vendors).*
- *SMR manufacturers need to demonstrate the capacity and capability to address nuclear safety requirements.*
- *Site construction and commissioning of SMRs is a Licensee activity. Licensees need to exercise oversight of in-factory manufacturing and testing to achieve an assembled SMR that is safe and meets all regulatory requirements*
- *Special attention needs to be paid to factory -fueled and sealed transportable reactor modules. This is because introducing nuclear material in the factory triggers a step change in nuclear safety risk and therefore the licensing and regulatory approach need to be commensurate with any other facility that handles fissile material.*

Chapter 3: Supply Chain Management

- *It is the responsibility of the Licensee to establish adequate Supply Chain Management (SCM) arrangements to ensure delivery of products and services safely and right first time*[3]
- *The Licensee needs to have both an organisation that is capable of providing intelligent customer capability, and a supporting management system.*
- *The Licensee needs to instill an appropriate nuclear safety culture amongst its suppliers and contractors, at all tiers in the supply chain.* [4]
- *The Licensee for the SMR needs to incorporate appropriate practices, codes and standards.*
- *The Licensee needs to identify and demonstrate how to mitigate risks arising from a more diverse, new and potentially global supply chain, particularly risks from counterfeit, fraudulent and suspect items (CFSI)*[5]*.*
- *The Licensee and its associated supply chain organizations, including the SMR vendor and suppliers, will need to be capable of managing deviations and non-conformances in a way that takes into account the characteristics of SMR build, and encourages reporting, collaboration and continuous improvement.*
- *The Licensee will be expected to use safety classification to support the justification of appropriate quality requirements applied to structures, systems and components for SMRs.*
- *Licensees are responsible for pre-qualification of their suppliers. Hence, they should recognize that supply chain companies for SMRs who have experience with modular design, manufacturing and construction, may* ***not*** *have experience of the nuclear sector.*

[3] IAEA Guide GS-R Part 2 Requirement 11
[4] IAEA Fundamental Safety Principles: Safety Fundamentals No SF 1.
[5] IAEA Guidance on CFSI : Managing Counterfeit and Fraudulent Items in the Nuclear Industry. NP-T-3.26

Chapter 4: Commissioning of SMRs.

- *The Licensee needs to demonstrate how the commissioning programme takes into account any uncertainties due to the lack of OPEX.*
- *If multiple units/modules are shared in one facility or some units/modules will be added later on:*
    - *there will be common SSC that may require certain commissioning activities to take place as the first modules are installed and placed into service;*
    - *due consideration needs to be made to common system performance when adding units or modules and whether additional or new or repeated commissioning tests may be needed (a common plant HVAC system, for example, is important to environmental qualification);*
    - *commissioning may have the objective to demonstrate/verify the compatibility with the existing plant.*

- *The Licensee is responsible for:*

    - *quality, transparency and independence of persons or entities directly responsible for performing the tests (the persons implementing this process should have the appropriate expertise in terms of manufacturing, detailed design and operation of the module to meet this objective).*

    - *conducting a review of deviations and of how these deviations are handled;*

    - *the decision on the continuation of the tests, or the definition of any subsequent test programme.*

- *Given the importance of the Commissioning program in future plant operations, the Licensee is responsible for the conduct of the program and is expected to specify where the tests will be performed and justify the representativeness of those tests regarding the on-site configuration. A further set of on-site commissioning tests will have to be performed to check that the results obtained off-site are valid for the plant*
- *When commissioning tests are performed in the manufacturing premises, the Licensee needs to be involved for the purpose of gaining experience for the future operation.*
- *The Licensee will need to justify the representativeness of full-scale replica tests results and FPOT tests if wanting to take credit for those tests in the commissioning phase, and detail the commissioning tests to be performed on the licensed plant to check their full applicability.*

Chapter 5: International cooperation

- *Information exchange about SMR activities may be affected by international agreements on intellectual property rights.*

Chapter 1: Implications of modularization

Introduction[6]

Module

In most industries, a *module* is generally understood to be a technological entity generally composed of a number of sub-assemblies that are sourced through the manufacturer's supply chain and include civil, mechanical, electrical and I&C systems and components. A module's technological complexity can range from a simple prefabricated structure to a complex arrangement of structures systems and components.

Figure 1a: Simplified Example: Petrochemical Water Treatment Module (courtesy Siemens)

Modular construction is an approach that organizes a complex construction / assembly process into discrete predictable steps using *modules*, where applicable, as the primary building blocks. The primary goal of modular construction is to improve efficiency of on-site construction and reduce the number of on-site crafts [7]needed to perform construction activities. In theory, many of the traditional on-site crafts would be moved back into the supply chain in the manufacturing facilities to ensure high quality before modules arrive at the site for installation.

[6] A number of articles are available on the web for readers who want to have a greater understanding of modularity. For example: National Institute of building sciences Off-Site and Modular Construction Explained at https://www.nibs.org/page/oscc_resources
[7] A *craft* is a term for a highly skilled trade or profession involving a strong degree of precision and quality in design, fabrication, assembly and testing.

All modern nuclear power plant projects use modularity in some form or another[8] but the degree of use varies from design to design. Developers of many SMR technologies are seeking to further develop these concepts and eventually demonstrate economies of scale in an effort to significantly reduce construction and commissioning times and related costs.

Modules in relation to SMRs

Common position: The terms "module" and "modularity" may mean something different depending on the design and business model for the SMR in question. All parties need to be attentive to what is included in the terms for the particular SMR being considered.

In some SMR designs, modules may simply be smaller versions of what is already done for large Nuclear Power Plant (NPP) designs, for example:

- Instrumentation & Control architectural modules
- pre-fabricated civil structure modules
- Diesel generator modules

SMR designs using this type of module present the same sort of safety-management challenges associated with larger NPPs, such as Licensee oversight of procurement in a global multi-tier supply chain.

In other types of SMR design, such as integral light water, the entire nuclear steam supply system is contained within a single module and may include:

- Reactor core and control mechanisms
- Pressurizer
- Steam generator(s)
- Containment structure
- Associated instrumentation and control features installed at the factory.

In this case, additional safety management challenges may exist such as the ability to inspect during manufacturing, upon receipt at the site, and during construction, commissioning and operation.

Another element of modular design being described by SMR technology developers is the concept of replacing one large (for example 500 MWe) reactor/process system pair with a number of smaller ones (for example, 10 SMRs of 50 MWe each) that could be installed in increments over the life of a facility as power demand increases. Sometimes a single unit SMR NPP of this type is referred to as a module. SMR vendors are also using the term module to denote the whole NPP.

