REGULATORY HARMONIZATION OF NUCLEAR SECURITY REQUIREMENTS FOR SMALL MODULAR REACTORS: CHALLENGES AND OPPORTUNITIES

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ABSTRACT

The word "harmonization" is central to the regulatory discussions surrounding the introduction of small modular reactors (SMRs). The IAEA has recently launched a new initiative on nuclear harmonization and standardization (NHSI) that brings together policy makers, regulators, designers, vendors, and operators to develop common regulatory and industrial approaches to SMRs. The initiative explores the harmonization of regulations and standards for both safety and security with the aim "to increase regulatory collaboration, to establish common positions on technical and policy issues, to pave the way to greater harmonization, initially in the pre-licensing phase for SMRs, with an agreed expectation of high levels of safety and security for these advanced designs." But how realistic is regulatory harmonization of nuclear security requirements for SMRs? International legal instruments for nuclear security, such as the Convention on Physical Protection of Nuclear Material and its Amendment (A/CPPNM), establishes nuclear security as a national responsibility, a principle that continues to be emphasized in the Nuclear Security Recommendations on the Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Rev. 5) and in all the other relevant IAEA Nuclear Security Series publications. Furthermore, the formulation of nuclear security requirements is underpinned and informed by the State's threat assessment and design basis threat (or representative threat statement), which involves a confidential process specific to that State. These nuclear security principles would impact the discussion on regulatory harmonization. This paper explores the challenges to regulatory harmonization for the security of SMRs by analyzing the relevant Nuclear Security Series publications and other related guidance and making parallels with similar nuclear safety efforts. It discusses the viability of regulatory harmonization in this context and offers some potential solutions to overcome the challenges identified.

I. INTRODUCTION

Small Modular reactors (SMRs) are small and advanced nuclear reactors with specific attributes such as modularity and simplified design features that allow for higher reliability and passive and inherent safety features, capable of producing electricity or heat around 300 MW(e) or less[i]. According to the IAEA, there are currently more than 70 commercial SMR designs under development in 18 countries[ii]. To establish a platform to unite experts in the SMR field to share experiences related to development and deployment of SMRs, the IAEA formed the Technical Working Group on Small and Medium Sized or Modular Reactors (TWG-SMR) and the SMR Regulators' Forum. The IAEA also launched a new initiative, the Nuclear Harmonization Standardization Initiative (NHSI) to harmonize regulatory and industrial approaches to SMRs by bringing together policy makers, regulators, designers, vendors, and operators. During the opening meeting of NHSI, held in Vienna in June 2022, the IAEA Director General Rafael

Mariano Grossi emphasized the importance of maintaining the highest nuclear security and safety standards for deployable reactors and that the role of "NHSI is not about cutting corners – it is about getting it right and getting there fast.[iii]" The opening meeting of NHSI consisted of regulators, technology holders and operators working on two separate but complementary regulatory and industry tracks.

The industry track aims to reduce the timelines for licensing and deployment and associated costs by developing standardized industrial approaches to SMR manufacturing, construction, and operation. The objectives of the industry track are four-fold: sharing information on national standards and codes; harmonizing high-level user requirements, which are based on the utilities' needs and in keeping with IAEA safety requirements; experimenting and validating simulation computer codes to model SMRs; and accelerating the implementation of nuclear infrastructure for SMRs[iv].

The regulatory track consists of three working groups focused on developing: an information sharing framework to increase collaboration; an international pre-licensing regulatory design review to reach common regulatory positions[v] without sacrificing security and safety; and approaches to leveraging other regulators' reviews, relying on conclusions of the SMR Regulators' Forum[vi] as well as experiences of embarking countries[vii].

Despite these various international efforts, harmonization of nuclear security regulatory frameworks for SMRs faces challenges and barriers, which include, but are not limited to: a) jurisdictional limitations; b) protecting the confidentiality of a State's threat assessment, Design Basis Threat and Representative Threat Statements; and c) States' differing regulatory approaches to licensing and procurement. Other challenges to harmonization of nuclear security regulatory frameworks for SMRs, which are outside the scope of this paper, involve cybersecurity, supply chain security, transport security, as well as the complexities caused by involvement of multinational corporations engaged in deployment of SMRs as opposed to the State-owned enterprises involved with operating the conventional reactors. First, SMR's remote monitoring capabilities make cybersecurity a must and a matter of evolving regulatory oversight with novel challenges. Second, the modular and transportable design of SMRs, which allows their manufacturing and assembly to be completed offsite as opposed to the conventional reactors that are built onsite, poses challenges to supply chain security. And finally, different SMR technologies and their fuel cycles create barriers to transport security.

