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Brazil's Space Legal Framework: A Comparison with International Approaches for a National Planetary Defense Initiative

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ABSTRACT

The Brazilian legal framework for space operations is examined in this paper to find areas lacking planetary defense and to suggest legislative changes that could integrate Brazil into worldwide projects in this field. Brazilian legislation was investigated using a qualitative methodology based on documentary and comparative research, including the current Law No. 14,946/2024, in contrast to the regulatory frameworks of six major countries that have a planetary defense initiative in place. The study revealed important components such as formal acknowledgment of the threat, assignment of institutional responsibilities, and finance systems. The findings expose that Brazil has major legislative gaps that hinder the efficient development of national planetary defense capabilities, even though it has an established space program and pertinent scientific capability in astronomy. With a rising tendency toward integration between near-Earth object (NEO) monitoring programs and national civil defense systems, the comparative research reveals that all the space powers examined—except Brazil—have particular legal provisions for planetary defense. The study concludes that incorporating planetary defense into the Brazilian legal system would not only be a reaction to a growing issue but also a strategic chance for national scientific and technological advancement as well as for establishing Brazil as a proactive participant in world space governance.

Keywords: Planetary defense; Space law; Near Earth asteroids; International law.

INTRODUCTION

Over the past few decades, planetary defense—an important component of space research and international security—has undergone tremendous change. According to Klavans (2021), it involves a variety of tasks for identifying, tracking, understanding, and mitigating the risk of near-Earth asteroids (PHAs) impact the planet. Planetary defense is the name given to planetary science applied to the risk of near-Earth object (NEO) impacts (Conway 2022), encompassing all the capabilities needed to detect and warn of potential asteroid or comet impacts on Earth, and then to avoid them or mitigate their potential effects (National Science and Technology Council 2023).

Asteroid impacts have significantly shaped Earth throughout its history, and NEO detection is a relatively new field of study concerning phenomena that have marked the planet's history with important events. The most well-known instance is the Chicxulub catastrophe, which happened about 66 million years ago and is believed to be the reason why dinosaurs became extinct (Koplow 2024).

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In 1908, a small asteroid exploded in mid-air over Tunguska, Siberia, destroying millions of trees—if it had arrived four hours later, it could have hit and destroyed Saint Petersburg. In 1930, a similar event occurred over the Brazilian rainforest. On 23 March 1989, an asteroid with a potential impact equivalent to 1,000 megatons, passed 6 hours from Earth's orbit. Years later, on 15 February 2013, the Chelyabinsk meteor entered the Earth's atmosphere undetected over Russia, seriously injuring more than 1,500 people. The object, approximately 20 m in diameter, exploded at an altitude of 23 km, producing an impact equivalent to 500 kt of dynamite.

These events illustrate the potential risks and mitigation possibilities related to NEOs, establishing planetary defense as an important global issue that must be addressed as a matter of global governance. Several countries have updated their space legislation to include planetary defense aspects, establishing institutional responsibilities, funding mechanisms, and international cooperation protocols (Graps *et al.* 2022).

Despite having an established space program and relevant scientific capabilities in astronomy, Brazil still has significant gaps in its legal framework for the effective development of national planetary defense capabilities, even considering the recent advances represented by Law No. 14,946/2024. This situation is particularly concerning given the country's geographical position, vast territory, and critical structures that could be affected by an impact.

This article aims to analyze the Brazilian legal framework for space activities, identify gaps related to planetary defense, propose legislative updates, and demonstrate the potential benefits of Brazil's participation in international planetary defense programs. The analysis is based on a historical review of the institutional and legal evolution of Brazil's space sector, a comparative analysis of international legislation, and an evaluation of the country's scientific and technological capabilities.

This study is relevant not only because it identifies vulnerabilities in the Brazilian legal system, but also because it proposes approaches that could contribute to national and global security and boost the country's scientific and technological development in an emerging strategic area.

CONCEPTUAL BACKGROUND

Planetary Defense

Planetary defense is a critical field of study and practice aimed at protecting Earth from potential impacts by asteroids and comets. It encompasses a range of activities, including detection, characterization, and mitigation of potentially hazardous NEOs National Science and Technology Council (2023). It is also defined as an international cooperative enterprise designed to provide protection to the nations of the world from devastating asteroid and comet impacts (Johnson 1995). It refers to the strategies, technologies, and coordinated efforts designed to detect, track, assess, and mitigate the threat of asteroids and comets. For several decades, the U.S. National Aeronautics and Space Administration (NASA) has conducted research on NEOs that can enhance scientific comprehension of the genesis and development of our solar system; establishing the Planetary Defense Coordinating Office (PDCO) in 2016 to manage the agency's diverse and rapidly growing efforts in the "applied planetary science" of planetary defense .