[8] For example, modular Instrumentation & Control platforms, turbine generator sets, back-up power platform are common technologies. The use of fully modular civil structures is less common in Nuclear Power Plant designs.

One challenge of modularity is, in essence, a complete nuclear island in a single module comprising all nuclear related systems needed to support defence-in-depth. In this case, the nuclear module may or may not be re-fuellable and the majority of traditional site construction activities may be performed in a manufacturing facility that may be in a different jurisdiction under different regulatory processes. This raises the question about whether offsite manufacturing should be considered as "construction" for the project site or "procurement" or a combination thereof. Consequently, if this form of modularity is part of an SMR design, then Regulators in each member state will have to recognise that the balance between what is defined as manufacturing and what is defined as construction will differ from historic approaches, and so they may need to be aware of how their own laws might be applied.

Experience with the use of modularity in the nuclear sector and safety implications.

Common position: *There are safety implications that arise from the use of modularity in building and operating SMRs, and the end-user (Licensee) needs to have the ability to address those implications to secure nuclear safety.*

Given that the number of successfully completed new build nuclear power plant projects is small, the majority of technology developers and, more importantly, Licensees of nuclear power plants currently have limited experience in the use of modularity in new nuclear power projects. This includes experience in understanding the safety implications of modularity in procurement, manufacturing, construction, commissioning and subsequent operation. The safety implications of modularity include (for example):

- constrained space on a module skid during build leads to operational constraints in inspection and maintenance;
- ensuring proper communication between software packages, that are often sold as modules, in safety significant Instrumentation & Control systems;
- ensuring that electronic systems are integrated and function effectively;
- achieving the theoretical benefits from modularity that arise from construction in factories to consistent quality standards;
- achieving Licensee and Regulator oversight given the manufacturing location and schedule for SMR module production;
- experience from commissioning and operation of any completed new build projects will not be available to designers or vendors of SMR technologies.

The intent behind manufacturing of modules is to deliver a 'ready to install and operate' portion of the plant to facilitate efficient construction and commissioning. This increases the onus of the Licensee and its Engineering, Procurement, Construction (EPC) partner (if applicable) to perform traditional site construction inspections off-site and to develop additional expectations around accepting the module for shipment from the factory, site receipt, readiness for installation etc.

The above factors significantly influence the ability of an end-user (Licensee) to articulate expectations to reactor vendors and the subsequent supply chain. Expectations include:

- Quality assurance requirements to support reliability specifications (in accordance with the safety classification process results)

- Evidence to be produced by manufacturers to support the Licensee's safety analysis expectations
- Objectives to be demonstrated in both factory and commissioning activities
- Constructability, operability, inspectability and maintainability
- Ageing management considerations
- Site conditions that need to be considered in the design of modules to address, for example, external events.
- defined interfaces between the suppliers, vendors and Licensee.

Chapter 2: Manufacturability

Common position: *Manufacturability has implications for demonstrating compliance with requirements, long- term maintainability and operability of structures, systems and components. There are safety implications that arise from these facts. The Licensee is responsible for addressing these aspects.*

Introduction

This chapter sets out the common regulatory position on manufacturability of SMRs and explains regulatory expectations for interaction between vendors, suppliers, and the Licensee.

Many new SMR designs are compact and complex and the manufacturability of some novel components may be a challenge for the industry.

Manufacturability is defined as the extent to which a good can be manufactured with relative ease, at minimum cost, and maximum reliability[9]. The manufacturability of SMRs is important to SMR reactor vendors to economically compete with other energy sources with a reactor design that meets or exceeds nuclear safety requirements.

There are a number of safety implications presented by the SMR manufacturing approach. For example, the compact nature of SMRs may limit physical accessibility to perform inspections, tests, and repairs/maintenance. SMRs may take advantage of new design features, manufacturing processes, components, and materials that have not been used previously in the manufacture and construction of nuclear power plants. Regulators should consider these elements as manufacturing requirements, licensing reviews, and manufacturing/construction oversight arrangements are developed.

The involvement of the suppliers during the design phase of components to check on manufacturability is fundamental. It may be necessary to manufacture some prototypes to test the feasibility of the design, different choices of materials, how they are joined together, and give due consideration for designs with multiple modules. The need to develop specific instruments for inspection during manufacturing and operation and maintenance needs to be assessed by the vendor, Licensee, and the supplier.

During the manufacture and construction of nuclear power plants, it is important that Licensees ensure that the necessary inspections, analyses, and tests are performed to confirm that the as-built plant is consistent with the approved design. In addition, it is important that there will be independent inspections of the manufacturing and construction activities to verify the level of quality. In contrast to the manufacture and construction of conventional nuclear power plants, the design of SMRs and their manufacturing location and schedule may affect the ability of the Licensee and Regulator to provide necessary oversight.

[9] Businessdictionary.com

Licensees, suppliers, and Regulators need to be knowledgeable regarding the capabilities and limits of SMR manufacturing practices, because they will be involved in design reviews, analyses, inspections, and tests to ensure latent design issues do not arise because of manufacturing activities.

Common position: *The Licensee needs to mobilize adequate competence skills early in the design stage to verify that the SMR design will fulfill safety requirements. Suppliers need to be involved at an early stage in the manufacturability, inspectability, operability, and maintainability assessments of modules for the purpose of specification.*

This principle emphasizes the importance of the vendor seeking involvement of potential suppliers to ensure that their design can be manufactured, inspected and maintained throughout the life of the SMR. Once a Licensee has been established, it should be organized to ensure that safety requirements (such as inspectability and maintainability) are considered in the design stage and reflected in manufacture.

Any manufacturing requirements and acceptance criteria established by Licensees, vendors and Regulators need to ensure that inspectability, operability, and maintainability will be addressed and need to be communicated in a systematic fashion to the supply chain. Regulators do not specify how a reactor should be built: it is the Licensee that specifies the overarching design criteria that the design must meet, taking into account the regulatory requirements.

Common position: *When assessing alternative or novel configurations of structures systems and components (SSCs), such as compact modular assemblies, licensees should work directly with the SMR designers and their vendor to evaluate and address appropriate provisions to enable access for required inspections, operations, and maintenance of SSCs. These provisions should also enable licensee to conduct specific oversight activities during manufacturing and construction such as witnessing key quality assurance activities during manufacturing or conducting receipt inspections at the site.*

Most SMR designs are designed to be compact to enable their manufacture at a factory and provide for ease of transportation to the plant site. However, the compact nature of SMRs may challenge the ability to perform the necessary inspections, operations, and maintenance, not only during the manufacturing stage, but for the life of the SMR. For instance, codes and standards for welding safety-related components require inspection and nondestructive examination of the welds. Manufacturing processes would need to be properly coordinated to allow accessibility for the necessary inspections and examinations. SMR vendors would need to consider up-front, how such inspections would be performed and discuss accessibility with potential Licensees and Regulators prior to finalizing such designs.

