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Exploring Responsibility for Space Launches by Stateless Vessels from the High Seas: Bridging the Law of the Sea and Space Law

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Abstract
This study aims to critically examine the responsibility gaps in international space law and law of the sea arising from space launches conducted by stateless vessels on the high seas, and to propose actionable reforms to ensure accountability, sustainability, and international cooperation. Employing a qualitative doctrinal methodology, the research analyzes primary legal sources—including the Outer Space Treaty, Liability Convention, Registration Convention, and UNCLOS—alongside secondary scholarly literature and comparative evaluation of state responsibility principles across space and maritime regimes. The analysis reveals that state-centric responsibility frameworks fail when stateless vessels operate beyond national jurisdiction, creating an unaddressed responsibility vacuum with economic, environmental, and strategic implications; practical solutions include amending existing treaties or adopting a new instrument to prohibit such launches, establishing an international regulatory entity for monitoring and coordination, and deploying AI-driven predictive technologies and strict export controls on launch-related equipment to prevent unauthorized activities.

Keywords: High Seas, Law of the Sea, Space Law, State Responsibility, Stateless Vessels

Introduction

In recent decades, the landscape of space activities has undergone a profound transformation, driven by technological advancements and innovative approaches, such as sea-based launch platforms (Sheetz, 2018). Based on that, the emergence of stateless vessels conducting space launches from the high seas presents a novel and complex challenge to the international legal order. These operations, unbound by state jurisdiction due to the absence of vessel nationality, evade conventional mechanisms of legal oversight that traditionally hold states accountable for their nationals' activities in outer space. Furthermore, launches from the high seas introduce significant jurisdictional ambiguities, as they occur beyond the sovereign control of any state, complicating the attribution of responsibility and undermining the foundational principles of responsibility in both space law and law of the sea.

The proliferation of such activities exacerbates a range of risks, including an increased potential for orbital collisions, the uncontrolled accumulation of space debris, and growing environmental concerns in Earth's orbit. These challenges reveal critical deficiencies in the existing international legal frameworks governing space and maritime activities. Without proactive measures to address these gaps, the long-term sustainability of space exploration and utilization may be jeopardized, potentially transforming outer space from a domain of cooperation and innovation into one marked by conflict and disorder.

To underscore the risks of unattributable space activities, consider two state-attributable ASAT tests. In 2007, China destroyed its Fengyun-1C satellite (>850 km), generating >3,000 trackable fragments (BBC News, 2012; Hadley, 2023), forcing ISS avoidance maneuvers (e.g., 2011 and heightening collision risks (Stickings, 2019; Strobeyko, 2020). In 2021, Russia obliterated Cosmos-1408 (~480 km), producing ~1,500 trackable pieces (Daud & Harun, 2022; Graham, 2021), doubling ISS threats, requiring crew sheltering and 2022 maneuvers, with ~9,000 initial conjunctions (Hitchens, 2022; Universe Space Tech, 2022). With clear attribution, the international community could impose diplomatic protests. Now envisage an anonymous ASAT strike from a stateless high-seas vessel, disrupting space activities—crippling satellites, navigation, and communications—without the slightest responsibility traceable to any actor. This unattributable interference would paralyze global space operations, erode trust, and invite rampant disorder with no recourse.

This study aims to critically examine the international legal frameworks governing responsibility for space launches conducted by stateless vessels on the high seas. Specifically, it addresses the following research questions: To what extent do existing space law conventions provide mechanisms to manage incidents arising from such activities? Are the provisions of law of the sea conventions adequate to regulate these operations? Additionally, the research explores the interplay between space and maritime legal regimes, proposing actionable solutions to bridge identified gaps.

Methodology

This study employs a qualitative doctrinal methodology to critically examine the responsibility gaps at the intersection of international space law and law of the sea, particularly concerning space launches by stateless vessels from the high seas. Doctrinal research, as a foundational approach in legal scholarship, focuses on the systematic analysis and interpretation of legal principles, rules, and doctrines derived from primary and secondary sources. This method is particularly suited to the objectives of the study, as it enables a rigorous evaluation of existing legal frameworks, identification of inconsistencies, and formulation of reform proposals without relying on empirical data collection beyond textual and interpretive analysis.

