Idealizing a Space Cluster in Alcântara, Brazil

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Introduction

During the Cold War, the world was characterized by a strategic-military bipolarity which drove what was known as the *space race*. However, after the fall of the Soviet Union, the US achieved an unparalleled state-of-the-art space infrastructure and has become a global leader in economic, technological, military, cultural and political areas, with many of its institutions and facilities serving as models for other countries. However, the *space race* appears to be returning to the international political scene, with new players such as China, India, the European Union, and private companies taking center stage. Meanwhile Brazil, like most developed countries, relies heavily on space services and products generated by satellites orbiting the Earth, whether for communications, geopositioning, meteorology, environmental monitoring, security, defense, among others.

In the US, three main government institutions are involved in space operations: the United States Space Force (USSF) in the military field, the National Reconnaissance Office (NRO) in the intelligence field, and the National Aeronautics and Space Administration (NASA) in the civilian scientific and technological fields. The USSF and NRO are subordinate to the Department of Defense (DOD), while NASA, a separate agency of the federal government, has facilities in different regions of the country (see Figure 1), as well as partnerships with other countries.[1]

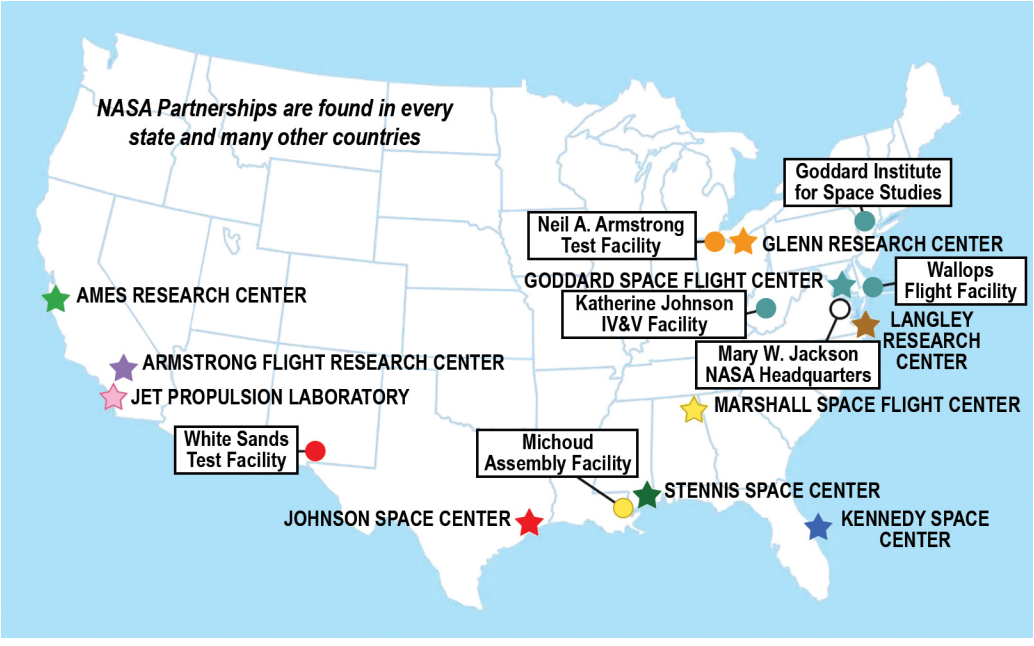

Figure 1: NASA facilities throughout the US

Source: NASA (2023)

In Brazil, however, space operations are divided in a triad slightly different from the US, with the Brazilian Space Agency (AEB—*Agência Espacial Brasileira*) and the National Institute for Space Research (INPE—*Instituto Nacional de Pesquisas Espaciais*) both being civilian bodies of the Ministry of Science, Technology and Innovation, while the Brazilian Air Force (FAB—*Força Aérea Brasileira*) represents the military field as part of the Ministry of Defense.

This article takes a comparative look at NASA's John C. Stennis Space Center (SSC), in Hancock County, Mississippi, as a reference for the development of the Alcântara Launch Center (CLA—*Centro de Lançamento de Alcântara*), in the state of Maranhão (MA), Brazil, with the aim to improve operationalization and strategic relevance as a satellite launching asset.

The SSC, located approximately 70km northeast of New Orleans, is one of NASA's 17 specially dedicated facilities in the US. Established in 1961 as a site for testing rocket engines and propellants, it now also stands out for its use of space resources to study the Earth.[2] In addition to NASA, the SSC is also home to more than 50 local, state, national and international institutions, both private and public.

Using the SSC as a model, this article proposes to create the Alcântara Academic, Industrial, Military and Space Cluster (CAIMEA—*Cluster Acadêmico, Industrial, Militar e Espacial Alcântara*) in Brazil, named after the theoretical concept inspired by Stuart W. Leslie and Rachel N. Weber.[3] According to Weber, the military industrial complex is a network of individuals and institutions involved in the production of weapons and military technologies. The term was first used by US President Dwight D. Eisenhower in his farewell speech on 17 January 1961. For Eisenhower, the "military-industrial complex" included members of Congress from districts dependent on military industries, the Department of Defense (along with the military services) and members of private military equipment corporations.[4] William Fulbright discussed the military-industrial complex associated with scientific academia, a concept further developed by Leslie, who mentioned a defense industry focused on his country's military objectives and supported by public policies specifically aimed at benefiting both.[5]

In deference to Brazil's pacifist tradition and principles, the CAIMEA cluster should be designed in such a way to promote peaceful endeavors, versus just military uses. Thus, CAIMEA would serve to transform CLA into a window to outer space, generating sustainable benefits for all those involved, to include academic, military, industrial, commercial, public and private space institutions, as well as local communities and the environment, by launching space rockets, with their payloads, into Earth orbits.

