Space, the New Geopolitical Arena: Satellites, Conflicts, and Space Situational Awareness

Aluísio Viveiros Camargo
Col Marcello Corrêa de Souza, Brazilian Air Force

Introduction

From the dawn of the Space Age to the advent of commercialized orbital flights and private satellite constellations, events in outer space are increasingly relevant to society.[1] Coupled with Great Power Competition, the aerospace environment—a new concept of territory and the growing impact of the space economy—influences geopolitics.[2] Space activities have become a critical dimension of power, influence, and strength for the security and defense of many countries and are a key factor in the contemporary geopolitical arena.[3]

Military power has always had a close connection with space activities. The beginning of modern space exploration coincided with the end of World War II, with the military's rapid development of rocket launch technology.[4] This was due to the similarity between development of rocket launch vehicles and ballistic missiles (capable of carrying weapons with great destructive power).[5] Military activities in the space sector expanded and consolidated in the 1950s and evolved in line with international politics, notably in the face of the belligerent relationship between the US and the former Union of Soviet Socialist Republics (USSR).[6]

Countries and private entities are overcoming technological and financial barriers to access outer space, enabling greater participation in manufacturing satellites, launch vehicles, space exploration, and manned missions.[7] However, while such technological and scientific advances bring new opportunities, they also introduce unprecedented risks for services linked to outer space.[8]

Recognizing the advantages of operations based in outer space, many nations continue to increase their investment in skills; this effort is meant to compromise the strategic ability of others to do the same. The military use of space assets for functions such as intelligence, surveillance, reconnaissance, communications, and navigation is an indisputable reality.[9] The rise of new players in the space arena, such as China and India, highlights the growing role of outer space in global geopolitics.[10] These new actors are investing substantially in space infrastructure and technologies, aiming to strengthen their geopolitical influence and national defense.[11]

In this context, the application of *Space Situational Awareness* (SSA) has emerged as a vital field of study, allowing nations to monitor and understand the space environment and improve their ability to detect, track and identify space objects.[12]

Space Geopolitics

The Influence of Space Exploration on Foreign Policy

Space geopolitics has emerged as a grand strategy in the international arena as the domination and exploration of outer space has become fundamental in the strategies and policies of states.[13] At its core, space power theory highlights the growing relevance of space in global strategic dynamics.[14] Space capabilities, once dominated by a few superpowers, are now seen as essential tools of deterrence, communication, and dominance, including by developing countries.[15]

Michael Sheehan suggests that by assuming an increasingly critical role in the national power environment, space activities have even shaped the course of armed conflicts and the balance of forces in the international geopolitical arena:

> A study of international space politics provides both a correction to the idea that space programs are science-driven bureaucracies and somehow oblivious to the harsher realities of politics, and reveals case studies of themes that are familiar in other dimensions of international relations. In space, as well as on Earth, we see the political power of ideology and nationalism, the use of propaganda and foreign aid, the centrality of "national security" issues and the pursuit of that security through the acquisition of military capabilities, tensions between the richer, industrially advanced states and the poorer countries of the "South," efforts to use the integration of national policies to promote the unity of Europe, the evolution of the understanding of security to embrace social, environmental and economic dimensions, and so on. There are few, if any, features of contemporary global politics that do not have their echoes in the use of space.[16]

Thus, it is critical to recognize the role of the military in space exploration. In *Modern Strategy*, Colin Gray dives into the evolutionary domain of strategy, highlighting its intricate dimensions in contemporary and future contexts.[17] Especially relevant is the way in which he emphasizes the interrelationship between politics and the unpredictability of human nature and strategy, resonating with Clausewitz's perspective of war as an extension of politics through other instruments. By comparing the limitations of modern strategy with Clausewitz's central principles, Gray underscores the continuity of strategic thinking and its crucial importance in the various theaters of war:

> Strategy is the bridge that relates military power to political purpose; it is neither military power per se nor political purpose. By strategy, I mean the use of force and the threat of force for the purposes of politics. This is an adaptation of Clausewitz, though certainly not an adaptation of his clear intent. In *On War*, Clausewitz provides an admirably concise and succinct, yet seemingly narrow, definition: "Strategy [is] the use of engagements for the purpose of war." Clausewitz's definition is superior … Its definition has an operational, even battlefield orientation, … it tells us that strategy is the use of tacit and explicit threats, as well as actual battles and campaigns, to further political purposes. Moreover, the strategy in question may not be the military strategy; rather, it can be a grand strategy that uses "engagements," meaning all relevant instruments of power as threat or in action, for the goals of the art of governing.[18]

The relationship between space initiatives and global politics is symbiotic.[19] While governments fund space missions to project their national influence, the power dynamics between nations shape not only space economic systems but also the dynamics of state power itself.[20]

Daniel Blinder advocates that political power is intrinsically linked to the modern state, defined by its "unity of territorial sovereignty ... and by the pursuit of greater power beyond its borders," and that the advancement of space technological capabilities, even by private entities, has the potential to impact and transform the strategic landscapes of various global powers.[21] From this perspective, Blinder indicates that, even if "geopolitical rivalries" drive nations to invest in outer space in search of scientific and technological innovations, the emergence of new space powers is intrinsically linked to political, economic, and military issues. Without the strategic autonomy offered by space, Europe would not be able to consolidate itself as a significant geopolitical power, essential to ensure its security and defense.[22]

The US strongly exemplifies how adaptability in the face of the technological transformations brought by the advancement beyond Earth orbit is necessary to compete, deter, and prevail in a multifaceted security context marked by intense GPC, especially with actors such as China and Russia. This implies changes in policies, strategies, operations, investments, and the development of specialized capabilities and expertise to project power in an unprecedented strategic scenario:

> Space-based capabilities are essential to modern life in the United States and around the world and ensure the availability of these indispensable components of US military power. Capabilities are critical to establishing and maintaining military superiority in all space domains and to promoting US and world security and economic prosperity. However, it is not a sanctuary for counterattacks and space systems are potential targets at all levels of conflict. In particular, China and

> Russia pose the greatest strategic threat due to the development, testing, and deployment of anti-space capabilities and their associated military doctrine for employment in conflicts that extend into space. China and Russia have weaponized space as a way to reduce the military effectiveness of the US and allies and challenge our freedom of operation in space.[23]

It is evident that the expansion and diversification of space activities are attributing an essential character to state initiatives in this sector. As a result, these activities are becoming increasingly linked to a country's concept of national power. Additionally, the current global environment, marked by the Russia-Ukraine Conflict, shows a significant increase in the use, by several nations, of military systems anchored in space, particularly for the purposes of positioning, intelligence, communication, and early warning of missile launches, to include the adoption of a controversial concept of military activity in space: the use of antisatellite weapons, among others. All these developments have the potential to completely redefine the current concept of modern warfare.[24]

"Just as oil was the fuel of the industrial age, space will be the fuel and engine of the information age."[25] With this categorical statement coming from an attentive observer of the constant transformations that the concepts of modern warfare have undergone over the last decades, General Howell Estes, commander of US Space Command from 1996 to 1998, was able to skillfully synthesize the importance of space geopolitics.