The research process is structured in three main phases: data collection, analysis, and synthesis. In the data collection phase, primary legal sources form the core of the inquiry. These include key international treaties such as the 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space (OST or Outer Space Treaty), the 1972 Convention on International Liability for Damage Caused by Space Objects (Liability Convention), the 1975 Convention on Registration of Objects Launched into Outer Space (Registration Convention), and the 1982 United Nations Convention on the Law of the Sea (UNCLOS). These documents were sourced from official repositories, such as the United Nations Treaty Series and the United Nations Office for Outer Space Affairs (UNOOSA) databases, to ensure authenticity and accuracy.

Complementing the primary sources, secondary materials were gathered to provide contextual depth and scholarly insights. This encompassed peer-reviewed legal scholarship, journal articles, books, and reports from reputable sources, including works by authors such as Freeland, Pedrazzi, Schmidt-Tedd & Tennen, and others cited throughout the study. Secondary literature was selected through targeted searches in academic databases, focusing on themes of state responsibility, liability regimes, and the interplay between space and maritime laws.

The analysis phase involves a comparative evaluation of state responsibility principles across space and maritime regimes. This comparative approach systematically contrasts the state-centric responsibility mechanisms in space law with the flag-state jurisdiction model in law of the sea. Gaps are identified through thematic coding of the sources, highlighting areas such as unattributable activities, jurisdictional vacuums on the high seas, and the implications for sustainability. This interpretive process adheres to principles of legal hermeneutics, ensuring that interpretations remain faithful to the text while considering evolving customary international law.

Finally, the synthesis phase culminates in the development of actionable recommendations, derived deductively from the identified gaps. These proposals, such as treaty amendments and the establishment of an international regulatory entity, are grounded in the analyzed sources and aim to promote accountability and international cooperation. Throughout the research, ethical considerations were

upheld, including accurate citation of sources to avoid plagiarism and balanced representation of diverse scholarly viewpoints. This methodology ensures a comprehensive, objective, and forward-looking examination of the research questions, contributing to the discourse on bridging space and maritime legal regimes.

Result and Discussion

Framework for Responsibility in Space Activities

The OST serves as the cornerstone of international space law, establishing fundamental principles for the peaceful exploration and use of outer space. Complementing the OST, the Liability Convention provides a framework for addressing liability arising from damages caused by space activities, delineating state responsibility for objects launched into orbit. Additionally, the Registration Convention strengthens this legal regime by mandating that states register all objects launched into outer space in both national and international registries (Robinson, 2020). This obligation enhances transparency, facilitates the attribution of liability, and promotes accountability in space operations (Schmidt-Tedd & Tennen, 2013; United Nations, Draft Convention on Registration of Objects Launched into Outer Space (UN Document A/AC.105/C.2/13, 1974)). Together, these documents form a comprehensive legal framework that governs state responsibilities, ensures the secure utilization of outer space.

1. Principles of State Responsibility

Article VI of the OST establishes that states parties bear international responsibility for all national activities in outer space. That is becasue such activities require authorization and continuous oversight by the appropriate state, which, in most cases, is the state of nationality. To illustrate, a private space enterprise may deploy its object from a location that is not within the territorial boundaries of a nation-state, including the high seas. In such a scenario, a solution can only be reached if the launching of the object is authorized and supervised by a national state. Complementing this, Article VII of the OST holds states liable for damage caused by objects they launch, procure to launch, or that are launched from their territory or facilities, reflecting their pivotal role in mitigating unintended consequences (Pedrazzi, 2008). These principles are further elaborated in Articles I (a, c(i), c(ii)) and II of the Liability Convention. Over time, the principle of state responsibility for space activities has evolved into a norm of customary international law. This development implies that even states not party to the OST or the Liability Convention may adhere to this principle, as it has gained widespread acceptance within the international community (Freeland, 2010).