The following two sections provide an analysis of the CPPNM and its Amendment and the Early Notification Convention[viii], among other instruments[ix] and IAEA Nuclear Security Series, specifically focusing on provisions related to these barriers, as well as addressing some of the existing gaps within these instruments. Section four of the paper explores the challenges that deployment of SMRs and their operational/organizational models will pose to States' jurisdictional authority and applicability of States' regulatory and legal frameworks to SMRs; and finally, the paper concludes with some recommendations.

II. INTERNATIONAL CONVENTIONS ON NUCLEAR SECURITY AND SAFETY

i. The Convention on Physical Protection of Nuclear Material and its Amendment (A/CPPNM)

The CPPNM, the main international binding instrument in nuclear security, entered into force on February 8, 1987, with 164 States Parties. The CPPNM requires each State Party to take appropriate steps "within the framework of its national law and consistent with international law" to ensure that nuclear material is used for peaceful purposes and protected while in international transport[x]. The Convention specifically recognizes that "nothing in this Convention shall be interpreted as affecting the sovereign rights of a State regarding the domestic use, storage and transport of such nuclear material.[xi]" The CPPNM also requires States to criminalize the commission, the threat or attempt to commit and participate in certain offenses, involving nuclear material, subject to the State's national law, with penalties commensurate with the gravity of the offense[xii]. The Amendment to the CPPNM, adopted on July 8, 2005, extended the scope of the Convention to cover *nuclear facilities* to include associated buildings and equipment used for peaceful purposes and nuclear material in domestic use, storage, and transport[xiii], but reemphasized the States' sovereignty rights. Article 2 of the A/CPPNM places the responsibility to establish, implement and maintain a physical protection regime "within a State Party" entirely with that State. Thus, the States' ability to implement A/CPPNM is limited by their jurisdictional reach.

The transboundary deployment of SMRs and transportable nuclear power plants (land-based or floating) will challenge the bounds of States' jurisdictional authority and legal frameworks, as well as the States' regulatory body in performing core regulatory functions such as licensing, inspection, enforcement, and response arrangements. In addition, depending on the ownership and operational models States utilize- Build-Own-Operate (BOO), Build-Own-Operate-Transfer (BOOT), or leasing model, the supplier States could seek favorable conditions on SMR delivery, operation, and inspections and the host State's regulations. And the States would have to reach agreements on designating who the host State is for the purpose of establishing a physical protection system based on its threat assessment[xiv]. Thus, under A/CPPNM, the States' responsibility to establish physical protection regimes governing nuclear material and nuclear facilities and their jurisdictional authority to enforce the same will face novel challenges with respect to SMRs. Although A/CPPNM's definition of nuclear material and nuclear facilities and its Annex 1 clearly govern SMRs, in that they encompass nuclear material and nuclear facilities in use, storage, and transport[xv] for peaceful purposes[xvi], the same is not true for nuclear material used for military purposes. In other words, the A/CPPNM applies to all SMR technologies, but it distinguishes between SMRs based on location (land vs. floating) or usage (peaceful purposes vs. military use). The A/CPPNM text thus contains ambiguities and inflexibilities that may pose challenges for States in regulating nuclear security of SMRs and any harmonization efforts that may ensue.

ii. Convention on Early Notification of a Nuclear Accident, INFCIRC/335

The Early Notification Convention or INFCIRC/335, entered into force on October 27, 1986, following the Chernobyl nuclear plant accident[xvii]. The Convention requires States to notify the affected States, either directly or through the IAEA, in the event of a nuclear accident "involving facilities or activities of a State party or of persons or legal entities under [the State's] jurisdiction or control,"[xviii] including providing available information to minimize the radiological consequences of the nuclear accident. Specifically, the Convention includes within the scope of covered facilities "any nuclear reactor wherever located" and "any nuclear fuel cycle facility" and within the scope of covered activities "transport and storage of nuclear fuels.[xix]" Notably, the Convention does not limit a State's ability to notify other States regarding other nuclear accidents not enumerated in the Convention,[xx] and it recognizes the need for bilateral and multilateral arrangements for States to exchange information and to strengthen cooperation in safe development and use of nuclear energy. The provisions promoting States to cooperate and exchange information, are great examples of international platforms available to States to collaborate on issues involving preventative and mitigating measures related to nuclear accidents involving SMRs. However, even though the Convention utilizes a broad brush in defining facilities and activities encompassing SMRs, if applied in the context of a nuclear security accident involving SMRs, and depending on the operational and organizational models utilized, then the Convention will pose questions on which State has jurisdiction or control over the facilities, activities or legal entities involved.