The South Korean company Innospace marked the beginning of a new era by launching its HANBIT-TLV (Test Launch Vehicle) rocket with a Brazilian payload from CLA's Area 1 (or SISPLAT/VLS) on 19 March 2023.[6] However, it would be advantageous for Brazil to develop an autonomous capacity to launch its own rockets.[7] Thus, CAIMEA encompasses the idealization of the optimum exploitation of CLA's potential by concentrating academic, industrial, military, and other capabilities (such as economics, politics, tourism, environmentalism, and education) in one place, with all of them focused on exploring and gaining continuous access to outer space. To be effective, consensus on the way ahead should be reached between the armed forces, researchers, municipal, state, and federal government organizations, then documented, publicized, and implemented to create the environmental conditions to attract the various government and private institutions suggested here.

This article does not discuss the economic viability or political expediency of implementing the CAIMEA concept, which should be the subject of future studies. Instead, it discusses the possibilities for the inclusion of different public and private entities to idealize the transformation of the current CLA infrastructure

and advance the debate for scientific and technological advancement with the aim of greater national independence and development.

Larry Rohter explains how CLA's location is its greatest virtue.[8] Due to Alcântara's proximity to the equatorial line (2º18' S), rockets launched from there can carry relatively heavier payloads than those launched elsewhere. The Earth's rotational speed is greater at the Equator than in the North and South zones, and the rotation pushes rockets and satellites into orbit more quickly and with less fuel. It facilitates launches from equatorial orbits (in horizontal bands), inclined orbits, and even polar orbits (in vertical bands), including any intermediate trajectory, within launch azimuths from 343º to 90º.[9] This translates into substantial savings for users and a longer service life for the satellites. Brazilian authorities estimate that a launch from Alcântara can be up to 30 percent more efficient than one from Cape Canaveral in Florida, at 28º north latitude. CLA is in a region with low population and aircraft traffic densities. Its northern and eastern launch areas are largely ocean or jungle, which means that, in the event of an accident, debris are unlikely to fall into populated areas. It has stable and favorable weather conditions practically all year round, with a low incidence of lightning, and is in a geologically stable position with no volcanoes or earthquakes. Furthermore, its proximity to the capital of São Luís contributes to the necessary logistical support.[10]

The development of the CLA is critical given the importance of having a fully operational space center for mastering the complete space cycle, namely, the ability to develop, produce, launch, and operate satellites autonomously, a strategic and military objective for Brazil since the publication of its National Defense Strategy in 2008.[11] What's more, CAIMEA has the potential to insert Brazil into the carrier rocket launch business, which is dominated by a growing number of countries and companies. Finally, CLA, among the 22 active spaceports worldwide, has many qualities that could make it the best geolocated space launch center in the world.[12] Because access to space is the privilege of only a few nations, in addition to the European Space Agency, other countries tend to align themselves with those who possess such a launch capability. Thus, a spaceport is attractive from both an economic and political point of view, where a growing number of state and private actors compete.

Furthermore, this article proposes a development model of excellence for the current CLA, which would place it at the forefront of the world's space centers, with CAIMEA emerging as a space cluster in the industrial, scientific, technological, military, commercial and social development aspects, projecting from the local (Alcântara) and state (Maranhão) levels, to the regional (Northeastern), national (Brazil), and even continental (South America), and global levels.

Methodology

To use NASA's SSC as a reference model for the CLA, the *Hard Capacity* model as an index to measure the capabilities needed to build, own and operate space assets and infrastructures connected to them.[13] Within the model, the authors, Marco Aliberti, Matteo Capella, and Tomas Hrzonesky, present a subgroup of comparative indicators between countries that have space capabilities. The one that shows the greatest affinity with the subject of this article is the ground-based space segment, comprised of ground stations, facilities, large mission control centers and launch centers.

An on-site literature review of internal CLA and SSC documents was conducted and cross-referenced with publicly available technical and scientific data to identify advantages of the SSC model that could be adapted to optimize the CLA.[14] Additionally, two participant observers were used as part of this methodology (in lieu of nonparticipant researchers due to the restricted access nature of both the CLA and SSC).[15] At the SSC, in participant observations were carried out during technical training as part of the visiting fellowship program of one of the authors for a period of three months between September and December 2011, totaling approximately 672 hours. It was the in-depth exposure to the operations of this space center that lent to its use as the ideal model for this study (although exposure to other space centers, especially spaceports, would be of benefit as well).

One author has been a full-time observer at CLA since 27 December 2021. The observational and literary data obtained by the two observers was cross-referenced, using qualitative methods, with the work of the other authors ex situ, who have complementary knowledge of the literature and the issues involved.

Based on the observations and literature review, elements perceived as notable SSC advantages were compared with their existence at CLA. Those elements considered lacking at CLA were treated as future CAIMEA capabilities to be developed for the effective transformation of the current CLA into the future Alcântara Space Center spaceport, aiming for operational excellence through the optimal use of the findings and recommendations of this study.

The twelve CAIMEA capabilities to be developed are: Federal City Status; Infrastructure Access; Environmental Responsibility; Private Initiative Facilities; Presence of Government Agencies; Tourism Development; Armed Forces Interoperability; Strategic Defense; Center for Advanced Studies; Space Situational Awareness Center; Rocket Launch and Test Platforms; and Available Geographical Areas.

In addition to using the SSC as a model, this article also recommends literature reviewed solutions from other space centers/ground-based space infrastructures,

as the CLA requires certain capabilities that the SSC does not have. For example, NASA's main space launch center for the US, the John F. Kennedy Space Center (KSC) in Florida, was used as a model for space launches, since the SSC does not perform launches.