The planetary defense cycle generally comprises several key stages. The first stage involves surveying the sky for asteroids or comets that approach Earth's orbit. Government agencies and scientific institutions use both space and ground-based telescopes to catalog and monitor these objects, with the PDCO and international partners playing a crucial role in this phase (NASA 2023).

Once detection occurs, the next step is to track the object's orbit and characterize its physical and chemical properties. Scientists determine the size, shape, mass, composition, rotation, and possible trajectory uncertainties. This characterization allows for a more accurate assessment of the potential impact risk (NASA 2023).

Using the data from tracking and characterization, experts assess the probability of an impact and its potential consequences. Tools such as the Sentry Impact Monitoring system can estimate impact probabilities decades in advance (NASA 2023). If a risk is identified, mitigation options are considered, ranging from deflection missions to evacuation planning, and international coordination for disaster response (Rivkin *et al.* 2021). The final stages, in case of a predicted impact, involve mobilizing emergency

response plans with governmental and international agencies. After an event, efforts focus on impact assessment, humanitarian relief, and recovery (NASA 2023) These steps form a continuous cycle, as new objects are discovered and tracked, while international collaboration and technological advancements improve Earth's planetary defense capabilities.

In 2021–2022, NASA undertook the Double Asteroid Redirection Test (DART) mission sending a small spacecraft 11 million km into the 160-m-wide asteroid Dimorphos, which posed no threat to Earth. The mission was a resounding success, validating the ability of the spacecraft's autonomous guidance system to accurately steer it to the impact point at 22,000 $km \cdot h^{-1}$. The test showed that the asteroid's original trajectory was significantly altered, even more than most previous calculations had predicted.

Following the DART mission, a significant initiative concerning planetary defense is the Hera mission, conducted by the European Space Agency (ESA). This project serves as a supplementary continuation of NASA's DART mission, integral to ESA's planetary defense strategy. Launched in 2024, with an anticipated arrival to the Didymos system in 2026, its objective is to evaluate the consequences of DART's influence by collecting comprehensive data on the asteroid's composition, mass, and the resulting impact crater. The Hera mission signifies a substantial advancement in enhancing our ability to safeguard Earth from prospective asteroid impacts, complementing the continuous endeavors of global space organizations to observe and mitigate hazards posed by NEOs.

Ultimately, planetary defense is a complex and evolving field that combines cutting-edge technology, international cooperation, and scientific research to address the potential threat of NEO impacts on Earth. It is not science fiction, but rather a highly developed scientific and engineering endeavor. It involves a variety of disciplines, including astronomy, physics, aerospace engineering, and public policy and as the field of planetary defense advances, it raises important ethical and policy questions. It is important to highlight that collaboration among space agencies, academic institutions, and governments is crucial for effective planetary defense efforts (NASA 2023).

National Planetary Defense Frameworks

The potential threat posed by NEOs has prompted the development of specific regulatory frameworks for planetary defense in several countries over the past two decades. This phenomenon represents a significant evolution in contemporary space law, which has traditionally focused on issues such as the registration of space objects, liability for damage, and the peaceful use of outer space. It is a particularly challenging field for public policy formulation, as it combines seemingly contradictory characteristics: a low-probability threat with potentially catastrophic impact; the need for robust national capabilities that can only be effectively addressed through international cooperation; and significant investments in the present to mitigate risks that may only materialize in the distant future.

United States

Scholars generally agree that the United States has created the most complete legislative and institutional framework for planetary defense worldwide (Gritzner and Kahle 2019). Over the past two decades, this strong framework has developed through several legislative acts and policy recommendations, therefore providing a methodical strategy to handle NEO hazards.

The NASA Authorization Act of 2005 explicitly mandated that the agency creates a dedicated program to "detect, track, catalog, and characterize the physical characteristics of NEOs equal to or greater than 140 meters in diameter," so establishing the basis of this framework (NASA 2005). This act marked a change from academic curiosity to national security concern, as Johnson *et al.* (2017) note: it was the first statutory demand for a thorough NEO detection program at the federal level.

Later expansion of this legal mandate came from the NASA Authorization Act of 2008, which set more particular criteria including the ambitious target of finding 90% of NEOs larger than 140 m by 2020 (United States 2008). Although this goal has not yet been completely reached, the creation of a defined, quantifiable purpose has spurred major institutional attention and technology advancement. This legislation transformed planetary defense from a peripheral scientific interest to a core mission component with dedicated resources and accountability mechanisms (Chapman 2020).

