**CHALLENGES IN THE HARMONISATION OF LEGAL INSTRUMENTS ON 3S (SAFETY, SECURITY, SAFEGUARDS) AND CIVIL LIABILITY FOR MARINE- NUCLEAR SYSTEMS BETWEEN THE INTERNATIONAL ATOMIC ENERGY AGENCY AND THE INTERNATIONAL MARITIME ORGANISATION**

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 **Abstract**

 Global shipping uses over 300 million t of fossil fuels every year, producing 3% of CO2 emissions. At a July 2023 meeting of the International Maritime Organization (IMO), representatives set a net-zero emissions goal for 2050, e.g., a 100% reduction by 2050 comparing to 2008 level. Supporting this goal, the maritime industry is pursuing deep decarbonization with nuclear ships, defined as a ship, which is provided with a nuclear power plant, powered by a SMR.

 Today, some 200 nuclear reactors are already operating on 160 vessels, mostly naval ships, icebreakers, and submarines. The interests in floating nuclear power plants (FNPPs) have grown since Russia deployed the *Akademik Lomonosov* with 2 SMRs in 2020. These include: SEABORG Technology, THORCON, and the American Bureau of Shipping (ABS), etc. The interests in nuclear ships have also grown since the IMO mandate on decarbonization**. These** include: NuProShip, Fincantieri and Newcleo, Imabari Shipbuilding, Core Power, HD **Korea Shipbuilding & Offshore Engineering, and China State Shipping Corp., among others.**

However, nuclear ships could pose risks in the events of reactor accidents, terrorists attacks, or proliferation threats, and the current legal instruments governing 3S (safety, security, and safeguards) and civil liability for marine-nuclear systems are not sufficient to address these risks. Hence, there are challenges in applying and harmonizing these legal instruments for marine-nuclear systems, including:

(a) The Convention on Nuclear Safety (CNS) is currently not applicable to marine-nuclear systems.

(b) The nuclear-security instruments by IAEA focus primarily on transport of nuclear and radioactive materials. And transport-security instruments by IMO would need to extend to nuclear ships. There is a need to harmonize these two sets of security rules and regulations for clarity and consistency.

(c) The safeguards mechanisms and inspection requirements of many non-water-based SMRs intended for nuclear ships by non-nuclear-weapons countries are not yet developed.

(d) Current Conventions on civil liability for nuclear damage may not be applicable to damages a nuclear ship incurred in attack by non-state actors in open sea or international water.

This study addresses the 3S-and-civil-liability legal instruments of the IAEA and the IMO for marine-nuclear systems, with focus on the harmonization of the rules and regulations between the two.

1. INTRODUCTION

The world is at the juncture of dealing with its twin challenges of climate change and energy security, many countries are now considering nuclear power in their energy mix due to its high energy density and emitting no CO2. Many are interested in small modular reactors (SMRs), e.g., reactors with electric-power output between 10 and 300 megawatts (MWe) and compact designs, which are suitable for small-grids and remote locations, as well as applicable for off-grid applications, such as process heat, desalination, and maritime-nuclear shipping.

Transportable, or marine-based SMRs, such as Russia’s *Akademik Lomonosov* deployed in the Russian Far East in May 2020, serve the electricity, heating, and water need of a remotely-located community. The twin KLT40S reactors on board the *Akademik Lomonosov* are pressurized water reactors (PWR), but many SMRs are of evolutionary-and-innovative designs (EID) [1]. Table 1 lists other transportable reactors developed by countries.

