The Brazilian Strategic Space Systems Program (PESE): Challenges, Opportunities, and Future Perspectives

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Introduction

Outer space is no longer the final frontier. Unlike the popular imagery fueled by 1960s films, the exploration of new worlds and their possibilities is not a glamorous odyssey, but a vital necessity to humanity itself. Today, a significant amount of human daily activities, to a greater or lesser degree, is intrinsically linked to space applications. This current dependence will only increase in the future as new advances cross the threshold of the information and communication age. Not all governments are prepared or willing to meet this critical societal need—outer space, far from the charms of the imagination, is a frontier of power. Few countries have comprehensive freedom to operate in the field of space technology. Brazil, for the time being, is outside this exclusive group. Thus, the need to establish relations with other countries to create conditions that guarantee preferred results.

In terms of territory, Brazil is a country of continental dimensions. There are more than 8.5 million km^2 of land territory and more than 3.5 million km^2 of exclusive economic zone, with Brazil also claiming the extension of its continental shelf by more than 2 million km^2. Overlying and complementing both territorial extensions is an area of almost 10 million km^2, in the Atlantic Ocean, where the country has agreed, through international agreements, to perform air traffic control and search and rescue missions. In total, there is a land, sea and air area of 22 million km^2, designated by the Brazilian Air Force (FAB) as "Dimension 22," in which the institution exercises the mission of "maintaining the sovereignty of the air space and integrating the national territory, with a view to the defense of the country."[1] The guarantee of autonomy in the use of outer space is essential for the fulfillment of this mission, and therefore the FAB, in coordination with the Ministry of Defense (MD) and other government bodies and institutions, established the Strategic Space Systems Program (PESE) in 2012.

In summary, PESE is a program aimed at implementing space systems to address the needs of the Brazilian MD and Armed Forces, in order to provide dual use products (civil and military).[2] The program is meant to ensure necessary support for joint armed forces operations while generating direct and indirect benefits for society as a whole. By doing so, the Brazilian government intends to put the country at a new level, a global scenario where "few have the managerial, operational, technological and industrial capabilities to make use of space."[3]

PESE forecasts the launch of six constellations of Low Earth Orbit (LEO) satellites and three Geostationary Orbit (GEO) satellites, providing ground observation, telecommunications, geo-positioning, and monitoring capabilities by 2022. Particularly in the military field, the program's developments will serve several systems already in operation, including the Brazilian Aerospace Defense System (SISDABRA), the Aeronautics Digital Link System (SISCENDA), and the Military Satellite Communications System (SISCOMIS). The program will also benefit systems that are currently in the implementation stage, such as the Blue Amazon Management System (SisGAAz) and the Integrated Border Monitoring System (SISFRON).

This article is exploratory in nature, as it addresses a program whose allocation of financial resources and specific initiatives are at an early phase, thus the observations presented hereinafter are incipient and deserve to be further explored by future research. The purpose of this paper is to analyze the challenges, opportunities, and prospects for PESE, particularly with regard to the integration of Brazilian space systems and joint operations between the Armed Forces and their defense systems. There are challenges in the governance of the space sector that directly impact the allocation and management of resources needed to implement the program. Additionally, there are opportunities for the federal government to leverage Brazil's national industrial capabilities in satellites.

This article is divided into three sections. The first section presents the historical background, institutional frameworks, and governance structure of the Brazilian space sector that are directly related to the PESE, thus providing the foundation of the recurring main issues of the Brazilian Space Program (PEB). The second section deals with PESE itself and how it was created, with emphasis on the enactment of the 2008 National Defense Strategy (END), and the evaluation of ongoing and planned actions for the coming years (until 2030). In the third section, this article analyzes the implementation of PESE and its strategic impact on Brazil's defense, security, science, technology, and innovation fronts, in addition to space.

PESE: Historical Background, Institutional Frameworks, and Space Sector Governance

The PESE is a strategic national defense program under the auspice of the FAB. With the promulgation of the first version of the END, in 2008, the Armed Forces underwent a restructuring process to ensure the best fulfillment of their constitutional assignments. The emphasis on modernizing the military apparatus and acquiring technical and operational capabilities guided this process, especially through the revitalization of the national defense industry, as well as its alignment to meet the strategic autonomous needs of the forces.[4] The Navy, Army, and Air Force were required to develop their respective strategic plans, which would later become part of the MD portfolio of strategic national defense programs and of the Brazilian Defense Articulation and Equipment Plan (PAED). Ideally, this portfolio would have guaranteed funding to ensure the continued execution of the actions foreseen in each program.

