Austral: Brazilian Journal of Strategy & International Relations
e-ISSN 2238-6912 | v.12, n.23, Jan./Jun. 2023 | p.11-39

THE CONSOLIDATION OF THE BRAZILIAN SPACE PROGRAM: CHANGES AND CHALLENGES IN THE THIRD SPACE AGE

Marco Aurélio Chaves Cepik[1]
Jaíne Garcia de Souza[2]
Vanessa Redel Dal-Berto[3]

Introduction

Among all Latin American nations, Brazil was one of the first to develop national space legislation and represents the Latin State that has made the most significant investments in space education in recent decades. Although the development of Brazilian rockets began in the 1950s, the Brazilian experience in the space sector in the last seven decades has suffered from several dilemmas and challenges, despite being considered a regional power (Froehlich et al. 2020).

In addition, Brazil has a geographical advantage that few space powers have: a launch base for space assets in an equatorial position. That is, carrying out launches along the equatorial line makes the object move 500 km/h faster after the moment of its launch, representing a 30% saving in fuel and a great attraction for other States that seek, through cooperation or bilateral

1 Department of Economics and International Relations, Universidade Federal do Rio Grande do Sul. Porto Alegre, Brazil. E-mail: mcepik@gmail.com. ORCID: https://orcid.org/0000-0003-4147-5486

2 Programa de Pós-Graduação em Estudos Estratégicos Internacionais, Universidade Federal do Rio Grande do Sul. Porto Alegre, Brazil. E-mail: jaine.gsouza95@gmail.com. ORCID: https://orcid.org/0000-0001-6625-2313

3 Universidade Nova de Lisboa. Lisboa, Portugal. E-mail: v.redel.dalberto@gmail.com. ORCID: https://orcid.org/0009-0000-5572-1487

agreements, take advantage of this advantage to put its space objects into orbit (Guimarães 2011; Souza 2022).

Given this context, the paper intends to investigate the space program's importance for Brazil's development in the Third Space Age. In addition, it seeks to understand how popularizing the relevance of the Brazilian Space Program (PEBR) would impact its consolidation, generating new capabilities, commercial opportunities, partnership initiatives, and sovereignty considerations. To this end, it seeks to answer the following problem: "*Why is the Brazilian space program stagnant?*"

It starts from the hypothesis that, as observed over these more than six decades of the Brazilian space program, the main reason for its apparent stagnation – and, in a certain way, decay – is the recurrence of false resumptions, resulting in negligible national advances in the field. The space sector has to partner with other space powers to advance in this sector. The growing technological barriers imposed by the great powers that hold the specific know-how regarding certain critical aspects of space technology end up making greater autonomy and less foreign dependence demanding.

In order to fulfill the proposed objective, this article has three sections. The first illustrates a general picture of the strategic importance of outer space and what are the reasons for more and more States to start investing in space assets. The second section presents an overview of the Brazilian space program in this Third Space Age. The third section is divided into two moments, initially illustrating the idea of regional space integration in Latin America and the possible Brazilian protagonism. And finally, specific prospects for Brazil in the space region.

It can be concluded that despite the potential for growth and possible strengthening of the Brazilian Space Program, the country lacks a long-term national space strategic plan that seeks to consolidate the base of any State that has ambitions in the space region: the workforce, infrastructure, economics, and products & innovation. Over the first two decades of the 21st century, it was possible to observe false resumptions in the Brazilian space sector. It resulted in a high dependence on other space powers to acquire the necessary know-how for national space technological development. Despite the situation that the PEBR finds itself to be shared among other emerging space powers, some cases, such as China and India, have become successful. However, contrary to the competitive profile observed in Asia, in Latin America, what prevails cooperation, and for Brazil, fostering regional space integration would result in national strategic advantages and regional ones.

The Growing Relevance of Outer Space to International Strategy

Since the first artificial satellite developed by the Union of Soviet Socialist Republics (USSR) was successfully launched into outer space in October 1957, the space sector has been constantly growing and adapting to new geopolitical challenges. The space question represents the transition in how the States noticed the possibility of obtaining advantages in outer space beyond purely scientific questions, thus enabling the consolidation of the objectives of each State in the intelligence, civil, commercial, and military sectors. This article understands outer space as the environment outside the atmosphere above 100 km from the Kármán Line (Klein 2006; Cepik 2015).

Throughout the Cold War, nations' investments in space assets revolved around three purposes: "establishing military superiority, maintaining national prestige, and gaining strategic independence" (Ribeiro e Vasconcellos 2017, 217). In this way, the legacy of the space race – initially between the United States of America (USA) and the USSR – resulted in a dependence on space-based resources, especially for strategic, tactical, and operational support of wars and conflicts since the 1990s. Because of this, several other emerging countries have decided to invest in technological means to gain access to the space region as India, Iran, South Korea, China, and Brazil. From then on, space is no longer used only for military purposes; a new direction for relations in space. There is an increase in private companies and the number of satellites in orbit for various purposes: telecommunication, espionage, meteorology, and navigation (land, air, and sea), among others (Harvey et al. 2010; Bowen 2020).

In this article, the Space Age has three moments in which the maturation levels of space programs are used as parameters, considering the layers present in the technological space ladder. For Wood and Weigel (2012), the ladder has four points. The first step represents opening a national space agency. The next layer consists of a State with enough know-how to build satellites for Low Earth Orbit (LEO) locally. At the third level, those States that have developed knowledge to the point of locally developing satellites for Geostationary Orbit (GEO) stand out. The last level of the ladder consists of space powers capable of launching satellites and manned missions.

Figure 1: The Space Age

Space Age	Period	Profile

First	1957-1969	The space programs of this era emerge due to pressures related to national security. Marked by the first space achievements of the great powers. From the first object in orbit to the first manned mission.
Second	1970-1990	The moment in which international treaties, agreements, and conventions on the peaceful use of outer space are consolidated. Marked by the rise of new space powers, which began to use the space region as tactical, operational, and strategic support. It was also characterized by the fall of the USSR and the dynamics, to a certain extent, "unipolar in the USA.
Third	2000-2023	The current moment in which the norms related to outer space that was established in the 20th century are challenged. Marked by discussions about space security, the possibility of a space war, the growing protagonist role of private companies in the space region, the militarization of space, and the congestion of satellites and space junk. Also marked by the oscillation between cooperation and competition.

Source: Own elaboration (2023) based on data from Garcia 2022.

The rise of emerging space powers has reinforced competition over cooperation in the space sector. Enjoying the successes of a robust space program means autonomy to the point of not submitting to the political, military, and economic interests of great powers that already have such capabilities for space power. Incorporated to the strategic importance of outer space, one must also consider access to certain positions and regions in space, such as the location of launch sites or even terrestrial orbits (Souza 2022). From the logic in these four moments mentioned above, it becomes easier to highlight the characteristics of the different Space Eras, as shown in Figure 1. One can see the evolution in how the space powers begin to deal with the region in question, to the point of adopting policies, operations, and

investments, especially in elaborating strategies to deal with this new strategic domain. According to Sadeh (2013),

> The purpose of space strategy is to coordinate, integrate, and prioritize space activities across security, commercial, and civil sectors. Without strategy, space activities continue to provide value, but it becomes difficult to identify and execute long-term programs and projects and to optimize the use of space for security, economic, civil, and environmental ends. Strategy is essential for all these ends, and all the more so, since dependence on, and use of, space is accelerating globally and space is integrated in the fabric of activities across all sectors and uses (Sadeh 2013, 1).