The publication of the "National Near-Earth Object Preparedness Strategy and Action Plan" by the National Science and Technology Council (2018) marks a major development in the American legal system as it presents a complete whole-of-government strategy for planetary defense spanning detection to encompass characterization, deflection research, and emergency reaction planning. This strategy document, according to Farnocchia *et al.* (2019), clearly defines roles and responsibilities for each of the

several federal agencies—including NASA, the Federal Emergency Management Agency, the Department of Defense, and the Department of Energy—so enabling a legal and policy framework for organizing activities among them.

The U.S. Commercial Space Launch Competitiveness Act of 2015 (also known as the SPACE Act) and Space Policy Directive-1 (2017) underlined the need for public-private partnerships and international cooperation in space activities, including planetary defense (United States 2015; 2017), so strengthening the legal basis for planetary defense activities. These laws have opened legal routes for private entities to engage in planetary defense projects, therefore perhaps quickening technical development and increasing detection capacity as observed by Weeden *et al.* (2020).

Established in 2016, NASA's PDCO constitutes a major institutional development with particular authority and responsibility for organizing planetary defense actions (NASA 2017). Supported by dedicated funding lines in the federal budget that have grown from roughly US$ 50 million annually in 2016 to over $150 million in recent years, PDCO is the lead agency for planetary defense, so attesting to ongoing governmental commitment to this mission area.

European Union

The European Union's approach to planetary defense reflects its multinational nature and tradition of coordinating policies among member states with varying capabilities and priorities. This approach is based on the EU Council Resolution on European Space Policy (2007/C 136/01), which explicitly includes protecting the planet as a strategic objective of European space policy (European Parliament 2021).

This policy orientation was formalized through the European Space Agency's (ESA) Space Situational Awareness Program, which was established in 2008 and expanded significantly in 2012. The program has a segment dedicated specifically to NEOs, with a legal mandate to develop European detection, tracking, and early warning capabilities (ESA 2020).

The European commitment to planetary defense was reaffirmed and strengthened in 2021 when Regulation (EU) 2021/696 was established. This regulation outlines the European Union Space Program for the period from 2021 to 2027 and explicitly includes the development of capabilities for mitigating risks related to NEOs as part of its space protection activities (Council of the European Union 2021). This formal inclusion in the regulation establishing the European space program represents a significant institutionalization of planetary defense in the legal framework of the European Union, ensuring stable funding and a solid legal basis for initiatives in this area."

Russia

In addition to the United States and the European Union, other space powers have developed unique regulatory frameworks for planetary defense that reflect their distinct administrative traditions, strategic priorities, and institutional contexts. For example, the Russian Federation incorporated planetary defense into its legal framework through the Federal Law on Space Activities (No. 5663-1), which was updated in 2015. This law assigns the Russian space agency, Roscosmos, the responsibility of ensuring the security of the Earth against threats of cosmic origin and integrates civil and military capabilities, emphasizing the dual use of technologies and infrastructure to maximize resource efficiency in a restrictive budgetary context (Russian Federation 2015).

Japan

Japan has established a legal basis for planetary defense through the Basic Space Act (Act No. 43 of 2008). This act includes the objective of "contributing to the safety of humankind" and authorizes the Japanese space agency, JAXA, to develop technologies for monitoring and potentially mitigating space threats (Japan 2008). It emphasizes that the Japanese approach is characterized by a strong emphasis on international cooperation (Japan 2025), integration with national disaster management systems, and the development of capabilities that complement those of other international actors.

China

The People's Republic of China has progressively developed its regulatory framework for planetary defense as part of its broader strategy to establish itself as a global space power. The 2016 White Paper on Space Activities sets the strategic objective of monitoring and protecting the Earth from space disasters (China 2006). The Chinese approach to planetary defense is characterized by integration with its broader asteroid exploration program and an emphasis on developing autonomous capabilities, reflecting its overall strategy of technological independence in strategic sectors (China 2021).

India

India has incorporated elements of planetary defense into its National Space Policy (2020), which sets as an objective "enhance the national space situational awareness capabilities and share observation data with relevant stakeholders" and "coordinate international cooperation and coordination in the area of global space governance and programs" (India 2023). The Space Activities Bill (2017), still pending, includes provisions on "planetary protection" and authorizes ISRO to develop programs dedicated to monitoring NEOs (ISRO 2023). Indian space defense efforts center on strengthening national observation capabilities and coordinating with existing disaster management initiatives.

International Planetary Defense Frameworks

Complementing national activities, there are several international agreements and coordination mechanisms. These multilateral frameworks provide essential legal foundations, coordination structures, and political support for planetary defense efforts across borders (Conway *et al.* 2022). The United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) formally established two complementary international bodies, IAWN and SMPAG in 2013. According to Pelton and Allahdadi (2015), this resolution transformed planetary defense from a mostly scientific issue to an acknowledged area of international security cooperation with official diplomatic support.