NASA Solutions Adaptable to the CLA

A notable difference between the SSC and the CLA is that the former is run by NASA, a civilian agency, while the latter is run by the Brazilian Air Force (FAB). As for CLA's aim to be a space center, the challenge lies in equipping it with the necessary technical capabilities and sufficiently trained personnel to launch space vehicles, especially if Brazil seeks to launch satellites into orbit autonomously.

The following are the solutions observed or inspired by NASA's SSC for the twelve CAIMEA capabilities to be developed previously identified:

1. Federal City Status

The land used for the SSC is considered federal versus state property. As such, it houses various facilities typical of a city, such as a medical clinic, fire department, police, banks, grocery store, kindergarten, gym, gas station and mechanic's shop, but falls under federal versus state government control. These facilities are provided free of most taxes (consisting only of a seven percent state sales tax, collected by the state of Mississippi, with no additional city, county, or other special taxes levied—the US has no federal sales tax).[16] This tax incentive makes the SSC more attractive to its more than 5,000 public and private employees. This lower-cost logistical support also contributes to creating a more pleasant working environment, being recognized by the Partnership for Public Service as one of the best places to work in the US.[17] Thus, the local workforce can count on quality, low-cost and practical services, such as entrusting their young children to the SSC's own daycare center. This urban infrastructure is set in an area of 13,800 acres, surrounded by a 125,000-acre acoustic buffer zone of marshy, river-filled green space (Figure 2).[18] At least two small towns were expropriated from the buffer zone and housing, occupation, and construction in the zone are prohibited.[19]

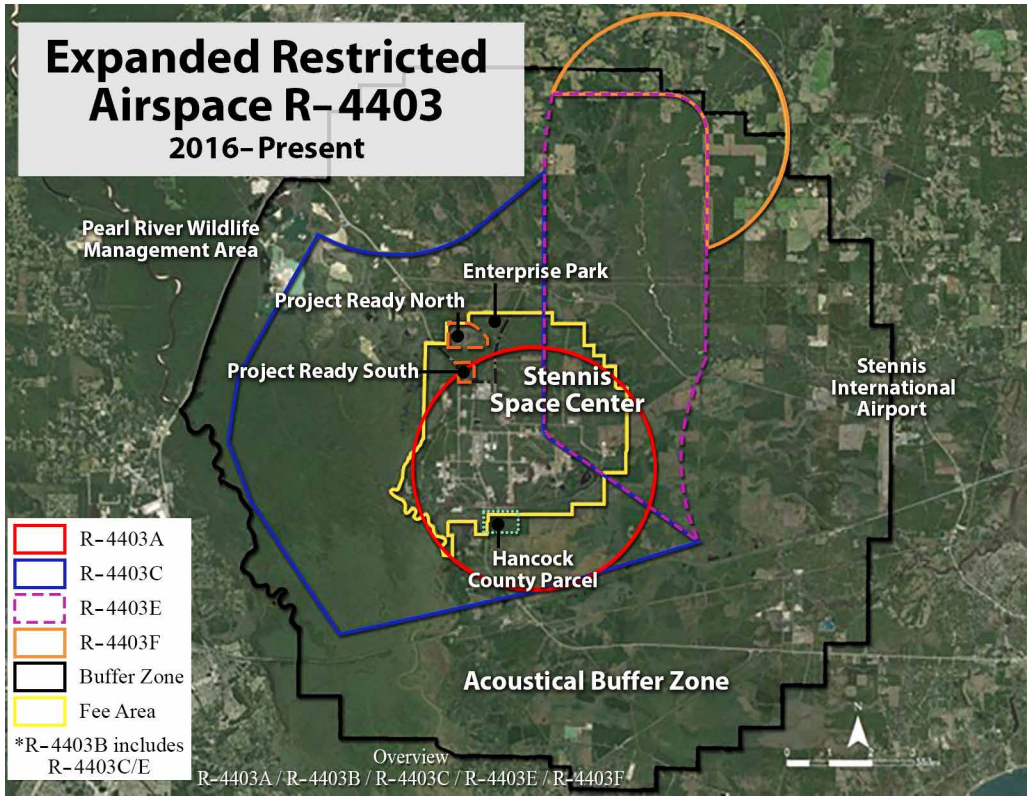

Figure 2: Map showing the SSC. The black line denotes the operational area (13,800 acres), called the Fee Area, while the red line indicates the 125,000-acre noise abatement zone, surrounded by towns in Hancock County, Mississippi.

Source: NASA (2020)

On the other hand, CLA has the status of a military organization linked to the FAB's Aeronautics Command and uses the municipality of Alcântara for command and control, preparation and launch, satellite control, support, and housing and hotels. However, it has its administrative office, medical post, and military village in Maranhão's (MA) capitol city of São Luís, while using the *Sítio da Raposa* station for tracking and technical support, and the *Ilha de Santana* island for payload rescue.[20]

Thus, this study recommends CAIMEA to follow the concept of SSC's Federal City (as the SSC calls its installation), and become a free trade zone, possible under Brazilian law if declared as an extraordinary military readiness and employment requirement.