The PESE reinforces, consolidates, and deepens a set of government initiatives, both civil and military, planned and in progress, related to the space sector. Since the 1960s, with the beginning of the PEB, the Brazilian government has spent considerable effort in this sector. One of the central objectives of PEB is to provide Brazil with autonomy in space activities,[5] and with three strategic axes: "satellites and their applications, launchers and launch centers."[6] In addition, PEB "allows the monitoring and management of its vast national territory; contributes to the mastery of communication and information technologies; enables weather forecasting; and allows the control of air and sea traffic, in addition to the development of new space technologies."[7]

In the 1970s, the Brazilian government set the basis for the first version of the National Space Activities Program (PNAE), which would become one of the main planning instruments related to PEB, later launching the National Space Activities Development Policy (PNDAE),[8] instituted in 1994. The general objective of the PNDAE is "to promote the country's capability, according to its own convenience and criteria, to use space resources and techniques in the solution of national problems and for the benefit of Brazilian society."[9]

Created in 1994, the Brazilian Space Agency (AEB) has as its institutional mission the formulation, coordination, and execution of Brazilian space policy. Two years later, the National Space Activities Development System (SINDAE) was created, in order to systematically organize all activities that affect the space sector, from main government bodies to universities and industries.[10]

The PNAE is currently in its fourth edition and establishes strategic guidelines for the 2012-2021 period. The main guideline that permeates the entire program is to stimulate industrial advancement in the space sector, through increased competitiveness, innovative capabilities, use of the purchasing power of the Brazilian government, and partnerships with other countries. The PNAE emphasizes the need to develop in-depth projects of critical technologies to encourage capability building in the space sector, as well as the importance of having broad participation from academia, industry, and science and technology institutions.[11] One of the priority actions listed in the fourth edition of the document is the achievement of the "capability to launch satellites from our territory."[12] Thus, the PESE complements the PNAE to meet specific military demands,[13] amongst much more comprehensive actions in the space sector.[14]

Besides sector-specific documents, as previously mentioned, the PESE also aligns with the structural documents of national defense—namely the National Defense Policy (PND), the END, and the Defense White Paper (LBDN). The first version of the PND, published in 1996, despite its generic nature, established that Brazil should "seek a level of scientific research, technological development and production capacity in order to minimize external dependency [...] regarding resources of a strategic nature of interest to its defense."[15] To some extent, the 2005 PND, being the second version of the document, discusses further implementation of the previous directive.[16] Neither version of the PND, however, presented specific considerations for the space sector, only general considerations that could be applied in this sector.

The 2008 END started to assign set of guidelines and specific actions to the space sector; defined as one of Brazil's strategic sectors—considered essential for national defense and capable of stimulating the acquisition of capabilities and technologies in partnerships with other countries and in military procurement abroad. Further reinforcing the provisions of sectorial documents (PNAE, PNDAE), as well as PND, it was established that the country should not depend on foreign technology and that the Armed Forces should be able to operate in a network.[17]

The 2008 END became a major milestone for Brazilian national defense, and the following structural documents were conceived to align with its principles. The 2012 END and PND incorporate, for example, the strengthening of strategic sectors, among them, space.[18] The 2016 version of the documents have changed little the priorities for the space sector.[19]

Any considerations about the historical background and institutional frameworks of the space sector in Brazil should be assessed in the context of governance. Essentially, two ministries have responsibilities in the space area, the MD and the Ministry of Science, Technology, and Innovation (MCTI); but these responsibilities are scattered among their respective institutions, particularly FAB and AEB. The dispersion of the responsibilities is reflected in a diffused governance structure, which can generate concurrent and overlapping actions, which fail to optimize space activity efforts.