Article I(c) of the Registration Convention mandates that each launching state register its space objects. Registration establishes a formal legal nexus

between the space object and the launching state, conferring upon the state the authority to exercise legislative and enforcement jurisdiction over the object, even beyond its terrestrial boundaries, as affirmed by Article VIII of the OST (Pečujlić, 2020). Thus, registration serves as both a foundation for jurisdiction and a mechanism to reinforce the launching state's regulatory responsibilities (Schmidt-Tedd et al., 2013). Based on the convention, the marking of space objects also enhances accountability in space activities. Although Article V of the Registration Convention does not mandate marking, it requires that any marked space object be registered (Jasentuliyana & Lee, 1981). This linkage between marking and registration facilitates the identification of the responsible launching state in cases of damage caused by space objects, enabling affected states to seek compensation efficiently. Together, these provisions strengthen the framework for traceability and responsibility of space activities.

2. Responsibility Standards

Under Articles VI and VII of the OST, states parties bear international responsibility for national activities in outer space and are subject to absolute liability for damage caused by their space objects, regardless of fault. This principle ensures that victims—whether the loss occurs in outer space or on the surface of the Earth, sea, or airspace—can seek compensation without the burden of proving negligence or intent (Albert, 2014). It reflects recognition of the transboundary and inherently hazardous nature of space activities, reinforcing state accountability across all domains affected by such activities. By contrast, Article III of the 1972 Liability Convention introduces a fault-based regime for damage occurring in outer space, limiting responsibility to cases where the harm results from the fault of the launching state or its personnel (Abrams, 2014; Beck, 2009). Furthermore, where the damage arises wholly or partly from gross negligence or an intentional act or omission by the claimant state or its nationals, the launching state is exempt from responsibility. Nonetheless, the Convention reinstates absolute liability in specific contexts—for instance, under Article VI(2), where activities are conducted in violation of international law, the launching state remains absolutely liable regardless of the location of the loss.

Legal Frameworks for High Seas Activities

Certain areas of the Earth, recognized as the common heritage of humankind (Bräuninger & König, 2000), lie beyond the national jurisdiction of any state and are considered shared resources belonging to all humanity (Garner, 2004). These areas, notably the high seas, embody the principle of global solidarity and are governed by international law, which permits their use and resource exploitation by all states on an equitable basis (Laver, 1986). The concept of the high seas is grounded in the principle of freedom of the seas, first articulated by Hugo Grotius

in the 17th century (Grotius, 2004), and later codified in the UNCLOS.

The principle of freedom of the seas carries two primary implications (Kish, 1973). First, it precludes national jurisdiction over the high seas. Article 87(1) of UNCLOS establishes that the high seas are open to all states, while Article 89 explicitly prohibits any state from asserting sovereignty over any part of these waters. Second, the principle guarantees freedom of activities, ensuring that all states enjoy equal rights to utilize the high seas for purposes (Tanaka, 2019) such as navigation, overflight, fishing, scientific research, and the construction of artificial islands (Hasanli, 2021). However, these freedoms are not absolute. They are subject to obligations outlined in other provisions of UNCLOS, which regulate the scope and conduct of activities on the high seas (Nandan, 2020). This balanced framework ensures that the exercise of freedoms coexists with responsibilities, promoting equitable and sustainable use of the high seas under international law (Theocharidis & Donner, 2017).

1. Jurisdiction and Responsibility of States

In law of the sea, a state's jurisdiction and responsibility over a vessel derive from the vessel's nationality, which establishes a legal nexus between the state and the vessel. Nationality is conferred through two interconnected mechanisms: registration and the display of the national flag (Meyers, 1967). Registration enables a state to assert jurisdiction over a vessel, granting it a national identity recognized at the international level (Tas, 2021). Additionally, registration authorizes the vessel to fly the flag of the state in which it is registered, a symbol historically associated with national protection and the exclusive jurisdiction of the state, commonly referred to as the flag state (Farthing & Brownrigg, 1997; Mansell, 2009b). The flag state's jurisdiction is a cornerstone of maritime governance, encompassing the authority to prescribe rules governing the conduct of vessel users, impose penalties for non-compliance, and enforce these regulations (Rothwell & Stephens, 2010). The national flag serves as the most visible manifestation of this jurisdiction, reinforcing the flag state's role in ensuring accountability and compliance with law of the sea (United Nations, 1956).