The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (also known as the Outer Space Treaty) of 1967 lays much of the legal basis for international planetary defense activities. Although this treaty dates back before official planetary defense programs, it offers broad ideas that researchers find relevant for NEO deflection and mitigating actions. Particularly pertinent for asteroid deflection projects that can disrupt orbital paths, Article IX of the treaty mandates nations to avoid harmful contamination of celestial bodies and adverse changes in the environment of the Earth (United Nations 1967).

Moreover, Article I's description of space as "the province of all mankind" and Article IX's requirements for "appropriate international consultations" create legal obligations for international collaboration in planetary defense (Jakhu and Pelton 2017). Beyond these fundamental processes, modern times have seen more advances in global cooperation. Conducted biennially since 2013, the Planetary Defense Conference Exercise has developed procedures that enable and constrain potential deflection missions, requiring international consultation while establishing worldwide cooperation and communication during possible impact events (Barbee *et al.* 2021). Furthermore, the series of Planetary Defense Conference held by the International Academy of Astronautics has helped to create technical standards and best practices that, although not legally enforceable, are nonetheless crucial soft law tools directing worldwide collaboration (Gritzner and Kahle 2004).

Brazilian Space Legislation

Brazilian space activities formally began in 1961 with the creation of the National Space Activities Organization Group (GOCNAE) through Decree No. 51.133, which later, in 1971, became the Institute for Space Research (INPE), thus consolidating the institutional structure for civil space research (Oliveira 2005). The 1980s represented a period of expanded ambitions, marked by the establishment of the Brazilian Complete Space Mission (MECB) and the Brazilian Space Activities Commission (COBAE), although the MECB was conceived in a context of economic optimism that soon dissipated with the foreign debt crisis, resulting in severe budget constraints that compromised its implementation.

With the redemocratization of the country, there was a significant restructuring of the Brazilian space program, culminating in the creation of the Brazilian Space Agency (AEB) in 1994, through Law No. 8,854, as a federal civil autarchy, which, according to Bittencourt Neto (2011), represented an 'institutional demilitarization' of the Brazilian space program, aligning it with international trends in civil management of space activities. This institutionalization process continued in 1996 with the establishment of two important legal instruments: the National Policy for the Development of Space Activities (PNDAE) and the National System for the Development of Space Activities (SINDAE), followed in 2001 by the approval of the National Space Activities Program (PNAE) for the period 2001-2010, which established specific goals and projects for the sector.

In 2012, the PNAE was approved for the period 2012–2021, with an emphasis on satellite applications for environmental monitoring, telecommunications, and meteorology, reflecting a change in priorities, with greater emphasis on practical applications

and less focus on the development of launch vehicles. International cooperation gained momentum in 2018 with the signing of the Technology Safeguards Agreement between Brazil and the United States, subsequently enacted by Decree No. 10,220/2020, aimed at enabling the commercial use of the Alcântara Launch Center, while in 2020, Decree No. 10,469 established the Strategic Space Systems Program in Portuguese, focusing on space applications for national defense and security.

The most recent milestone in this evolution occurred on July 31, 2024, with the enactment of Law No. 14,946, which establishes the New Legal Framework for Space, representing the most significant update to Brazilian space legislation since the creation of the AEB, introducing important innovations such as the establishment of a legal regime for commercial space activities, the definition of procedures for authorizing and licensing space activities, the creation of mechanisms to encourage private participation in the space sector, the regulation of safety and sustainability aspects of space activities, and the updating of the AEB's responsibilities as the national regulatory authority. Law No. 14,946/2024 represents an effort to modernize the Brazilian legal framework for the space sector, seeking to align itself with international trends toward greater private participation, although, even addressing several important aspects for the development of the Brazilian space sector, Law No. 14,946/2024 does not specifically address the issue of planetary defense."

RESEARCH METHODOLOGY AND STUDY DESIGN

Based on a qualitative approach, this study employs documentary and comparative analysis methods. The analysis included official documents, such as national and international legislation, government reports, space agency documents, and technical studies produced by scientific and academic institutions. Documentary research is a research methodology that focuses on the collection, analysis, and interpretation of information contained in written or non-written documents, which are characterized as primary sources (Marconi and Lakatos 2004), differing from bibliographic research only in the nature of the sources (Gil 2008). Both methods play important roles in academic research and complement each other: while documentary research provides a deeper understanding of events, bibliographic research is useful for situating the work in the context of existing knowledge and identifying gaps that require further investigation.