After the creation of AEB, a first attempt to establish a governance structure in the space sector dates to the creation of SINDAE in 1996. The SINDAE presupposes multi-sectorial governance and counts on a central organ, the AEB, to be responsible for its general coordination.[20] The model also includes sectorial bodies, such as the National Institute for Space Research (INPE) and the Department of Aerospace Science and Technology (DCTA), which are responsible for the coordination and execution of PNAE actions. In addition, the SINDAE also has participating agencies and entities, such as other ministries and secretariats of the Presidency of the Republic, subnational entities, as well as the private sector, in charge of executing specific actions related to the program.[21]

This first effort was quite vague in providing PNAE's responsibilities to the system's component bodies, without specifying what each of them should do exactly. Thus, each actor was able to follow their own path and fulfill their respective missions independently of the system, at most providing information and follow-up on activities, instead of planning, integrating, developing, and implementing them jointly. Thus, SINDAE did not alleviate the space governance problem, as it resulted in "isolation among its actors, causing many of their own decisions to be taken by them with consequent internal friction and conflict."[22]

India, for example, has solved their lack of governance problem by creating the Department of Space (DoS) in 1972. The DoS exists to this day, and it is an Indian governmental department, with a Minister responsible for the administration of the Indian Space Program. The DoS also manages the Indian Space Research Organization (ISRO) and several agencies and institutes related to space exploration and space technologies. This distinct and successful example from India allowed it to join the select group of nations capable of launching missions to Mars using its own launcher, satellite, launch center, and operational facilities.

In Brazil, given the latest version of PNAE,[23] there are few specific considerations of issues related to space applications for national defense, except for the Geostationary Defense and Strategic Communications Satellite (SGDC) and microsatellite and satellite launch vehicles. As observed, SINDAE gives AEB the role of a central agency, to which other agencies should apparently subordinate to. The MCTI, particularly through the AEB, is in fact responsible for the elaboration of the PNAE, but the agency's mission extends beyond it, and includes the formulation, coordination and execution of a general Brazilian space policy, together with the FAB.[24] However, the country does not have such a comprehensive document, and this general policy seems to be the sum of policies, programs, actions, and initiatives of different agencies focused on space.

The most recent developments related to space sector governance seem to suggest the resumption of a more centralized approach under the Presidency of the Republic, and no longer in AEB. In February 2018, the Brazilian government established the Brazilian Space Program Development Committee (CDPEB), through Decree No. 9,279, which would be coordinated by the Institutional Security Office (GSI), linked to the Presidency of the Republic, and composed of the following ministries: Civil House, Defense, Foreign Affairs, Economy and Science, Technology, and Innovation. In a more recent decree, the Attorney General's Office (AGU) was also included as a member of the committee. Accordingly, the central objective of the CDPEB is to set "guidelines and goals for the enhancement of the Brazilian Space Program and supervise the implementation of measures proposed for this purpose."[25]

In addition to a broad rearrangement related to the governance structure of the space sector, it is also noted that sectorial bodies have made efforts to improve the internal management of space activities. The FAB, for example, created the Governance Committee for Space Activities (CGE), which has representatives from the High Command of FAB, and the Executive Committee for Space Activities (CAESP), which has representatives from the FAB General Staff, the Commission for Coordination and Implementation of Space Systems (CCISE – responsible for PESE, as will be further detailed in the next section), the DCTA, and the Institute of Aeronautics and Space (IAE). Within this context, it should be observed that the continued improvement of the internal coordination of space activities will certainly contribute to the enhancement of the Brazilian space sector's multi-sectorial governance.

Finally, still within the framework of the reorganization of the space sector governance, AEB published Ordinance No. 107 on May 13, 2019, through which it established a working group (WG) to update the PNAE for the next decade. This group is composed by representatives of AEB and CCISE and may invite SINDAE entities to participate in the activities. One of the reasons for the composition of this WG was to address the need to integrate PESE into PNAE, harmonizing their respective projects and objectives.[26] This initiative seems promising and tends to make possible, in the future, a more institutionalized treatment of the program. So far, its execution appears to be limited to FAB and MD, although its applications are also of interest to other agencies. Naturally, given that PESE is a national defense program, some information may be confidential and not sharable, but there exists a need to discuss the best way to incorporate it in the governance of the space sector, to make the best use of the efforts made by all the organizations involved.