iii. The Convention on Nuclear Safety, INFCIRC/449 (CNS)

The Convention on Nuclear Safety or INFCIRS/449 (CNS), adopted in 1994 by a diplomatic conference of the IAEA defines "nuclear installation" as "any land-based civil nuclear power plant" under the jurisdiction of a Contracting party[xxi]. Based on this language, it is unclear if SMRs are within the scope of nuclear power plants and arguably floating reactors would not be included in CNS's definition[xxii]. In addition, CNS's current definitions may create barriers for nuclear newcomers, embarking on establishing a legislative and regulatory framework to govern safety of SMRs pre-deployment, including systems of licensing, inspection and assessments, and enforcement[xxiii].

III. IAEA RELEVANT NUCLEAR SECURITY SERIES

i. Objective and Essential Elements of a State's Nuclear Security Regime, NSS No. 20

NSS No. 20 provides States with a set of twelve essential elements for an effective and appropriate nuclear security regime, recognizing that the responsibility for implementing, maintaining, and sustaining a nuclear security regime rest entirely with the State. Under Essential Element 7, identification, and assessment of nuclear security threats, NSS No. 20, requires the State to ensure its nuclear security regime is based on updated threat assessments and that its nuclear security regime ensures that internal and external nuclear security threats are identified and assessed, even if the target of an internal threat is extraterritorial[xxiv]. The State's threat assessment is in turn integral to the State's identification and assessment of targets and potential consequences should they be compromised.[xxv] The State is also required to employ risk informed approaches in allocating its resources for nuclear security systems and measures as well as in conducting nuclear security activities, based on graded approach and defense in depth concepts[xxvi]. All these concepts are integral to the States' legislative and regulatory framework for nuclear security.

ii. Nuclear Security Recommendations on the Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Revision 5), NSS No. 13

The INFCIRC/225 also known as the IAEA Nuclear Security Series No. 13, sets forth the IAEA's recommendations on the physical protection of nuclear material and nuclear facilities. NSS No. 13 provides guidance to States in implementing a comprehensive physical protection regime for their nuclear material and nuclear facilities in keeping with their international obligations including CPPNM and its Amendment. It describes the elements of a State's physical protection regime, including its legislative and regulatory framework. Under Fundamental Principle A, NSS No. 13 provides that the responsibility for establishing, implementing and maintaining a physical protection regime "rests entirely with that State," and it extends the State's responsibility to ensure adequate protection for nuclear material to "international transport until that responsibility is properly transferred to another State[.][xxvii]" The State's responsibility to establish a legislative and regulatory framework, governing the physical protection regime, includes defining requirements based on the threat assessment or Design Basis Threat (DBT), as well as licensing requirements applicable to all nuclear material and nuclear facilities "regardless of whether [they are] under State or private ownership.[xxviii]" Fundamental Principle G on Threat, requires the State to develop threat assessments and DBTs relying on credible information sources, and to require operators, shippers and carriers to use threat assessments and DBTs as the basis for the design and implementation of the physical protection system. The State's evaluation of the threat and its determination regarding acceptable levels of risk and necessary levels of protection against the threats, are also utilized to ensure that the State's physical protection requirements employ a graded approach[xxix]. Finally, under Principle L, Confidentiality, NSS No. 13 requires that States establish confidentiality requirements for any information, the unauthorized disclosure of which could compromise the physical protection of nuclear material and nuclear facilities, specifically any information "addressing possible vulnerability in physical protection systems[.][xxx]"

iii. Implementing Guide on Physical Protection of Nuclear Material and Nuclear Facilities, NSS No. 27-G

The IAEA NSS No. 27-G or the Implementing Guide to INFCIRC/225/Rev. 5 provides guidance to States on establishing, implementing, and sustaining a physical protection regime for nuclear material and nuclear facilities. NSS 27-G states, in pertinent part, that if a State "accepts nuclear material and nuclear facilities within its borders, that State has also accepted *responsibility* for the protection of those material from unauthorized removal and … from sabotage[.]"[xxxi] To satisfy this responsibility, the State's risk management approach should address its assessment of threats and DBT, as well as the potential consequences of sabotage and unauthorized removal and vulnerabilities of targets. The State's responsibility for establishing a legislative and regulatory framework governing its physical protection regime extends to the "introduction of new types of nuclear material and nuclear facilities.[xxxii]" States could employ three distinct regulatory approaches, including the prescriptive approach, performance-based approach, and the combined approach[xxxiii] to specify the regulatory requirements addressing the State's threat assessment and DBT. Under the performance-based approach, the operator utilizes the DBT to design the physical protection system, and the competent authority evaluates the same based on the DBT. Under the prescriptive approach, a threat assessment may be sufficient for the competent authority to define the physical protection measures that the operator will be required to implement exactly[xxxiv]. In the combined approach, a combination of these approaches is utilized. The State is also responsible for setting licensing requirements in relation to physical protection systems, as well as for issuance, renewals, and amendment of existing licenses throughout the lifecycle of a nuclear facility. Finally, the State is responsible for defining regulatory enforcement measures as part of its physical protection regime and to enforce compliance with its licensing regulations.