That said, it is essential to highlight certain positions and regions in space due to the strategic advantages that a State, organization, or even specific groups can acquire from them – even to the point of being able to shape international treaties or space laws. Inherent to the value of these positions, the space command stands out. Meaning that upon acquiring space command status – which can acquire through presence, coercion, or force – a space power would have "the ability to ensure access to and use of CLOCs when needed to support the instruments of national power" and would also be able to "to prevent or deny the enemy's access to and use of his CLOCs, or at least minimize the most severe consequences an adversary can deliver along them." In short, commanding space reflects how a State manipulates the celestial lines of communication to achieve its civil, military, commercial, and intelligence purposes (Cepik e Machado 2011; Klein 2019, 23).

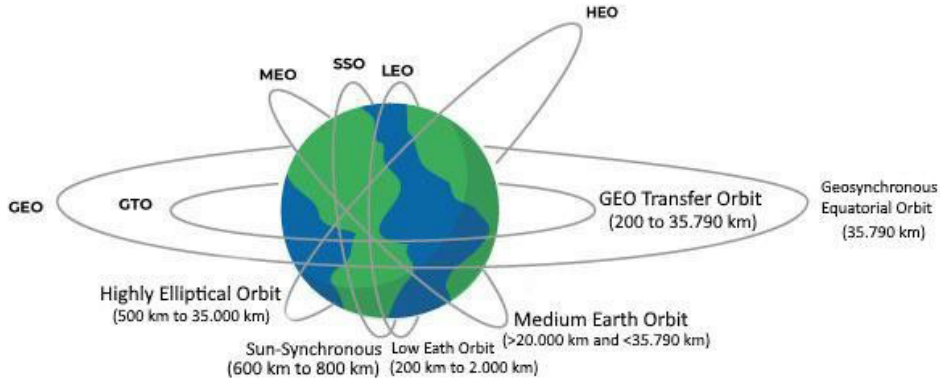
As Klein (2006) illustrates, strategic positions are broader than just considering the military issue since non-military actors also have interests in outer space. Such positions "confer some advantage or have some measure of value and, therefore, diplomatic efforts may be necessary to regulate or limit access to such positions.". In response to the high level of competition for these limited sites, only a select group of countries will succeed in accessing and using these sites and, from them, will achieve political or diplomatic gains because of this advantage (Klein 2006, 80).

Those positions deal with physical communications, moving equipment, spacecraft, or personnel. Those dealing with non-physical communications tend to deal with electromagnetic transmissions and the effects of weapons. Therefore, space activities have choke points: celestial-based crosslinks and downlinks or terrestrial-based uplinks, which transmit and receive data and information. Based on this panorama, the strategic importance of the different orbits in which satellites launch becomes central to future analyses. This article uses six types of orbits as a basis for research,

as shown in Figure 2, namely:

1. Low Earth Orbit (LEO)
2. Medium Earth Orbit (MEO)
3. Geosynchronous Equatorial Orbit (GEO)
4. Sun-Synchronous Orbit (SSO)
5. Highly Elliptical Orbit (HEO)
6. GEO Transfer Orbit (GTO)

Figura 2: Os Tipos de Órbitas Espaciais



Source: Adapted from Souza 2022, 46.

Each location has specific characteristics that help in the success of space missions. Over the last decades, the LEO and GEO orbits are increasingly congested and may even represent a chokepoint. It means that the space power that achieves the best positions in the *space heartland* (LEO and GEO orbits) would be closer to consolidating the space command status, therefore, having the power to the point of influencing economic, political, and security issues (Space Report 2021; Souza 2022).

Currently, the space region has more than 5,000 operational satellites in orbit, with 86% (4,700) in LEO orbit and 10% (565) in GEO orbit. Between 2010 and 2020, there was a considerable increase in state spending on space activities of 18% compared to previous decades. Among the actors that stood out in investments in the space sector, the main ones in 2020 were the United States, ESA, and China. However, the increase in Japan's space budget is also worth mentioning - surpassing Russia, which pointed to a more than 30% reduction. In addition, France's growth in the space economy is evident, surpassing the budgets of India and Germany (Space Report 2021; UCS 2022).

In 2021, the global space economy reached a total of US $469 billion, showing considerable growth compared to 2020, representing a total of US $447 billion. Furthermore, according to data from the Space Foundation (2022), the sector that recorded the highest increase in revenue was the commercial sector, registering 6.4% since 2020. As Cepik (2015) points out, countries increasingly depend on outer space and cyberspace due to the energetic, technological, and demographic structural transition. Given this, emerging space powers' evolution and presence in the space region increasingly impact current astropolitics dynamics as more space programs reach significant maturation levels. This point of view ends up translated into space guidelines developed – and sometimes revised – in recent decades, such as

1. *Russia: "Federal Space Program for 2016-2025", from 2016,*
2. *Paraguay: "Política Espacial del Paraguay," of 2019,*
3. *China: "China's Space Program: a 2021 perspective (White Paper)", from 2022,*
4. *India: "SpaceRS Policy" and "SpaceRS NGP," from 2020, and*
5. *Brazil*: "National Space Activities Program (2022-2031)", from 2022.

All these elements presented throughout this section point to some reasons for a country to start investing in space assets; among these advantages would be: "communication, surveillance, reconnaissance, navigation, meteorology, marketing and anti-satellite weapons (ASAT), the first warning of missiles and rocket launches" (Souza 2022, 63). Based on this reality, it becomes difficult to predict the direction of international relations in outer space when there are still countless questions characteristic of the Third Space Age without answers since such discussions are concentrated mainly among the grand space actors. Also, outer space in the 21st Century re-signifies itself as a new frontier but with an old reality.