Considering the information presented, we can conclude that the structuring documents of national defense, as well as space sector documents, since their first versions, presented guidelines that are contemplated in PESE, mainly regarding the opportunities that the program generates for the Brazilian domain of strategic technologies. Additionally, we also observed that the diffused governance structure of the space sector in Brazil might result in difficulties for the implementation of the program, thus creating the need to discuss its integration. In this regard, the following section analyzes PESE itself.

The Creation and Implementation of PESE: Ongoing Actions and Future Paths

After a brief presentation of historical background and institutional frameworks that are directly linked to PESE, as well as the governance of the Brazilian space sector, we now address more precisely the context of the creation of the program. The 2008 END placed on MD, MCTI, AEB, among other bodies, the responsibility to "promote a series of measures aimed at ensuring the autonomy of production, launching, operation and replacement of space systems, through the development of satellites, space access vehicles and ground systems that guarantee access to space in low and geostationary orbits."[27]

Almost a year after the enactment of the 2008 END, the MD published Ministerial Guideline No. 14/2009, through which it placed, under the responsibility of FAB, the definition and development of programs and actions related to the space sector, to be performed in coordination and integration with other forces and the MD itself,[28] focusing on the fulfillment of tasks foreseen in the document.[29] The guideline also established some specific considerations, among which: "the need to [...] conceive or improve the conception of strategic systems that make use of space technology, [...] projecting them in the time span of 20 years."[30]

To conduct activities related to Ministerial Guideline No. 14/2009, the FAB General Staff (EMAER) established the Strategic Space Sector WG, with representatives of the three armed forces, the MD, and the former Secretariat of Strategic Affairs of the Presidency of the Republic (SAE/PR). From the beginning, the MD, together with each of the forces, conceived the integrated use of space systems to ensure interoperability between their respective defense systems (SisGAAz, Sisfron, and Sisdabra). This WG produced a final report detailing sector objectives and strategies, which resulted, among other programs, in the creation of PESE.[31]

PESE was officially instituted by Ordinance No. 224/GC3 of May 10, 2012, which approved the Implementation Guidelines of the Strategic Space Systems Program – PESE. The document assigned the management of PESE to CCISE, created by Ordinance No. 184/GC3 on 17 April 2012. This commission was assigned with the mission of defining and implementing space systems related to national defense, including their orbital elements, and supporting infrastructure. CCISE would have at least three managerial positions (president, vice-president, and technical-operational coordinator) and a WG, appointed by the Commander of the FAB, and could include representatives of the two other forces appointed by their respective commanders.[32]

As previously mentioned, PESE had an initial forecast of launching six constellations of LEO satellites and three GEO satellites. Among the main objectives of the program's execution, its purpose is especially noteworthy:

> provide space infrastructure for the Blue Amazon Management System (SisGAAz), the Integrated Border Monitoring System (Sisfron), the Brazilian Aerospace Defense System (Sisdabra), and the Amazon Protection System (Sipam), among other projects in operation or planning phases. Also, PESE foresees annual launches of satellites – mostly small in size and with a shorter life cycle – aimed at low orbits, in order to reduce launch costs, with the exception of communication and meteorology satellites (geostationary and larger in size).[33]

In 2012, the Brazilian federal government announced the construction of the SGDC and enacted Decree No. 7,769, through which it established the governance structure for this project.[34] The main purpose of the SGDC is to "meet the demand for official strategic communications (civil and military) and support the National Broadband Program (PNBL)."[35] Thus, the satellite operates in two different bands, in order to meet both military and civil demands.

The SGDC has become one of the main projects of PEB and PESE itself,[36] containing three strategic objectives: the development of autonomous satellite communication capability, the promotion of digital inclusion, and increasing the national industry's innovation and technological competitiveness.[37] One of the most emphasized points in the document was the transfer of technology, so that AEB would own the intellectual property of technologies generated under the SGDC.[38] Thales Alenia Space (TAS), a French company, won the bidding for the construction of this first satellite, and Telebras formed a joint venture with Embraer Defense, creating the Visiona Tecnologia Espacial company to carry out space systems integration, which resulted in the launch of SGDC-1 on 4 May 2017.[39]

Other projects were born within the scope of PESE, such as the Carponis, Lessonia, and Atticora Projects. The first established the launch and implementation of "Earth observation satellites with high ground resolution optical sensors", and the second, of "Earth observation satellites with radar sensors."[40] The Atticora Project aims to establish a small satellite constellation in LEO for tactical communications. The construction of the Space Operations Center (COPE) was also another important project included in PESE, although already foreseen in the scope of SGDC, with the purpose of controlling all Brazilian space systems satellites.[41] The SGDC itself integrates the Calidris Project, which consists of satellites in Geostationary Orbit (GEO), for communications.