Under international law, vessels are not recognized as legal subjects capable of bearing liabilities independently (R. Churchill et al., 2022; Zwinge, 2011). Instead, their ability to exercise freedoms on the high seas is contingent upon the nationality conferred by a flag state, as these freedoms are exclusively reserved for states (Oral, 2018). This principle highlights the intrinsic link between the rights granted to flag states and their corresponding obligations, which form the foundation of the responsibility regime for vessels' activities (Bennett, 2021; Goodman, 2009; Hosanee, 2009; Tas, 2021). Article 94 of the UNCLOS explicitly requires flag states to exercise effective jurisdiction and control over vessels flying their flag, ensuring compliance with international norms. Thus, this responsibility extends

beyond symbolic association, mandating flag states to establish and maintain a robust regulatory framework (Hosanee, 2009). For example, Article 211 of UNCLOS obliges flag states to enforce stringent safety standards, covering vessel construction, equipment quality, and crew training. Similarly, Article 217 reinforces the flag state's proactive role by requiring the adoption, monitoring, and enforcement of internationally accepted rules and standards. Collectively, these provisions of UNCLOS underscore the dual nature of flag state rights and responsibilities, ensuring accountability and adherence to global maritime governance standards (Allen, 2008; Bateman, 2015; Fagnon, 2021; Galley, 2014; Mansell, 2009a; Nguyen, 2023).

2. Vessels Without Nationality

Article 91 of the UNCLOS does not explicitly mandate that vessels must be registered or fly a flag. Instead, it requires states to establish conditions for granting nationality to vessels, facilitating their registration within the state's territory and authorizing the right to fly its flag. Complementing this, Article 92 stipulates that a vessel may sail under the flag of only one state and is prohibited from simultaneously claiming the nationalities of multiple states. Notably, this article also requires a vessel to fly a flag. Consequently, these provisions allow for the possibility of stateless vessels, those without nationality, navigating the high seas, highlighting a potential gap in the regulatory framework governing maritime activities (Dubner & Arias, 2016).

The absence of vessel registration in any state is widely recognized as a primary indicator of statelessness (Tas, 2021). However, statelessness may also arise under specific circumstances: (1) when the political entity granting nationality to a vessel lacks recognition as an international legal person; (2) when a vessel loses its nationality due to violations of flag state laws, as stipulated in Article 104 of the UNCLOS, or fails to meet the flag state's requirements; or (3) when a vessel illegitimately claims the nationality of multiple states despite possessing a valid nationality (Bennett, 2021). Although precise data on the prevalence of stateless vessels on the high seas is unavailable, these scenarios suggest that a significant number of vessels may operate without nationality, posing challenges to international maritime governance.

International legal instruments do not explicitly designate the lack of vessel nationality as a universal crime (Meyers, 1967). However, Article 110(d) of the UNCLOS authorizes warships to board and inspect vessels suspected of being stateless. Legal scholars widely argue that stateless vessels, lacking nationality, do not enjoy the freedom of navigation and are consequently deprived of state protection. As a result, such vessels may be seized and arrested on the high seas (Churchill & Lowe, 1999; Gauci & Aquilina, 2017; Heijer, 2012; Schoenbaum, 2001). This stems from the principle that freedom of navigation is reserved for registered vessels (Attard,

2016). Although no explicit international rule mandates vessel registration or the display of a flag, the need for predictability, order, and safety in international waters, for commercial, military, and recreational vessels (United States v Marino-Garcia 679 F 2d 1373 (11th Cir 1982)), underpins the practical necessity of this doctrine in maritime governance (Bennett, 2021; R. Churchill et al., 2022; McDorman, 1994).

Stateless vessels pose a significant challenge to international and law of the sea, particularly in the context of responsibility. The absence of nationality complicates the attribution of responsibility, as no state is readily willing to assume international responsibility for the actions or inactions of such vessels. Under international law, responsibility is typically assigned to the flag state, whose nationality establishes a legal nexus with the vessel, enabling the state to exercise jurisdiction and control (McDorman, 1994). However, in the case of stateless vessels, no state can assert such authority on the high seas (Churchill & Lowe, 1999). Consequently, it is impractical to hold any state accountable for activities beyond its ability to regulate or monitor, highlighting a critical gap in the international legal framework governing maritime responsibility (McDorman, 1994).