Analysis of accessibility can be aided with the help of scale models and computer animations that accurately depict the three-dimensional space between objects. This issue is compounded when working with new materials and chemistry environments that may require additional in-service inspections to gather material performance data (for example, data on ageing).

In addition to the physical accessibility challenges for performing inspection and tests on SMRs, Licensees may also be challenged in gaining access to certain manufacturing facilities. Specifically, SMR vendors may choose to manufacture long-lead components, or entire modules, before there is a license issued to their ultimate end-user customer. Therefore, the Licensee may not have the opportunity to perform oversight of certain safety-related manufacturing processes (e.g., large component forging), for which they are responsible. The safety implication of this is that the component cannot be demonstrated to meet requirements. This is compounded by the fact that some regulatory bodies may only have access to a vendor's activities through a Licensee's new construction activities. Third party accreditation and inspection might be considered by Regulators as a method to provide sufficient independent oversight of certain code and standards activities.

The Licensee should encourage the vendor to involve the main suppliers during the design phase and in the validation of the design of safety significant components and the choice of materials. During licensing activities, suppliers, Licensees and Regulators should engage early in the process to discuss unique manufacturing processes. In addition, due to the compactness of SMR designs, Licensees and suppliers should evaluate potential manufacturing issues that may arise due to physical inaccessibility, use of unique materials, new designs/components, or use of new or alternative manufacturing processes.

Common position: *As standard practice, industry stakeholders and, where applicable, regulators, should work with the standard development organizations to address potential gaps in existing standards related to manufacturing and construction issues.*

Industry stakeholders and, where applicable, regulators work with standards development organizations that provide more specific requirements and guidelines with respect to manufacturing and construction activities. These codes and standards may be incorporated as part of regulations or used as guidance by the Regulator. Because SMRs may use novel manufacturing techniques and new materials, the respective codes and standards may need to be updated. Industry stakeholders and, where applicable, regulators should, as a matter of standard practice, work through the standards development organizations to address potential manufacturing and construction issues. When codes and standards are modified or developed, a strong opportunity exists to harmonize practices among the standards development organizations and, as a result, enable greater opportunities for Regulators in different countries to leverage the information in their decision making.

Common position: *If there are aspects of SMR manufacture that are not covered by an appropriate existing standard, then the SMR intelligent customer should set a tailored standard for that aspect with appropriate surveillance, third party oversight and witnessing, proportionate to the risk to nuclear safety. Good engineering practices should be used in the derivation of tailored standards, consistent with the regulatory requirements.*

In the absence of appropriate existing standards, industry stakeholders and, where applicable, regulators should work through the standards development organizations to create appropriate standards. However, it is recognized that standards development is informed by credible industry experience that takes time to develop. In the interim, regulatory mechanisms should exist to address the use of alternative practices provided that they are adequately supported by credible science and engineering information and that suitable control measures are established to address uncertainties due to lack of experience. Licensees, vendors, and Regulators should engage with standards development organizations to ensure that the necessary codes and standards are established to address the unique design and manufacture of SMRs. If any gaps are identified in the current codes and standards, they should be addressed to ensure inspect-ability, operability, and maintainability of SMRs.

Common position: *Manufacturing processes, if not implemented correctly for safety significant modules, could result in potential latent issues. Hence, the development and implementation of manufacturing processes need to contain sufficient control measures to prevent latent issues.*

Licensees are responsible for ensuring appropriate quality during manufacture and construction, commensurate with safety importance. Suppliers have the responsibility to ensure quality requirements to the satisfaction of the Licensee. Manufacturing processes are a potential source of latent flaws if not correctly implemented in safety significant modules, e.g lean manufacturing principles seeking to cut costs over time. Licensees need to ensure that a quality assurance process is established and implemented, including audits of their supply chain. If these processes work correctly, latent issues are less likely to occur.

For some SMR designs, the manufacturing processes may be similar to those used in the manufacture of structures, systems, and components for conventional nuclear power plants. Other SMRs, particularly advanced reactor designs, may require use of new and exotic materials. These materials may require special handling, storage, fabrication, and treatments to ensure the desired properties in the material are maintained and not lost during the manufacturing process.

There may be instances where new manufacturing processes may be used. For example, additive manufacturing, i.e., 3-D printing of metallic components, may be beneficial from a manufacturability standpoint when traditional fabrication methods are complex and/or expensive. In this case, complex metallic structures that would be difficult to manufacture using traditional machining methods could be manufactured by additive manufacturing potentially reducing cost while maintaining the desired material and structural properties. If there are aspects of SMR manufacture that are not covered by an appropriate existing standard, then the SMR intelligent customer should set a tailored standard for that aspect with appropriate surveillance, third party oversight and witnessing, proportionate to the risk to nuclear safety. Good engineering practices should be used in the derivation of tailored standards, consistent with the regulatory requirements.

Licensees, vendors and Regulators would need to understand the technical aspects of these new processes, materials, and techniques. From this knowledge, appropriate benchmarks can be applied by vendors, suppliers, and Licensees, and inspected by the Regulator.

Common position: *Configuration management and stability needs to be verified from the first-of-a-kind (FOAK) manufactured SMR to the Nth-of-a-kind (NOAK) SMR (including situations that involve changes in manufacturing facilities or vendors).*

One of the claimed advantages of SMRs is the greater level of standardization that can be achieved; not only with respect to plant design, but also having a consistent manufacturing process which includes procedures, equipment, and personnel. Standardization may allow for better identification and application of construction and operating experience to a fleet of nuclear power plants. If properly leveraged, the application of construction and operating experience can provide improvement upon the safety of those plants. As NOAK SMRs are manufactured, corrections could be implemented on the NOAK design based on construction and operating experience. While configuration management is not a new concept in the nuclear industry, there is a balance between configuration stability (i.e., standardization) and continuous improvements to the design. It is important that these changes are controlled in such a way to enhance the safety of the NOAK (configuration control plus evaluation of changes to ensure no unanticipated consequences). This would include consideration for implementing changes on previously manufactured SMRs. As Licensees and vendors incorporate the necessary corrections and lessons learned as SMRs are manufactured, they will also ensure the proper configuration control and design changes that result from the corrections and lessons learned.