Although actions resulting from the PESE were in progress since 2013, there were discontinuities in the program, such as lack of allocation of budgetary resources, which resulted in adjustments to the schedule. Thus, the development of the program required the establishment of an explicit institutional framework at a higher level, which occurred through Normative Ordinance No. 41/MD, on 30 July 2018. This ordinance included a general characterization of the program since its creation in 2012, and a detailed description of premises, phases, and products expected for the following years.[42]

There are six classes of products to be developed under PESE: communications, Earth observation, information mapping, positioning, spatial monitoring, and the Space Operation Center. The Carponis, Lessonia, Atticora I, Atticora II, Atticora III and Atticora IV projects were meant to launch and operate fleets of non-geostationary satellites, providing communications services, Earth observation, and information mapping. The Calidris I, II and III projects were to launch and operate fleets of geostationary satellites, providing, in addition to the previous services, positioning. The SGDC-1, for example, is part of the Calidris I fleet. All these projects will compose the Aquila System.[43]

To understand the future challenges which the PESE must cope with, we should also consider the FAB's current situation, as well as the increasing international military presence in space. The FAB was born in the wake of the application of an advanced and innovative technology in the fields of combat: the airplane. This avant-garde feature of the FAB has not been lost over time. On the contrary, in the search for more advanced levels of development and knowledge, the FAB, already in its second generation, developed air navigation routes, flights across the country, and the creation of the aeronautical industry in Brazil. The third generation of the FAB emerged as a natural sequence, thanks to the technological advancement of air vectors, the use of modern weapons, and the consolidation of Aerospace Power in the air environment.

Today, in the first half of the 21st century, the FAB is at the door of yet another significant technological leap, applying Aerospace Power in a challenging environment: outer space. The greater ability to operate in this new Combat Domain can be considered as the beginning of a new generation: the 4th generation of this Force. During the 2016 Olympic Games in Rio de Janeiro, the Space Operations Center Nucleus (NuCOPE) began its operational phase by controlling the payload of the high-resolution Israeli optical satellite EROS-B and, later in 2017, the

Space Operations Center (COPE) started to control the SGDC from Brasília and Rio de Janeiro. After 3 years of SGDC operations in temporary facilities, new COPE facilities were completed in April 2020 in both cities. This opened a new operational cycle for the FAB, now with advanced facilities and with a well-trained team composed of military personnel from the Armed Forces under the command of the FAB, which facilitate an efficient and safe operation of multiple satellites.

This cycle begins at a very opportune moment, as the world is turning to new challenges and military interests in outer space, and where several countries have come to understand that the use of this environment for self-defense is necessary. Brazil, with its physical dimensions and its National Power already has a leading role in several areas in the world and cannot evade the right to occupy its place in the concert of nations involved in space activities.

The FAB seeks to be prepared to advance and deepen its knowledge and capabilities for the best use of Space Power in support of military operations, operating jointly with the other branches of the Armed Forces in the other Combat Domains, such as Maritime, Land, Air, and Cyber. According to General David Goldfein, 21st Chief of Staff of the United States Air Force,

> multi-domain operations is really about thinking through how we penetrate, where we need to penetrate; how we protect what we need to protect inside a contested space; how we persist in that environment for the period of time that we have to remain there. […] Our nation knows how to do that, but that muscle has atrophied a bit. That's why you hear a lot of us talking about this attribute of speed. It's not only speed in executing warfare. It's speed in how we're preparing for warfare. It's speed in how we acquire. It's speed in changing our concept of operations. It's speed in terms of how we develop the leaders of the future. […] Our MDC2 (Multi-Domain Command & Control) structure directing operations will be resilient and operationally agile – General David Goldfein, 21st Chief of Staff of the Air Force – 2018.[44]

In this context, the military facet of PESE should increasingly enable the Armed Forces to take part in the Space Combat Domain with resilience and freedom of action, while reducing the freedom of action of opponents, and promoting unity of operational command, necessary for the execution of the actions of Space Control and Defense in an efficient and resilient way.