The Brazilian Space Program in the Third Space Age

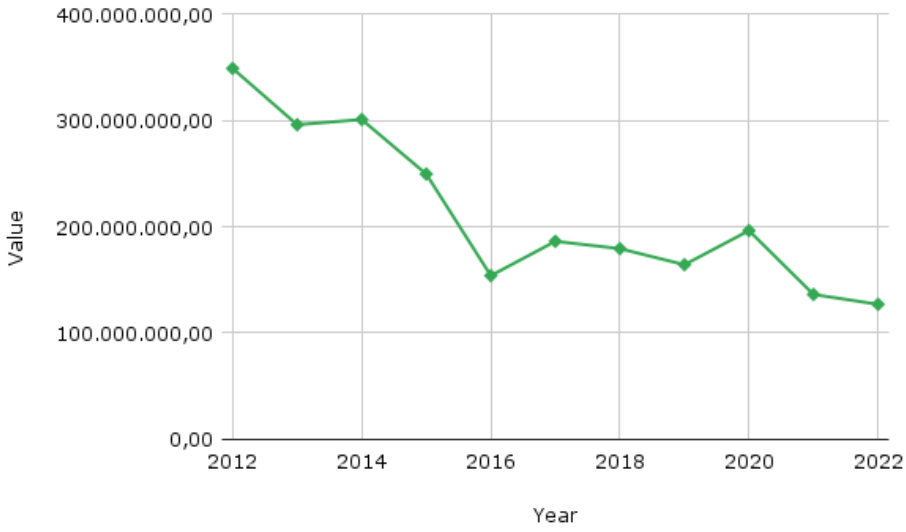
Contrary to what was observed in previous decades, the beginning of the 2000s proved to be optimistic for the Brazilian space sector, as economic growth, the creation of the National Defense Strategy (END), and a more significant effort to adopt a more active foreign policy. In this context, the Brazilian Space Program (PEBR) is now recognized as a strategic project, resulting in the creation and resumption of some projects strongly supported by space assets, such as

1. Amazon Protection System (SIPAM)
2. Amazon Surveillance System (SIVAM)
3. Integrated Border Monitoring System (SISFRON)
4. Blue Amazon Management System (SISGAAZ)
5. Air Defense and Air Traffic Control System (SISDACTA)
6. Military Satellite Communications System (SISCOMIS)
7. Brazilian Aerospace Defense System (SISDABRA)

In response, these systems enable and reinforce border monitoring and the protection and use of data for the various national sectors, especially defense. Given that Brazil is one of the countries that make up Latin America, holding the most extensive land and coastline, holding a great diversity of natural resources, which has in its territory one of the most extensive forests in the world, the Amazon. In addition, abundant water resources and oil reserves in the South Atlantic region demonstrate the need for Brazil to invest in its space program (Cossul 2019; Matos and Ferreira 2020). In order to support all socioeconomic, civil, and military strategic projects, there is a need for a solid basic spatial structure, that is, the complete mastery of space technologies, which can divide into four elements. The first would be a launch base on Brazilian soil, with an infrastructure capable of supporting launches of different types of space assets. The second and third summarized the national production and launch capacity of satellites and launch vehicles. The last element – and the most ambitious to consider, considering an emerging space power – would be the development, command, and control (C2) of an independent national global navigation system (Cepik 2015).

The ambition was to develop three elements mentioned above through the Complete Brazilian Space Mission (MECB) (satellites, launch vehicles, and launch site). However, as Matos (2021, 140, own translation) points out, "the most ambitious projects suffered continuous impasses related to technological embargoes, budget restrictions, and the lack of clarity in the definition of a public space policy.". According to Matos and Ferreira (2020), regardless of the optimistic projections for the Brazilian space sector at the beginning of the Third Space Age, the oscillations in the space budget between 2003 and 2011 pointed to a little advance of the sector in the country. This situation worsened from 2013 onwards, as shown in Figure 3. In the following years, it declined, registering 154 million reais in 2016. In 2017, it reached the highest level compared to the previous year but fell again, reaching 2022 with an average investment of only 127 million in the budget.

Figure 3: Budget of the Brazilian Space Program (2012-2022)[4]



Source: Own elaboration (2023) based on data from Brasil 2022.

The budget destined for the related areas oscillates in grand proportions during its route, and the result is reflected in the capacity to operate the aerospace means. Therefore, when analyzing the budget of the Brazilian Space Program, it is noted that even with the space command's relevant role in the Third Space Age, Brazil still needs to achieve independent access to this region. Many projects need to be on time, postponed, and gaining new deadlines. Most were postponed to the next edition of the National Space Activities Program (PNAE). Projects not finalized in the 2012-2021 PNAE are now included in the new PNAE, which ends in 2031 (Câmara dos Deputados 2010; Brasil 2021).

In summary, the low investment in the development of space assets makes Brazil heavily dependent on other space powers, even more so when the country could be advancing at an increasing pace to the point of seeking new markets. However, it has focused mainly on the development of nanosatellites. The history of failures and cancellations of the Satellite Launch Vehicles (VLS) program reinforces space dependence, so much so that the launch of the *Amazônia-1* satellite, which the Brazilian VLS would carry out, was canceled and, as an alternative, the launch was carried out by India in 2021 (Matos and Ferreira 2020).

4 The data used to elaborate this figure are in millions of reais.

Concerning the launch site, the Alcântara Launch Center (CLA) has become the second best-located space base on Earth for launching artifacts into space. Currently, the base that occupies the best strategic location is represented by the Space Center of Kourou, in French Guiana, under French rule. As illustrated in the previous section, the CLA's strategic advantage is due to its geographical position close to the equator, which saves considerable fuel for the ships. In addition, the climate in this region is stable, allowing launches during a good part of the year. Launching artifacts in all orbits is also possible due to their angle (equatorial and polar orbits) (Brasil 2018; Câmara dos Deputados 2010).

However, the CLA, over time, ended up becoming scientifically obsolete due to the lack of interest on the part of Brazil that it would be necessary to invest in R&D to achieve global scientific and technological advancement. One of the options to encourage such progress would be using the base for private purposes, raising investment to fund Brazilian operations in search of mastery of space operations, and guaranteeing the supremacy of its activities. However, to do so, clear regulations are needed that protect operations on Brazilian soil by states or foreign companies, given that the CLA is, within the country's potential, one of the most relevant strategic assets (Brasil 2019).

From 1985 to 2022, Brazil launched many space objects, many of which were launched with or without foreign partnerships and is described throughout Figures 4 to 6. The country has carried out nearly 50 launches of satellites to the space region, among successful and unsuccessful missions, with launches carried out throughout the Third Space Age reaching a total of 37. The Geostationary Defense and Strategic Communications Satellite (SGDC), for example, was developed in partnership with France and reached Earth orbit in 2017 directly from the Kourou base since, for this type of launch, Brazil did not have the necessary infrastructure for its launch through the CLA (UNOOSA 2022; AEB 2023).This satellite has dual-use (civil and military) under the power of the Brazilian administration, meaning Brazil holds the cryptographic key of the SGDC. It is possible, through the SGDC, to bring broadband to locations that used to be inaccessible previously, in addition to assisting in the monitoring of other Brazilian systems linked to the navy, army, and air force. In this way, Brazilian autonomy with the SGDC allows the country to act with greater sovereignty in managing its military means without interference in data visualization by means external to Brazil. Furthermore, the success of the SGDC emerges as one of the achieved goals of the 2012 PNAE (Marques 2017; Telebras 2018; Redel 2018).