Regulators expect quality assurance and oversight of suppliers by Licensees. Change of suppliers could happen from the FOAK to NOAK SMR. Economics tends to drive the industry to use a proven supplier, so long as the supplier can provide products in a timely and quality manner that meets cost expectations. Changing suppliers can incur certain costs, including retooling for a new supplier, establishing contractual arrangements, and other starting costs. If different suppliers are used on the manufacturing of the NOAK, Licensees would need to verify adequate quality assurance and oversight of those suppliers.

If any supplier changes are made, they would likely be at the sub-supplier level. Contracts (such as purchase orders) from the main supplier should permit lessons learned from previous manufacturing experience to be shared throughout the supply chain, and Licensees should verify that the main supplier provides adequate oversight of their sub-suppliers.

The use of test results from one SMR to the next to be manufactured could be beneficial. SMR vendors are claiming that subsequent SMRs manufactured after the FOAK would have a reduced set of required inspections and tests. This aspect has been discussed in the MDEP Common Position on First Plant Only Tests which could also theoretically be applied to SMRs. It is an important aspect of regulatory oversight that should be established during the regulatory review as to which inspections and tests could be credited from the FOAK SMR to the NOAK SMR. If the same design and quality processes are used for the manufacture of the NOAK SMR, it would be reasonable to expect the NOAK to have similar reliability to the first SMR. This is not unlike seismic or environmental qualification testing of a prototype component, for which the qualification test results on the prototype can be applied to a set of manufactured components over many years so long as the design does not change. If significant design changes occur between the FOAK SMR and the NOAK SMR, certain FOAK tests may need to be re-performed on the NOAK or, at a minimum, analyzed to see if the prior test results are still applicable.

Licensees of NOAK SMRs for which the FOAK was constructed in a different country, may want to take credit for testing performed on the original FOAK. Regulators should collaborate on the potential for which SMR FOAK tests could be credited in other countries and how regulatory oversight would be applied.

Common position: *SMR manufacturers need to demonstrate the capacity and capability to address nuclear safety requirements.*

On capacity, currently, some Licensees and vendors may not yet possess the necessary expertise to manufacture SMRs. They may compensate for this by teaming up with more experienced suppliers.

However, new FOAK designs can be a challenge in achieving the necessary level of quality in manufacture and construction.

On capability, SMRs may pose challenges with new design and manufacturing features for which a workforce may need additional qualification. Once experience has been gained manufacturing new features, it is expected that the factory environment would support appropriate quality since the suppliers would be able to maintain a skilled workforce in a close proximity.

Regulators may inspect the technical expertise of the Licensee and suppliers to ensure the necessary expertise in manufacturing an SMR. This is particularly challenging for the FOAK SMR as there will likely be little to no experience with such new designs.

Common position: *Site construction and commissioning of SMRs is a Licensee activity. Licensees need to exercise oversight of in-factory manufacturing and testing to achieve an assembled SMR that is safe and meets all regulatory requirements.*

SMRs may shift the balance of construction activity from the plant site to a factory, such as a manufacturing facility and/or an assembly facility. For Licensees, they need to make the necessary provision to gain access to important activities to verify proper quality controls at the factory. This would require, at a minimum, consideration of proper access and proper notification of activities in purchase contracts.

Shifting more of the manufacturing and construction from the site to factories may also change how and where initial plant tests are conducted, as compared to conventional nuclear power plants. Many tests that were previously initial plant tests conducted at the site may now be factory tests, conducted by the supplier. Since the Licensee remains responsible for the design and construction of the SMR, the Licensee would have to provide sufficient oversight of any factory tests performed as part of initial plant testing.

A Licensee for a SMR on a specific site involving construction and commissioning is accountable under their license for the safe and satisfactory completion of all construction and commissioning activities, including the procurement of equipment and services. The Licensee is expected to demonstrate how effective oversight of these activities will be carried out. All construction and commissioning activities should be governed by the provisions of the Licensee's quality management system.

A construction program, as defined by the vendor and Licensee, is expected to contain provisions to demonstrate that the plant has been fabricated and constructed in accordance with the design (including the procurement of equipment and services). It should also describe how the commissioning program will confirm that the equipment, structures, systems and components (SSC), and the plant as an integrated unit will perform and function in accordance with the design specifications, regulatory requirements, and as credited in the safety analyses.

Some of the factory tests may also fall into the category of FOAK tests only. Performing these tests in a factory setting has advantages and disadvantages. The advantages include the ability to have test equipment with greater testing capabilities and sophistication, a more controlled test environment, and greater access to the engineers involved with the design and construction of the components. The disadvantages include the potential lack of full integration with other plant systems and less control by the Licensee. In addition, FOAK components may require qualification testing using prototypes which can reveal design and manufacturing issues. Therefore, it is important that qualifications tests begin early and all stakeholders witness them. For the Regulators, having early access to these test activities and their results can play a role in licensing and oversight of SMRs.

Where there is significant modularity, in particular at offsite manufacturing facilities which could be offshore and out of the regulatory jurisdiction of the member state, the Licensee's oversight of manufacturing, including related test activities, extends to these manufacturing facilities. In some cases, components may be traditional long lead items due to their simplicity, and have traditional site acceptance, installation and commissioning approaches. However, as the safety significance of a module increases, the manufacturing facility needs to give proper assurances to the Licensee before shipping the module to the site for installation. This increases the number and thoroughness of inspections and tests conducted at the factory and introduces additional off-site inspection/oversight activities conducted by the Licensee and in some cases, the member state's Regulator. In addition, some of these factory tests may inform and influence the nature of the on-site commissioning activities. The construction and commissioning program should take account of these factors.

If an SMR is being manufactured in its entirety in a country different to where the SMR will be installed, then the Licensee should still ensure that they have adequate oversight of the design, construction and testing of the SMR[10].

Taking into account the safety significance of structures, systems and components (SSCs) within the SMR, and the use of novel features or approaches, there is likely to be a difference in Licensee oversight approaches if the procurement is under a long lead item process versus a construction program-controlled process.

Long-lead items may be procured outside of the licensing process, at the Licensee's economic risk, and some Regulator's compliance activities may be different from those performed on a construction program, which is part of the facility's licensing basis. For a SMR with significant factory testing prior to delivery to the site, then the site activities to accept, install and commission the module may vary if one process is used versus another (licensing versus construction). Additional review of whether this presents regulatory issues is needed because this influences how the Regulator organizes itself to conduct its compliance program such as placement and role of resident inspectors.