 Table 1 Transportable or Marine-Based SMRs Developed by Countries

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Country** | **Reactor** | **Type** | **Developer** | **Shipbuilder** | **Status** |
| **Russia** | KLT40S | PWR | OKBM Afrikantov | Baltic Shipyard | Operated in Pevek, Russian Far East since May 2020. |
| RITM200M | iPWR | OKBM Afrikantov | Baltic Shipyard | First RITM-200 was installed on board Arktikaicebreaker  |
| **China** | ACP100S | iPWR | CNNC | Jiangnan Shipyard Co. | To be completed in 2023 to power chemical factories [2] |
| ACPR50S | PWR | CGN | China State Shipbuilding Co. | To be completed in ~2020, for oil and gas exploration [3] |
| **ROK** | BANDI-60S | PWR | KEPCO | Daewoo Ship-bldg & Marine Engr. | Under development since 2016 [4]. |
| **Demark** | SEABORG MSR | MSR | SEABORG Technology | Likely a ROK Shipyard | Expected completion after 2027 [5]. |
| **USA** | ThorCon, MSR | MSR | ThorCon, USA | Daewoo Ship-bldg & Marine Engr. | For PT PAL Indonesia, a study to build a 500 MWe plant on a barge [6]. |
| NUSCALE, iPWR | iPWR | NUSCALE | Prodigy Clean Energy of Canada | NUSCALE/Prodigy/Kinectric for a marine power station [7] |

 Deemed transportable, the *Akademik Lomonosov* is actually a power barge, towed to its destination by tug boats. This type of maritime-nuclear system is called floating nuclear power plant (FNPP), which is different from another type, a nuclear ship, e.g., a ship’s propulsion is provided by nuclear reactor(s). Historically, there have been four nuclear merchant ships built by four different countries in the world. Table 2 lists the nuclear merchant ships built and operated.

Table 2 Nuclear Merchant Ships built and operated

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Country** | **Name** | **Type****(MWt)** | **Developer** | **Shipbuilder** | **Remark** |
| **USA** | Savanah | PWR(80) | B&W | New York Shipbuilding Co. | World’s first nuclear merchant ship, operated in (1962 – 1971) |
| **Japan** | Mutsu | PWR(36) | Mitsubishi | Ishikawajima-Harima Heavy Industries Co. | Many repairs since 1974, operated in (1991 – 1992) |
| **Russia** | Sevmorput | PWR(135) | OKBM Afrikantov | Baltic Shipyard | Commissioned in 1988, still in operation |
| **Germany** | Otto Hahn | PWR(38) | Dampfkesselwerke AG&INTERCAtom | Howaldtswerke DeutscheWerft AG | Reactor replaced with diesel in 1983, operated in (1970 –1982) |

The interest in nuclear-propelled ships (e.g., merchant, container, cargo, etc.) have grown since the International Maritime Organization (IMO) mandate of 2023 on decarbonization for maritime shipping to achieve net zero of carbon emission by 2050. **These** include: the NuProShip, a Norwegian maritime consortium that aims to develop a GEN-IV reactor for marine vessels; the Italian shipbuilding company Fincantieri and Newcleo that plans to deploy a 30-MWe lead-cooled reactor on commercial ships; the Japanese shipping company Imabari Shipbuilding that joins with UK’s Core Power to develop a FNPP using a **small modular reactor (**SMR) which can also be applied for ships [8]; the South Korean HD **Korea Shipbuilding & Offshore Engineering (KSOE) that plans to develop a SMR for use in shipping in cooperation with UK's Core Power, the US's Southern Company and TerraPower [9]; and China State Shipbuilding Corporation (CSSC) that plans to build a 24,000 TEU containership using a molten salt reactor [10].**

However, nuclear ships could pose risks in the events of reactor accidents, terrorists attacks, or proliferation threats, and the current legal instruments governing 3S (safety, security, and safeguards) and civil liability for marine-nuclear systems are not sufficient to address these risks. This study addresses the 3S-and-civil-liability legal instruments of the IMO and the International Atomic Energy Agency (IAEA) for marine-nuclear systems, with focus on identifying the challenges in the harmonization of the legal instruments governing the rules and regulations of maritime-nuclear systems by the two organizations.

2. INTERNATIONAL LEGAL INSTRUMENTS (BINDING OR NON-BINDING) ON NUCLEAR 3S (SAFETY, SECURITY, SAFEGUARDS) AND CIVIL LIABILITY GOVERNING MARITIME NUCLEAR SYSTEMS

 Table 3 lists the relevant legal instruments governing the nuclear 3S (safety, security, and safeguards) by the IMO and the IAEA on maritime-nuclear systems. These legally-binding or non-binding instruments were written primarily for transport of nuclear/radioactive materials. But it includes the International Convention for the Safety of Life at Sea (SOLAS) Chapter 8, which contains the Code of Safety for Nuclear Merchant Ships, adopted by the IMO through Resolution A.491.XII in 1981.