Figure 4: Space Launches of Brazil (1985-2022) – Part I

Name of Sapce Object	Launch	Orbit	Function of the space object	Space Object Type
BRASILSAT A1	08/02//1985	X	Geostationary communication satellite launched from Kourou French Guiana. It was initially ogerated by Embratel and then leased to PANAMSAT in 1995. In March 2002, it was re-orbited, reaching a disposal orbit above the geostationary arc.	Brazilian satellite with a foreign partnership
BRASILSAT-A2	28/03/1986	X	Geostationary communication satellite launched from Kourou, French Guiana, operated by Star One S.A. In March 2004, the satellite was re-orbited in a disposal orbit.	Brazilian satellite with a foreign partnership
MICROSAT 2 (DOVE, *Oscar17*)	22/01/1990	in orbit	The satellite is not registered with the United Nations.	Brazilian satellite
SCD 1	09/02/1993	in orbit	A satellite designed to collect meteorological data transmitted by data collection platforms distributed throughout the national territory	Brazilian satellite
BRASILSAT B1	10/08/1994	X	Satellite dedicated to telecommunication services. In December 2010, it was re-orbited and is now in the disposal orbit.	Brazilian satellite with a foreign partnership
BRASILSAT B2	28//03/1995	GEO	Satellite dedicated to telecommunications services launched from Kourou, French Guiana.	Brazilian satellite with a foreign partnership
BRASILSAT B3	04/02/1998	GEO	Satellite dedicated to telecommunications services launched from Kourou, French Guiana.	Brazilian satellite with a foreign partnership
SCD 2	23/10/1998	in orbit	The primary function of this satellite is Earth observation.	Brazilian satellite
SACI 1	14/10/1999	in orbit	The Sino-Brazilian satellite supports scientific experiments (study of plasma bubbles, observation of abnormal cosmic and solar rays in the magnetosphere).	Brazilian satellite
CBERS 1 (*Zi Yuan 1*)	14/10/1999	in orbit	The Sino-Brazilian monitoring satellite, using optical sensors, of terrestrial resources and remote sensing in Brazil and China	Brazilian satellite with a foreign partnership

BRASILSAT B4	17/08/2000	GEO	The satellite is dedicated to telecommunications services and was launched from Kourou, French Guiana.	Brazilian satellite with a foreign partnership
CBERS 2	21/10/2003	X	It was decommissioned in 2009.	Brazilian satellite with a foreign partnership
Estrela do Sul 1 (*EDS1/ TELSTAR 14*)	10/01/2004	X	In a geostationary orbit, a communication satellite that offered comprehensive coverage throughout Latin America launched from the Sea Launch platform Odyssey. In November 2011, the satellite was re-orbited and is currently in a disposal orbit.	Brazilian satellite with a foreign partnership
AMAZONAS -1	04/08/2004	GEO	Geostationary telecommunication satellite launched from Baikonur, Kazakhstan. It has C and Ku band transponders.	Brazilian satellite with a foreign partnership
CBERS 2B	19/09/2007	X	It was decommissioned in 2010.	Brazilian satellite with a foreign partnership
STARZONE C1	14/11/2007	GEO	Telecommunications satellite launched from Kourou, French Guiana. It operates in the © and Ku bands, belonging to Embratel Star One S.A.	Brazilian satellite with a foreign partnership
STARZONE C2	18/04/2008	GEO	Telecommunications satellite launched from Kourou, French Guiana. Belonging to Embratel Star One S.A., it operates in the C, Ku and X bands.	Brazilian satellite with a foreign partnership
AMAZONAS -2	01/10/2009	GEO	Telecommunications satellite launched from Kourou, French Guiana. Provides service to North and South America, in C and Ku bands.	Brazilian satellite with a foreign partnership
Estrela do Sul 1 (*EDS1/ TELSTAR 14*)	20/05/2011	GEO	Telecommunications satellite launched from Baikonur, Kazakhstan. It was developed to replace the EDS1, but after launch. it had the same flaw as the EDS1, which resulted in only 60% of its total capacity. Provides Ku-band coverage.	Brazilian satellite with a foreign partnership

Source: The authors (2023) elaborated, based on UNOOSA 2022; AEB 2023.

Figure 5: Space Launches of Brazil (1985-2022) – Part II

Name of Sapce Object	Launch	Orbit	Function of the space object	Space Object Type
STARONE C3	10/11/2012	GEO	Telecommunications satellite launched from Kourou, French Guiana. It operates in the C and Ku bands, providing broad coverage throughout South America, Florida (USA), and the pre-salt region.	Brazilian satellite with a foreign partnership
AMAZONAS 3	07/02/2013	GEO	Telecommunications satellite launched from Kourou French Guiana. The launch of this satellite expanded the coverage of the Amazonas-1 satellite services. It has transponders in Ku, C, and Ka bands. In addition, it provides services to several cable TV operators (Vivo TV, CTBC TV, and Movistar IV Digital Latinoamérica).	Brazilian satellite with a foreign partnership
CBERS 3	09/12/2013	X	Satellite successfully launched; however, due to a failure, it became inoperative.	Brazilian satellite with a foreign partnership
AMAZONAS 4A	22/03/2014	GEO	The satellite is not registered with the United Nations.	Brazilian satellite with a foreign partnership
NanoSatC BR1	19/06/2014	em órbita	Technological development satellite aims to collect data from the Earth's magnetic field, especially in the South Atlantic Magnetic Anomaly region (AMAS and the Brazilian sector of the Ionospheric Equatorial Electrojet. It was released from Dombarovsky, Russia, and developed in partnership between UFSM and INPE	Brazilian satellite
CBERS 4	07/12/2014	em órbita	Operational satellite.	Brazilian satellite with a foreign partnership
AESP 14	05/02/2015	X	The second Brazilian CubeSat was developed by the Technological Institute of Aeronautics (ITA) in partnership with INPE, launched by a Falcon 9 v1.1 at Cape Canaveral, USA. Despite the launch's success, after a month in orbit without receiving feedback, AB declared it inoperative due to several failures.	Brazilian satellite

STARONE C4	15/07/2015	GEO	Telecommunications satellite launched from Kourou, French Guiana. It has Ku band operations - and its orbital position is considered hot - and is used by Claro TV.	Brazilian satellite with a foreign partnership in commercial operation.
SERPENS	17/09/2015	X	Third national CubeSat to be launched into space, jointly developed by UnB, UFABC, UFSC, UFMG, IFF, and INPE, with support from AEB. It also had international partners such as the University of Vigo (Spain), Sapienza Università di Roma (Italy), and the US Morehead State University, California State Polytechnic University. With a shelf life of six months, it was possible to collect environmental data on a platform developed by Brazilian students. In March 2016, it disintegrated upon re-entering Earth's atmosphere.	Brazilian satellite with a foreign partnership
Eutelsat 65 West A	09/03/2016	em órbita	It is operated by Eutelsat (linked to ESA), broadcasting and broadband services in Latin America for civilian use.	Brazilian satellite with a foreign partnership
STARONE D1	21/12/2016	GEO	Telecommunications satellite launched from Kourou, French Guiana. It is the first satellite of Embratel Star One S.A.'s fourth generation, with the capacity to cover the South, Southeast, and Northeast regions; and parts of the North and Midwest regions of the country. It is equipped with transponders in C, Ku, and Ka bands.	Brazilian satellite with a foreign partnership
Tancredo 1	16/01/2017	X	Picosatellite was developed by the Presidente Tancredo Almeida Neves school (SP), with the support of INPE, AEB, and the Italian company GAUSS Srl. It was launched from the Tanegashima Space Center, Japan, destined for low Earth orbit. After ten months in orbit, the satellite re-entered Earth orbit.	Brazilian satellite

Sky Brasil-1 (*Intelsat 32E*)	14/02/2017	GEO	Telecommunications satellite, owned by the American company DirecTV, was developed to expand the services of the company Sky Brasil. It has Ku and Ka band transponders.	Brazilian satellite with a foreign partnership

Source: The authors (2023) elaborated, based on UNOOSA 2022; AEB 2023.