2. Infrastructure Access

One of the main attractions for population growth and business development is the existence of accessible infrastructure that allows for the efficient flow of qualified personnel, amenities, and logistical support. According to its official website, the SSC is very well served in terms of transportation infrastructure, consisting of: two interstate highways, I-10 from east to west and I-59 from north to south; two major airports within a radius of 80 km: New Orleans and Gulfport; five major maritime ports within a radius of 160 km; and two major railroads within a radius of about 32 km.[21] Additionally, there is a 12-kilometer-long canal system that connects several waterways to the Gulf of Mexico, allowing big shipments to be transported by barge.[22]

On the other hand, one of the biggest obstacles to the development of CLA and surrounding regions in general is the lack of transportation infrastructure. Thus, this study proposes, as part of the CAIMEA initiative, that the Alcântara region be converted to Brazil's only five-modal logistics municipality, bringing together highways, maritime ports, railroads, airport, and spaceport facilities, all connecting directly to CLA and revolutionizing regional and national infrastructure.[23]

The current road structure depends on the BR-135 highway in São Luís and the MA-106 highway, which connect Alcântara to Pinheiro (MA) on a single lane, two-way road with no shoulders. CAIMEA encourages government studies and plans for possible improvements to the MA-106 and proper maintenance of both highways. To increase the region's potential, some of the roads close to the CLA should be built up or refurbished as highway strips, capable of both land vehicles and camouflaged airfield operations. This is a strategic requirement for Brazil, which has added the F-39 Gripen NG fighter jet (which can use highways as runways with a minimal infrastructure) to its FAB inventory. Sweden, its developer, uses this strategy to disperse its air combat force throughout the country in the event of a conflict, making it more difficult for the enemy to detect and destroy. The presence of forests in the CLA region would facilitate the concealment of these fighters, operating from highway strips, as well.[24]

The current transportation from São Luís to Alcântara, which today is mainly done by boat through São Marcos Bay, is slow and exhausting. The great variation in local tides also greatly reduces the daily window of opportunity for crossings. CAIMEA proposes evaluating a land route connecting both towns, either by a bridge or an underwater tunnel. Due to the high investments required for both solutions, it may be advantageous to plan for the cost of adding a train, streetcar or metro line between the two-way lanes, which would act as an alternative for

public and freight transportation, also benefiting urban mobility and the development of the Baixada Maranhense region.

CLA already has an aerodrome and a 2.6 km runway, allowing the operation of Brazil's largest existing aircraft. However, commercial flights are restricted and can only operate from São Luís International Airport, 33.3 km away.

As for maritime routes, the Port of Itaqui, in São Luís (close to two other Private Use Terminals (TUP), Ponta da Madeira and Porto da Alumar, both of which transport minerals), is 29.2 km from the CLA; while 24.6 km away (in a straight line) is the Ponta da Espera Terminal in São Luís, with ferries crossing São Marcos Bay to the Cujupe Terminal, 54 km from CLA. Approximately 23 km away (in a straight line) is the Espigão Ponta D'Areia, in São Luís, which supports watercraft crossing São Marcos Bay to the Port of Jacaré, only six km from CLA.

With regard to rail transportation, Açailândia (MA) is an intersection point for the North-South Railroad, which connects the Port of Santos (SP) to the Port of Itaqui, and the Carajás Railroad, which connects Carajás (PA) to the same port. There is also the Transnordestina Railway, which connects several cities in the Northeastern part of Brazil to the Port of Itaqui.

On a bright note, the private construction of the Alcântara Port Terminal (TPA) on Cajual Island has already been approved. The same infrastructure project includes an expansion of the local rail network, with plans are underway to build a new transport route via the Maranhão Railroad, via a new 540 km railroad line that will leave Açailândia and go as far as Cajual Island in Alcântara. CAIMEA is proposing a feasibility study to extend this rail network to CLA.

In addition to improving the infrastructure for physical access to CLA, there is a need for better information technology infrastructure. Throughout the Alcântara region, the quality of the internet signal is still low and spotty, thus requiring the improvement of its transmission network, whether by cable, radio or satellite; preferably using diverse suppliers to provide greater reliability and promote competition. Access to high-quality internet is vital not only for CLA, which already has its own, more reliable, means, but also for the local population, as computer interconnectivity is essential for both business and entertainment in society. Such an improvement would increase the city's ability to provide an environment conducive for study, work, and entertainment from home, which would attract more qualified personnel for CLA. Additionally, a sub-fluvial fiber optic cable linking São Luís to the CLA is already being laid for this purpose.[25]

3. Environmental Responsibility

NASA's Environmental Assurance Program (EAP), in place at SSC, periodically evaluates the environmental performance of its operations and incorporates

people, procedures and work practices to ensure that environmental impacts are identified and mitigated. The EAP adopts the Environmental Management System (EMS), a model built on "Plan, Do, Check, Act." The four areas are set forth as: Identify environmental impacts and set goals for how to address them (Plan); Implement programs and controls to achieve these goals (Do); Monitor and correct the course of these actions (Check); and review progress, making the necessary changes to the EMS (Act). The EMS consists of six programs: Energy Consumption, Water Consumption, Sustainable Facilities, Remediation, Hazardous Waste, and Solid Waste.[26]

Documents such as the "Draft Environmental Assessment for Launch Complex 48," detail how the US monitors immediate and cumulative environmental and social impacts on landscape, noise, biological resources, cultural resources, air quality, water quality, climate change and rising sea levels, hazardous materials and waste, geology and soil quality, human health and safety, and transportation and infrastructure.[27] The SSC adopts the regulations, licenses, and permissions for the use of restricted and hazardous materials, such as those for radiation procurement and use from its Radiation Safety Committee, as well as those specially developed by its Health Physics Committee. These documents all serve to exemplify how socio-environmental care is not an impediment to the country's strategic need to launch space vehicles.

The SSC buffer zone contributes to the conservation/environmental preservation of 125,000 hectares of marshland and forests around the SSC and functions as an environmental compensation mechanism. The same can be said for the CLA, with the difference that, in addition to the rainforest, a large part of it lies offshore, due to its position on the coast.