Space Control and Defense actions distinguish the military use of Space Power from the mere use of civilian services. Like any military action, Space Control and Defense actions need a command unit to have efficient and effective employment, especially when there are multiple users, with multiple requisitions and scarce resources. They are used in space, or through it, to ensure control and freedom of action in space, within a level of sustainable resilience throughout Brazil. These missions may be carried out alone or together with the other forces in the different domains. They can also be made effective through space coalitions. These missions serve as a deterrent to the actions of possible opponents contrary to national interests. An example of Space Control and Defense action in South America occurred, indirectly, during the Malvinas War (Falklands War), when satellite weather information was denied to Argentines by United Kingdom's allies. Therefore, PESE should provide the necessary support for the doctrinal evolution of military employment in the space environment and serve as the basis for Space Control and Defense missions, considering existing threats in the Space Combat Domain, such as weapons against Space Systems (Antisatellite Weapons – ASATs).

A wide variety of ASATs are available for potential opponents, capable of producing different types of effects, with different levels of technological sophistication and with different levels of demand in terms of the needs of financial and human resources for development and implementation in the field.

ASATs differ in the way they are employed and how difficult they are to be detected/have their location identified. They can be classified into four major groups: kinetic, non-kinetic, electronic, and cybernetic. The effects of these weapons also vary in duration, and may be temporary or permanent, depending on the type of system employed.[45] It should be noted that, in section 14.10.3, the US War Law Manual ratifies the prevailing understanding that Article IV of the Space Treaty prohibits only the use and placement of weapons of mass destruction in orbit and does not prohibit placement of other weapon systems in space. As of this time, the Manual expressly mentions ASAT laser weapons and other conventional weapons, which include suborbital defensive weapons such as the Terminal High Altitude Area Defense system, as weapons free from the prohibition contained in Article IV.[46]

Military activities in outer space, from or in transition to it, have offensive and defensive characteristics that need to be considered by military planners, and can be implemented under the United Nations Charter (self-defense) and the Space Treaty (non-aggression, except for self-defense), in addition to other treaties that can be invoked in conflict situations under international humanitarian law.[47]

This practice in Brazil is in line with other nations that are involved with the Space Treaty in times of peace or war, that interpret the term "peaceful purposes", contained in that Treaty in its preamble and Article IV, as equal to the term "not aggressive." This interpretation also maintains the military presence in outer space consistent with the United Nations Charter and other international standards, which recognizes a state's right to self-defense, guaranteed by its military presence.[48]

Considering that PESE already has some products entering their operational phase, it is necessary to seek a better operational process organization, capable of:

- Properly identifying and integrating civilian and commercial space resources in military operations and national emergencies declared by the President of the Republic
- Maintaining the necessary means for the operation of Space Systems adequate to planned needs, in periods of normalcy, peace, or even in crises or wars, for the fulfillment of missions
- Maintaining the efforts directed at anti-satellite capabilities, including spatial monitoring systems for situational awareness of the Space Domain, providing an integrated alert, notification, verification, and contingency response capability that can effectively react to threats

These three points portray a change in the perspective of Space, going from a phase in which it only supports the increase in efficiency of the other forces to a new role in the battle environment, to guarantee greater effectiveness of military space actions, as well as to optimize the application of products from the space sector, even in crisis situations.

In this new phase, it is necessary for the FAB to evolve, moving from operations aimed at application of science, technology, and innovation and services provided in facilities that today operate in an environment without adversaries, to more dynamic operations focused on the desired effects of military actions, with the integrated use of Space Power for the defense of Brazil—combining military, civil, and even private means, for operation in times of crisis and under threat from rational opponents. It is necessary to avoid fragmentation of efforts, to reduce the vulnerability of the Brazilian Space Systems, establishing an operational focal point in order to pave the way for the creation and evolution of Space Control and Defense missions, and Spatial Support. This operational command unit would facilitate management during crises or in battles involving the Space Domain while integrated with other domains.