Figure 6: Space Launches of Brazil (1985-2022) – Part III

Name of Sapce Object	Launch	Orbit	Function of the space object	Space Object Type
SGDC	04/05/2017	GEO	Communication satellite, whose objective is to provide a safer network for the country's strategic and military communications, under the coordination of Telebrás and the Ministry of Defense. It was launched from Kourou, French Guiana, and has transponders in X (providing internet and communication to the government and the Armed Forces) and Ka bands	Brazilian satellite
AMAZONAS 5	11/09/2017	GEO	The satellite is not registered with the United Nations.	Brazilian satellite with a foreign partnership
SES 14	25/01/2018	GEO	Communication satellite operated by the company SES S.A., launched from Kourou, French Guiana. It has transponders in the C and Ku bands. The data collected by this satellite serve the aeronautical, maritime, and residential markets.	Brazilian satellite with a foreign partnership
Al Yah 3	25/01/2018	GEO	Satellite for telecommunications services and broadband internet.	Brazilian satellite with a foreign partnership
Telstar 19 VANTAGE	22/07/2018	GEO	It was built by Space Systems/ Loral, operated by Telesat Canada, to expand its broadband services via satellite	Brazilian satellite with a foreign partnership
ITASAT	03/12/2018	em órbita	Satellite for technological development.	Brazilian satellite
CBERS 4A	20/12/2019	em órbita	Earth observation satellite.	Brazilian satellite

FloripaSAT-1	20/12/2019	em órbita	CubeSat was developed by SpaceLab at UFSC (Federal University of Santa Catarina) through amateur radio retransmission services, with the primary objective of technological development.	Brazilian satellite
AMAZONIA 1	28/02/2021	em órbita	The satellite is not registered with the United Nations	Brazilian satellite
NanoSatC-Br2	22/03//2021	em órbita	The CubeSat contains two missions: scientific and technological. It was launched from the Baikonur Cosmodrome, Kazakhstan.	Brazilian satellite
STARONE D2	30/07/2021	GEO	The satellite is not registered with the United Nations.	Brazilian satellite with a foreign partnership
ALFACRUX	01/04/2022	em órbita	The satellite is not registered with the United Nations.	Brazilian satellite
CARACÁ I	25/05/2022	em órbita	The Project Lessonia - 1 project launched through the SpaceX Falcon 9 rocket at the Kennedy Space Center, in Cape Canaveral, in the United States. Low-orbit, dual-use satellites of remote sensing radar (SRR).	Brazilian satellite with a foreign partnership
CARACÁ II	25/05/2022	em órbita	The satellite is part of the Lessonia-1 Project and has radar technology for soil monitoring and as an aid in the fight against drug trafficking and illegal mining. This satellite has dual technology, and the region that will benefit most from its monitoring will be the Amazon region.	Brazilian satellite with a foreign partnership
SPORT	26/11/2022	em órbita	Nanosatellite in partnership between the Brazilian Space Agency (AEB) and the North American Space Agency (NASA). with takeoff from Kennedy Space Center (Florida). For scientific research in the ionosphere.	Brazilian satellite with a foreign partnership

Source: The authors (2023) elaborated, based on UNOOSA 2022; AEB 2023.

Other partnerships emerged over the first two decades of the 21st century. They resulted in the creation of other satellites, as in the case of China, and the series of remote sensing satellites (CBERS), which only the

CBERS-4 launched in 2014. Cooperation with Germany, present in the project to develop the Microsatellite Launch Vehicle (VLM), and cooperation with Russia, which seeks, in addition to joint studies for creating a new launch vehicle, a database for testing a liquid propellant rocket engine. Ukraine also proved to be another exciting partner for Brazil in terms of the space sector since both nations reached an agreement that would result in the construction and launch of the Cyclone-4 rocket on national soil; however, this partnership ended in 2015 (Machado 2014; Missagia 2020).

Brazil still does not have a space law, which would be decisive for the regularization of space operations on Brazilian soil. The Brazilian Space Law Code is currently under discussion between the government and the Brazilian Association of Aeronautical and Space Law (SBDA) in the form of a preliminary proposal "on the foundations of the Brazilian legal system applicable to the country's space activities, complemented by national legislation pertinent and the instruments of international law to which Brazil is committed.", in essence, the Spatial Code deals, throughout its text, with issues such as space infrastructure, the private sector, and even remote sensing (Froehlich et al. 2020, 57).

Brazil's strategic plans are under the AEB, which, through the PNDAE, promotes the development of space activities of national interest. Thus, every ten years, new guidelines are promoted by the PNDAE, which is currently in its fifth edition: 2022-2031. The current objectives of the PNAE are aimed at the continuous and stable development of the space sector as a strategic representative for the State. Therefore, to guide the Brazilian space sector, the country currently has the following Strategic Space Objectives (OEEs) (AEB 2022, 16, own translation)

1. Elevation of PEBR's presence in the State's set of priorities
2. Fostering entrepreneurship and the competitiveness of the national productive sector
3. The scientific and technological development that seeks to nurture needs concerning space goods and services
4. A continuous search for sovereignty and elevation of Brazil's autonomy in space activities

Bill 1006/22 was drawn up in 2022, outlining the general rules for institutional means, licensing companies, and authorizing space launches. This law would result in a regulatory framework for space operations, such as using frequency bands and orbital positions, the peaceful use of facilities and machinery aimed at space projection, international cooperation, preservation of the environment, and the performance of the private sector. In addition,

the law develops the proposal for creating the *Brazilian Space Registry* and the *Brazilian Space Cadastre*, which help centralize information, registration of products, services, research, and other information on artifacts. However, the project still needs to be analyzed in terms of a vote so that it will come into force later (Agência Câmara de Notícias 2022).

Therefore, recent Brazilian initiatives can demonstrate an update of Brazilian spatial thinking, by decision-makers, to accelerate the country's aerospace capabilities. However, stagnation remains a challenge to be faced in the coming decades, which is related to the current lack of political coordination and financial resources, exacerbating its deficiencies. An example of this is the projects that were supposed to be completed in the PNAE (2012-2021), and have been transferred to the PNAE (2022-2031).