IV. Challenges and Barriers to Harmonization

i. Jurisdictional Barriers

Jurisdictional divides and States' interest in protecting their sovereignty are a major obstacle to the harmonization of nuclear security regulatory frameworks. As discussed *supra,* the deployment of SMRs will place constraints on States' exercise of jurisdiction over SMRs depending on the organizational and operational model utilized. It will also pose challenges for nuclear security and A/CPPNM implementation. For example, in a BOO model, the supplier State, as owner and operator of SMR would arguably be responsible for nuclear security. With that said, it would be difficult to determine which State's threat assessment would be utilized to establish an effective physical protection system. On the other hand, the host State's legal framework could still be applicable for the core regulatory functions of inspection and enforcement, but the supplier State may challenge or set conditions on the scope and extent of the same or the applicability of host State's legal framework[xxxv].

Concurrently, recognition of the States' sovereignty and discretion in regulating nuclear security within their national legal frameworks is key to strengthening international cooperation and ensuring States' continued commitment to ensuring adequate physical protection for nuclear material and facilities. During the negotiation phase of the CPPNM that began in 1977 and lasted for two years, the majority of States agreed on the necessity of a legally binding instrument to govern physical protection of nuclear material. However, significant disagreements remained with respect to the scope and reach (universality) of CPPNM, due to the States' legal, security, political, and technical differences. Some States sought to extend the scope of the CPPNM to nuclear material for domestic use, storage and transport and even nuclear facilities, while others pursued limiting the scope to nuclear material in international transport. Similarly, some States sought to focus CPPNM's reach to nuclear material for peaceful purposes, while others sought to extend the requirements to military uses as well[xxxvi]. Even during the negotiation phase of the CPNNM Amendment in 2005, while States recognized the need to strengthen the CPPNM provisions by extending its scope to nuclear material in domestic use, storage, and transport as well as nuclear facilities, considerable aversion remained with respect to measures requiring regular reporting by States about their implementation of the CPPNM, and towards requirements for mandatory peer review of their physical protection regimes. Finally, the process of revising the reach and scope of CPPNM (which entered into force in 1987) to its Amendment in 2016, lasted just short of three decades. This exemplifies the extent of negotiations and political will necessary for States to reach a consensus on constraining their sovereignty by entering into the only multilateral treaty regarding the physical protection of nuclear material and nuclear facilities used for peaceful purposes.

Articles 14 and 16 of the CPPNM could be utilized to encourage or even require States exporting SMR technology to inform IAEA of their implementing laws and regulations relevant to SMRs or to communicate that information to other States. It could also be leveraged to regularly convene Conferences of States to review the adequacy of the CPPNM provisions to address SMRs, which could enable nuclear newcomers to learn about the legislative guidance and practices of States with SMR technology. In addition, enhanced IAEA nuclear security guidance on legislative and regulatory frameworks for SMRs and continued provision of IAEA legislative and technical assistance[xxxvii], tailored towards physical protection of SMRs is critical to incentivizing States to comply with international nuclear security frameworks while adjusting to the particular needs of SMR technologies; the IAEA legislative and technical assistance includes bilateral legislative assistance in drafting and reviewing implementing legislation, international seminars and regional and national workshops, and publication of SMR specific reference material and non-legally binding nuclear security series. This would ensure building upon the existing cooperation and information sharing platforms and preparing States to acquire and protect SMR technologies, by striking a balance between State's jurisdictional sovereignty, international cooperation, and information sharing

ii. States' Threat Assessment, Design Basis Threat (DBT) and Representative Threat Statement (RTS)

Another major barrier to harmonization of nuclear security regulatory frameworks is States' identification of threats and development of threat assessment documents, including DBT and RTS. The States' threat assessment, DBT and RTS form the basis of their physical protection requirements, involving highly sensitive and confidential information and intelligence analysis, which cannot be disclosed or disseminated. NSS No. 13, Fundamental Principle C requires the States to establish and maintain a national legislative and regulatory framework to govern physical protection, thereby providing for a system of evaluation, licensing, and inspections and means of enforcing the applicable requirements. Under this framework, the States should, based on the "threat assessment or design basis threat" define physical protection requirements for nuclear material in use, storage, and transport and for nuclear facilities.

