

Regulatory Issues in the Marine Utilization of Non-Light-Water SMRs and Their Remedies

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1. Introduction

The 2023 IMO strategy on greenhouse-gas emissions from ships, targeting net-zero international shipping by 2050, has concentrated attention upon nuclear propulsion at sea [1]. In Korea a special act to invigorate the small modular reactor (SMR) industry was enacted in February 2026, and plans to apply non-light-water SMRs to ship propulsion and, secondarily, to floating power generation are advancing [2]: the molten-salt reactor (MSR) for propulsion, and the MSR, the high-temperature gas-cooled reactor or the sodium-cooled fast reactor aboard a floating nuclear power plant (FNPP). The IAEA has proposed the ATLAS initiative to develop an international framework for the safe marine use of nuclear energy [3], and the IMO has acknowledged the need to revise the light-water-based Code of Safety for Nuclear Merchant Ships, with adoption targeted for the end of 2030 [4].

Marine nuclear utilization engages statutes administered by two ministries at once: the nuclear safety legislation of the NSSC [5-7] applies together with the ship-safety legislation [8] and Notice [9] of the MOF, while SOLAS Chapter VIII [10] and Resolution A.491(XII), the 1981 Code [11], apply internationally. Korean nuclear safety legislation, however, prescribes licensing requirements only for light- and heavy-water reactors used for generation and research on a fixed land-based site; no licensing basis exists for a reactor that propels a ship or generates power aboard a floating installation, the sole adjacent instrument being the MOF Notice "Standards for Nuclear Ships" [9] under Article 26 of the Ship Safety Act. Following the NSSC roadmap of 12 February 2026 [12], this paper identifies the regulatory issues arising, assigns a remedy to each at the level of the instrument in which it must sit, and treats in particular the two questions that no single instrument resolves: the division of jurisdiction between the nuclear and the maritime regulator, and the allocation of that jurisdiction over structures, systems and components (SSCs) serving both a nuclear and a ship safety function.

The gaps arising at sea separate along two conditions: a reactor-type mismatch, the reactor not using water as a coolant, and an environmental mismatch, the installation being mobile and floating. Reform responding to the first is common to land-based installation and is treated in separate projects, so this paper is confined to the second.

Ten States were surveyed to 30 June 2026, each having an active civil program with an identified design, a historical civil nuclear merchant ship, or a published gap analysis or working group. An issue was treated as structural and common only where it was independently confirmed in five or more of the ten jurisdictions and its resolution lay beyond the unilateral competence of any single State.

Technical issues were derived by asking, at each marine-specific life-cycle stage, which provisions presuppose a fixed site, a shore connection, or a stationary exposed population; and a three-part test was applied to each remedy, prior amendment of the parent statute being required where the measure creates a new regulated object or licensing category, restricts third-party rights, or waives a requirement that the statute itself prescribes.

2. Common Regulatory Issues and Remedies

Seven issues satisfied both conditions (Table 1). Because most States have selected non-light-water types while the current Code presupposes the PWR alone, revision of that Code governs project schedules worldwide, and the marine MSR under development in Korea is dependent upon it.

Table 1. Seven common regulatory issues and their remedies.

Issue	Proposed remedy
PWR dependency: the 1981 Code addresses PWR designs alone and predates the ICRP dose recommendations [13]	Revision of the Code, the global critical path; performance-based domestic routes, as in 10 CFR Parts 53 and 57 [14], in the interim
No legal status for the non-self-propelled FNPP: nuclear law presupposes a fixed site, and SOLAS Ch. VIII, the Code and UNCLOS [15] a self-propelled ship	A dedicated international code; bifurcation of status per the INLEX texts [16] - moored, a nuclear installation; moving, transport of nuclear material; the site redefined as a licensed operating area
Division of nuclear-maritime jurisdiction unresolved in eight of the ten States; the UK alone has codified the transfer [17, 18], the US using an agreement [19]	Statutory allocation of authority, a standing joint NSSC-MOF working group, and a demarcation methodology for interface SSCs [20] (Sections 3, 4)

Issue	Proposed remedy
Liability vacuum: the Vienna, Paris and CSC regimes exclude any reactor with which a means of transport is equipped [21], and the 1962 Brussels Convention never entered into force [22]	A renewed IMO instrument severing the civil case from the military one, whose inclusion caused the 1962 failure; an insurance pathway [23]
Port entry: acceptance rests on ad hoc diplomacy, Otto Hahn having been refused Panama and Suez transit throughout [24, 25]	Standard entry conditions and port-State recognition of the flag-State inspection, settled in the Code revision
Dual licensing: design change is impossible once criticality has been achieved, and the recipient State's findings cannot be reflected [26]	The flag-State principle by analogy: the flag State approves, the recipient reviews rather than approves [26]
Vicious cycle: absent demonstration the regulator has no data, reform is delayed, and delay prevents demonstration[27]	Staged domestic demonstration at a designated port, with the hold points defined before design completion

3. Division of Regulatory Jurisdiction

Jurisdiction may be divided by regulated object, by life-cycle phase, or by regulatory function. Combining these with the mode of inter-agency linkage yields the five models of Table 2, each in force or expressly pursued in at least one State. Single-agency regulation of both reactor and ship is confirmed only in past regimes - the AEC licensing of NS Savannah, and the maritime-led logic of the 1981 Code itself - and is recorded as historical rather than counted as a model.