The Space Sector and Contemporary Brazil

All progress observed in the space program, especially after the military dictatorship (1964-1985), came about through the intention of transforming the country into a medium-sized power. However, this vision of Brazil's projection was fading away with time. Based on the analysis of data about the evolution of the PEBR in the last six decades, it is possible to perceive that, as Machado (2014, 74, own translation) points out, "the Brazilian State as a whole has not yet recognized, until now, that the lines of space communications are strategic infrastructure for the country and that, therefore, command of space is a necessary condition for the realization of the great national strategy.". This section discusses two critical elements that can positively impact the Brazilian space sector. The first deals with regional spatial integration as a critical factor for a pivotal position on the part of Brazil in Latin America; then, from the Brazilian space performance in this Third Space Age, an analysis is made on possible perspectives for the future of Brazil in the space region.

Regional Space Integration in Latin America

Bearing in mind the strategic plan necessary for Brazil to be able to place itself in the sphere of command of space and escape the stagnation it faces, a viable alternative would be to invest more in its relations with the neighboring states of Latin America – the countries considered Latinos are in three different geographic regions of the American continent (North, Central, and South), consisting of a total of 33 nations, covering an area of about 13% of the Earth's land surface. Thus, cooperation can play a significant

role in promoting regional protection. However, the area in question has a late development in space operations and is still very dependent on sensitive technology from the great space powers (Froehlich et al. 2020).

Brazil is currently facing the loss of its leadership profile in the region, which affected the abrupt end of the Dilma government (2006-2011) – due to the impeachment in 2016 –, the Temer (2016-2018) term to the presidency, and the presidency of Bolsonaro (2019-2022)—a period characterized by the internal political and economic crisis, intensified in 2020 by the coronavirus pandemic, which resulted in complex social, economic and political crises in Latin America—resonating together, with the weakening of many of the regional bodies. Furthermore, in Latin America's space arena, reality still points to a dependence on space agencies and industries from other more robust space powers. For example, Mexico, Chile, Argentina, and Brazil have agreements or treaties with NASA, ESA, or even private companies to, based on joint work, obtain sufficient know-how to build satellites, launch space assets, and collect data (Portales et al. 2014).

Among the nations mentioned above, all have a space program; however, these programs have a different investment in space education than Brazil currently has. Furthermore, it can be observed that only two Latin nations are more committed to space activity: Argentina and Brazil. Both nations possess space skills and capabilities, which resulted in possession of earth observation, communication, and science and technology satellites. Peru, Venezuela, Chile, and Mexico only have capabilities in two sectors – communication and Earth observation or technology and education. The nations with know-how in just one sector are Bolivia, Costa Rica, Colombia, Ecuador, Guatemala, Nicaragua, and Uruguay. In contrast, nations with little or no capacity in the space sector are mostly Caribbean states (Froehlich et al. 2020).

Regarding launch capacity to the space region, as mentioned in other sections, some Latin American nations have favorable conditions for launching because they are close to the equator. Despite this advantage, only Brazil and Argentina have developed launch capabilities with orbital and suborbital launch sites. There are also nations with only suborbital launch sites, like Mexico, Peru, and Panama (Froehlich et al. 2020). The space cooperation experience in Latin America in space activities included the creation of spaces for dialogue and reflected on the space issue. It is essential to mention some of them:

1. Space Conference of the Americas (SCA)
2. Central American Aeronautics and Space Association (ACAE)
3. Space Generation Advisory Board (SGAC)

4. Latin American Remote Sensing Society (SELPER)

Unlike other regions, Latin America still needs a specific space cooperation and integration body that would work similarly to the European Space Agency (ESA) or the Organization for Space Cooperation in Asia-Pacific (APSC). Therefore, to change this situation, in 2011, during the meeting of the UNASUR Defense Council, the possible creation of the South American Space Agency (SASA) was discussed. However, there was a significant rejection by Brazil, which argued that this would be an organism with much bureaucracy and little progress. As illustrated by Froehlich et al. (2020, 90),

> The SASA could enable countries to exchange more information on natural disasters and climate change, as well as strengthen actions related to the digital divide or security cooperation. The creation of SASA would reinforce the region and would work as a proactive structure to advance new regional alliances. At the same time, a regional agency that can support a space regional program would guarantee stability to the space agenda when the region faces political and economic fluctuations. (Froehlich 2020, 90).

Another attempt, this time joined by some States, took place in 2021 with the creation of the Latin American and Caribbean Space Agency (ALCE), based in Mexico. Currently, the agency has 19 member countries[5], highlighting Argentina and Mexico, both nations that boosted this project to get off the ground. This creation represents a new attempt – now focused on the space sector – to go beyond the peripheral region label and more, to seek means through *regional space integration* to elaborate strategies that reduce, over time, dependence on robust space powers for launch capability, technologies, and experience. This idea has been maturing for more than a decade.

Once again, Brazil chose not to be part of this regional integration initiative, given that the country showed no interest at the time of the negotiations – Jair Bolsonaro's government (2019-2022). The absence of the most extensive space power in Latin America in this space agency resulted in a low budget for the activities since the contributions were from Argentina and Mexico, resulting in an investment of US$100 million for 2022. In this way, few established institutionalization components remained stagnant after the pandemic without demonstrating continuity of efforts (Santana 2022).

5 At the time of the writing of this article; the following are part of ALCE: Antigua and Barbuda, Argentina, Bolivia, Costa Rica, Cuba, Dominica, Ecuador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Dominican Republic, Santa Lucia, Saint Vincent, and the Grenadines and Venezuela.

Observations and Perspectives for the Future

When examining which countries have three indicators in common – GDP (over US$ 1 trillion), Area (over 2 million km²), and Population (over 100 million inhabitants) – in the year 2022, it is found that only five states are at the intersection of these three indicators: India, Russia, China, United States, and Brazil. It is curious to consider that this group is composed mainly of members of the BRICS and, when highlighting the space capacity of each one, is noted the discrepancy in the levels of maturation of the space programs of these States when compared to Brazil, as well as the space strategy developed and improved in the Third Space Age. The Brazilian space program's maturation level is far below what is expected of a State with such dimensions.

The rise of emerging space powers, especially those from Asia, reinforces the competitive characteristic of outer space, implying a spill-over effect on other issues such as the security dilemma and the arms race. While other space powers invest in building a space station – as is the case with China –in crewed missions, launch vehicles, or even in global satellite navigation systems, Brazil finds itself inert between the production of nanosatellites and space agreements with countries like China, Ukraine, Germany, and the USA, for example. In short, the Brazilian advance in the space sector has not been able to keep pace with the space development of its partners.

Because of this, most of the companies dedicated to space technology in Brazil still need to be more significant. This lack of investment in technology, innovation, and science establishes a delay in the development process of space operations, unlike what was observed in the evolution of the national space sector in other States, as in the cases of South Korea and India, for example. In the Brazilian case, there needs to be a clear national awareness of the importance of investing in outer space and its strategic value, both by State decision-makers and society. This lack of strategic vision leads to short-term public policies, which result in the discontinuation of many projects in the area (Guimarães 2011).