Common position: *Special attention needs to be paid to factory -fueled and sealed transportable reactor modules. This is because introducing nuclear material in the factory triggers a step change in nuclear safety risk and therefore the licensing and regulatory approach need to be commensurate with any other facility that handles fissile material.*

A factory-fueled and sealed transportable reactor module is a special case because it represents a significant nuclear island component manufactured and likely tested, or even commissioned, to some degree off-site. This transfers a significant nuclear construction activity offsite, which is novel in the civilian nuclear power sector. Unlike other typical plant components, some vendors are designing the

[10] IAEA Nuclear Series Guide: Procurement Engineering and Supply Chain Guidelines in Support of Operation and Maintenance of Nuclear Facilities.

reactor module interior to be inaccessible to the site Licensee to provide further safeguards reassurances by preventing the possible diversion of fissile materials. But this presents challenges for activities such as in-service inspections. In addition, some vendors are proposing that a vendor/assembler factory may consider low-power nuclear testing of the reactor module before the module leaves the factory. The intent would be to reduce the likelihood of factory issues appearing at the site and to reduce the site's construction/commissioning times. The challenge presented in this case is that these testing activities would require an operating license in the factory's jurisdiction and the Licensee proposing to perform these tests may not have been identified. If the factory is in another member state, different regulatory requirements and licensing processes may also apply. Transportation regulations regarding transporting partially irradiated fuel would also need to be considered. Therefore, many of the principles expounded in this document will be difficult to apply to this special case. We commend the ongoing work by the IAEA in this area and recommend that the SMR Regulators´ Forum considers it when the results are in hand.

Chapter 3: Supply Chain Management

Context

This chapter sets out a common regulatory position on supply chain management for SMRs, and explains how regulatory expectations may need to be adjusted to the likely business models for SMR construction.

SMRs may use familiar approaches to building new reactors, but emphasize certain aspects more, such as greater use of modularization, more construction and testing in factories and designs that may be replicated and supplied to a number of different operators in different countries. Hence, SMR supply chain models may place extra demands upon existing regulatory approaches.

Common position*: It is the responsibility of the Licensee to establish adequate Supply Chain Management (SCM) arrangements to ensure delivery of products and services safely and right first time*[11]

This IAEA safety requirement emphasizes the importance of one organization, the Licensee, being in charge of all the fundamentals that secure nuclear safety at an operating reactor, including all the fundamentals that are put in place before operation begins, through design and build.

This principle holds good for SMRs, but it has extra demands placed upon it by aspects of the SMR supply chain model. One extra demand is to ensure that there is a single organization in charge (the Licensee), given that the companies that design, market, sell and build the reactors may not subsequently operate the reactors that they design and build, and might (or might not) be licensed. Hence, the design fundamentals and the supply chain fundamentals may be under the control of organizations that are not licensed. In this situation, the ultimate operator (the Licensee) needs to be resourced and capable of establishing adequate oversight and influence over the design and procurement so as to secure nuclear safety, including those aspects of nuclear safety secured by design and quality standards in the period of first supply and assembly.

Common position: *The Licensee needs to have both an organisation that is capable of providing intelligent customer capability, and a supporting management system.*

The primary responsibility for the safety of a nuclear installation rests with the Licensee. The Licensee should be able to demonstrate sufficient knowledge of the plant design and safety case for all plant and operations on the licensed site. The Licensee is expected to be in control of activities on its site, understand the hazards associated with its activities and how to control them, and have sufficient competent resource to be an ‘intelligent customer’ for any work it commissions externally.

As an intelligent customer, in the context of nuclear safety, the Licensee will be expected to know what is required, to understand the need for a contractor's services, to specify requirements, to supervise the work and be able to technically review the output before, during and after implementation. The concept of intelligent customer relates to the attributes of an organization rather than the capabilities of individual post holders.

[11] IAEA Guide GS-R Part 2 Requirement 11

One of the contractors is likely to be the vendor of the SMR technology.

The Licensee should have the capability to plan and organise the supply chain system from end-to-end, have appropriate qualification standards for suppliers in use, realistic metrics set for performance, and an effective quality assurance programme in place covering factory based, as well as site-based, construction. "Capability" should include, in particular, sufficient numbers of qualified and experienced people for activities novel to SMRs, such as new materials that are challenging to produce, test and certify. The Licensee should inspect safety aspects that are delivered by suppliers in factories as well as overseeing transport to site and assembly at site.

There should be proportionate arrangements for intelligent customer oversight by the Licensee of all organizations in the supply chain based on the risk they present to nuclear safety.

The Licensee management system should include the resources necessary to oversee new suppliers and novel approaches, and cope with SMR manufacture in multiple locations. The system should set a capability standard expected of suppliers, particularly those who are new to nuclear, and mandate inspection by the Licensee to check that suppliers meet these standards. The system should include targeted inspection of quality compliance, together with checks of quality assurance arrangements and the management of deviations. The SMR supply chain model emphasizes the repeat production of modular assemblies, incorporating a variety of components, to a consistent design, so the Licensee management system should include oversight on the interfaces between components, the quality of repeat modules, and on the management of changes and configuration control.

The SMR supply chain model may mean that there is deployment of the same reactor design after the FOAK reactor is operating. In this case, the Licensee that is deploying a replication of the original reactor design may be able to use the supply chain that was set up for the FOAK, and consequently adjust their intelligent customer activities over this supply chain in proportion to risk and experience. A focus for this second Licensee would be on establishing a competent design authority who can access the design through a controlled process and a programme of work to manage knowledge transfer from the vendor to the Licensee.

The supply chain may evolve as SMR deployment occurs over time and hence the oversight of the chain needs to be reviewed by the Licensee on a periodic basis. In some jurisdictions, this will also lead the Regulator to undertake certain regulatory activities within the supply chain.

Common position: *The Licensee needs to instill an appropriate nuclear safety culture amongst its suppliers and contractors, at all tiers in the supply chain.* [12]

In common with all nuclear facilities, the Licensee of an SMR should set and sustain a positive culture working with (and through) its "extended enterprise" of suppliers and contractors. The culture throughout the supply chain should be collaborative but with a questioning attitude, and encourage open reporting for the purpose of improvement. The culture should be maintained and reinforced by leaders who recognize that certain characteristics of the SMR supply chain model may push against a positive culture. These characteristics include complexity, novelty, time pressures, global sourcing and the pace expected in construction.

[12] IAEA Fundamental Safety Principles: Safety Fundamentals No SF 1.

The Licensee should systematically demonstrate understanding of its supply network and the risks presented to nuclear safety from the products or services each supplier provides[13].

Common position: *The Licensee for the SMR needs to incorporate appropriate practices, codes and standards.*

The Licensee, in its role as the SMR intelligent customer, should specify manufacturing codes and standards for products and services that the SMR should comply with as they are procured through the supply chain. The codes and standards should be acceptable in the country where the SMR and Licensee will be located. If there is more than one code or standard to be used, then this should be documented. If there are aspects of SMR manufacture that are not covered by an appropriate existing standard, then the SMR intelligent customer should set a tailored standard for that aspect with appropriate surveillance, third party oversight and witnessing, proportionate to the risk to nuclear safety. Good engineering practices should be used in the derivation of tailored standards, consistent with the regulatory requirements.