IAEA Implementing Guide on National Nuclear Security Threat Assessment, Design Basis Threat, and Representative Threat Statements, NSS No. 10-G (Rev.1) further provides States with a detailed methodology on conducting a national nuclear security threat assessment, including physical and cyber security, as well as development, maintenance, and use of DBT and RTS. The States utilize their DBT[xxxviii], RTS, or a combination thereof, to develop risk informed approaches to nuclear security and risk management at individual facilities and activities, as well as to design and evaluate nuclear security systems and measures[xxxix]. The States' assessment of nuclear security risks depends on their determination of threats of concern, new and emerging threats, international and regional threats, political and financial factors, policy factors, and their population's perception of risk.

All relevant competent authorities, including law enforcement, intelligence organizations, foreign affairs ministries, military services, custom and border control authorities, and regulatory bodies are involved in developing and maintaining threat statements. The States' competent authorities consider all credible threat information, including national intelligence and other sensitive information, past nuclear security events, and relevant non-nuclear activity events. They also consider comprehensive information regarding all potential adversaries (internal and external), and their intentions and capabilities. Given the sensitivity of this information, the States are responsible to develop appropriate security measures to ensure the confidentiality of information, as well as arrangements for information sharing. "Both the national nuclear security threat assessment documentation and the details of the intelligence sources are typically protected as sensitive information.[xl]" In addition, under Principle L, Confidentiality, NSS No. 13 requires States to establish confidentiality requirements for any information, the unauthorized disclosure of which could compromise the physical protection of nuclear material and nuclear facilities, specifically any information "addressing possible vulnerability in physical protection systems[.][xli]" Thus, ensuring confidentiality of threat assessments, DBT and RTS is of utmost importance for States. Furthermore, States utilize the threat assessment documentation to develop material, facility, or activity specific DBT and RTS, which will be subject to review and revision by the competent authorities. The States' decision to review and revise their threat assessment is an ongoing process, dependent on a range of factors including the States' defined review cycle, changes to the States' threat environment, new or emerging threats, nuclear security evens and the operators' input.

Finally, States' regulatory approach will determine the extent to which they will share their DBT or RTS with operators, if at all. In States employing a performance-based approach, the operator will design and implement nuclear security measures based on objectives set by the State according to the DBT, disseminated by the regulatory body. In States employing the prescriptive approach, the regulatory body, without sharing the threat information with the operator, establishes the specific measures that it determines necessary to satisfy the nuclear security regulatory objectives, which the operator will utilize as baseline measures. In States employing the combined approach[xlii], a combination of these approaches will be used. Thus, States retain absolute discretion on sharing or even disseminating to operators, their threat assessment, DBT, and RTS. Additionally, their ability to share the same is restricted by confidentiality requirements to protect sensitive information and intelligence analysis data, evolving legal, political and policy factors, as well as their nuclear security regulatory approach.

iii. Licensing & Procurement Barriers

Another challenge to harmonization of nuclear security regulatory frameworks with respect to SMRs would be the States' varied regulatory approaches to licensing and procurement. According to the IAEA, as of 2021, there were more than 70 different SMR design concepts under development around the world with different technology and licensing readiness levels[xliii]. Even from the perspective of harmonizing safety requirements for SMRs and even though majority of SMR designs incorporate higher levels of passive or inherent safety systems and features, SMR technologies still must overcome the technical hurdles of global safety assessments and licensing[xliv]. The leading reactor vendors for SMRs are in the United States, China, Russia, India, and South Korea, making their Licensing Processes (LPs) particularly important to gain credibility and build economies of scale[xlv]. Although, the Emergency Planning Zones (EMZs) create issues for the LPs due to coupling of SMRs with other industrial plants, other aspects of the LP should be taken into consideration such as: a) the typology of licensing approaches within these countries; b) duration and predictability of the LP; c) regulatory harmonization and international certification process; d) manufacturing licenses; and e) ad hoc legal and regulatory frameworks[xlvi].

As discussed above, the States' varied regulatory approaches to physical protection system requirements, licensing, procurement, evaluations, and enforcements create significant challenges to harmonization of nuclear security regulatory frameworks. Licensing is also an ongoing process throughout all life stages of a nuclear facility, which may be modified, "but always by and under the control of the State.[xlvii]" In addition, an applicant or operator's request for a license, including the physical protection system developed for the facility or activity is subject to the State's continued review, assessment, and approval, which should be based on the State's evolving threat assessment or DBT. Applicant's access to the threat assessment and DBT would in turn be contingent on the State's regulatory approach in that they must either demonstrate their compliance with regulatory conditions (performance based) or follow the State's specific steps to satisfy regulatory requirements (prescriptive approach)[xlviii].