Brazil should consider expanding the measures it adopts for the use of restricted and hazardous materials to account for the possibility of equipping spacecraft with nuclear reactors or other hazardous fuels in the future. Establishing the presence of offices representing government environmental bodies such as the Ministry of Environment (MMA) and the Brazilian Institute for the Environment and Renewable Natural Resources and regulatory agencies at the CLA, as in the SSC and KSC models studied, would not create more restrictive mechanisms for research and development of space technologies, but instead would be important agents for monitoring the risks and impacts involved, in order to understand and mitigate them for the advancement of national capabilities in a sustainable matter, without preventing the further development of this gateway to space.

CLA was granted an Operating License (No. 1653/2022 13413478) valid for ten years, according to the Brazilian Federal Official Gazette (DOU) on 15 September 2022, after complying with the environmental requirements demanded

by Brazil's *Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis, Licença de Operação (Brazilian Institute of the Environment and Renewable Natural Resources*).[28] As part of this license, it provides instructions for, and discussions with local communities and agro-villages on environmental concerns and waste recycling. To improve its energy resilience, on 16 June 2023, CLA implemented the Intelligent Electricity Microgrid (Microgrid), a mini solar power plant capable of supplying small towns with renewable and clean energy.[29]

For the safety of the launches, CLA already has the infrastructure to obtain meteorological data, but this could be improved by further incorporating Brazil's *Centro de Previsão do Tempo e Estudos Climáticos* (Center for Weather Forecast and Climatic Studies—CPTEC/INPE) capabilities.

CAIMEA calls for even more to be done in terms of increasing environmental monitoring capability and effective conservation, including raising awareness among the local population. Mastering space launch capacity and maintaining such a spaceport for Brazil and its trading partners is strategic for Brazil, as advocated by the National Defense Strategy and the National Defense Policy.[30] A lesson to be learned from NASA is that both socio-environmental responsibility and strategic need can advance together, neither should be neglected nor made to hinder each other. Socio-environmental responsibility must be constantly observed and continuously improved as Brazil's strategic demands for the use of CLA increases. The space, meteorological and oceanographic research required for its optimum operation also has a lot to contribute to local and global environmental understanding and conservation and the quality of life of the Brazilian and world population. Space sciences are already essential for environmental studies and for the lifestyle of contemporary society, with a tendency to play more and more roles in this regard.[31]

4. Private Sector Facilities

Numerous private sector facilities operate within the SSC, at least four companies (Aerojet Rocketdyne, Lockheed Martin IS & GS Defense Systems, Power Dynamics, and Rolls Royce North America) and 14 contractors, including the defense giant Northrop Grumman. Even outside the SSC, the region is a *high-tech corridor*, home to commercial partners such as Airbus, Boeing, Chevron, GE Aviation, Shell, and Textron. To manage negotiations with private institutions, the SSC established a Strategic Business Development Office, which uses various flexible business models to integrate the services provided by NASA, private partners, and even real estate deals for the use of land or facilities within the space center.[32]

Similarly, the future CLA has the potential to attract and house the industrial and research operations of numerous companies from Brazil's Defense Industrial

Base (BID). By creating tax, legal, real estate, and infrastructure incentives, Alcântara, state of Maranhão state, and federal agencies could join forces to encourage a Brazilian space industrial complex to flourish in Alcântara, integrated with the current aerospace complex in São José dos Campos (in the state of São Paulo). There is precedence for this concept within the Brazilian political structure, as national private partnerships such as AEL Sistemas, Avibras, Grupo Inbra (especially Inbra Aerospace), Embraer, Emgepron, NAV Brasil, Orbital Engenharia, Telebrás, Visiona, already exist, to which companies such as those listed in the Catalog of Brazilian Space Companies should be added as well.[33]

With the recent news that CLA is opening to private launchers, even foreign companies could negotiate the presence of temporary or permanent facilities without harming national sovereignty. In 2022, a partnership between Innospace, a South Korean satellite launcher, and the Department of Aerospace Science and Technology was announced for the launch of an inertial navigation system (SISNAV), with financial support from the Financier of Studies and Projects (FINEP) of the Ministry of Science, Technology and Innovation, and the Brazilian Space Agency.[34] Canada's C6 Launch Systems obtained a license for its first space vehicle launch through CLA, with the first launch expected to take place in 2024.[35] Additionally, US company Orion Applied Science and Technology (AST) has also obtained authorization to implement a universal space services platform and before its bankruptcy auction in 2023, US Virgin Orbit had obtained authorization to test rockets, low Earth orbit satellites, and operate its Boeing 747.[36]

5. Presence of Government Agencies

The SSC is host to several departments from the federal government (equivalent to ministries in Brazil) and, notably, from two states, Mississippi, where the space center is located, and Louisiana, a bordering state, where many SSC employees live and whose nearby towns' economies are dependent on the SSC. Louisiana established the Louisiana Technology Transfer Office and the Louisiana Business & Technology Center to help foster business and research; while Mississippi maintains the Enterprise for Innovative Geospatial Solutions, Mississippi Enterprise for Technology, the Marine Industries Science & Technology Cluster, and the National Oceans & Applications Research Center. Meanwhile, the US Federal Government maintains the Government Publishing Office, the Government Services Agency with its National Center for Critical Information Processing and Storage, and various departments: DOD, with ten military organizations (nine from the Navy and one from the Army), Department of Homeland Security, Immigration & Customs Enforcement, US Citizenship & Immigration Services,

Department of Transportation, Department of the Interior (including the US Geological Survey (USGS) and the Hydrologic Instrumentation Facility), Department of Energy (with the Strategic Petroleum Reserve), and Department of Commerce (with its National Oceanic & Atmospheric Administration (NOAA), National Weather Service (NWS), National Data Buoy Center, National Marine Fisheries Service, and National Center for Environmental Information (NCEI)).

Similarly, CAIMEA aims to create a process that encourages the Brazilian space market to attract more institutions, government bodies, and agencies to have presence with staff and offices of various sizes, depending on their needs, in the CLA.