This paper examines the legal frameworks and regulatory initiatives related to planetary defense across various countries. Through analysis of governmental policies, international agreements, and national legislation, this study identifies common approaches, unique elements, and potential gaps in the global legal infrastructure for addressing NEO threats. The comparative analysis reveals varying levels of institutional development, funding commitments, and legislative support for planetary defense initiatives worldwide; it also examined the legislation and planetary defense programs of the six main jurisdictions: the United States, the European Union, Russia, China, India and Japan. Key elements identified include formal recognition of the threat, assignment of institutional responsibilities, funding mechanisms, integration with civil defense systems, and international cooperation protocols.

To analyze the Brazilian case, we examined the primary legal instruments that govern space activities in Brazil, including laws, decrees, policies, and programs. We paid special attention to Law No. 14,946/2024, which was recently enacted. We identified gaps by comparing them with international best practices and evaluating technical reports produced by Brazilian institutions.

RESULTS

The Brazilian space legislation has significant deficiencies regarding planetary defense when compared to international counterparts. These legislative gaps present substantial challenges to Brazil's capacity to address NEO threats effectively. This analysis examines these deficiencies and proposes comprehensive legislative reforms to strengthen Brazil's planetary defense capabilities.

Brazilian space laws expose a worrisome lack of particular clauses handling planetary defense obligations. Unlike the United States, the European Union, and Russia, Brazil lacks laws clearly assigning institutional responsibility for NEO threat detection, monitoring, or mitigation. It can be noticed that neither Law No. 8,854/1994, which founded the AEB, nor Decree No. 1,553/1996, which describes the National Policy for the Development of Space Activities (PNDAE), have clauses addressing asteroid risks.

The lack of official links between space operations and Brazil's National Civil Protection and Defense System set forth in Law No. 12, 608/2012 aggravates this institutional gap. Countries such as Japan and India, who have clearly included their NEO monitoring systems into national catastrophe warning systems, contrast sharply with this disconnection. The lack of legislative integration between the space sector and civil defense represents a missed opportunity for developing response capabilities to potential NEO impacts.

Another major shortcoming in Brazil's planetary defense system is financial sustainability. Unlike the United States and the European Union, which have set out allocated funds for planetary defense projects, Brazilian law offers no legal tools ensuring particular and ongoing financing for such projects. Budget lines for planetary defense are not included in either the PNAE nor other planning tools.

Financial sustainability is mandatory for planetary defense programs, which require long-term investments in observation infrastructure and technology development, so underlining how this funding gap compromises Brazil's capacity to develop and maintain vital detection and monitoring capabilities.

Furthermore, Brazil's systems of international collaboration are very limited. Though Brazilian is a signatory to several space treaties, it lacks certain clauses allowing involvement in international planetary defense projects as the IAWN and SMPAG. This runs counter to nations such as Japan and members of the European Union, who have set unambiguous legal policies regarding foreign interaction, with reference to effective participation in international warning and mission planning networks requires not only formal membership, but also an internal legal framework that facilitates the sharing of data and resources. This way, Brazil's legislative shortcomings limit its capacity to engage significantly in global planetary defense activities.

DISCUSSION

Based on the comparative analysis and gaps identified, this section presents some viable actions that would be relevant to update Brazilian legislation.

Updating the AEB Law (Law No. 8,854/1994)

The Brazilian Space Agency, established by Law No. 8,854/1994, calls for major legislative modernization in order to address the new issues of planetary defense. The establishment of a comprehensive national framework for reducing the threat of NEOs critically depends on this update, which is the first step. Pereira (2021) emphasizes the fundamental nature of this legislative reform for Brazil's planetary defense capabilities, since updating the AEB Law is essential to clearly establish institutional responsibilities and create a legal basis for the development of specific programs.

The proposed amendments to Law No. 8,854/1994 would extend the AEB's statutory mandate to explicitly include responsibility for planetary defense. These clauses would designate the AEB as the main coordinator of a National Planetary Defense Program, thereby clearly institutionalizing these efforts within the Brazilian government. As demonstrated by the United States' designation of NASA's Planetary Defense Coordination Office as the lead agency for NEO-related activities, this approach aligns with international best practices. Furthermore, the legislative amendments would entrust the AEB with the task of developing Brazil's NEO detection and monitoring capabilities, thereby addressing a significant shortcoming in the country's current space infrastructure. Establishing a legal mandate for detection capabilities creates the necessary foundation for long-term investment in observational infrastructure and data processing systems. This clause would enable the AEB to organize current astronomical resources and create new capabilities specifically for planetary defense.

Updating the Brazilian Space Law (Law No.14,946/2024)

In order to incorporate planetary defense initiatives into Law 14,946/2024, we propose a reformulation that begins with the inclusion of a precise definition and specific objectives for planetary defense. This definition would stress the requirement of observing, conducting risk analysis, and reducing hazards from celestial bodies. This strategy would demand extending the authority of space policy-linked organizations such as INPE and the AEB. These organizations would handle tracking of NEOs and get the required technical and scientific backing to carry out defense plans.