Common position: *The Licensee needs to identify and demonstrate how to mitigate risks arising from a more diverse, new and potentially global supply chain, particularly risks from counterfeit, fraudulent and suspect items (CFSI)[14].*

The Licensee and their associated supply chain should manage CFSI mitigation, and other product risks, to the same level as currently expected for other new build and operating nuclear plant[15]. The challenge to achieving this objective arises from the need to have more, and differently skilled, personnel and systems to take account of SMR supply chain characteristics, such as more use of modular techniques, factory-based production and international suppliers. This means that additional management attention and resources may be needed to achieve the same level of CFSI mitigation as is expected for current new build, due to the characteristics of the SMR supply chain model. Detection and prevention activities will need to be tailored to the characteristics of each organization in the supply chain for an SMR.

Common position: *The Licensee and its associated supply chain organizations, including the SMR vendor and suppliers, will need to be capable of managing deviations and non-conformances in a way that takes into account the characteristics of SMR build, and encourages reporting, collaboration and continuous improvement.*

As now, for current new build, unplanned departures (deviations) from the Licensee's requirements will need to be properly managed. For example, where activities related to manufacturing, construction and commissioning of SMRs are occurring away from the Licensee's site, then communication of non-conformances between the Licensee and suppliers is likely to be more challenging. Licensees, SMR vendors and their suppliers will need to have more robust and integrated management systems to deal with deviations found after physical work is underway, and changes (to

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[13] ONR / Safety Directors Forum guidance at https://www.nuclearinst.com/write/MediaUploads/SDF%20documents/SCQ/GPG_Supply_Chain_Mapping_Issue_1_20170412.pdf.

[14] IAEA Guidance on CFSI: Managing Counterfeit and Fraudulent Items in the Nuclear Industry. NP-T-3.26

[15] An example of the management standard expected is at section 6.10 of http://www.onr.org.uk/operational/tech_asst_guides/ns-tast-gd-077.pdf.

specification) requested prior to work starting, which are proportionate and targeted on nuclear safety risks inherent in the particular SMR design. The management systems should include notification of deviations and non-conformances and encourage sharing of OPEX. Sub-contractors should be involved in the OPEX process.

In the field of mass manufacturing of components, there is a balance to be struck between lean manufacturing practices and nuclear safety quality management, so as to have a clear understanding of what constitutes a non-conformance or deviation from specification.

- There needs to be clarity on when manufacturing companies should notify the Licensee of changes to the manufacturing practices
- The risk of CFSI needs to be considered in selecting alternative procurement paths for components, which may require additional management attention;
- Some suppliers may be less likely to produce components that meet the nuclear specification, especially if they produce the majority of those components for other industry sectors' quality standards. This requires targeted oversight by the Licensee to ensure the supplier is meeting the specifications.

Common position: *The Licensee will be expected to use safety classification to support the justification of appropriate quality requirements applied to structures, systems and components for SMRs.*

As now, with current new build, the extent to which "off-the-shelf" commercial items are to be used should be identified, and proven in the design, relative to achieving nuclear safety.

The SMR vendors may propose greater use of commercial items[16]. There are a number of reasons for this approach, including economic considerations, and taking credit for any inherent safety characteristics in SMR designs. Safety classification permits the safety characteristics of any items to be considered and (if proven) allow the use of commercial items.

The Licensee, as intelligent customer should accept the outcome of safety classification and pay particular attention to commercial items to ensure that regulatory requirements are met. Similarly, with commercial services in design and testing, the intelligent customer should evaluate the design and testing protocol relative to nuclear safety, perhaps assisted by specialists in the field.

Particular attention should be paid to commercial items incorporated into assemblies of wider importance to nuclear safety functions. The Licensee should manage the extent of commercial items and services relative to nuclear safety in a way that takes into account the characteristics of the SMR design.

Common position: *Licensees are responsible for pre-qualification of their suppliers. Hence, they should recognize that supply chain companies for SMRs who have experience with modular design, manufacturing and construction, may* ***not*** *have experience of the nuclear sector.*

[16] Commercial items refers to items that are purchased "off the shelf" and should not be confused with the US NRC definition of commercial grade item defined in *10 Code of Federal Regulations (CFR) Part 21*, Section 21.3, Definitions. (Other countries may have similar legal definitions).

SMR technology developers have different levels of competence in nuclear design practices ranging from start-up companies working with more senior nuclear design partners to established design companies who are adapting their design practices to produce SMR concepts. A number of these companies are working jointly with others who have experience with modularity from other industrial sectors such as shipbuilding, defence or aerospace. At a strategic level, this approach brings together nuclear design and modular design to yield technological improvements in SMR concepts, as part of the SMR supply chain model. However, the degree of nuclear supply chain experience by these partner companies can vary from extensive military sector experience to no relevant experience of applying nuclear quality assurance requirements. Consequently, the Licensee should ensure that the vendor and supply chain have the competencies and processes in place commensurate with the safety significance of the product or service, very early in their design program to, amongst other things:

- Articulate properly the specifications to their partner companies and suppliers, and also to obtain the necessary information from them to support ongoing iterative design and safety analysis processes;
- Evaluate, qualify and oversee their partner companies and the supply chain such that the specifications will be met and
- Within the supply chain, instill nuclear safety culture and relevant technical knowledge of the final end use of the components and modules being designed, manufactured and tested, to prevent the introduction of latent design flaws into the overall SMR.

Chapter 4: Commissioning of SMRs

Introduction

Commissioning of a nuclear installation contributes to the demonstration "that the plant meets the design intent as stated in the safety analysis report"[17].

The Licensee is responsible for the entire commissioning programme.

Commissioning aims to verify:

- the capability of structures, systems and components (SSCs) to perform the functions accordingly to the safety studies (ECCS flowrate, time for control rods drop etc.),
- operating procedures, including those for operational periodic tests, and, to the extent possible,
- the emergency operating procedures.

The commissioning phase is also used to further train operating personnel and maintenance personnel.

Commissioning traditionally address the following key activities[17]:

- Non-nuclear[18] testing, which includes:
  - Individual pre-operational tests of systems and components;
  - Overall pre-operational systems tests;
  - Structural integrity tests, integrated leakage rate tests of the containment and of the primary system and secondary system.

- Nuclear testing, which includes:
  - Initial fuel loading;
  - Subcritical tests;
  - Initial criticality tests;
  - Low power tests;
  - Power ascension tests.