According to Daganit Paikowsky, all the patterns of modern warfare in the information age, unlike the wars of the industrial age, are based much more on quality than quantity.[26] In this case, quality equates to the information superiority mainly obtained from operating in outer space. Although space is not the only factor, it is a central element for the concept of war based on information and knowledge, which has driven significant investments in research and development. This has also broadened the possibility of conflicts having repercussions in space, as a growing number of nations turn to space resources to support a wide variety of activities.[27] At this juncture, space dominance is perceived as essential for acquiring power, be it military, economic, or geopolitical, with considerable and profound implications on the global stage.[28]

The Rise of New Actors in Space Geopolitics

While the US and the former USSR were the pioneers in the growth of space activities over the last six decades, technological advances and lower costs have made it feasible for other nations to develop the capacity and autonomy for functions ranging from communications and navigation to financial transactions and weather observation. Their ability to accomplish these functions also allows them to exert influence and power in the space domain (as illustrated in Figure 1).

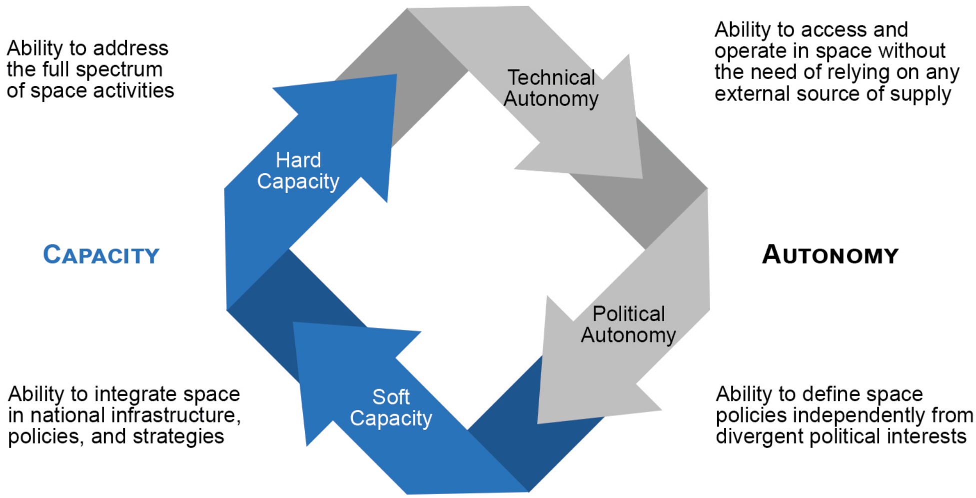

Figure 1. Space Power Requirements

Source: European Space Policy Institute[29]

Globally, the relevance of space activities is on the rise in military, commercial, environmental, scientific, and other areas. This new space race reflects the growing understanding of its strategic importance and the need to develop autonomous and robust space capabilities to secure a nation's position on the international stage.[30]

The race for space dominance is mainly fueled by ambition, initially motivated by security reasons, to obtain a global position as a powerful space power. To meet this goal, it is crucial to develop the capability to create a space economy with an industry that can produce highly complex systems, such as satellites, probes, and rocket launchers, among others—which in turn contributes to an image of geopolitical power.[31] Another aspect of the space race, quite evident in recent years, is the growing commercialization of outer space with the entry of the private sector as a relevant player in the world space market.[32] Space has become not only a rivalry between government actors, but also a rivalry between the biggest private venture capitalists of the world, triggering a new era known worldwide as *New Space*.[33]

The global space environment encompasses a wide range of governmental and private actors. By 2035, the space economy is projected to reach $1.8 trillion, up from $630 billion in 2023 and averaging a growth rate of 9 percent per annum.[34] Additionally, the space sector plays a crucial role as a catalyst for the progress of other vital segments of the economy.[35] The advent of *New Space*, combined with the perception of the importance of the space domain for the geopolitical ambition of government actors, has brought new space powers that were not present in the recent past. Countries such as China and India, powers recognized as economically influential in their regions, have gone in just a few decades from supporting actors in the space market to true world giants.[36]

According to Rajeswari Pillai Rajagopalan, China's space program began in the late 1950s with help from the former USSR, while India's program began in the 1960s after support from the US and France.[37] Both countries have gone through a long and intense technological journey, making efforts to secure a foothold in this area, as global geopolitical battles have been increasingly involving the space frontier:

> China's emergence as a great power and its competition with other Asian powers mean that we are likely to see intense space competition in Asia in the coming years. As Joan Johnson-Freese, a professor of national security affairs at the U.S. Naval War College pointed out in a 2014 article in the space magazine ROOM, the image, prestige, and techno-nationalism that characterized the space competition between the U.S. and the Soviet Union are becoming a reality in Asia today. In addition, there are genuine national security-related concerns driving Asian space programs.[38]

One example of Chinese space technology is BeiDou, its global positioning system, with 35 known navigation satellites: 27 in medium orbit, 5 geostationary, and 3 in inclined geosynchronous orbits. The BeiDou system constellation is significant for China, as it eliminates a major vulnerability represented by the world's dependence on the US Global Positioning Satellite and European GALILEO systems, of strategic significance in the event of a conflict.[39] In addition, China has already undertaken various manned space missions, which is considered a great feat, previously achieved only by the US and Russia.[40]

In turn, India's achievements in the space also do not go unnoticed. The country has reached a remarkable milestone in the field of space exploration, becoming the fourth nation to successfully land on the moon and the first in its south polar region, an area of immense scientific interest. This feat, as outlined by Clea Simon, not only symbolizes advances in science and engineering but also represents the accumulation of decades of work and dedication by Indian scientists.[41] Despite budgetary challenges compared to giants like NASA and SpaceX, India's approach and commitment to innovation have shown significant results; which reinforces the need for an educational approach focused on problem-solving, promoting creativity and entrepreneurship in the face of budget constraints.