Table 3 Legal Instruments on Nuclear 3S Governing Maritime-Nuclear Systems

|  |  |  |
| --- | --- | --- |
| **Safety** | **Security** | **Safeguards** |
| **IMO** | **IAEA** | **IMO** | **IAEA** | **IAEA** |
| UNCLOS[[1]](#footnote-1), SOLAS Ch.3 to 14[[2]](#footnote-2) (except Ch.11),SOLAS Ch.8[[3]](#footnote-3),MARPOL[[4]](#footnote-4),IMDG Code[[5]](#footnote-5) (for fresh HALEU fuel)INF Code[[6]](#footnote-6) (for spent fuel) | CNS[[7]](#footnote-7),SSR-6Rev1[[8]](#footnote-8),SSG-26Rev1[[9]](#footnote-9),SSG-33[[10]](#footnote-10),SSG-65[[11]](#footnote-11),SSG-66[[12]](#footnote-12),SSG-78[[13]](#footnote-13),CENNA[[14]](#footnote-14),CANA[[15]](#footnote-15),JCSSF&RWM[[16]](#footnote-16)CoC[[17]](#footnote-17) | SOLAS Ch.11ISPS Code[[18]](#footnote-18),IMDG Code,INF Code, SUA Convention[[19]](#footnote-19),Protocol of SUA[[20]](#footnote-20), Amendment to Protocol of SUA[[21]](#footnote-21)  | CPPNM&A[[22]](#footnote-22),NSS 26-G[[23]](#footnote-23),NSS 27-G[[24]](#footnote-24),CoC | NPT[[25]](#footnote-25),CSA[[26]](#footnote-26),AP[[27]](#footnote-27),VOA[[28]](#footnote-28),Pre-NPT[[29]](#footnote-29) |

 Table 4 lists the Civil Liability Conventions for Nuclear Damages. It includes the 1971 Convention on Civil Liability for the Carriage of Nuclear Material by Sea, and the non-ratified Liability Convention for Operators of Nuclear-Powered Ships of 1962.

Table 4 Civil Liability Conventions for Nuclear Damages

|  |
| --- |
| **Civil Liability** |
| OECD – Paris Convention[[30]](#footnote-30), and the Brussels Supplementary Convention[[31]](#footnote-31), | The OECD's Paris Convention on Third Party Liability in the Field of Nuclear Energy of 1960 which entered into force in 1968 and was bolstered by the Brussels Supplementary Convention in 1963. The Paris Convention set a maximum liability of 15 million Special Drawing Rights (SDRs, defined by the International Monetary Fund, approximately equal to 1.34 US dollars in April 2023), but this was increased under the 1963 Brussels Supplementary Convention up to a total of 300 million SDRs. |
| IAEA – Vienna Convention[[32]](#footnote-32), | The Vienna Convention was adopted on 21 May 1963 and entered into force on 12 November 1977. The amended IAEA Vienna Convention of 1997 sets the possible limit of the operator's liability at not less than 300 million SDRs and entered into force in 2003. It also provides for jurisdiction of coastal states over actions incurring nuclear damage during transport. |
| Convention on Supplementary Compensation for Nuclear Damage (CSC)[[33]](#footnote-33) | The Convention (CSC) was adopted on 12 September 1997 and entered into force on 15 April 2015.  The CSC provides additional amounts beyond the Vienna Convention's first-tier 300 million SDRs through contributions by States Parties collectively on the basis of installed nuclear capacity and a UN rate of assessment, basically at 300 SDRs per MW thermal. It is an instrument to which all States may adhere regardless of whether they are parties to any existing nuclear liability conventions. |
| The 1971 Convention on Civil Liability for the Carriage of Nuclear Material by Sea  | In 1971 IMO, in association with the IAEA and the OECD, convened a Conference which adopted a Convention to regulate liability in respect of damage arising from the maritime carriage of nuclear substances. The Convention provides that a person otherwise liable for damage caused in a nuclear incident shall be exonerated for liability if the operator of the nuclear installation is also liable for such damage by virtue of the Paris Convention or the Vienna Convention. |
| The Liability Convention for Operators of Nuclear-Powered Ships of 1962 (not yet in force)  |  |