Either because of CLA's geographical position in São Marcos Bay, right in the middle of the Maranhão coast, or because of Brazil's political condition, with less state autonomy, cooperation between more than one state, as in the SSC, is uncommon and seems unlikely. However, at the city level, intergovernmental cooperation is more prevalent, with São Luís, the state capital, being the city most likely to be logistically integrated with Alcântara to derive mutual benefits from association with the CLA. São Luís can provide part of the qualified workforce that will be increasingly needed, as well as industrial supplies, thus boosting its local economy. Therefore, both municipalities (and potentially others) would be encouraged to cooperate on the implementation of infrastructures and other fiscal and legal measures for regional development, including having their own offices at CLA.

Ministries of the Brazilian government that could be interested in being present would include Defense; Science, Technology, and Innovation; Economy; Environment, Education, Communications, and Foreign Affairs. The Brazilian Space Agency would be the most obvious government agency to need to expand its facilities, even though it already has its Regional Unit in Alcântara. INPE should also require a dedicated CAIMEA support team. Other government agencies with a potential interest in having physical representation at CLA would be the Brazilian Intelligence Agency, the Maranhão State Secretariat for Science, Technology and Innovation, the *Brazilian Institute of the Environment and Renewable Natural Resources,* the Maranhão State Federation of Industries, and the Maranhão State Federation of Trade in Goods, Services and Tourism.

6. Tourism Development

A correctly implemented tourism program can have a positive impact on winning the minds and hearts of populations. The US Space Act of 1958 required NASA to disseminate its activities and results as widely as possible.[37]

To this end, the space agency has an Office of Communications, which disseminates its programs, missions, and centers to the public in the US and around

the world, using marketing strategies in internal and external newspapers, websites, social networks, videos, movies, lectures, events and even its own channel on the YouTube video platform. NASA, maintaining a strong institutional presence on social networks and overseeing the licensing of its products and its exposure in films, have all contributed to building an image synonymous with advanced and reliable science, technology, and innovation and has made its name and logo pop culture icons (even winning the collective imagination of Brazilians).

As part of this effort, its space centers usually have special areas and programs for guided tours and open scientific exchanges. At the SSC, this effort has been operated by a nonprofit organization called the Infinity Science Center, which runs the Visitor Center and promotes visits to the museum, souvenir store and bus tour along a defined route within the space center.[38]

In 2009 NASA invested five million dollars, or 0.026 percent of its budget (compared to civilian companies which normally invest three to five percent of their annual budgets in marketing), for this effort.[39] All these promotion efforts have made it easier for NASA to get funding from the US government throughout the years, as internally it's used by the US government to justify the investment made in NASA to the American public and externally, it serves as soft power, selling the world an image of the US as a benefactor for all humanity.

Brazil could proportionally do something similar: tourism and marketing associated with CLA's activities are initiatives that can do much to increase the visibility of the entire Brazilian space program, giving it prestige, admiration, and popular support. Space tourism and marketing would also help to stimulate the formation of new generations of collaborators, financiers or, at least, supporters.

For example, a framework could be established to provide guided tours of the CLA along predefined routes, perhaps evolving into launching tourists into space in the future. Additionally, the local tourist potential, with the region's tropical coastline, the Amazon jungle, traditional communities, and a rich archaeological heritage, is enormous.[40]

To this end, CLA has established a House of Aerospace Culture in the center of Alcântara, which aims to publicize its activities. The very activity of space exploration is of immense cultural wealth and tourist appeal, but additionally, dinosaur fossils have already been found in Alcântara and the region, raising the real possibility of a slogan "From dinosaurs to outer space" for the local tourism.[41] Ecotourism also presents itself as a sustainable alternative for the development of the region, which combines marine beach and Amazonian landscapes.[42] With a view to the synergy needed to attract national and international tourists, there are half a dozen thematic axes for the development of tourism in Alcântara and the region: historical tourism (colonial/imperial Brazil); space tourism; adventure

tourism; religious tourism (i.e., pilgrimages to Alcantara's churches); dinosaur tourism (especially on Cajual Island); and ecotourism (the native *guarás* birds and wildlife and mangroves).

The Ministry of Tourism may not be physically present at CLA, but it certainly can collaborate with Brazil's National Historical and Artistic Heritage Institute, the Maranhão State Secretariat for Tourism and the Alcântara Municipal Secretariat for Culture and Tourism, the São Luís Municipal Secretariat for Tourism, and the Raposa Municipal Secretariat for Tourism; everyone should be involved in the CAIMEA development plans for the CLA and the region.

Thus, spreading recognition and awareness of the importance of space sciences for everyday life in telecommunications, agriculture, defense, among others, is vital for gaining popular support and consequently political strength, within the state and federal governments, for Brazil's National Space Activities Program.

7. Armed Forces Interoperability

The SSC stands out for having a great partnership with the DOD. At least nine Navy military organizations are present (Commander, Naval Meteorology & Oceanography Command; Navy Detachment Stennis; Navy Facilities Southeast (CNMOC); Naval Oceanographic Office (NAVO); Navy Office of Civilian Human Resources; Naval Research Laboratory (NRL); Navy Small Craft Instruction and Technical Training School (NAVSCIATTS); Navy Special Boat Team 22 (SBT-22) and Naval Special Warfare Center (NSWC), as well as the Army Corps of Engineers. In addition to benefiting from the conventional patrolling of a military base, the space center regularly hosts military training, especially around its buffer zone and navigable canals and the small towns that were expropriated and abandoned when the SSC was founded.