By testing different system configurations, commissioning contributes to validation of the overall operation of the plant (from normal operation to abnormal transients and some incidental operating conditions[19]).

Implications for commissioning of FOAK SMR plants using evolutionary or innovative design features

For evolutionary or innovative design, commissioning tests are of the utmost importance due to the lack of operating experience and uncertainties on the models used during the design. The type and nature of activities will be commensurate with novelty of features to be "proved" in the design. Then, commissioning tests will be used to collect data, performing measurements that will be used to validate and improve calculation models and sometimes, for instance for passive systems that could

[17] IAEA SSG-28
[18] This refers to activities prior to first fuel load
[19] Loss of Offsite Electrical Power (LOOP) for instance

not be fully validated by R&D activities, the fulfillment of safety requirements. Moreover, when safety relies on inherent characteristics, some complementary elements can only be available after the first core loading.

For NOAK plants, a minimal set of commissioning activities, including tests, will still need to be performed relative to FOAK plants to confirm that the plant (or the module), as built, is compliant with safety requirements.

The way that any commissioning programme is developed will be influenced by the desire of some SMR vendors to provide 'ready to install and operate' sections of the plant or modules. Hence, some important aspects of non-nuclear testing are likely to be done off-site. The Licensee will need to justify how representative these off-site tests are, because physical and functional interfaces may differ from the integrated configuration on site.

The commissioning phase is a unique opportunity to train operation and maintenance personnel. On large NPP, commissioning lasts several months during which the vendor and the Licensee will be on-site together, preparing for the transfer of responsibility. The transfer is progressive, system-by-system or part by part. For SMRs, some commissioning tests may be performed at manufacturer premises, at least unitary systems tests and pre-loading tests. Consequently, there may be an impact on the understanding of future plant operators and maintainers. The Licensee would need to manage the safety implications of this situation.

Common position: *The Licensee needs to demonstrate how the commissioning programme takes into account any uncertainties due to the lack of OPEX.*

The commissioning approach has to take account of the lack of OPEX and the novelty of the design, for both FOAK SMRs and for NOAK SMRs where sufficient OPEX is not yet available.

An objective of proving the design and understanding the uncertainties could be assigned to the FOAK tests, even if partial testing needs to be made prior to the commissioning to validate the concept. This is generally because these tests may not be possible or practicable during R&D activities. In any case, the Licensee should clearly specify the contribution of the commissioning tests in the safety demonstration from the initial plant tests to physical start-up tests. This may in particular have an impact on the licensing process, for innovative designs, to support effectiveness of safety provisions in the operating license.

The commissioning approach should propose a very wide-ranging programme of validation of the design, rather than a programme of verification of the compliance of the plant regarding safety requirements. For some SMR designs, there may be multiple units inside common structures, and so the commissioning programme should encompass the whole intended facility. Other SMRs may be deployed as very separate units, and so the commissioning programme can reflect this approach.

For FOAK SMRs, specific measurement devices may be installed for the commissioning tests, to tackle uncertainties and understand the behaviour of the plant during operation. All the possible configurations have to be tested, as far as possible, including performance of SSCs during accident conditions. First Plant Only Tests (FPOT) can be considered as they may provide adequate basic data on the operational properties of SSCs for use as a basis for operation.

Common position: *If multiple units/modules are shared in one facility or some units/modules will be added later on:*

- *there will be common SSC that may require certain commissioning activities to take place as the first modules are installed and placed into service;*
- *due consideration needs to be made to common system performance when adding units or modules and whether additional or new or repeated commissioning tests may be needed (a common plant HVAC system, for example, is important to environmental qualification);*
- *commissioning may have the objective to demonstrate/verify the compatibility with the existing plant.*

Common position: *The Licensee is responsible for:*

- *quality, transparency and independence of persons or entities directly responsible for performing the tests (the persons implementing this process should have the appropriate expertise in terms of manufacturing, detailed design and operation of the module to meet this objective).*
- *conducting a review of deviations and of how these deviations are handled;*
- *the decision on the continuation of the tests, or the definition of any subsequent test programme.*

Given the importance of the Commissioning program in future plant operations, the Licensee is responsible for the conduct of the program and is expected to specify where the tests will be performed and justify the representativeness of those tests regarding the on-site configuration. A further set of on-site commissioning tests will have to be performed to check that the results obtained off-site are valid for the plant.

For SMRs, it is likely that the commissioning tests may be partially performed at the vendor and relevant supplier premises. Communication and contractual arrangements between the Licensee and the vendor and relevant suppliers regarding the preparation, conduct and analysis of the commissioning tests have to be clearly set up in the commissioning programme.

The Licensee is expected to provide, in the general commissioning programme, for each SSC, safety requirements and identify tests or test sequences that will enable verification of each of these requirements and the location of the premises where the tests will be performed. The representativeness of the different tests should be justified, introducing some complementary tests to be performed on-site with the objective to check the validity of tests performed off-site for the commissioning of the plant.

The commissioning organization set up should clearly define:

- who develops the commissioning tests procedures,
- who plans and performs the commissioning tests,
- who analyses the results of the tests, including any deviations,

- how the Licensee ensures that the people preparing the test procedures, conducting the tests or analyzing the results have the necessary skills,
- who determines the impacts of the commissioning tests results on the continuation of the testing programme,
- who ensures the processing of all deviations identified during the commissioning tests,
- who ensures the traceability of the final results for each commissioning tests.

For SMRs, where commissioning activities may be performed off-site, the process should anticipate the need to repeat or perform additional tests on-site or off-site, to modify the conditions for conducting the commissioning tests planned in the following phases or to adapt the operating envelope to address the results of the commissioning test.
The Licensee needs to justify the representativeness of the tests regarding the site configuration. In particular, justify any impact that the transportation and storage of the module, and the works to be done on-site to install it (connection to the I&C, to the turbine for instance) is identified and that it still complies with safety requirements.

Commissioning tests results may result in engineering design change for NOAK SMR and modification of the FOAK one. For SMRs, the balance between the desire for a standardized design over time may be challenged by the need for modifications due to commissioning results. As a minimum, commissioning results should be used to further validate calculation codes supporting the safety demonstration.

Commissioning tests results should be shared by all interested parties, including regulators, and the vendor should justify any lessons learnt by the commissioning of a FOAK plant for the NOAK designs. For the NOAK plant, the Licensee should review the safety demonstration and the commissioning programme accordingly.