3. CHALLENGES IN EXISTING LEGAL INSTRUMENTS GOVERNING MARITIME-NUCLEAR SYSTEMS BY THE IMO AND THE IAEA

(a) Legal instrument associated with the safe transport of FNPP barges loaded with fresh/irradiated nuclear fuel in the reactor core has not been developed by countries in cooperation with the IAEA, nor is there any current mechanism to enable multilateral approval of the transport by the relevant competent authorities outside of IAEA SSR-6 (Rev1). In other words, there is not an IAEA legal instrument that address the safe transport of fuel (fresh/irradiated)-loaded reactor core.

(b) There is a “Code of Safety for Nuclear Merchant Ships” in the International Convention for the Safety of Life at Sea (SOLAS) applying to ships that have a nuclear propulsion system, which was adopted by the IMO Assembly through Resolution A.491.XII in 1981. The Code is based solely on PWRs, which may or may not applicable to other non-water-cooled EID technologies. Plus, an integral PWR design where the steam generators are located inside the reactor vessel may trigger nuclear export control restrictions. Hence, a new Code of safety for nuclear-propulsion ships is needed for non-water-cooled EID reactors and to resolve nuclear export control issues.

(c) The IAEA Safety Standard Requirement (SSR-6) and all the Safety Standard Guides (SSGs) requires that fresh and irradiated fuel are transported in their respective appropriate package types (for fissile packages) as approved by the competent authority. The SSR and SSGs as written would not be applicable to transport by sea of a FNPP barge containing fresh/irradiated fuel in the reactor core. Plus, The IAEA SSR and SSGs are developed for water-cooled reactor, they may or may not be applicable to non-water-cooled reactors, such as pebble-bed or molten-salt.

(d) The 2005 Protocol to the SUA Convention consider an offense for the transport “on board a ship of any equipment, materials or software or related technology that significantly contributes to the design, manufacture or delivery of a biological/chemical/nuclear (BCN) weapon, with the intention that it will be used for such purpose”. This may present a problem for FNPP of molten-salt reactors equipped with a side-stream processing system for removing fission products from the fuel-coolant mixture, as such processing technology may be considered as contributing to the manufacturing of nuclear weapon.

(e) The Convention of Nuclear Safety (CNS) is not applicable for maritime-nuclear systems (e.g., FNPP barges in transport, or nuclear-propelled ships) because it was written for stationary, land based nuclear power plants (NPPs). However, a FNPP may be considered a land-based nuclear installation if it is fixed at a particular geographical position, e.g., a “site”. If this is the case, the IAEA safety standards, requirements, and guides (SRGs, for siting, design, licensing, construction, modification, accident evaluation, radiation protection, emergency response, decommissioning, waste management, etc.) may be applicable to FNPP, with modifications and additions due to differences in reactor, fuel, and fuel-cycle types, operating and maintenance procedures, etc. Similarly, the IAEA security SRGs may also be applicable with modification and additions. The IAEA Safety and Security SGRs will not be applicable if a stationary location, e.g., a site does not exist. Hence, they will not be applicable to nuclear-propelled ships.