Challenges and Suggestions

The concept of sea-based satellite launches emerged in the early 1960s with Robert Truax's Sea Dragon project at Aerojet (Avilla, 2020), which proposed a two-stage super-heavy rocket launched directly from the ocean (Grossman, 2017). Financial limitations and the closure of NASA's Future Projects Branch led to its cancellation (Whittington, 2020). In 1994, Boeing and its partners initiated studies that culminated in the formation of Sea Launch in 1995, a multinational consortium utilizing the Odyssey platform—a repurposed oil rig—and the Sea Launch Commander ship (Cain, 2003). Between 1999 and 2014, this platform conducted 36 equatorial launches using the Zenit-3 rocket, achieving 32 successes but facing economic and operational challenges (BBC News, 1999; Sea Launch, 2014). More recently, China entered the domain of marine launches in 2019, leveraging repurposed ballistic missile technology to launch a small satellite from a floating platform (New Space Economy, 2023). A significant milestone was reached on January 11, 2024, when China's private company Orienspace successfully launched the mid-sized Gravity-1 rocket from the Yellow Sea, deploying three satellites into orbit. These developments underscore the growing global interest and advancements in sea-based launch capabilities, driven by both public and private sectors (Chuanren, 2024).

Sea-based vessels have transformed space launches by offering distinct advantages, including the ability to operate far from populated areas, thereby enhancing safety and operational flexibility. Offshore launches also reduce environmental impacts, such as noise, dust, and debris, addressing key ecological concerns. Although sea-based launches currently account for a small fraction of

global launch activities, their prominence is expected to increase as private entities continue to innovate and develop launch platforms. However, the rise of space activities raises significant concerns regarding unregulated rocket launches, particularly the potential for stateless vessels to conduct such operations from the high seas. This section will examine this emerging issue in detail, analyzing its legal, operational, and environmental implications. The following subsection will propose targeted solutions to address the associated regulatory gaps, ensuring the sustainable and responsible use of outer space and maritime domains.

1. Challenges

Under international space conventions, liability for damages caused by space activities is attributed to five categories of states: (1) states that launch a space object, (2) states that procure the launch of a space object, (3) states that facilitate such launches, (4) states that permit their territory to be used for launches, and (5) states whose nationality is associated with the space object (Article VI and VII of the OST and Article II of the Liability Convention). While these categories provide a framework for assigning responsibility, they may prove inadequate in addressing emerging challenges. A significant concern is the use of stateless vessels on the high seas for launching space objects. Operating without national affiliation and beyond any state's territorial jurisdiction, these vessels introduce a critical gap in the existing responsibility regime, complicating the attribution of responsibility for their activities.

Firstly, as no state can claim sovereignty over the high seas (Cheng, 1998), launches conducted by such vessels fall outside the scope of the conventions' responsibility regimes (Bückling, 1982; Fenema, 1973). Secondly, the absence of a national flag or registration severs the critical link to a state's nationality, which is fundamental for attributing responsibility under the conventions (Pozdnakova, 2020). Consequently, key responsibility categories—those related to launching, territorial use, or nationality—become inapplicable. While categories concerning states that procure or facilitate launches may remain relevant, their application is fraught with challenges. The deliberate use of stateless vessels often stems from malicious intent, leveraging their anonymity to obscure the identities of states involved in procuring or facilitating such launches. As a result, tracing the responsible state becomes exceedingly difficult, undermining the effectiveness of the existing responsibility framework.

Launches from stateless vessels on the high seas pose multifaceted risks that extend beyond legal challenges, threatening global investment, security, and sustainability in space. By exploiting anonymity, such launches enable actors to target and destroy critical space assets, including satellites, space stations, and other infrastructure. These hostile acts could result in substantial economic losses, erasing years of public and private investment and creating strategic vulnerabilities (Stubbe, 2017). Such disruptions are likely to undermine investor confidence, deterring funding for ambitious space ventures (Defense Intelligence Agency, 2022).