Table 2. Models for the division of jurisdiction.

Model	Allocation rule	Instance
I. Object-based parallel	Reactor facility and vessel are separated, each regulator taking its own object across the whole life cycle, an agreement linking schedules and documents	US: NRC and USCG, MOU of June 2026 [19]
II. Phase-based transfer	The competent authority changes by operation of law at defined life-cycle transitions and reverts at others	UK: ONR and MCA [17, 18]; Japan: NRA and MLIT, in desuetude [28]
III. Unadjusted dual compliance	Both regimes are to be satisfied independently, with no transfer or conflict rule	Russia: Rostekhnadzor and RMRS [26]
IV. Joint review	A standing joint body and a single intake window, interface questions issued as one decision	Pursued: ANVS working group [29]; Canadian multi-agency body [30]
V. State-led single window	One regulator is the single window within a State-controlled project structure	China: NNSA [25, 31]

No model is superior on every criterion. Efficiency and ease of demarcation favor Models V and II; utilization of the scarce nuclear regulatory workforce

favors Models I and IV; safety management and extensibility favor Model IV; coherence with international norms favors Model II. Model III is weakest on four of the five criteria and is significant chiefly because it is what results when no allocation is enacted at all. For Korea, where workforce utilization and extensibility carry the highest weight, Model I is proposed as the framework, Model IV superposed where object-based demarcation fails, and the statutory clarity of Model II borrowed for the enabling provisions. By phase: the nuclear regulator for land-based manufacture and for decommissioning; both jointly for installation aboard the vessel and for berthing in port; and the maritime regulator for navigation.

4. Jurisdiction over Interface SSCs

4.1 Scope and duality

An interface SSC performs a nuclear and a ship safety function at once, or its loss of either leads directly to loss of the other. The reactor space is a compartment of the ship, bounded by the hull, the bulkhead deck, and the cofferdams, so the nuclear-exclusive domain lies inside a structure under maritime jurisdiction; jurisdiction therefore cannot be divided spatially and must be divided by function and boundary point. Classification requirements decline to recognize the shell plating as a shielding barrier under any operating condition, yet require that deformation of the hull and of the reactor space neither impair structural integrity nor cause a release, and require the scantling calculation of the hull interface to be included in the containment and shielding arrangement [32]. The hull is thus not a nuclear barrier and yet determines the integrity of one, which is the root of the difficulty. Nine groups were identified: power conversion; electrical supply; seawater cooling; fire protection; control room and instrumentation; bilge, ballast, and waste transfer; containment support and hull connection; ventilation; and mooring.

4.2 The five aspects in which duality appears

Dispute takes the form not of asking which authority looks at a component, but of asking by reference to which safety duty five things are fixed. In *classification*, no mapping rule exists between the nuclear safety class and the essential-ship-service class, so a component may be non-safety under the one and primary essential under the other. In *code*, material, welding, examination and test-pressure requirements diverge and no rule determines which applies. In *inspection*, the nuclear intervals and the refueling cycle are not integral multiples of the annual and five-year special survey, and whether dry-docking is required follows from the notation selected at design, so inspectability is fixed before operation. In *modification*, one change proceeds through two parallel approvals. In the *post-accident judgement*, continued reactor operation for the safety of the ship is contemplated by international norms, but the deciding authority is undetermined.

Ten matters must accordingly be fixed for each interface SSC: the two safety functions; the two class

assignments and their correspondence; the class-survey scope and review boundary; the applicable codes and the conflict rule; responsibility for generating the design loads; the reviewing and inspecting authority; the modification approval power and intake window; the in-service inspection scope, interval and dry-docking requirement; the authority for the post-accident judgement; and the transfer of jurisdiction at each state transition. The fifth and the ninth are regulated in none of the regimes surveyed - the maritime side generating the input to the nuclear safety analysis, and the post-accident case being the one aspect in which the two safety objectives conflict head-on.

4.3 Recommended allocation

Boundary demarcation is adopted as the framework: the boundary point of each system is fixed in advance and codified as a schedule to the technical standards rule, upstream falling to the nuclear organization and downstream to the maritime organization - the first secondary-side isolation valve and generator output terminal for power conversion, the hull penetration for seawater cooling, the signal conversion stage for instrumentation, and the controlled-area boundary and overboard discharge valve for fluid systems. Mooring is assigned exclusively to the maritime organization, its loss entering the nuclear safety analysis as an initial condition. Joint judgement is then superposed, but only on the four segments of Table 3, in which either no boundary point exists or both sides share a single failure cause.

Two procedural conditions govern whether the framework survives into operation. The applicant should submit a regulatory interface document, with an integrated SSC register and a code-and-standards matrix, at the joint pre-application stage, its approval fixing authority; and a single intake window for modification control must be maintained during operation, on the principle of one submission and one integrated determination per change. Where it is not, the framework degenerates into unadjusted dual compliance. Duplication is removed by reliance review and joint inspection rather than by transferring authority.