(f) For safeguards consideration, IAEA Safeguards inspectors need to be present, and the continuity of safeguards knowledge need to be maintained, whenever there are loading/unloading of the fresh or irradiated fuels, e.g., loaded into or unloaded from the packages or the reactor core of the maritime-nuclear systems. For a FNPP, the vendor State, in which the initial loading of fresh fuels or final unloading of spent fuels occur[[34]](#footnote-34), may have a different Safeguards Agreement with the IAEA than the host State where the FNPP is deployed, or other States where the FNPP is in transit, e.g., such State may either be a nuclear weapons State (NWS) with a voluntary offer agreement (VOA), or a non-nuclear weapons State (NNWS) with an INFCIRC/66-type agreement, or a NNWS with a comprehensive safeguards agreement (CSA) alone, or with an additional protocol (AP). Each of these specific Safeguards Agreements is a legal instrument governing the safeguards provisions applied to that particular State by the IAEA. Plus, the IAEA has experience safeguarding water-cooled reactors, the safeguards methods, equipment, and procedures for other EID concepts, such as molten-salt, pebble-bed, etc. have not yet developed by the IAEA Safeguards in cooperation with the host/vendor States.

(g) Since the Liability Convention for Operators of Nuclear-Powered Ships of 1962 has not yet ratified, and both nuclear liability conventions (Vienna and Paris Conventions) exclude nuclear propelled ships[[35]](#footnote-35), insurance coverages are not commercially available for nuclear-propelled ships. This prohibits ships from calling in ports. Without port calls, ships are redundant. However, even with port calls, nuclear-propelled ships will still face a daunting challenge as most port States lack the acceptability of nuclear power-driven merchant ships. Considering if the container ship which brought down the bridge at the Baltimore Harbor were a nuclear-propelled ship, it would be a major negative blowback for the maritime-nuclear industry.

4. CONCLUSIONS

(a) Emission controls and long-term energy and economic advantages are raising the possibilities of maritime-nuclear applications, in the forms of FNPPs and nuclear-propelled ships. To realize the goals of seeing FNPPs operated in remote locations or nuclear-propelled ships operated between specific trade routes, new nuclear technologies (other than the traditional PWR) must be employed and new/modified legal instruments governing the rules and regulations of maritime-nuclear systems must be available to support such technologies. This study identified several essential challenges in the harmonization of the legal instruments governing the rules and regulations of maritime-nuclear systems by the IMO and the IAEA.

(b) In a case where a FNPP is transported without nuclear fuel in the reactor core to the site of installation in its original journey, and later, back with its core also empty of irradiated fuel to other site or to the vendor, the legal instruments governing the safety and security by the IMO and the IAEA may be sufficient for such transport and operation as the fresh or irradiated fuels are contained in their respective certified “packages” during transport, and such packages can be shipped on board the FNPP barge or shipped separately. During the operation of the FNPP, the Convention of Nuclear Safety (CNS) may be narrowly-interpreted as applicable for the FNPP as it is moored into a “fix site” for the operation of such nuclear installation.

(c) For cases where the FNPPs are transported with fresh or irradiated fuel in the reactor core(s), or nuclear-propelled ships with non-PWR reactors on board, the current legal instruments governing the safety and security of the maritime-nuclear systems are deemed inadequate, from the perspectives of technologies, safety-and-security provisions, and civil liability. As new EID technologies will be employed in maritime-nuclear systems, the IMO should consider revising the SOLAS A.491.XII provisions (for nuclear-propelled ships), the IAEA should amend and expand its SSR and SSGs to cover maritime-nuclear systems, and both organizations should work together to ratify the Liability Convention for Operators of Nuclear-Powered Ships, and join together with both insurers and re-insurers to establish commercial insurability of maritime-nuclear systems.

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5. IMDG Code – International Maritime Dangerous Goods Code. [↑](#footnote-ref-5)
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31. The Brussels Convention was supplementary to the Paris Convention by establishing a solid financial bond among member states, it entered-into-force in 1974. [↑](#footnote-ref-31)
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34. It is assumed here that the vendor State will take back all spent fuel generated by the FNPP, in a similar way as Russia will take back spent fuel from operation of the *Akademik Lomonosov*. However, if the vendor State does not take back its spent fuel, the host State will be the owner of such spent fuel, and the final unloading of spent fuel will occur in the host State (or in a consigned State, which agrees to take away the spent fuel based on prior agreement with the vendor and/or host State). [↑](#footnote-ref-34)
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