An effective way to harmonizing licensing and procurement regulations could be a consensus-based and holistic movement by States to incorporate the concept of Security by Design (SeBD) in their regulatory requirements as early as possible, through the design, construction, operation and decommissioning of SMRs, including the supply chains. Incorporation of SeBD in States' regulatory framework would reduce physical protection costs and simplify maintenance of the same, while making the licensing and procurement processes more efficient and flexible[xlix]. Both NSS 35-G on Security during the Lifetime of a Nuclear Facility and NSS No. 27-G, *supra,* respectively recognize and promote inclusion of nuclear security at the design stage and implementation of SeBD through a systematic approach beginning at the planning phase of the facility and continuing through its design, construction, operation, and decommissioning phases[l]. To minimize conflict with other design requirements, NSS No. 27-G recommends eliminating potential vulnerabilities by suitable engineering and to make decisions regarding siting and layout of the facility earlier[li]. NSS 35-G offers recommendations on "design actions" for the competent authorities and operators, which are applicable to SMRs. However, to incorporate SeBD, a State's confidential threat assessment and DBT must be considered; and in States employing a prescriptive regulatory approach, foreign designers/vendors of SMRs may face difficulties in accessing classified threat assessment and DBTs, when designing a reactor. Alternatively, States could adopt a similar approach to that of the Canadian Nuclear Safety Commission (CNSC) to streamline their licensing process[lii] by requiring incorporation of the SeBD and moving towards a performance-based approach with less prescriptive requirements[liii]. This regulatory approach requires sharing of confidential threat assessment and DBT with national and foreign SMR designers, which may not be suitable for States with prescriptive regulations. However, balancing prescriptive and performance-based requirements could provide advantages in flexibility and cost savings to nuclear newcomers with less-developed regulatory frameworks, who plan on deploying SMR technologies. Thus, the deployment of SMRs and their organizational/operational models will challenge the States' exercise of jurisdiction and regulatory core functions, as well as pose issues in the delineation of States' responsibilities to establish a physical protection system based on confidential threat assessment and DBT.

V. CONCLUSIONS AND RECOMMENDATIONS

The fact that nuclear security is intertwined with States' national legal frameworks including national defense and security, confidential intelligence gathering, energy production, and States' political will and technological advances, means that harmonization of nuclear security regulatory frameworks will infringe on States' national sovereignty and jurisdictional authority. The States could instead utilize Articles 14 and 16 of the CPPNM to encourage or even require supplier States to inform IAEA of their implementing SMR laws and regulations. This process would also enable nuclear newcomers to learn about the legislative guidance and practices of States with SMR technology. The States could also convene Conference of States to review the adequacy of the CPPNM provisions to address SMR technologies and enhance IAEA nuclear security guidance on legislative and regulatory frameworks for SMRs. In addition, the States could opt into incorporating the concept of SeBD into their national nuclear security regulatory frameworks throughout all stages of SMR lifecycle to streamline their licensing and procurement requirements and to reduce physical protection costs and timeliness of maintaining the same. Finally, States could streamline their licensing and procurement processes by moving towards a performance-based approach with less prescriptive requirements.

VI. REFERENCES

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[i] Based on their core design current SMR technologies are: High Temperature Gas Cooled Reactors (HTR), fast Neutron Reactors (FNRs), light Water Reactors (LWRs), and Molten Salt Reactors (MSRs), see https://www.iaea.org/topics/small-modular-reactors

[ii] see Advances in Small Modular Reactor Technology Developments, A Supplement to: IAEA Advanced Reactor Information System (ARIS), 2022, available at: https://aris.iaea.org/Publications/SMR_booklet_2022.pdf

[iii] see https://www.world-nuclear-news.org/Articles/IAEA-initiative-to-accelerate-deployment-of-SMRs

[iv] see https://www.world-nuclear-news.org/Articles/IAEA-initiative-to-accelerate-deployment-of-SMRs (The challenge with harmonizing the codes and standards that would be applicable to all countries is that equivalencies among existing requirements must be identified, collected and shared on a platform. It is then critical for the two tracks to facilitate information sharing on SMR designs and their safety and security implications.)