Common position: *When commissioning tests are performed in the manufacturing premises, the Licensee needs to be involved for the purpose of gaining experience for the future operation.*

In factory commissioning, the operator should have a role in the conduct of commissioning tests for the purpose of training operating and maintenance personnel on plant systems in preparation for plant operation. Off-site commissioning presents challenges to the license in this regard particularly when manufacturing facilities are remote from the site.

Common position: *The Licensee will need to justify the representativeness of full-scale replica tests results and FPOT tests if wanting to take credit for those tests in the commissioning phase, and detail the commissioning tests to be performed on the licensed plant to check their full applicability.*

Several SMR designs rely on passive systems, and so the performance of SSC may not be fully testable during the commissioning tests, especially for protection and safeguard systems that are not used during normal operation or for systems that are not used in the same configuration in normal and accident conditions. Therefore the Licensee should provide alternative tests to ‘prove the design’, and determine parameters that can be checked on the plant to demonstrate that the performance obtained on any full-scale replica is applicable to the module/plant.

The Licensee is responsible for:

- assessing the potential use of each FPOT results for its unit(s) and to conclude such FPOT results can be credited in the commissioning process before formally presenting the case to the regulator.
- assessing the similarity of the unit on which the test was conducted and the one which will credit the FPOT (and have access to all necessary data for this purpose).
- Justifying why any possible differences in design, manufacture and installation of the FPOT component or system, in the environmental and operating conditions and practices, or the codes and standards applied, do not affect the validity of the FPOT results to other unit(s).
- giving reasons for taking credit from certain FPOT tests (severity of loadings for instance).

The Licensee needs to justify that:

- the design, implementation, and plant conditions are so similar that the possible existing differences do not affect the applicability of the results to the unit where the test will not be performed.
- the test is adequate to verify the requirements and acceptance criteria that may differ from one country to another.

The Licensee commits to:

- giving full access to data; and to
- document the performance and results of any tests performed in another jurisdiction.

This data and documentation could be used to design and validate a less complex or alternative test that may be used during commissioning of follow-on units to characterise the performance or behavior of the component or system and thus help validate application of the FPOT data.

The Licensee has then to document its role during the definition of the tests, the performance and the analysis of results and that it has the information needed to check the representativeness of the test.

The Licensee has to ensure the adequacy of the quality assurance programme of tests for the FPOT unit, considering the quality assurance requirements of the unit where FPOT may be credited. This includes ensuring the adequacy of the quality assurance programme for instrument calibration.

Chapter 5: International Cooperation

International Cooperation between Regulators and international organisations

Introduction

There is a worldwide interest in small modular reactors (SMRs) because of their safety claims and role in global energy development as part of an optimal energy mix. The new reactors that are defined as SMRs are very diverse and use innovative technologies including passive safety systems. Despite their novelty and variety in designs, the proposed SMR are within the existing international nuclear safety and legal framework.

Common position

1. SMRs are NPPs and are expected to comply with existing international conventions[20].
2. The IAEA General Safety Requirements are applicable to SMRs which contain provisions for use of alternative approaches as well as the use of risk informed decision making.
3. Bilateral and multilateral cooperation of national nuclear Regulators within the SMR licensing procedure is good practice to be pursued as far as legal constraints will allow. National Regulators may be able to use as evidence (or leverage) the outcome of activities performed by another national Regulator in their jurisdiction. The SMR industry are encouraged to facilitate the sharing of information.
4. Like any new reactor technology, most SMR technologies will contain innovative features or may apply proven technologies differently and consequently there will be areas of limited practical experience. Hence, an ongoing mechanism of cooperation between national nuclear Regulators for SMRs will be beneficial at the international level. This cooperation could extend to more detailed and technology specific cooperation, so as to share experiences where detailed technology specific assessments or licensing processes between countries align well.
5. More work is needed to understand how transportation of fuelled reactors is covered by existing international conventions.
6. Design and manufacture of SMRs in different jurisdictions increases the need for cooperation between national Regulators, particularly in areas involving on-site inspections[21].
7. Information exchange about SMR activities may be affected by international agreements on intellectual property rights.

[End]

[20] Link to website IAEA for these conventions.
[21] Ref MDEP Vendor Inspection Cooperation working group outputs.

APPENDIX 1: The Manufacturing (and construction), Commissioning and Operations Working Group (MCCO – WG).

The MCCO-WG was established to develop common position statements and areas of enhanced cooperation where practicable to inform near term SMR projects being undertaken by member states for:

- Manufacturing and Construction: Document Regulatory views of SMR specific construction issues and implications in the Licensee oversight and regulatory inspection programs
- Commissioning: Document regulatory views of expected SMR commissioning issues and implications in the Licensee oversight and regulatory inspection programs
- Operation: Document the implications on in service inspection programs from, for example, compact system design, sealed vessels or inaccessible systems.

This issue specific working group is composed of volunteer representatives from the following IAEA member states who are also members of the SMR Regulators' Forum:

- United States – U.S. NRC (Chair)
- United Kingdom – Office of Nuclear Regulation
- Canada – CNSC
- France – IRSN
- Russian Federation – Rostechnadzor
- Finland – STUK
- China (from March 2019 meeting).

APPENDIX 2: Abbreviations used in this document

SMR: Small Modular Reactor.

NPP: Nuclear Power Plant.

MCCO WG: Manufacturing, Construction, Commissioning & Operations Working Group of the SMR Forum.

IAEA: International Atomic Energy Agency

FOAK: First of a Kind

NOAK: nth of a Kind (where n is any number above 1)

SCM: Supply Chain Management

CFSI: counterfeit, fraudulent and suspect items

OPEX: Operating experience (from events)

SSC: Structures, systems and components

HVAC: Heating, ventilation and air conditioning

I&C: Instrumentation and control

MWe: Mega-watt, electrical

EPC: Engineering, Procurement, Construction

MDEP: Multinational Design Evaluation Programme

FPOT: First Plant Only Tests

ONR: Office for Nuclear Regulation (The nuclear regulator for the United Kingdom)

US NRC: United States Nuclear Regulatory Commission**.**

CFR: Code of Federal Regulations (in the United States)

ECCS: Energy Core Cooling Systems

R&D: Research and Development

LOOP: Loss of Offsite Electrical Power

APPENDIX 3: Representatives of the MCO Working Group

Country	Institution
Canada	Canadian Nuclear Safety Commission (CNSC)
France	Institut de Radioprotection et de Sûreté Nucléaire (IRSN)
Finland	Radiation and Nuclear Safety Authority (STUK)
Russian Federation	Federal Environmental, Industrial and Nuclear Supervision Service of Russia (Rostechnadzor)
United Kingdom	Office for Nuclear Regulation (ONR)
USA	U.S. Nuclear Regulatory Commission (NRC)