Maintaining the status quo and Brazil's current coma also affect how the civilian population and decision-makers see the Brazilian space program. To a certain extent, it can be stated that the PEBR stagnation ends up being harmful only for Brazil because, in general, the coma situation forces the country to form alliances with advanced space powers since it does not it has the capabilities to promote the security of its vast territory. On the other hand, changing this condition of dependence to greater autonomy would imply

more significant investment and national development of spatial capabilities, freeing itself from the peripheral condition and assuming a more significant role in the international scenario concerning the space region.

It is challenging to find ways to popularize the relevance of the Brazilian Space Program precisely because they are high value-added technologies, and the discussions about it are restricted to academic, corporate, and governmental circles. In Brazil, no popular culture clearly illustrates how outer space supports national interests, whether in peace or war. For example, the national defense systems – SIPAM, SISFRON, SISGAAZ, SISDACTA, and SISCOMIS – need the space environment to achieve interoperability between forces. However, none of this is critical at the national level when the idea linked to investment in the space sector is highly criticized among the civilian population, emphasizing that the amount of money destined for space projects should be reallocated to other sectors (Machado 2014).

As Câmara (2001, 3, own translation) points out, "It is necessary to change the conduct of the space program, to treat it as an industrial program, in which the training of national companies and the synergy between the different sectors are the guiding concerns of the strategy of contracts government.". As seen, therefore, the author's vision exposed more than two decades ago remains the reality of the PEBR and ends up encompassing an even more significant problem, which is the difficulty of Brazil in being able to see its role as a space power - whether focusing only on the projection regional, or possibly aspiring to a more significant role in the international space scene -, and start behaving as such.

There is a clear need for the country to develop more specific and less broad Strategic Space Objectives (OEEs) in order to effectively consolidate the national strategic foundation of the space sector. With that being said, a potential option to overcome the stagnation phase faced by the space program would involve focusing on four key areas. The first area would entail increased investment in Research and Development (R&D) to foster national space technological development and attain mastery over these capabilities. Secondly, within the realm of economic investment, attention should be given to the construction and improvement of infrastructure for centers and units dedicated to the space sector. The third aspect takes into account the growing role of the private sector in the Third Space Era. Consequently, there is a need for the establishment of a "National Space Promotion Center" with the objective of regulating space activities and the use of facilities. This would serve as a means to regulate the relationship between the public and private sectors. Lastly, the fourth point to be raised emphasizes the urgency of a "National Space Law." As mentioned in the previous section, the country lacks a framework to govern space activities. Therefore, the enactment of such

legislation is of paramount importance.

Space technological development and integration with countries in the Global South may represent a first step out of the stagnation that the country currently finds itself in, but also serve as an example, as seen in the cases of China and India. These space powers connect an industrial policy to a vision that values national development through their space programs (Matos 2021). Today, the Brazilian State is still South America's most significant military power; it has a strategic territory (Legal Amazon and the Blue Amazon) with the longest South American border. It also has the second-best base for artifact releases (CLA). Furthermore, together, Latin America, which has one of the regions with the most significant natural strategic diversity in the world, and today is on the margins of global space policies. Therefore, it is necessary to overcome the space scientific backwardness and act in the dynamics of the third space age.

Final Remarks

This article sought to investigate the possible causes of the stagnation of the Brazilian Space Program in the 21st century. For this, it was necessary to provide theoretical and conceptual subsidies on the macro environment of Space Power in international relations. In this way, the Brazilian Space Program's consolidation is still long and challenging. It is possible to verify significant advances, but also frustrating setbacks. An overview of Brazil in the Third Space Age was illustrated in this article.

Investment in science, technology, and innovation must be a strategic priority for long-term national development. Brazil must keep up to date and adapt to constant technological innovations and the demands of the space market, which implies a proactive stance in research and development. Brazil must invest in technical training for the aerospace industry and qualified labor to continue moving forward. In addition, it must seek improvements to its infrastructure and consistent and lasting State public policies, which transcend governments and political parties, so that they leverage its nascent development.

Therefore, given the necessary attributes of a national and regional strategy in the Third Space Age, Brazil has finite capacities to raise national development in space operations alone, given the limitations verified in this article. However, regional cooperation proves to be an essential strategy to overcome national limitations and achieve a more influential role in the challenges of the Third Space Age. Regional collaboration allows sharing of knowledge and resources, sharing costs and risks, and expanding market

opportunities. Thus, joining efforts and transforming their national space policies into more effective regional policies capable of overcoming stagnation and technological restriction could result in a more effective insertion of space resources in disputes around the command of space.

The consolidation of Brazilian space capabilities becomes fundamental, not only for its defense tactics but also for expanding the country's socioeconomic development. Space technology has practical applications in areas such as agriculture, health, safety, environment, and communications, generating benefits for society and progress for the country. Therefore, to overcome stagnation and technological barriers, a joint and coordinated effort is needed from several national actors, such as the government, the aerospace industry, universities and research centers, and society

REFERENCES

Aron, Raymond. Paz e Guerra entre as Nações. Brasília, Edunb, 1986.

AEB. 2022. "Programa Nacional de Atividades Espaciais (PNAE)". https://www.gov.br/aeb/pt-br/programa-espacial-brasileiro/politica-organizacoes-programa-e-projetos/politica-nacional-de-desenvolvimento-das-atividades-espaciais-pndae. Acesso em: 13 mar. 2023.

AEB. 2023. "Objetos Espaciais Brasileiros". https://www.gov.br/aeb/pt-br/programa-espacial-brasileiro/objetos-espaciais-brasileiros. Acesso em: 16 jan. 2023.

Agência Câmara de Notícias. 2022. "Projeto institui marco legal das atividades espaciais no Brasil". https://www.camara.leg.br/noticias/872926-projeto-institui-marco-legal-das-atividades-espaciais-no-brasil. Acesso em: 11 mar. 2023.

Bowen, Bleddyn. 2020. War in space: strategy, spacepower, geopolitics. Edinburgh: Edinburgh University Press.

Brasil. 2018. "O Centro de Lançamento de Alcântara: abertura para o mercado internacional de satélites e salvaguardas para a soberania nacional". http://repositorio.ipea.gov.br/bitstream/11058/8897/1/td_2423.pdf. Acesso em: 07 mar. 2023.

Brasil. 2019. "Conhecendo o Acordo de Salvaguardas Tecnológicas Brasil e Estados Unidos". https://static.poder360.com.br/2019/11/Entenda-o-AST.pdf. Acesso em: 01 mar. 2023.

Brasil. 2022. "Orçamento da Despesa Pública". https://www.portaltransparencia.gov.br/orcamento/despesas?paginacaoSimples=true&tamanhoPagina=&offset=&direcaoOrdenacao=asc&de=2012&ate=2021&orgaos=OR20402&grupo=1%2C2%2C3%2C4%2C5%2C6%2C9&colunasSelecionadas=ano%2Corgaosuperior%2Corgaovinculado%2Cfuncao%2CsubFuncao%2Cprograma%2Cacao%2CcategoriaEconomica%2CgrupoDespesa%2CelementoDespesa%2CorcamentoInicial%2CorcamentoAtualizado%2CorcamentoRealizado%2CpercentualRealizado. Acesso em: 17 out. 2022.