Although none of the countries mentioned above have made explicit statements, all their programs signal a growth in the global space race, as well as a still unbalanced competition landscape in the Asian region. Disregarding the relevant geopolitical tensions between India and China, it is increasingly evident that the dominance of outer space may emerge as a new and important field of geopolitical dispute in that region.[42]

The Military's Dependence on Space Assets

Space has once again become the focus of attention for decision-makers and the public. New cosmic discoveries, coupled with the emergence of new space powers, cement outer space as an arena fraught with political, economic, and even military nuances.[43] The military's reliance on space assets for functions such as intelligence, surveillance, reconnaissance, communications, and navigation is an indisputable reality.[44] Satellites enable capabilities ranging from obtaining strategic information to accurately guiding weapons systems and to providing secure and global communications—they are the backbone for modern military operations.[45]

The Gulf War, often referred to as the First Space War, marked the beginning of a new era in global conflicts and the inception of the concept of modern warfare.[46] Since then, there has been a profound evolution of the military skills required for success on the battlefield. At its core, this metamorphosis was guided by the principle, as stated by US Secretary of Defense Donald Rumsfeld, of fighting with leaner, faster, and more agile forces with increased destructive power. In this context, technology, especially space, assumes a prominent position in combat dynamics.[47]

In Secretary Rumsfeld's own words, it is possible to discern the magnitude of the role that space plays in the military operations of contemporary conflicts:

> Space is embedded in the way the US military conducts its business and plays a big role in its success. In simple terms, space technology provides "see," "declare," and "stop" capabilities to the United States far beyond those of any other military. "Seeing" capabilities are those intended to provide, in military parlance, "universal situational awareness," the power to cut through the fog of war and gain an advantage over an opponent by having the most accurate information about the battle environment. The capabilities to "declare" involve command and control, with communication as a key element. Knowing what's going on and being able to relay that to troops on the front lines for effective use of force are two very distinct capabilities. The "stop" capabilities are exactly what they sound like, ranging from non-lethal actions to precision-guided munitions.[48]

The contemporary paradigm of Network-Centric Warfare (NCW) represents one of the most striking manifestations of militarization in the information age, based on a set of systems called C4ISR, which refers to Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance. As

Nuno Gonçalo Miguel's states in his "System of Systems: The Triumph of Technology?" study, the practical application of the NCW concept is unthinkable without the use of space resources that provide such capabilities.[49]

In a study of dependence on space technology for military operations, author Engel Pedro Costa shows that there is a dependence on the use of space technologies for success in military operations.[50] For him, the concept of systems integrator (from which the concept of NCW arises) also applies to space technology, in which the amassing of force is replaced by the search for the amassing of effects—asserting the need for the efficient and effective use of resources. This concept is based on the ability to obtain information superiority and using it to leverage force, mitigating uncertainty in decision-making.

Thus, space geopolitics has emerged as a central dimension in contemporary international relations, reflecting the growing importance of outer space in global power dynamics. The theory of space power, influenced by concepts such as mutually assured destruction and dominance of celestial lines of communication, reveals the complexity of political, economic, and military interactions in space.[51] This interaction is amplified by the critical role that space activities play in shaping armed conflict and balancing geopolitical forces. The militarization of space, exemplified by the concept of NCW and its reliance on C4ISR systems, highlights the inseparability between space technology and military strategy.

Space, therefore, is not just an environment for scientific exploration but a strategic battlefield, where nations seek to establish dominance and secure their interests. The increasing introduction of new players in the space arena coupled with the commercialization of space reinforce the need for monitoring and SSA.

Space Situational Awareness

Overview

According to information from the United Nations Office for Outer Space Affairs, as of September 2023 there were more than 4,550 active satellites or space objects in Earth orbit, managed by more than 50 countries and multinational entities. Of these, 2,948 were in low-Earth orbit, 1,278 in mid-Earth orbit, and 324 in geostationary orbit.

Since the launch of the first satellite in 1957 (by the USSR), Earth orbit has been accumulating debris resulting from routine operations, accidents, and detonations. Over the past six decades, there have been more than 500 fragmentation events, including disintegrations, collisions, and explosions of space artifacts.[52]

According to Richard Crowther, the expanding artificial orbital debris population is a growing problem that can pose a significant risk to the safety of space operations.[53] Debris can range in size from small particles to large inoperable satellites, which pose a risk of collision with functioning satellites, as they cannot be tracked in their entirety. Collisions of satellites with debris are a relatively rare event, but the high number of satellites and debris in Earth orbit has increased this risk.

Figure 2. Distribution of objects in Earth orbit
Source: Space Explored[54]

The space race established the requirement for space monitoring, the ability to locate man-made objects in Earth orbit, determine their position and orbital speeds, and anticipate their future whereabouts. Figure 2 illustrates how critical monitoring is to not only ensure the operation and safety of space assets, but to the efficiency of contemporary military operations.[55]

Throughout the Cold War, the emergence and large-scale deployment of intercontinental ballistic missiles capable of carrying their nuclear arsenals on ballistic trajectories through space prompted both the US and the USSR to create networks of monitoring and warning radars in their territories.[56] Furthermore, the advancement of space capabilities for intelligence and communication activities required the installation of optical telescopes to further enhance space tracking abilities. Additionally, unique specialized instruments were incorporated into existing monitoring capabilities to gather technical information on missile experiments.[57] Within this environment, SSA flourished with the intent of understanding the orbital interactions of both natural entities and human artifacts.

However, the specification of circumterrestrial space is still the subject of fierce debate. Although it certainly falls within the cislunar scope and extends to a radius of at least 100,000 km from the planet, encompassing most artificial devices currently in orbit, there is still no consensus on its framework.[58]

In the most current version of its highest-level strategic document, the *National Space Activities Program* (PNAE), the Brazilian Space Agency, does not propose a definition of this important topic, a fact that causes a lot of concern, since the PNAE represents the strategic vision for the Brazilian space sector for the years 2022–2031.[59] It should be noted that in the document a small reference calls for implementing a regular system of periodic reviews, given that the date of the work for the formulation of this program began in 2019, a period in which SSA was still quite incipient.

The European Space Agency (ESA) proposes an expanded definition for SSA, segmenting it into three distinct domains of expertise: 1) "SST - Space Monitoring and Tracking of Objects," dedicated to the observation of objects in Earth orbit; 2) "SWE - Space Meteorology," which focuses on the monitoring of solar conditions, solar wind and the Earth's magnetosphere, ionosphere and thermosphere; and 3) "NEO - Near-Earth Objects," which aims to identify natural objects with the potential to collide with our planet.[60]

John A. Kennewell and Ba-Mgu Vo point out that the US, which has the most extensive set of global monitoring assets, defines SSA as follows:

> ... the immediate and anticipated understanding of space events, threats, activities and conditions, as well as the state of space systems (including space, ground and connections). This definition encompasses capabilities, limitations, and applications, targeting both current and future scenarios, whether friendly or adverse. This perspective allows leaders, decision-makers, strategists, and operators to achieve and preserve space dominance in varied conflict contexts.[61]

This definition encompasses not only the definition of the space domain itself but also the terrestrial infrastructures that sustain it, as strategic attributes for the entity's mission and objectives. In fact, we can infer two types of concepts directly related to this ability to monitor the space environment:

- Space Situational Awareness (SSA)—the surveillance of space objects to maintain custody of them in outer space (passive analysis).
- Space Domain Awareness (SDA)—a concept that goes beyond the definition of SSA, as it takes into account more subjective operational issues, such as responsibility for the space object, mission to be executed, future intentions, capabilities and vulnerabilities (active analysis).