[v] To reach a common regulatory position on pre-licensing regulatory review, the regulators' focus would have to be narrowed to the pre-licensing review of the generic design, excluding the site-specific and organizational aspects of the design, leaving the latter to the national regulatory assessment, see https://www.world-nuclear-news.org/Articles/IAEA-initiative-to-accelerate-deployment-of-SMRs

[vi] see https://www.iaea.org/topics/small-modular-reactors/smr-regulators-forum: The SMR Regulators Forum was established in 2015 to provide a venue for member States and stakeholders to share their SMR regulatory knowledge and experience, to enhance nuclear safety by identifying and resolving common safety issues that would challenge SMRs' regulatory review and facilitate a more robust regulatory process.

[vii] see https://www.iaea.org/topics/small-modular-reactors/smr-regulators-forum

[viii] The Vienna Convention on Civil Liability for Nuclear Damage, INFCIRC/500 and the Protocol to Amend the Vienna Convention on Civil Liability for Nuclear Damage, INFCIRC/566, although not an international convention related to nuclear security, is applicable to the subject of this paper because its liability regime could impact the nuclear security measures applicable to SMRs, and potentially their procurement and deployment. This Convention entered into force in 1977 with the goal of harmonizing the contracting parties' national laws through setting minimum standards regarding damages caused by peaceful uses of nuclear energy.

[ix] see Council Directive 2014/87/Euratom of 8 July 2014 amending Directive 2009/71/Euratom establishing a Community framework for the nuclear safety of nuclear installations, OJ L 219 (25 July 2014) (2014 Amended Safety Directive)(The Directive 2009/71/Euratom and its 2014 Amendment, adopted by the Council of European Union in 2009 to establish a community framework for uniform safety standards of nuclear installations may also be of relevance to the discussion on harmonization of nuclear security regulatory framework. The Directive specifically carves out authority for Member States to apply "more stringent measures of protection" regarding the uniform

safety standards in keeping with the Court of Justice case law and emphasizes the national responsibility of the member State for nuclear safety as well as the prime responsibility of the license holder. Further, the Directive defines nuclear installations as nuclear power plants and research reactor facilities, among others, but it is not clear if this definition encompasses SMRs and what types of SMRs[ix], which may pose issues for European newcomers embarking on nuclear power utilizing SMRs.)

[x] CPPNM, Art.2-3

[xi] CPPNM, Art. 2

[xii] CPPNM, Art. 7

[xiii] A/CPPNM, Art. 1- 2

[xiv] Man, M., Fialkoff, M., Karcz, J., *Nuclear Security Is the Responsibility of the State, but Which State? Emerging Challenges by Advanced Reactors to the CPPNM and its Amendment*, INLA Inter Jura Congress 2022

[xv] CPPNM, Art. 1(c) defines nuclear material transport as "the carriage of a consignment of nuclear material by any means of transportation intended to go beyond the territory of the State where the shipment originates beginning with the departure from a facility of the shipper in that State and ending with the arrival at a facility of the receiver within the State of ultimate destination."

[xvi] A/CPPNM, Art. 1-2

[xvii] see also, the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, INFCIR 336.

[xviii] Convention on Early Notification of a Nuclear Accident, Art. 1-2

[xix] Convention on Early Notification of a Nuclear Accident, Art. 1.2

[xx] Convention on Early Notification of a Nuclear Accident, Art. 3

[xxi] CNS, Art. 2(i)

[xxii] While one might argue that micro SMRs would not be included in the definition of a nuclear power plant under the CNS, the question remains regarding what does and does not qualify as a nuclear power plant.

[xxiii] CNS, CNS, Art. 7

[xxiv] NSS No. 20, 3.7

[xxv] NSS No. 20, Essential Element 8

[xxvi] NSS No. 20, Essential Element 9

[xxvii] NSS No. 13, Fundamental Principle B states that the State's responsibility should be determined "either by the borders of its sovereign territory or the flag of registration of the transport vessel or aircraft." And that State's physical protection regime should retain jurisdiction and continuous control over nuclear material in transport with clearly defined lines of responsibilities among the involved States.

[xxviii] NSS No. 13, 3.11

[xxix] NSS No. 13, Fundamental Principle H

[xxx] NSS No. 13, 3.54

[xxxi] NSS No. 27-G, 2.2, italics added for emphasis

[xxxii] NSS No. 27-G, 3.7

[xxxiii] NSS No. 27-G, 3.59

[xxxiv] See NSS No. 27-G, 3.59, except where Category I nuclear material is held and/or the sabotage of the nuclear facility could potentially lead to high radiological consequences.