Simultaneously, it is imperative to create funding systems ensuring ongoing budgetary resources to improve monitoring systems and foster creative technologies. Together with coordinated financial collaboration with international organizations to support worldwide technical interchange and integrated cooperation initiatives, these mechanisms could comprise public-private partnerships, credit lines, and tax incentives. Expanding relationships with academic institutions and government agencies, the law might also be changed to support applied research and the building of cooperative networks between universities, research centers, and the technology industry. Effective space surveillance and the application of planetary defense policies depend on scientific interactions and access to complementary information and data; hence these alliances would help to facilitate both of these aspects.

Updating the legislation would also entail revising the regulatory provisions that govern the use of space. This revision would integrate operational protocols and metrics for evaluating planetary defense initiatives, ensuring that the legislation keeps pace with technological developments and international demands. At the same time, social participation and transparency should be prioritized.

Integration with the Civil Defense Law (Law No. 12,608/2012)

The effective management of NEO threats necessitates formal integration between planetary defense capabilities and civil defense systems. Amending Law No. 12,608/2012, which established Brazil's National Civil Protection and Defense System, represents a critical step toward creating a comprehensive response framework for cosmic threats. A formal integration between planetary defense and civil defense is essential to ensure effective responses in the event of potential impacts, following international best practices.

The proposed amendments would explicitly incorporate NEO threats into Brazil's national disaster registry, acknowledging cosmic impacts as a recognized hazard category within the country's disaster management framework. This classification would align with international standards established by the United Nations Office for Disaster Risk Reduction, which has increasingly recognized astronomical hazards within comprehensive disaster typologies (Ferreira 2022). By formalizing this categorization, Brazil would establish the legal foundation for developing specific mitigation and response strategies for NEO threats. Furthermore, the legislative revisions would establish specific protocols for alerts related to space objects, addressing critical gaps in current warning procedures that could significantly impair response effectiveness during time-sensitive scenarios. These protocols would define information flows, decision-making authorities, and public communication strategies, creating standardized procedures for managing potential impact scenarios across all relevant stakeholders.

The proposed amendments would also mandate the integration of space monitoring data into Brazil's early warning systems, creating formal channels for astronomical observations to inform emergency management decisions. This integration addresses the technological disconnection that currently exists between scientific monitoring capabilities and civil defense operations. An effective early warning requires not only detection capabilities but also established pathways for translating technical observations into actionable emergency information, underscoring the importance of this systems integration.

Finally, the legislative revisions would establish requirements for specialized training of civil defense managers regarding NEO threats and impact scenarios. This provision acknowledges the unique characteristics of cosmic hazards and the specialized knowledge required for effective response planning. The distinctive nature of NEO threats requires specialized training that addresses both the astronomical aspects of detection and the practical challenges of impact response, highlighting the importance of this educational component.

Update of the PNAE and PNDAE

Brazil's strategic space policy documents require significant revisions to incorporate planetary defense as a core national priority. The PNAE and the National Policy for the Development of Space Activities (PNDAE) establish the foundational framework for Brazil's space initiatives, making their update essential for institutionalizing planetary defense within the country's space governance structure.

The PNAE stablish seven strategic goals which seek to direct the Brazilian Space Sector in a way that enables the country to meet the following agendas: increase the presence of the Brazilian Space Program in the State's set of priorities; foster the entrepreneurship and competitiveness of the national production sector; scientific and technological development that is guided by the country's needs regarding space goods and services; and the continuous search for sovereignty and the increase of Brazil's

autonomy in space activities. Each goal is linked to actions and until 2031, eight sectors represent opportunities in national priorities: Infrastructure, Agriculture and Livestock Farming, Mining, Environment, Education, Civil Defense, Public Safety and National Defense (Brazilian Space Agency 2022).

In order to support a planetary defense initiative, two main adaptations could be implemented in the PNAE:

- Revision of Strategic Objectives
  - Update the missions and objectives of the documents to explicitly include the identification, monitoring, and mitigation of potentially impactful celestial bodies (asteroids, comets, space debris, etc.).
  - Align planetary defense goals with the existing scope of national space policy, promoting integration with civil and defense space activities.
- Strengthening International Partnerships and Cooperation
  - Adapt the PNAE and PNDAE to coordinate cooperation with international organizations specializing in planetary defense, such as the United Nations, ESA, and NASA, ensuring data exchange and integration into global monitoring networks.
  - Encourage bilateral/multilateral agreements and arrangements that enable access to cutting-edge technologies and knowledge acquired in other countries with defense-oriented space policies, strengthening national technological sovereignty.