Thus, SDA is defined, in short, by the identification, characterization and effective knowledge of any factor, active or passive, associated with the space domain that may affect space operations and consequently impact security, the economy, or the space environment.

According to Maj Gen John Shaw, at the time Deputy Commander of US Air Force Space Command, there was a need to move beyond the benign concept of SSA to the broader mindset offered by the SDA, as the environment had become a combat domain.[62]

> The implication of space as a warfighting domain requires us to shift our focus beyond the SSA mindset of a benign environment to achieve a more effective and comprehensive SDA, in the same way that the Navy works to achieve maritime domain awareness in support of naval operations and the Air Force strives to gain maximum air domain knowledge to achieve air superiority.[63]

According to Flavio Américo, the concept of multidomain operations related to military operations can be defined by the wide range of interactions observed between the five main fields of action (combat domains) of the armed forces during a conflict: air, sea, land, space, and cyber.[64] The vision of space as a combat domain requires a change of mentality as proposed by Major General Shaw, since a military advantage in the space domain can represent a change of course in any conflict that occurs today.

Countries with advanced SSA and SDA capabilities, such as the US and perhaps Russia, can influence geopolitical relations, shape the behavior of state and nonstate actors, and drive global trends.[65] According to the US Department of Defense'*s Space Policy Review and Strategy on Protection of Satellites*, threats to the US and its allies, especially represented by China and Russia, drive the US *National Security Strategy* (NSS) 2022 and the *National Defense Strategy* (NDS) 2022, in order to safeguard its security, prosperity and its way of life.[66]

NSS 2022 outlines three lines of effort for the US to protect free and open international order:

- Invest in the underlying sources and tools of American power and influence.
- Build the strongest possible coalition of nations to increase our collective influence.
- Modernize and strengthen our armed forces so that they are equipped for the era of strategic competition with the great powers.[67]

DOD's priorities, as articulated in NDS 2022, are:

- Defend the nation in the face of the growing multidomain threat posed by the People's Republic of China.
- Deter strategic attacks against the United States, its allies and partners.

- Deter aggression by prioritizing the People's Republic of China's challenge in the Indo-Pacific region and then Russia's challenge in Europe.
- Build a resilient Joint Force and defense ecosystem.[68]

In fact, since military space activities have expanded very rapidly, SSA/SDA have become essential in the decision-making process of space systems operations. This was made urgent not only by the evident military interests but by the fact that space systems have a wide spectrum of critical applications for the various sectors of the economy.[69] Analogous to the air domain, where there is no airspace control without sensors capable of performing adequate surveillance, in the space domain one cannot consider SSA or SDA capacity without sensors capable of detecting, characterizing, and monitoring space objects.

Currently, the Brazilian Air Force benefits from SSA and SDA services provided by the US under the *SSA Sharing Agreement* signed in 2018 and has chosen this agreement to ensure the integrity of its satellite and launch operations, particularly with regard to risks of collisions with space objects. Additionally, this agreement gives the country information about space weather conditions and potential threats from other nations. This dependence highlights the lack of national sensors that could give Brazil full autonomy in its space operations.[70]

Monitoring Space Objects

The control of the air and space environment is an essential condition for the Brazilian Air Force to carry out actions aimed at guaranteeing sovereignty, national heritage, and territorial integrity, its constitutional mission.[71] Furthermore, exercising control of the space environment equates to the guaranteeing conditions for the development of national power.

Safeguarding the command and control (C2) capabilities of the armed forces in possible conflicts is fundamental for the success of military operations, especially in remote regions of the national territory. Thus, Brazil must carry out measures to guarantee the physical integrity of these space platforms throughout its orbital operations, such as preservation of their useful life through optimization of resources or their eventual repositioning in orbit.[72] In addition, the situational awareness of objects residing in orbits close to Brazilian space resources, especially those located in geostationary orbits and of military or strategic interest, is essential for the analysis and mitigation of possible electromagnetic interference, electronic eavesdropping, or remote sensing.

The strategic requirement to safeguard space assets has led several nations to adopt various solutions. These solutions usually combine data obtained from a network of different types of sensors and collaboratively updated data from private and government entities. In the US, the Joint Task Force–Space Defense Commercial Operations Cell (JCO) is responsible for coordination between public and private entities for the integration and generation of SSA data in support of US Space Command.[73]

Space Control

In recent years, a growing number of countries and commercial actors have become involved in space activities, resulting in a contested, competitive, and congested environment, as illustrated in current literature.[74] This triad of adjectives has become the most notable characterization of the difficulties encountered by states in the quest for domination of outer space, perceived as necessary for their military capability and national security.

The increasing use and dependence on space for national security purposes has driven several countries to invest in the development of capabilities in Adversary Offensive Space Operations (AOSO). This concept, detailed in publications such as the US "Challenges to Security in Space (2022)" report, encompasses a set of techniques and skills designed to establish control of space, which refers to a country's ability to use space capabilities for its own strategic objectives, while preventing or limiting their use by adversaries.[75] The relevance of these capabilities and the impacts of their uses can be exemplified through historical events.[76]

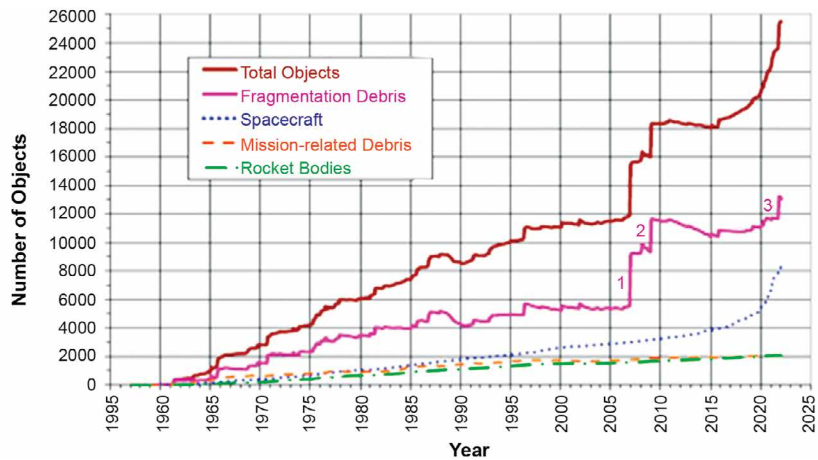

Figure 3. Growth of objects in Earth orbit

Source: NASA[77]

The antisatellite (ASAT) test conducted by China in 2007 and Russia in 2021 both resulted in the creation of space debris, as illustrated by points 1 and 3 in Figure 3. This debris poses a risk not only to satellites in orbit but also to future space operations. Furthermore, point 2 reveals a different incident from the 2009 collision between the inactive Kosmos 2251 satellite and Iridium 33. This event, while not directly related to AOSO, highlights the vulnerability of space systems to collisions and the importance of SDA to monitor and prevent such occurrences.