Thus, the evolution of PESE entails:

- A need to unify Space Domain actions in a capable unified command, increasing the efficiency and effectiveness of integrated actions jointly with the other four Combat Domains: Maritime, Land, Air and Cyber
- Actions in the Space Domain which affect all forces, from planning to application of products from space
- Current technologies to allow the use of space segment resources not only strategically/operationally, but tactically as well

Currently, the main expectations from PESE for the next few years involve the initial operation of the Carponis system (until 2021), greater technical and operational capability of the Space Operations Center, nationalization of at least 70 percent of LEO satellites and 50 percent of geostationary satellites (until 2025), and economic support to Brazilian national industry.[49] The achievement of these expectations may give Brazil a new political, industrial, technological and operational status regarding the space sector, highlighting the potential contribution of PESE to the Brazilian strategic autonomy and development, which will be further discussed in the next section.

PESE and Brazilian Strategic Autonomy

The domain of space technology is an indispensable condition for any country to increase its strategic autonomy internationally. Such autonomy manifests itself in the political, industrial, technological, and operational environments. Politically, it concerns the sovereignty of the state and its freedom of action and decision-making in relation to other countries. Industrially and technologically, it concerns having a national infrastructure capable of ensuring security and defense, based on a modern and competitive indigenous defense industry. Operationally, it refers to the planning, management, and use of material and technological resources to ensure security and defense, including using military means if necessary.[50] Therefore, the development of PESE will contribute to Brazil's gradual domain of the manufacturing and application of satellite technologies, thus expanding Brazil's strategic autonomy in the world.

Politically, together with other programs related to the space sector, PESE should provide Brazil with full capabilities to place satellites in orbit, independent of political, economic, and military interests of foreign governments. There is a select group of countries that fully dominate the cycle of space activity, from autonomy in launching satellites to effective control of space applications, because there are, above all, restrictions on technology transfer in this area.[51] Among the countries in this group are the United States, China, Russia, and joint initiatives of European Union countries.[52]

The high dependence nature of countries that do not dominate space activities share a notable characteristic. The 2012 PNAE stated, for example, that all of the 40 plus geostationary telecommunication satellites then operating in Brazil were foreign and manufactured abroad, while Brazilian companies produced only ground equipment and antennas for control stations and mobile TV services.[53] Even though Brazil is among the ten countries that have some initiatives in the space sector, it still maintains a marginal position in this area and faces a technological gap when compared to the countries that are in the forefront—notably the United States, China, and Russia.[54] The development of PESE, therefore, can give

Brazil autonomy in space applications, which are indispensable for the full guarantee of security and defense of the country.

In the industrial and technological environment, PESE should leverage the Brazilian space industry (and, by extension, the national production chains directly related to it), increase the competitiveness of the country's economy, and contribute to the promotion of national security and defense. The Brazilian space industry provides high value-added products, far above other industries. Considering the value added of products by weight, for example, the space segment, specifically the production of satellites, can generate US$50,000 per kilogram, which is 50 times more than the value added in the manufacturing of commercial airplanes.

It is also important to point out that there recently has been a major transformation in terms of access to space. A large number of private actors, from large corporations to small companies, have been participating in the development of space applications—thus, the origin of the term "New Space" (referring to the emergence of private space industry). This process leads to new challenges and opens possibilities regarding space activities, including, for example, the potential involvement of small businesses and even startups in the space market. This global trend represents an important window of opportunity for the development of a country's space sector—states need to explore ways to benefit from this new dynamic and build appropriate public policies for it.

The demand for sophisticated technology is what makes the space industry a driver of other industrial segments and other sectors of society, as well as being an integrator of multidisciplinary knowledge.[55] On the one hand, this industrial sector uses the infrastructure (physical, logistics, human assets) available in a country. On the other hand, at the same time it depends on investment in research and innovation to maintain competitiveness and requires a highly qualified and paid workforce capable of occupying high-level jobs at all stages of the production process (design, manufacturing, and after-sales services).[56]

Despite a favorable international environment, the advantages of a strong space industry and the future vision of PESE, Brazil reveals potential areas that remain unexplored. The space segment has generated less than 0.5 percent of the revenues of the Brazilian aerospace industry between 2012 and 2016—reaching 0.09 percent in the last two years of this period. Moreover, most of the country's indigenous national industries do not operate in the final stage of the production chain, that is, the manufacturing of satellite launch vehicles and satellites and the processing of images and satellite information. Instead, they mostly produce inputs, subsystems, and components for satellites and launch vehicles, as well as supplies and services for the launch and operation ground infrastructure.[57]

Specifically addressing the innovation potential of the aerospace industry, most of the assets and services in this segment in Brazil are directed to meet specific demands of institutes such as the INPE.[58] The development of PESE, in turn, extends this demand to other agencies, such as MD, MCTI and the Armed Forces, which can contribute to leverage the satellite industry in Brazil, taking advantage of the potential already existing in the aerospace segment. The specific requirements of the main defense systems, such as SisGAAz,[59] Sisfron,[60] and Sisdabra, could sustain the performance of the satellite industry in the final stage of the production chain and, thus, contribute to the Brazilian independence in the space sector.