CLA, as a large space rocket launch center, will require land, air, sea, cyber and space defense. This necessitates interoperability between Brazil's three armed forces and joint commands. Even with the CLA subordinated to the FAB, there are great advantages to include the Brazilian Navy (*Marinha do Brasil*—MB) in the CAIMEA project and establish a naval and port facility to transport large space equipment, as waterways and cabotage are usually more viable and efficient than air and land alternatives. According to discussions in the Brazilian armed forces, the MB could be even more active in the CLA if it selects Maranhão for its future Second Fleet Aeronaval Base (*Segunda Base Aeronaval da Frota*—BASE), a name proposed by Bruno Martini & Maria Célia Barbosa Reis da Silva.[43] The island of São Luís is already the favorite destination to host an aeronaval base worth approximately US $600 million for the MB's Second Fleet. [44] Thus, much could be gained in the defense of this geostrategic region by integrating the future

capabilities of the CLA-FAB and BASE-MB. The possibility of using specific areas of the CLA as training grounds for troops from these two forces should also be considered, including special training for commandos, such as MB's Combat Diver Group, Marine Corps Special Operations Battalion (COMANF), and the FAB's Aeroterrestrial Rescue Squadron (PARA-SAR). Ideally, one PARA-SAR and one COMANF unit could be permanently stationed at the CLA and/or BASE in the future, with training specifically tailored for their operational needs.

The Brazilian Army (*Exército Brasileiro*—EB) is also important for CLA's defense capacity, as it is primarily responsible for cyber operations, crucial to the entire security of the complex in the event of an enemy attack. The EB's Cyber Defense Center aims to coordinate and integrate information security systems, intrusion detection programs, hardware for cybersecurity and cyberwarfare laboratories and simulators, stimulating the production of national software such as antivirus, seminars events, and specialized training programs.[45]

8. Strategic Defense

Obviously, this is a critical and classified issue, which makes open source data difficult to obtain. Without violating any security agreements, the experience of working in situ at both the SSC and the CLA by some of the authors provides key areas of knowledge for the purposes of this study. While there are number of military personnel throughout both facilities, there is no overt security, except on access roads or access to certain facilities, such as their respective and remote rocket launch or propulsion test areas. As previously mentioned, the SSC is heavily guarded by US armed forces, especially the US Navy, which, as well as defending it, uses it for various training activities, counterintelligence, and scientific research and technological development (such as CNMOC, NAVO, NRL and NSWC).

A Brazilian space center with full access to space represents a sensitive national security area needing to be defended, thus requiring tactical and strategic point-defense, with necessary lethal weapons systems to defend against armed conflicts and non-lethal ones to prevent civilian attacks. CLA's point-defense should be part of EB's strategic installation Protect Program (PROTEGER). It would also be important to list CLA as one of the priority areas to have its coastline and adjacent open sea well monitored by a sophisticated network of sensors from the MB's Blue Amazon Management System.

As per Filipe Ferreira da Veiga & Humberto Lourenção, armored vehicles, important for the defense of airfields, should be used to defend a spaceport.[46] Armored vehicles such as the Guarani and the Light Multirole Vehicle (LMV-BR) with its automated machine gun turret are options available for patrol and defense. Light Airborne General Purpose Vehicles (Gaúcho) could also be used for patrols

and parachute launch training exercises. Deployment of short and medium range anti-aircraft defense systems already in the Brazilian arsenal should also be considered. The CLA should be included among the priority facilities involved in Brazil's ongoing studies for an optimal long-range defense system, as the CLA's is strategically located for defense against incoming aeronaval threats from either the Caribbean, North America, or Europe. Equipping the CLA with an over-the-horizon radar would be advisable, to be operated for the dual purpose of monitoring space objects launched at acute angles and for long-distance surveillance of threats. Additionally, an anti-ship capability would also be desirable, either by land-to-sea missiles, or aircraft with air-to-sea missiles, such as the Super Cougar helicopters in the AH-15B anti-ship attack version.

All this defense infrastructure would be more feasible with the creation of MB's Second Fleet and BASE in Maranhão. In this case, the CLA-FAB and the BASE-MB would become strong candidates to receive a squadron of fighter planes. In addition to its headquarters at Campo Grande Air Base, PARA-SAR could establish a second base at the CLA.

9. Alcântara Center for Advanced Studies (CEsAvAl)

The SSC's Center for Higher Learning functions as a consortium of universities offering employees and the local community the opportunity to enhance their careers, with most courses usually at the graduate level. It has advanced campuses with classrooms and laboratories at Mississippi State University, Pearl River Community College, the University of Mississippi, the University of New Orleans, and the University of Southern Mississippi. There are non-academic courses and academic graduate programs not only in space sciences, but also in marine sciences, computer technologies and other multidisciplinary fields, with the ability to develop on-demand courses with in-person or online classes.[47]

This model could be emulated at CLA, with the proviso that Brazil's federal and state universities are free, while in the US they are for profit, only offering discounts of around 25 percent for SSC employees. Therefore, on one hand, study opportunities would become even more attractive at CLA, while on the other hand, they would burden the budgets of the public universities involved. For this reason, in addition to the Federal University of Maranhão (UFMA), the State University of Maranhão (UEMA), the Federal Institute of Education, Science and Technology of Maranhão (IFMA) Alcântara Campus, and the State Institute of Education, Science and Technology of Maranhão (IEMA), it might also be convenient to incorporate private universities that offer discounts, scholarships and student financing for the space center employees. Universities from outside Maranhão would also be welcome, especially the FAB's Technological Institute of

Aeronautics (ITA). Institutions with recognized courses and researchers in the areas of space and defense should also be encouraged to set up campuses at CLA, such as the National University of Brasilia (UNB), the University of São Paulo (USP) and many others across the country. These efforts would foment agreements for research of interest to CLA and internship programs.