Offensive space operations can be used to deceive, disrupt, deny, degrade, or destroy any of the three elements of a space system: the satellite, the supporting ground system, or the communication link between them. A key factor in the proliferation of offensive space capabilities is the increased use of space in modern warfare. For much of the Cold War, space was limited primarily to a relevant role in gathering strategic intelligence, enforcing arms control treaties, and warning of possible nuclear attacks. Although the Cold War saw a significant development of offensive space operations testing, the close link between space capabilities and nuclear war provided a level of deterrence against actual attacks on space systems at that time in history.

With the end of the Cold War, many of these strategic space capabilities found new roles, directly supporting conventional warfare by providing operational support and tactical benefits to troops on the ground. This has increased incentives for countries to develop offensive space operations capabilities while decreasing the deterrent value of nuclear capability.

The "Global Counterspace Capabilities" report, which provides an analysis of offensive space operations used over time, presents a mapping of the main military actions that have taken place in space in recent years.[78] The increase in the number of ASAT weapons tests is an indicator of the increasing militarization of space. The report addresses, in addition to tests with ASAT missiles with kinetic impact, other relevant actions carried out from space.

The analysis of Figure 4, which represents the number of ASAT tests carried out by the main players in the space scene over the last 60 years, shows that Russia, the USA, and China carried out the highest number of tests. The chart also shows that the number of ASAT tests has increased significantly in recent years, mainly due to the development of new technologies such as directed energy weapons.[79]

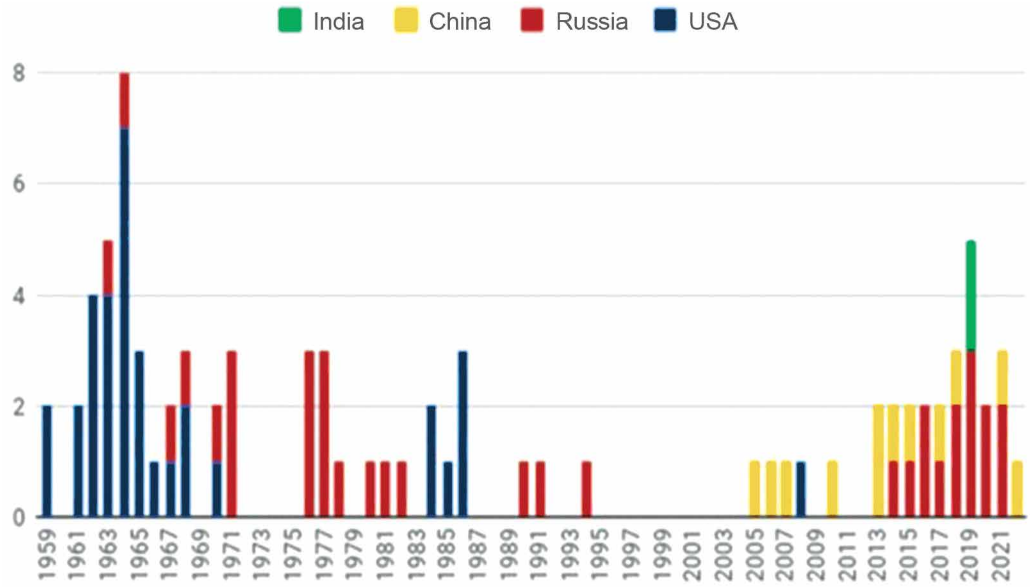

Figure 4. Number of ASAT tests, per year, by country

Source: Secure World Foundation [80]

Indeed, the increasing proliferation of offensive space operations significantly increases the risk of incidents in space, potentially triggering or exacerbating global conflicts. This trend threatens the sustainability of the use of the space domain, which, through a variety of tactics, can destroy or disable satellites, generate significant orbital debris, compromise critical infrastructure, and promote severe instability in the geopolitical arena. Thus, outer space, once considered the last frontier of humanity, has turned into a stage where political, military, and technological complexities are played out. Brazil's ambition to secure its sovereignty and advance its national interests in space is in line with the global trend of maximizing the benefits that the space domain can offer.

The intensified engagement in space, while promising in many ways, also reveals a more worrying aspect. The fierce competition for space dominance and control, together with the proliferation of offensive space operations and the growing number of tests with antisatellite weapons, paints a picture of rapid transformation. In this context, the security and sustainability of the space domain emerge as crucial concerns for the near future. Therefore, as space activity continues to expand its frontiers, it is imperative to recognize and address these emerging challenges to ensure a safe and sustainable space for future generations.

Final Thoughts

As the main objective of this study was to investigate how the development of SSA can influence or contribute to national defense and power projection in the international geopolitical scene, this research was based on methodological premises, seeking to outline the relationship between space exploration and military power and to highlight the growing importance of satellites in military operations and civilian activities. The work identified how SSA and SDA refer to the ability to detect, track, predict, and characterize the behavior of objects in orbit around the Earth and that such abilities are fundamental to support safe operations in space and protect critical space assets.

Given the increasing reliance on these space assets for a variety of applications, from global communications to weather forecasting and national defense, the ability to monitor and understand the space environment has become a strategic necessity supporting both cooperative security and national sovereignty. Outer space, once seen as a vast emptiness, is now recognized as a contested domain, where nations and commercial entities compete for orbital positions and radio frequencies.

Challenges for SSA and SDA include the rapid increase in the number of objects in orbit, the presence of space debris in large quantities, and the lack of clear international standards and agreements on space operations. What's more, the miniaturization of satellite technologies and the increasing accessibility to space have led to the launch of constellations of small satellites, which has increased the complexity of the space environment.

Recognizing the criticality of space access and operations, several nations have invested in advanced technologies and systems to improve their SDA. These include ground-based radars, optical telescopes, and satellites dedicated to tracking objects in orbit. Furthermore, there is a growing movement towards international collaboration to share data and improve SSA accuracy and coverage at a global level. The private sector also plays a vital role in the evolution of SSA. With the advent of New Space and the increasing commercialization of space, private companies are developing their own SSA capabilities, often in partnership with government agencies. As space continues to become more congested and contested, the need for a robust and reliable SSA will only increase. This is likely to see an increase in international cooperation, as well as the integration of civilian, commercial, and defense capabilities to ensure a safe and sustainable space environment.

The emergence of space geopolitics as a central consideration in international relations highlights the critical role that outer space plays in global power dynamics. The increasing reliance on space assets, the militarization of space, and the need for effective SSA in the space environment are all indicative of the strategic importance of space in contemporary times. As we move into a future where space plays an even more central role in everyday life and military operations, the ability to understand and operate effectively in this domain will be of paramount importance.