Moreover, these launches often disregard environmental best practices, leading to unregulated emissions, substandard rocket designs, and the intentional or accidental generation of space debris. This debris increases the risk of Kessler Syndrome, a scenario involving cascading collisions that could render critical orbital zones unusable (Wall, 2022). Collectively, these consequences threaten to hinder advancements in space technology, disrupt essential satellite-based services such as telecommunications and navigation, and restrict humanity's access to space, exacerbating our dependence on space-based systems (Jacobson, 2020; Newsweek, 2024; Suri, 2022).

Launches conducted by stateless vessels on the high seas pose significant risks to international relations, potentially escalating tensions among spacefaring nations. The difficulty in attributing responsibility for hostile actions undermines trust between states, increasing the likelihood of retaliatory measures and potentially triggering an arms race in outer space. Such developments would contravene the core principle of peaceful use enshrined in international space treaties (Mowthorpe, 2004), notably the 1967 OST. This erosion of cooperation threatens the safety and viability of current and future space missions, jeopardizing the collaborative framework essential for sustainable space exploration and utilization (Robertson, 2011). Indeed, the emergence of space launches from stateless vessels on the high seas creates a legal gray area, where the applicable responsibility regime for space activities remains ambiguous. As space ventures expand, there is an urgent need to clarify responsibility mechanisms for incidents arising from such launches.

2. Suggestions

To solve the challenges posed by stateless vessels conducting space launches on the high seas and to establish a robust regulatory framework, a comprehensive set of measures is essential. The following actionable proposals aim to prevent the exploitation of the high seas as a safe haven for unauthorized space activities, ensuring accountability and compliance with international law. These measures seek to bridge existing legal gaps, enhance global governance, and promote the sustainable use of both maritime and space domains.

2.1. Establishment of an International Prohibition and Sanctions

To address the challenges posed by launches from stateless vessels on the high seas, the international community should prioritize the establishment of an explicit prohibition against such activities. Currently, no express or implied legal barrier exists within international law to regulate these launches. This could be achieved by amending existing frameworks, such as the OST or the UNCLOS, or by drafting a new international instrument. Such a prohibition would provide a clear legal basis for classifying launches from stateless vessels as unlawful, enhancing accountability for states and entities engaged in space activities.

Complementing this prohibition, the implementation of comprehensive sanctions targeting entities—whether states or private actors—involved in unauthorized launches is recommended. These sanctions could include asset freezes, exclusion from international space initiatives, and substantial financial penalties. By imposing significant costs on violators, sanctions would serve as a robust deterrent against illegal launches. Uniform application and rigorous enforcement of these measures would underscore the international community's commitment to upholding the rule of law, fostering greater compliance with global space and maritime governance frameworks.

2.2. Foundation of an International Entity and Development of Predictive

Existing maritime regulatory bodies, including the 1958 International Maritime Organization (IMO), International Seabed Authority (Part XI of UNCLOS), International Tribunal for the Law of the Sea (Part XV of UNCLOS), Commission on the Limits of the Continental Shelf (Article 76 of UNCLOS), and Regional Fisheries Management Organizations (Article 118 of UNCLOS), are primarily focused on the protection and governance of marine environments. However, these entities lack the mandate or capacity to address risks associated with space activities conducted on the high seas. To bridge this gap, the establishment of a dedicated international entity to monitor and regulate space activities on the high seas is proposed. This entity could incorporate specialized units trained to detect and intercept vessels suspected of preparing for unauthorized space launches.

The proposed entity would serve as a coordinator among international maritime and space organizations, such as the IMO and the UNOOSA, facilitating collaboration and information sharing. A centralized reporting mechanism, including a real-time database accessible to authorized stakeholders, would provide up-to-date intelligence on high-risk vessels and regions. By enhancing transparency and fostering global cooperation, this initiative would strengthen collective capacity to address emerging threats. Through pooled resources and expertise, participating states could form a unified response to hostile or unregulated space activities on the high seas, ensuring greater accountability and security in both maritime and space domains.