5. Life-Cycle Issues and the Limits of Delegation

Fourteen technical issues were derived across the marine-specific stages. At siting and installation they are the unit against which the license period runs, the inapplicability of the site concept, marine external events and dynamic loads, the absence of two independent offsite power circuits, and interaction accidents with adjacent shipboard plant; at operation, the want of any licensing procedure for a domestically built nuclear ship, the mobile emergency planning zone and the emergency plan that travels with the vessel, inclination and stability criteria linked to the reactor trip setting, and operator licensing, manning and inspection intervals; at maintenance, port entry and port-State control, the alignment of class survey, regulatory inspection and

refueling cycles, and shipyard maintenance and radioactive-waste transfer; and at decommissioning, scheduled and abnormal termination including recovery after sinking, and the funding and the responsible entity [33].

Table 3. Segments reserved for joint judgement.

Segment	Reason for reservation	Object of joint judgement
Containment support and hull connection	Hull and containment form one structural system, so no boundary point exists, and hull bending acts on containment integrity	Design loads and their transmission, scantlings of the connection, permissible deformation, submergence pressure
Fire protection at the reactor-space boundary	Fire crosses the boundary, firefighting itself affects nuclear safety, and two regimes govern the same space	Fire integrity of the bulkhead, extinguishing medium, detector arrangement, concurrent failures
Electrical supply, normal and emergency	The system performs both a nuclear safety function and an essential ship service, so division is impossible	Supplied loads, autonomy duration, single-failure assumption, load priority, battery capacity
Seawater cooling intake and discharge	A boundary may be drawn at the hull penetration, but both sides depend on the same heel, grounding, tide, berthing or docking condition	Redundancy of intake, availability by state, discharge while berthed, cooling while in dock

Each was traced to the article in which it sits and a remedy assigned to the competent instrument - variously the Enforcement Rule, the technical standards rule, or a new NSSC notice.

Applying the three-part test to all the remedies above shows seven to fall outside the existing delegation: (i) the definition of the regulated object, the Act defining a reactor by generation and research on a fixed site; (ii) licensing of the construction and operation of nuclear ships, a new category with its legal effects and penalties; (iii) substitution of a route and ports of call for the site; (iv) the mobile exclusion area and emergency planning zone, which restrict third-party rights; (v) substitution or exemption of a requirement prescribed by the statute itself, such as offsite power; (vi) entry, departure and safety certificates, and the powers of the issuing authority; and (vii) allocation of ministerial authority, including the legal effect of the joint-judgement and consultation powers of Section 4. The order of reform is thereby fixed: amendment of the Nuclear Safety Act; then the Enforcement Decree and Rule; then the technical standards rule with the necessary NSSC notices. Subordinate instruments made in advance of the first step would be open to challenge as exceeding their delegation.

6. Conclusions

Seven issues are structural and common, each observed independently in five or more of the ten jurisdictions and each beyond unilateral competence; revision of the 1981 IMO Code, targeted for 2030, is the global critical path. Five models of jurisdictional division are in force or expressly pursued and none is superior on every criterion, so for Korea an object-based framework with joint judgement superposed, the enabling provisions given statutory form, is proposed.

The decisive question is not how the reactor and the ship are divided but who determines, and by what procedure, the part that cannot be divided. Of the ten matters to be fixed for each interface SSC, design-load responsibility and post-accident authority are regulated in none of the regimes surveyed; joint judgement should be confined to the four segments of Table 3.

Seven matters require prior amendment of the Nuclear Safety Act, which fixes the order of reform. The survey rests on publicly available instruments and is current to 30 June 2026, and several programs remain at conceptual-design stage, so the positions recorded here may shift.

NOMENCLATURE

ANVS: nuclear safety authority of the Netherlands; CSC: Convention on Supplementary Compensation for Nuclear Damage; FNPP: Floating Nuclear Power Plant; ICRP: Int. Commission on Radiological Protection; IMO: Int. Maritime Organization; INLEX: Int. Expert Group on Nuclear Liability; MCA: Maritime and Coastguard Agency (UK); MLIT: Ministry of Land, Infrastructure, Transport and Tourism (Japan); MOF: Ministry of Oceans and Fisheries (Korea); MOU: Memorandum of Understanding; MSR: Molten Salt Reactor; NNSA: National Nuclear Safety Administration (China); NRA: Nuclear Regulation Authority (Japan); USNRC: US Nuclear Regulatory Commission; NSSC: Nuclear Safety and Security Commission (Korea); ONR: Office for Nuclear Regulation (UK); PWR: Pressurized Water Reactor; RMRS: Russian Maritime Register of Shipping; ROK: Republic of Korea; SMR: Small Modular Reactor; SOLAS: Int. Convention for the Safety of Life at Sea; SSC: Structures, Systems and Components; UNCLOS: UN Convention on the Law of the Sea; USCG: US Coast Guard.

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