While outer space offers immense opportunities, it also presents significant challenges. For Brazil, investment in space capabilities and the adoption of a strategic approach are essential to ensure that the country not only benefits from space, including a voice and a role in the geopolitical arena, but also contributes to its peaceful and sustainable use. Given the growing importance of outer space for the country's security, economy, and development, it is essential that Brazil adopts measures to position itself more strategically in this scenario. The research carried out in this academic study, analyzing specialized literature and the Brazilian normative and legal framework, reveals an apparent inertia or inadequate prioritization of this effort, despite its importance for power projection, as evidenced by the Brazilian Space Agency being silent about SSA in its recently released PNAE 2022–2031. Although it is the main instrument for civil planning of space activities for the upcoming decade, the document does not even mention the subject, demonstrating a mismatch with other nations active in the space sector. However, there is an expectation that this will be addressed in a possible future update to the PNAE.

Meanwhile, the Brazilian Air Force has been increasingly training in both SSA and SDA. Although it still lacks the sensors capable of producing adequate monitoring data, it already has an organization responsible for receiving and analyzing the data shared through the *SSA Sharing Agreement* with the US. The Brazilian Air Force has also developed plans for the acquisition of telescopes and radars for monitoring space objects, but still lacks the necessary resources allocated for the establishment of an adequate Space Monitoring System.

That said, one of the contributions of this study is to inform decision-makers that the development of national SSA and SDA capabilities will not only decrease dependence on other nations but also ensure that the country has real-time information about its own space assets and possible threats, thus allowing for their adequate protection. In addition, investment in research, innovation, and development of space technologies is crucial to improve SSA and SDA capabilities and ensure Brazil is at the forefront of space exploration and its utilization.

While national capacity building is essential, international cooperation on space issues is equally critical. This can include data sharing, collaboration on space missions, and joint development of technologies. Lastly, it is essential for Brazil to establish a clear regulatory and legal framework for activities in outer space. The leading countries in the space technological context, capable of projecting power on the international geopolitical scene through their space capabilities, have centralized governance and a history of efforts in defining guidelines on launches, satellite operations, space debris mitigation, and offensive space operations, activities that are essential for the ambitions of any country in the space sector. ❑

Notes

1. Steven J. Dick, *Remembering the Space Age* (Washington, DC: NASA, 2008); Matthew Weinzierl, "Space, The Final Economic Frontier," Journal of Economic Perspectives, Vol. 32, No. 2, 2018, 173–192, https://pubs.aeaweb.org/doi/pdfplus/10.1257/jep.32.2.173.
2. Carlos Eduardo Valle Rosa, *Aerospace Geopolitics* (São Paulo: Dialética, 27 July 2022).
3. Organization for Economic Cooperation and Development (OECD), "Space 2030: Exploring the Future of Space Applications" (Paris: OECD, 2004), https://www.oecd-ilibrary.org/economics/space-2030/background-paper-3_9789264020344-10-en.
4. Walter Peeters, "Evolution of The Space Economy: Government Space to Commercial Space and New Space," Astropolitics, Vol. 19, No. 3, 2021, 206–222, https://www.tandfonline.com/doi/full/10.1080/14777622.2021.1984001.
5. Michael Robert Migaud, Robert A. Greer, and Justin B. Bullock, "Developing an adaptive space governance framework," Space Policy, Vol. 55, February 2021, https://www.sciencedirect.com/science/article/abs/pii/S0265964620300424?via%3Dihub; Roger D. Lanius, John M. Logsdon, and Robert W. Smith, *Reconsidering Sputnik: forty years since the soviet satellite* (London: Routledge, Taylor & Francis Group, 2000).
6. Steven J. Dick, *Remembering the space age* (Washington, DC: NASA, 2008).
7. Gil Denis, Didier Alary, Xavier Pasco, Nathalie Pisot, Delphine Texier, and Sandrine Toulza, "From new space to big space: how commercial space dream is becoming a reality," Acta Astronautica, Vol. 166, January 2020, 431–443, https://www.sciencedirect.com/science/article/pii/S0094576519313451?via%3Dihub.
8. Ministry of Defense, "National Defense Policy and National Defense Strategy" (Brasília, DF: Brazilian Ministry of Defense, 2016); Department of Defense, "Defense Space Strategy Summary" (Washington, DC: US Department of Defense, 2020), https://media.defense.gov/2020/jun/17/2002317391/-1/1/1/2020_defense_space_strategy_summary.pdf.
9. Malcolm R. Davis, "Australia confronts a contested space domain and a rising China," Australian Strategic Policy Institute, September 2020, 1–20, https://www.aspi.org.au/opinion/australia-confronts-contested-space-domain-and-rising-china; Xiaodan Wu, "China and Space Security: how to bridge the gap between its stated and perceived intentions," Space Policy, Vol. 33, No.1, August 2015, 20–28, https://www.sciencedirect.com/science/article/abs/pii/S0265964615300023?via%3Dihub.
10. James Clay Moltz, "The Changing Dynamics of Twenty-First Century Space Power," Journal of Strategic Security, Vol. 12, No. 1, 2019, 15-43.
11. Euroconsult, "Euroconsult Projects Government Space Project Budgets to Reach $1 Billion During the Next Decade," Satnews, January 2022, https://news.satnews.com/2022/01/05/euroconsult-projects-government-space-projects-budgets-to-reach-1-billion-during-the-next-decade/.

12. John A. Kennewell and Ba-Ngu Vo, "An overview of space situational awareness," Paper presented at the International Conference on Information Fusion, (Istanbul: 9–12 July 2013), https://ieeexplore.ieee.org/document/6641108; Brian Weeden, Paul Cefola and Jaganath San karan, "Global Space Situational Awareness Sensors," Paper presented at the AMOS Conference, 2010, https://www.researchgate.net/publication/228787139_Global_Space_Situational_Aware ness_Sensors.

13. Everett C. Dolman, *Astropolitik: classical geopolitics in the space age* (London: Frank Cass Publishers, 1st ed., 2002).

14. Brain E. Fredriksson, *Globalness: toward a space power theory* (Montgomery, Alabama: Air University Press, 2006).

15. Robert C. Harding, *Space Policy in Developing Countries: the search for security and development on the final frontier* (London: Routledge, 2012).

16. Michael Sheehan, *The International Politics of Space* (London: Routledge, 2007).

17. Colin Gray, *Modern Strategy* (New York: Oxford University Press, 1999).

18. Colin Gray, *Modern Strategy*.

19. Henry Mintzberg, Joseph Lampel, James B. Quinn and Sumantra Goshal, *The strategy process: concepts, contexts and selected cases* (Porto Alegre: Bookman, 2007).

20. Matthew Mowthorpe and Thomas Kane, *Geopolitical Developments and The Future of the Space Sector* (France: OECD, 2004), https://www.oecd-ilibrary.org/economics/space-2030/background-paper-3_9789264020344-10-en; Daniel Blinder, "Geopolítica y recursos naturales espaciales;" Everett C. Dolman, *Astropolitik*.