Regarding operations, PESE will provide better conditions for planning, management, and employment of material and technological resources to guarantee Brazil's security and defense. The main demands of the Armed Forces and the MD that will be met by PESE are related to the supply of information for defense systems, as observed. These systems reinforce interoperability integrated between the forces and promote the protection of the entire national territory (in maritime, land and air spaces).

In summary, we can observe that PESE will play a fundamental role in the integration of all Brazil's defense systems, as the information coming from satellites and space devices will come from an integrated system, which will feed user systems with a single database. This integration will help the Armed Forces, in coordination with the MD and other federal agencies, to become more interoperable and perform joint operations more successfully. Moreover, the implementation and consolidation of all these defense systems bring greater incentives for the strengthening of the national defense industry, as well as better conditions for the country to achieve strategic autonomy in the development and application of key technologies.

Final Remarks

In order to contribute to the sovereignty of airspace and to guarantee the autonomy in the use of outer space, PESE proposes to provide Brazil with improvement of its operational, technological and industrial capabilities in space. With the launch of the satellites foreseen in the program, the country will be able to count on ground observation, telecommunications and positioning services, contributing directly to national defense, monitoring of its territory and control of air and sea traffic, besides promoting the development of space, communications, and information technologies.

This article sought to present the main characteristics of PESE, as well as its history and future perspectives. It detailed the relevance of its development not only for national defense, but also for the enhancement of science, technology, and innovation applications in Brazil. Currently, the domain of space technologies is a fundamental factor for national sovereignty, so that autonomy in this sector should be treated as a national strategic priority, as indicated by the Brazilian END. The challenges related to the effective implementation of the program and possible directions to be followed for the optimization of its potentialities were also addressed.

Among the main demands of the program's execution is the restructuring of spatial governance in Brazil. Thus, the creation of a centralized body, interministerial in nature and linked directly with the Presidency of the Republic, with the purpose of providing strategic guidelines regarding issues related to space, should be considered. The improvement of governance can also offer greater interoperability among the agencies involved in space activities and optimization of budgetary resources.

Considering the strategic importance of PESE, as well as the various positive outcomes arising from the development of the space sector, we have detailed the importance for Brazil to reach greater capability in its space activities. Furthermore, as different communication, positioning, observation, meteorology services depend on satellites, the development of the space sector is not limited to defense and security issues, but also relates to economic and social ones. The technological spillover resulting from the development of space technologies, which are difficult to import, of high commercial value and innovative potential, is another element that favors the prioritization of space within the scope of national public policies. The dynamics of "New Space" must also be considered in terms of the implementation of PESE and of a comprehensive national space policy. The recent trend of private participation in the space market results in new challenges and opportunities for the Brazilian space sector, opening a number of possibilities for national companies, from large corporations to startups.

It is important to highlight that, in addition to the benefits promoted for national defense and for the technological development of the country, the implementation of PESE contributes significantly in areas of great interest to Brazilian society. The remote sensing infrastructure developed under the program may also be used in support of precision agriculture, environmental disaster prevention, telecommunications, and meteorology. The information provided from imagery collection may also assist public security and environmental protection. Furthermore, the civil applications of PESE collaborate directly with the National Broadband Plan (PNBL), expanding broadband service in the country and allowing this service to reach remote communities. We can thus conclude that the advances provided by the program, in the most diverse fields, directly benefit the development and sovereignty of the country and generate positive changes for society, further corroborating its relevance. Therefore, the development of PESE, as well as issues related to the space sector, in general, should be addressed via state policy, with the necessary and continued resources for the achievement of realistic and well-defined short-, medium-, and long-term objectives. ❑

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