The proposed updates would formally establish planetary defense as a strategic objective within Brazil's space policy framework, elevating NEO threat mitigation to a recognized national priority. By explicitly identifying planetary defense as a strategic objective, Brazil would create the policy foundation for sustained programmatic development and also provide for dedicated budget allocation for planetary defense initiatives.

Creation of a Specific Law on Planetary Defense

The establishment of dedicated planetary defense legislation would be a significant advancement for Brazil's legal framework regarding threats from NEOs. Inspired by the United States' successful institutionalization of planetary defense through specific statutory provisions, Brazil could significantly benefit from enacting a specialized law to address the multifaceted challenges of cosmic threat mitigation. A specific law on planetary defense would allow for a comprehensive approach to the multiple aspects involved, from scientific development to emergency management.

Such legislation would establish clear programmatic objectives and quantifiable goals for Brazil's national efforts, creating measurable benchmarks for assessing progress. This approach aligns with international best practices, as exemplified by the U.S. NASA Authorization Act of 2008, which set specific targets for observing NEOs. By codifying these objectives in primary legislation, Brazil could achieve long-term programmatic stability, which would transcend administrative changes and political cycles. This would address the critical need for programmatic continuity in long-duration scientific and security initiatives, as identified.

The proposed legislation would also create an interministerial coordination committee to institutionalize cross-governmental collaboration, which is essential for effective planetary defense. This governance structure acknowledges the inherently multidisciplinary nature of planetary defense, spanning scientific research, technological development, emergency management, and international relations. Effective planetary defense requires formalized coordination mechanisms that integrate diverse institutional competencies and technical capabilities across governmental bodies, which emphasizes the importance of an interministerial approach.

Technical requirements for NEO detection and cataloging would be another critical component of the proposed legislation. By establishing specific parameters for observation capabilities, data processing systems, and information management protocols, the legislation would provide clear technical guidelines for program development. The establishment of formal communication and alert protocols is a particularly significant element of the legislation.

These provisions would define the flow of information between technical detection systems and emergency management authorities, and address the critical gaps in current warning procedures that could significantly impair response effectiveness during time-sensitive scenarios, as identified by Ferreira (2022). By codifying these protocols in primary legislation, Brazil would ensure standardized communication procedures across all relevant stakeholders. Finally, the proposed law would establish financing mechanisms dedicated to planetary defense activities, addressing a fundamental constraint in current Brazilian space initiatives.

These provisions would create sustainable funding streams insulated from annual budgetary fluctuations, enabling long-term planning and infrastructure development.

In the case of creation of a specific law for planetary defense, other Strategic National Plans should be reviewed, so they would be aligned to this initiative.

Creation of Scientific Cooperation Mechanisms

Leveraging Brazil's existing scientific infrastructure for planetary defense requires formal coordination mechanisms that integrate diverse research capabilities into a cohesive national network. The proposed legal framework would establish structured scientific cooperation systems specifically designed to enhance NEO detection and characterization capabilities. The formalization of a national observation network would allow existing scientific capabilities to be leveraged and enhance their contribution to planetary defense, highlighting the potential of coordinated scientific efforts.

The proposed mechanisms would establish a Brazilian NEO observation network, creating a formal structure for coordinating astronomical observations across multiple facilities and institutions. This network would standardize observation protocols, data formats, and quality control procedures, enhancing Brazil´s collective observational capabilities.

The proposed mechanisms would also facilitate the sharing of data and resources among participating institutions, creating standardized protocols for information exchange and collaborative research.

Finally, the legal framework would promote the training of specialized human resources in planetary defense-related disciplines, addressing critical workforce development needs. This educational component acknowledges the specialized knowledge required for effective NEO detection, orbit determination, and impact risk assessment.

Establishment of a Legal Framework for International Cooperation

Brazil's effective participation in global planetary defense efforts requires a robust legal framework facilitating international engagement and cooperation. The proposed framework would formalize Brazil's participation in the International Asteroid Warning Network (IAWN) and Space Mission Planning Advisory Group (SMPAG), the primary international coordination mechanisms established by the United Nations Committee on the Peaceful Uses of Outer Space. This formalization would establish clear institutional responsibilities for engagement with these bodies, addressing the institutional ambiguities that currently limit Brazil's effective participation in international coordination mechanisms. By clarifying these responsibilities, Brazil would enhance its representation in these critical forums.

Furthermore, the legal framework would establish protocols for international data sharing, creating standardized procedures for exchanging observational data, orbit determinations, and impact assessments with international partners. It would also facilitate Brazil's participation in international mitigation missions, establishing legal provisions for contributing to multinational deflection or disruption initiatives.