21. Daniel Blinder, "Geopolítica y recursos naturales espaciales."

22. Daniel Fiott, *The European space sector as an enabler of European Union strategic autonomy* (Belgium: European Parliament, 2020), https://www.europarl.europa.eu/RegData/etudes/IDAN/2020/653620/EXPO_IDA(2020)653620_EN.pdf.

23. Department of Defense, "Defense Space Strategy Summary," (Washington, DC: US Department of Defense, 2020), https://media.defense.gov/2020/jun/17/2002317391/-1/-1/1/2020_defense_space_strategy_summary.pdf.

24. Romain B. Bosc and Michelle Hermes, "Geospatial technology's Role in The Conflict in Ukraine," GMFUS News, Oct. 2022, 1–5, https://www.gmfus.org/news/geospatial-technologys-role-conflict-ukraine.

25. Engel Pedro Costa, "Dependence on space technology in military operations" (Pedrouços: Institute of Higher Military Studies, 2013), https://comum.rcaap.pt/handle/10400.26/9985.

26. Daganit Paikowsky, "Space Technology, Patterns of Warfare and Force Build-Up: Between a Power and a Small State" (Tel Aviv: Samuel Neaman Institute for Advanced Studies in Science and Technology, 2017), https://www.neaman.org.il/EN/Between-Power-Small-State.

27. Martin N. Sweeting, "Modern Small Satellites-Changing the Economics of Space," Proceedings of the IEEE 106, No. 3, 2018, 343–361.

28. United States, Defense Intelligence Agency, "Challenges to Security in Space," Military Power Publications, Vol. 46, 2019, https://www.dia.mil/Portals/110/Documents/News/Military_Power_Publications/Challenges_Security_Space_2022.pdf power publications/space_threat_v14_020119_sm.pdf.

29. European Space Policy Institute, "Emerging Spacefaring Nations – Full Report," ESPI Report 79, (Vienna: ESPI, 2021), https://www.espi.or.at/wp-content/uploads/2022/06/ESPI-Report-79-Emerging-Spacefaring-Nations-Full-Report.pdf.

30. Organization for Economic Co-operation and Development, *OECD Handbook on Measuring the Space Economy* (Paris: OECD Publishing, 2nd ed., 2022).

31. Bleddy E. Bowen, *War in Space: strategy, spacepower, geopolitics* (United Kingdom: Edinburgh University Press, 2020).

32. I. Sourbès-Verger, *L'espace, Lieu Particulier des Rivalités Politiques et Technologiques,* Revue Défense Nationale, No. 851, June 2022, 73–78.

33. Lucie Sénéchal-Perrouaultand and Liffran C., "La stratégie d'innovation chinoise dans le domaine spatial: les lancements spatiaux chinois à la conquête du marché," Asia Trends, No. 5, 2019; Xavier Pasco, *Le nouvelâ gespatial: de la guerre froideau New Space* (Paris: CNRS Éditions, 2017); Ken Davidian, "Definition of New Space," Mary Ann Liebert, Inc., Vol. 8, No. 2, 2020, 53–55, https://www.liebertpub.com/doi/abs/10.1089/space.2020.29027.kda?journalCode=space.

34. Nikolai Khlystov and Gayle Markovitz, "Space is booming. Here's how to embrace the $1,8 trillion opportunity," World Economic Forum, 8 Apr 2024, https://www.weforum.org/agenda/2024/04/space-economy-technology-invest-rocket-opportunity/.

35. Alicia Cechin and Scarlett Queen Almeida Bispo, "The Chinese rise in the aerospace sector" (Brasília, DF: IPEA Repository, 2022), https://repositorio.ipea.gov.br/handle/11058/11488.

36. Zaaem Shabbir, Ali Sarosh, and Sheikh Imran Nasir, "Policy Considerations for Nascent Space Powers," Space Policy, Vol. 56, May 2021, https://www.sciencedirect.com/science/article/abs/pii/S0265964621000060.

37. Rajeswari Pillai Rajagopalan, "From Earth to Space: India and China's Space Programmes Gear Up for Intense Competition Ahead," Observer Research Foundation, June 2020, https://www.orfonline.org/research/from-earth-to-space-68717/.

38. Rajeswari Pillai Rajagopalan, "From Earth to Space: India and China's Space Programmes Gear Up for Intense Competition Ahead."

39. Rajeswari Pillai Rajagopalan, "From Earth to Space: India and China's Space Programmes Gear Up for Intense Competition Ahead;" James Clay Moltz, "The Changing Dynamics of Twenty-First Century Space Power," *Journal of Strategic Security*, Vol. 13, No. 1, 15–43, 2019, https://scholarcommons.usf.edu/jss/vol12/iss1/2.

40. Rajeswari Pillai Rajagopalan, "From Earth to Space: India and China's Space Programmes Gear Up for Intense Competition Ahead," Observer Research Foundation, June 2020, https://www.orfonline.org/research/from-earth-to-space-68717/.

41. Clea Simon, "Entrepreneurial approach to space exploration," The Harvard Gazette, August 2023, https://news.harvard.edu/gazette/story/2023/08/india-takes-entrepreneurial-approach-to-space-exploration/.

42. Rajeswari Pillai Rajagopalan, "From Earth to Space: India and China's Space Programmes Gear Up for Intense Competition Ahead;" Robert C. Harding, *Space Policy inDeveloping Countries: the search for security and development on the final frontier*.

43. Daniel Fiott, *The European space sector as an enabler of European Union strategic autonomy* (Belgium: European Parliament, 2020), https://www.europarl.europa.eu/RegData/etudes/IDAN/2020/653620/EXPO_IDA(2020)653620_EN.pdf.

44. Bleddy E. Bowen, *War in Space: strategy, spacepower, geopolitics* (United Kingdom: Edinburgh University Press, 2020); Angeliki Papadimitriou, Maarten Adriaensen, Ntorina Antoni and Christina Giannopapa, "Perspective on Space and Security Policy, Programmes and Governance in Europe," Acta Astronautica, Vol. 161, December 2019, 183-191, https://www.sciencedirect.com/science/article/abs/pii/S0094576518303485?via%3Dihub.

45. Joan Johnson-Freese, *Space as a strategic asset* (New York: Columbia University Press, 2007).

46. Peter Anson and Dennis Cummings, "The first space war: the contribution of satellites to the gulf war," The RUSI Journal, Vol. 136, No.4, March 2008, 45–53, https://www.tandfonline.com/doi/abs/10.1080/03071849108445553.

47. Joan Johnson-Freese, *Space as a strategic asset*.

48. Joan Johnson-Freese, *Space as a strategic asset*.

49. Nuno Gonçalo Miguel, "Sistema de Sistemas: o triunfo da tecnologia?" (System of Systems: the triumph of technology?), Nação e Defesa, Vol. 122, No. 4, 2009, 203–217, https://comum.rcaap.pt/bitstream/10400.26/507/1/NeD122_NunoGoncaloMiguel.pdf.