Câmara, Gilberto. 2001. "Programa Espacial: C&T e Desenvolvimento Industrial". http://www.dpi.inpe.br/gilberto/present/cnct_politica_espacial.pdf.

Câmara dos Deputados. 2010. "A Política Espacial Brasileira". https://www2.

camara.leg.br/a-camara/estruturaadm/altosestudos/arquivos/poliespacial/a-politica-espacial-brasileira. Acesso em: 07 mar. 2023.

Cepik, M.; Machado, F. 2011. "O Comando do espaço na grande estratégia chinesa: implicações para a ordem internacional contemporânea". Carta Internacional 6 (jul.-dez.): 112-131.

Cepik, Marco. 2015. "Espaço e relações internacionais". http://professor.ufrgs.br/marcocepik/files/cepik_et_al_-_2015_-_curso_espaco_ri_caderno_estudos.pdf. Acesso em: 28 fev. 2023.

Cossul, Naiane. 2019. "Potencialidade do Programa Espacial Brasileiro para a Integração Regional: aprofundamento da cooperação regional por meio do emprego das tecnologias de informação e comunicação". Revista Videre 11, 21 (jan-jun): 209-225. DOI: 10.30612/videre.v11i21.10131.

Froehlich, A., Soria, D. e Marchi, E. 2020. Space supporting Latin America: Latin America's Emerging Space Middle Powers. Cham: Springer.

Guimarães, Samuel. 2011. "Conferência de Abertura". http://ftp.demec.ufpr.br/foguete/bibliografia/desafios_do_programa_espacial_brasileiro.pdf. Acesso em: 6 mar. 2023.

Harvey, B., Smid, H. e Pirard, T. 2010. Emerging space powers: the new space programs of Asia, the Middle East, and South America. 2ffi ed. Chichester: Praxis Publishing.

Klein, John. 2006. Space warfare: strategy, principles and policy. New York: Routledge.

Klein, John. 2019. Understanding Space Strategy: the art of war in space. New York: Routledge.

Machado, Felipe. 2014. " Estratégia Nacional de Desenvolvimento das Atividades Espaciais do Brasil: Justificativas, Requisitos e Componentes". Dissertação de Mestrado, Instituto de Filosofia e Ciências Humanas, Universidade Federal do Rio Grande do Sul. http://hdl.handle.net/10183/114430.

Marques, Luciana. 2017. "Satélite vai deixar Brasil mais "blindado" contra espionagem, diz ministro da Defesa". www.fiesp.com.br/arquivodownload/?id=228219. Acesso em: 13 mar. 2023.

Matos, Patrícia; Ferreira, Marcos. 2020. "Indústria Aeroespacial Brasileira: especificidades e contrastes entre os setores aeronáutico e espacial". Revista Brasileira de Estudos Estratégicos 12, 23 (jan-jun): 10-35. http://www.rest.uff.br/index.php/rest/article/view/208/170.

Matos, Patrícia. 2021. "Geopolítica e Programa Espacial Brasileiro: da

busca pela autonomia ao acordo de salvaguardas tecnológicas". Revista Brasileira de Estudos Estratégicos 13, 25 (jan-jun): 129-145. DOI:10.29327/230731.13.25-6.

Missagia, Raquel. 2020. "Brasil e Ucrânia no setor espacial: análise da constituição de uma parceria (1997-2006)". Revista Brasileira de História da Ciência 13, 2 (jul-dez): 188-200. https://rbhciencia.emnuvens.com.br/revista/article/view/31/13.

Portales, Carlos et al. 2014. "El hemisferio en transformación: Regionalismo, multilateralismo y políticas exteriores en un entorno cambiante". http://www.cries.org/wp-content/uploads/2014/06/PP-39-web.pdf.

Redel, Vanessa. 2018. "A Importância do Programa Espacial Brasileiro e os Impactos para a Defesa Nacional no Século XXI". Trabalho de Conclusão de Curso, Faculdade de Negócios e Relações Internacionais, Centro Universitário Ritter dos Reis. https://www.gov.br/defesa/pt-br/arquivos/ensino_e_pesquisa/defesa_academia/cmdn/2019/4a_aa_importanciaa_doa_programaa_espaciala_brasileiroa_ea_osa_impactosa_paraa_aa_defesaa_nacionala_noa_seculoa_xxi.pdf.

Ribeiro, Renata; Vasconcellos, Rodolpho. 2017. "Comparative Perspective of the Brazilian and Indian Space Program". Astropolitics 15, 3 (oct): 217-234. https://doi.org/10.1080/14777622.2017.1378960.

Rosental, Simon. 2008. "Tecnologias Sensíveis". Revista da Escola Superior de Guerra 24 (jul.-dez.): 153-167. https://revista.esg.br/index.php/revistadaesg/article/view/280/250.

Sadeh, Eligar. 2013. Space Strategy in the 21st Century: theory and policy. New York: Routledge.

Santana, Christian. 2022. "El despegue de la Agencia Latinoamericana del Espacio". https://www.unav.edu/web/global-affairs/el-despegue-de-la-agencia-latinoamericana-del-espacio.

Souza, Jaíne Garcia. 2022. "Desenvolvimento do Programa Espacial Indiano (1957-2021): do uso civil à aplicação dual". Dissertação de Mestrado, Faculdade de Ciências Econômicas, Universidade Federal do Rio Grande do Sul. http://hdl.handle.net/10183/246462.

Space Foundation. 2022. "Space Foundation Releases The Space Report 2022 Q2 Showing Growth Of Global Space Economy". https://www.spacefoundation.org/2022/07/27/the-space-report-2022-q2/. Acesso em: 10 mar. 2023.

Space Report. 2021. The space report 2021 Q1. Washington: Space Foundation.

Telebras. 2018. "Satélite Geoestacionário de Defesa e Comunicações Estratégicas-SGDC". https://www.telebras.com.br/telebras-sat/conheca-o-sgdc/. Acesso em: 13 mar. 2023.

UCS. 2022. "UCS Satellite Database". https://www.ucsusa.org/resources/satellite-database. Acesso em: 10 mar. 2023.

UNOOSA. 2022. "Online Index of Objects Launched into Outer Space". https://www.unoosa.org/oosa/osoindex/search-ng.jspx?lf_id=#?c=%7B%22filters%22:%5B%7B%22fieldName%22:%22en%23object.launch.stateOrganization_s%22,%22value%22:%22Brazil%22%7D%5D,%22sortings%22:%5B%7B%22fieldName%22:%22object.launch.dateOfLaunch_s1%22,%22dir%22:%22desc%22%7D%5D%7D. Acesso em: 18 out. 2022.

Wood, D. e Weigel, A. 2012. "Charting the evolution of satellite programs in developing countries: the space technology ladder". Space Policy 28 (janeiro): 15-24. Doi:10.1016/j.spacepol.2011.11.001.