Finally, the legal framework would promote the development of specific bilateral and multilateral agreements focused on planetary defense cooperation, creating tailored collaborative relationships with key international partners. Pereira (2021) notes that targeted bilateral agreements can address specific collaborative opportunities that complement broader multilateral frameworks, underscoring the complementary value of these focused agreements alongside participation in global coordination mechanisms.

CONCLUSION

The Brazilian space program is guided by a legal and institutional framework that aims to promote scientific, technological and industrial development, while also ensuring national sovereignty over the use of space. In contrast, planetary defense does not have an autonomous and explicitly outlined legal framework in the Brazilian context. Instead, Brazilian participation in this global effort is incorporated into broader scientific research and national security mandates, often via institutions specializing in astronomy and space sciences. However, despite its fundamental structure, gaps in the Brazilian legal framework become more evident in the face of rapid technological evolution and geopolitical changes, particularly with regard to commercial space regulation, space debris mitigation, and space cybersecurity.

In this paper, a comparative analysis of international legislation on planetary defense reveals significant gaps in the Brazilian legal framework. While countries such as the US, Russia, China, Japan, and members of the European Union have specific legal provisions that assign institutional responsibilities, establish financing mechanisms, and promote international cooperation, Brazil lacks a legal framework dedicated to this emerging issue. The proposals presented aim to fill these gaps, aligning Brazilian legislation with international best practices and creating conditions for the development of a national planetary defense program. Such an initiative would not only contribute to global security, but also bring scientific, technological, geopolitical, and socioeconomic benefits to Brazil. Updating Brazilian space legislation to incorporate aspects of planetary defense represents an opportunity for the country to strengthen its position in the international space arena and develop capabilities that transcend the initial objective, with applications in multiple strategic sectors.

It is important to note that Space Cybersecurity is currently one of the topics of greatest interest to the Brazilian Ministry of Defense. This refers to the protection of satellites, ground stations, ground segments and communications against cyberattacks. The absence of a legal framework defining security standards, responsibilities and response mechanisms for cyber incidents affecting space infrastructure leaves the country vulnerable. Technological threats such as the rise of quantum computing directly impact this legislative gap in space cybersecurity, as quantum computing poses a fundamental threat to the cryptographic schemes widely used today that form the basis of information security in global systems. In response, the US National Institute of Standards and Technology (NIST) has initiated a robust and transparent process to standardize post-quantum cryptography (PQC) algorithms capable of withstanding attacks from large-scale quantum computers (Alagic *et al.* 2025). NIST has developed extensive benchmarks and standards for quantum cryptographic systems and organizations such as ISO/IEC are also actively launching projects to standardize quantum cryptographic protocols, which is crucial to ensuring information security in the post-quantum era, as well as facilitating a coordinated global transition to new cryptographic solutions (Radanliev 2024).

The convergence of the rise of PQC with the needs of the Brazilian space program highlights critical areas where legislation needs to evolve. The gaps identified in the Brazilian legal framework are exacerbated by the quantum threat and, at the same time, offer opportunities for PQC to strengthen space security.

The analysis shows that, although fundamental, the Brazilian legal framework for space activities has significant gaps that are exacerbated by the imminent arrival of quantum computing. The standardization of post-quantum cryptography, spearheaded by initiatives such as those of NIST, is a vital means of mitigating the cyber vulnerabilities of space infrastructures. Proactively integrating PQC into Brazilian legislation, particularly with regard to space cybersecurity, the protection of sensitive data, and international cooperation, is imperative to ensuring Brazil's security, resilience, and sovereignty in space. Notable similarities exist between the legal challenges in space activities, planetary defense initiatives and cybersecurity, highlighting the need for regulatory agility, international cooperation, and a forward-looking approach to defining responsibilities. Addressing these interconnections and similarities in an integrated and strategic manner will strengthen Brazil's position as a responsible and technologically advanced space actor, ready to face the challenges of protecting Earth from asteroids and the quantum era.

CONFLICT OF INTEREST

Nothing to declare.

AUTHORS' CONTRIBUTION

Conceptualization: Pegetti AL; **Methodology:** Pegetti AL; **Software:** Pegetti AL; **Validation:** Belderrain MCN; **Formal analysis:** Belderrain MCN; **Investigation:** Pegetti AL; **Resources:** Pegetti AL; **Data Curation:** Pegetti AL; **Writing:** Pegetti AL; **Writing – Review & Editing:** Pegetti AL, Belderrain MCN; **Visualization:** Pegetti AL; **Supervision:** Pegetti AL, Belderrain MCN; **Project administration:** Pegetti AL; **Funding acquisition:** Pegetti AL; **Final approval**: Pegetti AL.

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