50. Engel Pedro Costa, "Dependence on space technology in military operations" (Pedrouços: Institute of Higher Military Studies, 2013), https://comum.rcaap.pt/handle/10400.26/9985.

51. Carlos Eduardo Valle Rosa, *Aerospace Geopolitics* (São Paulo: Dialética, 27 July 2022).

52. Organization for Economic Cooperation and Development, "Space Sustainability: the economics of space debris in perspective."

53. Richard Crowther, "Orbital debris: a growing threat to space operations," *Philosophical transactions of the royal society a mathematical, physical and engineering sciences,* Vol. 361, No. 1802, November 2002, 157–168, https://royalsocietypublishing.org/doi/10.1098/rsta.2002.1118.

54. Arin Waichullis, "NASA says falling satellite poses a 'risk of harm' on Earth [Update]," Space Explored, April 2023, https://spaceexplored.com/2023/04/21/old-nasa-satellite-falling-to-earth/.

55. Lal Bhavya et al, *Global trends in Space Situational Awareness (SSA) and Space Traffic Management (STM)* (Washington: IDA Science & Technology Policy Institute, 2018).

56. David Frank Winkler and Julie L. Webster, *Searching the Skies: the legacy of The United States Cold War Defense Radar Program* (Illinois: Headquarters Air Combat Command, 1997), https://nuke.fas.org/guide/usa/airdef/1997-06-01955.pdf.

57. Brian Curt Weeden, Paul Cefola and Jaganath Sankaran, "Global Space Situational Awareness Sensors," Paper presented at the AMOS Conference, 2010, https://www.researchgate.net/publication/228787139_Global_Space_Situational_Awareness_Sensors.

58. John A. Kennewell and Ba-Ngu Vo, "An overview of space situational awareness," Paper presented at the International Conference on Information Fusion, (Istanbul, 09–12 July, 2013), https://ieeexplore.ieee.org/document/6641108.

59. Brazil, Ministry of Science, Technology and Innovation, Brazilian Space Agency, "National Policy on Space Activities: 2022-2031," (Brasília, DF: Ministry of Science, 2nd ed., Technology and Innovation, 2023).

60. N. Bobrinsky and L. Del Monte, "The space situational awareness program of the European Space Agency," Cosmic Research 48, n. 5, 2010, 392-398, https://link.springer.com/article/10.1134/S0010952510050035.

61. John A. Kennewell and Ba-Ngu Vo, "An overview of space situational awareness."

62. Sandra Erwin, "Air Force: SSA is no more; It is 'Space Domain Awareness," Space News, 2019, 9-12, https://spacenews.com/air-force-ssa-is-no-more-its-space-domain-awareness/.

63. Sandra Erwin, "Air Force: SSA is no more; It is 'Space Domain Awareness."

64. Flávio Américo, "Multidomain Operations, a perspective," Terrestrial Military Doctrine Journal, Vol. 9, No. 27, July – September 2021, 4-9, https://www.ebrevistas.eb.mil.br/DMT/article/download/8409/7289.

65. Lal Bhavya et al, *Global trends in Space Situational Awareness (SSA) and Space Traffic Management (STM).*

66. Department of Defense, *Space Policy Review and Strategy on Protection of Satellites.*

67. The White House, *National Security Strategy* (Washington, DC: The White House, 2022), https://www.whitehouse.gov/wp-content/uploads/2022/10/Biden-Harris-Administrations-National-Security-Strategy-10.2022.pdf.

68. Department of Defense, *National Defense Strategy of the United States of America* (Washington, DC: US Department of Defense, 2022), https://apps.dtic.mil/sti/trecms/pdf/AD1183514.pdf.

69. N. Bobrinsky and L. Del Monte, "The space situational awareness program of the European Space Agency," Cosmic Research, Vol. 48, No. 5, 2010, 392-398, https://link.springer.com/article/10.1134/S0010952510050035.

70. Brazil, Air Force Command, "Brazil and the U.S. sign a cooperation agreement in the space area," (Brasília, DF: Agência Força Aérea, 2018). https://www.fab.mil.br/noticias/mostra/32598/ESPA%C3%87O%20-%20Brasil%20e%20EUA%20assinam%20termo%20de%20coopera%C3%A7%C3%A3o%20na%20%C3%A1rea%20espacial.

71. Brasil, Comando da Aeronáutica, "Portaria nº 2.102/GC3," Boletim do Comando da Aeronáutica, No. 180, 2018.

72. Brasil, Comando da Aeronáutica, "Portaria Normativa nº 1.691/EMCFA/MD," Diário oficial da União 149, agosto 2015.

73. Theresa Hitchens, "SPACECOM plans: new, unified 'Commercial Integration Office' to work with private firms," Breaking Defense, March 2023, https://breakingdefense.com/2023/03/spacecom-plans-new-unified-commercial-integration-office-to-work-with-private-firms/.

74. Department of Defense, *National security space strategy: unclassified summary* (Washington, DC: US Department of Defense, 2011), https://www.hsdl.org/?view&did=10828.

75. Department of Defense, *Space Domain Awareness,* (Washington, DC: US Department of Defense, 2023), https://www.starcom.spaceforce.mil/Portals/2/SDP%203-100%20Space%20Domain%20Awareness%20(November%202023)_pdf_safe.pdf.

76. NASA, "The intentional Destruction of Cosmos 1408," Orbital Debris Quarterly News, Vol. 26, No. 1, Mar 2022, https://orbitaldebris.jsc.nasa.gov/quarterly-news/pdfs/odqnv26i1.pdf.

77. NASA, "The intentional Destruction of Cosmos 1408."

78. Secure World Foundation, "Global Counterspace Capabilities Report: an open-source assessment," No. 4, 2023, https://swfound.org/counterspace/.

79. Secure World Foundation, "Global Counterspace Capabilities Report: an open-source assessment."

80. Secure World Foundation, "Global Counterspace Capabilities Report: an open-source assessment."

Aluísio Viveiros Camargo

Professor at the Faculty of Economics, Management, Accountancy and Public Management of University of Brasília (UnB). PhD student and researcher at the Center for Advanced Multidisciplinary Studies (UnB) and National Council for Scientific and Technological Development (CNPq), with focus on New Space economics, geopolitics, innovation, and complex project management. He has a master's in economics and a bachelor's in law. His multifaceted professional and academic endeavors have taken him to hold leadership positions at the Brazilian Space Agency and private sector.

Col Marcello Corrêa de Souza, Brazilian Air Force

Graduated Brazilian Air Force Academy in 1996 with a Bachelor of Science in aeronautical sciences. Postgraduate of Naval Postgraduate School in 2018 with a Master of Science in space systems operations. Current serves as Deputy Director of the Brazilian Air and Space Operations Command Planning, Budgeting and Management Center.