[xxxv] Man, M., Fialkoff, M., Karcz, J., *Nuclear Security Is the Responsibility of the State, but Which State? Emerging Challenges by Advanced Reactors to the CPPNM and its Amendment*, INLA Inter Jura Congress 2022

[xxxvi] Herbach, J., *Strengthening the International Legal Framework for Nuclear Security: Means and Methods to Facilitate Compliance and Enhance Transparency*, Centre for Conflict and Security Law

[xxxvii] Other IAEA technical services include the peer review and advisory services offered through the International Physical Protection Advisory Service (IPPAS) to ensure compliance of a State's physical protection system with INFCIR/225 and the International Nuclear Security Advisory Service (INSServ) missions where State's nuclear security regulatory framework and nuclear and radioactive physical protection is reviewed.

[xxxviii] The State's use of DBT, RTS or a combination of both would depend on its regulatory approach. For States using a performance-based approach, DBT could be used to develop regulatory requirements to protect against higher consequence facility or activity whereas for States utilizing a prescriptive approach, RTA may be used to develop the regulatory requirements for a subset of lower consequence material and facilities. NSS 10-G [2.10]

[xxxix] Based on their national nuclear security threat assessment, States have the discretion to define different RTS or DBT for different categories of material and for different facilities and activities, for different adversaries' objectives, to address particular policy considerations, to protect assets that may be specifically targeted by cyber-attacks, and to exclude certain threats that will be included in contingency plans. [2.11-2.13]
[xl] NSS No.10-G (Rev. 1), 5.21; see also, CPPNM, Art, 6(2) which emphasizes the States' right to keep confidential any information that would be contrary to their national law, jeopardize their security or the physical protection of nuclear material.
[xli] NSS No.13, 3.54
[xlii] Utilizing the performance-based approach for facilities and activities where greater level of assurances are necessary due to potential consequences of a nuclear security event and a prescriptive approach where a nuclear security event would result in less severe potential consequences, see NSS 10-G (Rev. 1), 7.7-7.8.
[xliii] Liou, J., *What are Small Modular Reactors (SMRs)?*, IAEA Office of Public Information and Communication, https://www.iaea.org/newscenter/news/what-are-small-modular-reactors-smrs (04.11.2021)
[xliv] Cognet, G., Bartak, J., Bruna, G., *SMR Safety-Advantages and Challenges*, NENE 2021 (For example, during the preliminary licensing assessments, the following safety topics must be addressed: a) the conventional safety requirements must be examined and revised accordingly, to address the modular assembling and remote construction and qualification of SMR equipment; b) SMR designs should be examined to ensure that redundancy, diversity and physical separation for safety systems are incorporated, to mitigate common cause failures; c) exclusive adoption and deployment of passive safety systems; d) the SMR designs should combine passive and active safety systems to increase resilience to common cause failures; e) inherent or passive safety features should be granted priority over ones needing actuation; and f) harmonization of licensing processes with respect to incremental extensions of modules. In addition, IAEA developed the TEDDOC 1936, focusing on light water and high temperature gas cooled SMR technologies to apply the design safety requirements to SMR technologies for the near-term deployment.)
[xlv] Increase the size of the reactors to maintain their economic competitiveness
[xlvi] Sainati, T., Locatelli, G., Brooks, N., Giorgio, *Small Modular Reactors: Licensing constraints and the way forward,* Elsevier.
[xlvii] NSS No. 26-G, 3.34
[xlviii] see https://www.greentechmedia.com/articles/read/regulatory-harmonization-an-upcoming-hurdle-for-smrs
[xlix] NSS No. 27-G
[l] NSS No. 27-G, 4.9 (To be commensurate with the SeBD approach, NSS No. 27-G recommends developing a physical protection system based on a 3-phased process at the time of construction of new nuclear facilities and new installations on existing nuclear facilities, and for upgrading existing physical protection systems; this 3-phased process includes: 1) identifying the objectives and requirements for the physical protection system; 2) designing the physical protection system to satisfy the objectives and requirements of phase 1; and 3) analyzing and evaluating the effectiveness of the physical protection system defined in phases 1&2.)
[li] NSS No. 27-G, 4.10
[lii] see INLA Inter Jura Congress 202, slide 205, available at https://aidn-inla.be/content/uploads/2022/12/inla-2022-nuclear-inter-jura-congress-live-inla-presentations_compressed.pdf
[liii] Duguay, Raphael, *Small Modular Reactors and Advanced Reactor Security: Regulatory Perspectives on Integrating Physical and Cyber Security by Design to Protect Against Malicious Acts and Evolving Threats*, 2020, International *Journal of Nuclear Security:* Vol. 7: No. 1, Article 2