2.3. Development of Predictive and Detection Technologies

Advancements in artificial intelligence (AI) offer significant potential for identifying maritime behavioral patterns that may indicate preparations for space launches. By combining predictive analytics with data from global monitoring systems, authorities can potentially identify illegal activities before they occur. This technology enables the real-time analysis of vast

datasets, uncovering correlations and trends that may otherwise go unnoticed by human observers. Integrating AI-driven tools with existing monitoring infrastructure could result in a more agile and responsive system, capable of adapting to evolving threats. By investing in cutting-edge technologies, the international community could stay ahead of malicious actors, ensuring that preventive measures remain effective in an increasingly complex and dynamic environment.

2.4. Strict Control of Space-Launch-Related Equipment

One potential measure to address the issue is the implementation of strict export controls on technologies and materials critical for space launches, including rocket fuels, guidance systems, and propulsion components. It would be prudent for both governments and international organizations to establish robust licensing frameworks that ensure these items are only provided to entities with verifiable credentials and lawful purposes. Such frameworks should incorporate thorough vetting procedures for buyers, as well as regular audits of suppliers to prevent the diversion of materials. By fostering international cooperation, countries can effectively address vulnerabilities in the supply chain that may be exploited by malicious actors.

2.5. Deployment of Disruption Technologies

In addition to the preventive measures previously discussed, it would be prudent to consider the development of technologies designed to safely neutralize unauthorized launches. These technologies could include a variety of tools, such as anti-rockets capable of intercepting and neutralizing rogue launches, advanced electronic jamming systems that disrupt the operational control of such devices, or remote disabling mechanisms that deactivate unauthorized equipment without physical intervention. To govern the use of these technologies, it would be essential to establish comprehensive and transparent international guidelines. These guidelines should clearly define the criteria for their application, including the scope, permissible circumstances, and accountability mechanisms to ensure compliance with international standards. The regulations must prioritize the principles of responsibility, proportionality, and necessity, preventing the misuse of such technologies as instruments of coercion or conflict escalation. By embedding these technologies within a well-structured and regulated framework, the international community can enhance security, providing an essential contingency measure in situations where conventional preventive strategies fall short or prove ineffective.

Conclusion

This study elucidates the intricate legal challenges surrounding responsibility for space launches conducted by stateless vessels on the high seas,

revealing significant shortcomings in the current international legal framework. These gaps arise from the lack of an integrated legal structure bridging space law and law of the sea, compounded by the absence of state sovereignty over the high seas and the inability to attribute responsibility to stateless vessels. The analysis demonstrates that foundational space law treaties, such as the OST and the Liability Convention, operate on a state-centric model that assumes a clear nexus between space activities and a responsible state—a premise that fails when stateless vessels are involved. Similarly, the UNCLOS, while effective for traditional maritime governance, does not address the novel challenges posed by high seas space launches.

The implications of this legal void are profound. Economically, the uncertainty surrounding responsibility erodes investor confidence, discouraging funding for innovative space ventures. Environmentally, unregulated launches contribute to the escalating problem of space debris, heightening the risk of Kessler Syndrome, where cascading collisions could render critical orbital zones unusable, threatening both existing and future space infrastructure. Strategically, the inability to attribute responsibility risks exacerbating geopolitical tensions among spacefaring nations, potentially leading to retaliatory measures, an arms race, or the militarization of space, outcomes that would violate the principle of peaceful use enshrined in international space law.

To address these challenges, this study proposes a multifaceted reform agenda. First, it advocates amending existing treaties, such as the OST and UNCLOS, or developing a new international instrument to explicitly prohibit space launches from stateless vessels and establish clear responsibility mechanisms. Second, it recommends the creation of an international regulatory entity to coordinate efforts between maritime and space organizations, such as the IMO and the UNOOSA. This entity would oversee monitoring, compliance, and enforcement, supported by a centralized intelligence-sharing platform to enhance global transparency. Third, the study emphasizes the role of advanced technologies, particularly artificial intelligence and predictive analytics, in detecting and preventing unauthorized launches. Additionally, implementing stringent export controls on space-related equipment and developing disruption technologies could further deter illicit activities. These approaches uphold the vision of outer space and the high seas as global commons, governed by principles of accountability, equity, and mutual benefit for current and future generations.

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