The feasibility of these efforts was further advanced when CLA was declared a Scientific, Technological and Innovation Institution (ICT) in 2007.[48] Since then, the CLA has signed agreements for Space Engineering Internship Grants with UFMA, published in the DOU on 25 April 2022, and with UEMA, for technical and scientific exchange in engineering, published in the DOU on 9 June 2021.

Ideally, these educational institutions could also work together as a consortium, coordinating their efforts around a Center for Advanced Studies in Alcântara (CEsAvAl). The CEsAvAl could have courses in space sciences, technology, the environment (including oceanography and atmospheric sciences), engineering, information technology, anthropology, and archaeology (for example, to study the culture and history of traditional communities, such as the indigenous and the African descendants who long-escaped from slavery in Brazil, the "*quilombolas*"), paleontology (to study local fossils), space economics, as well as more technical courses such as languages (especially English and Spanish), computing, tourism, entrepreneurship, and other cultural courses (such as art, cooking and handicrafts). CAIMEA foresees the ability to offer special quotas on certain courses offered for local traditional populations (such as *quilombolas*) if they express such interest. Additionally, Brazil's S System (made up of nine corporate institutions created by the federal government), could be a partner in professionalizing part of the local workforce, through the National Industrial Apprenticeship Service (SENAI), Industry Social Service (SESI), Brazilian Micro and Small Business Support Service (SEBRAE), National Commercial Learning Service (SENAC), Social Service of Commerce (SESC), National Rural Apprenticeship Service (SENAR), National Cooperative Apprenticeship Service (SESCOOP), National Transport Apprenticeship Service (SENAT), and the Social Transport Service (SEST).

CEsAvAl could also create activities to involve teachers and students. Suggested measures include training courses for teachers, guided tours for schools, rocket launch competitions, lectures by CLA professionals in schools, and community involvement with the House of Aerospace Culture. As CLA is now an ICT, it could foster a laboratory with the structure to enable engineering students to develop start-ups in the space field.

The SSC also promotes a Small Business "Boot Camp" Project, where it brings the student community, small business owners and other segments of society to its facilities for a few days to learn about funding opportunities, project submission,

use of patents, and many other opportunities provided by NASA and the companies and government institutions present there.[49] CLA can find its own profile to carry out similar activities to increase the engagement of society and promote the development of both.

10. Brazilian Space Situational Awareness Center

The SSC does not have a structure specifically dedicated to space situational awareness, as the infrastructure the US has spread across many other regions of its territory and the world. Known as Space Domain Awareness (SDA), the US uses a system of ground, in-orbit, and cyber sensors capable of "rapidly detecting, alerting, characterizing, attributing and predicting threats to national, allied and commercial space systems."[50] Figure 3 shows the main sites for this US ground network, which in 2017 was still called the US Space Surveillance Network.[51] The ground infrastructure for monitoring objects in space relies on optical telescope systems and specialized radar systems. Thus, CAIMEA should establish a Brazilian Space Situational Awareness Center operating in combination with analogous systems from partner nations and companies, and which could also serve local education and tourism.

Figure 3: US SDA primary sensors and operation centers in 2017

Source: Eun-Jung Choi et al. (2017)

Space situational awareness can be subdivided into space weather, the tracking of objects of anthropic origin and non-anthropic space objects. The study of space weather allows observations to be made of weather conditions in the region, feeding archive databases, providing testing models, making space weather forecasts, and issuing alerts to operators and users of its services. The tracking of non-anthropogenic near-Earth objects detects, catalogs, and identifies the trajectory

and speed of objects such as asteroids and comets, estimating their risk of colliding with Earth. Tracking anthropogenic objects aims to identify active and inactive satellites and orbital debris in terms of their origin, original purpose, capabilities, and trajectories and is essential for the security of space operations.

Depending on Brazil's needs and interests, sensor arrays can form various systems for monitoring not only the Earth's outer layers, such as the ionosphere, magnetosphere, and thermosphere, but also the Sun, solar wind, solar storm, coronal mass injection, cosmic rays, and radiation levels. There is already a rocket tracking and telemetry structure in Maranhão, installed in Alcântara and Raposa. However, more powerful equipment such as radio telescopes, radars, and Satellite Laser Ranging should be deployed at CLA to track objects in space. Depending on demand, a support structure can be provisionally installed in Santana or Barreirinhas (MA).

11. Rocket Launch and Test Platforms

The SSC has three complexes and five platforms (A-1, A-2, B-1, B-2, and E) used for testing rocket propulsion and its components (none intended to carry out space launches). Meanwhile, the KSC has six launch pads (LC-37, LC-39A, LC-39B, LC-39C, LC-40 and SLC-41), with only Launch Complex 39 (with its A, B and C pads) being exclusive to NASA and the other three leased to the private sector (KSC has 90 private partners).[52]

CLA calls for at least two state-owned launch platforms capable of modular and independent operations (mainly for redundancy). For safe testing, some additional platforms may be needed as well. Ideally, there should be at least two test platforms, one to simulate the operation of the thrusters at sea level, and another simulating their trajectory in space at an altitude of around 60,000 feet.

At CLA, the Mobile Integration Terminal (TMI) is under national control, with the South Korean company Innospace terminal nearby.[53] There are also plans to set up another terminal, C6, for additional companies to have their own leased launch terminal inside CLA.[54]

Additional zones should be established for the potential future implementation of alternative and innovative logistics for space launches, such as the "centrifuge-spinning sling" (a concept from US startup SpinLaunch), a space elevator, or an electromagnetic ballistic projectile launcher.

12. Available Geographical Area

In the 125,000-acre area of the SSC (see Figure 2), the towns of Gainesville and Logtown were expropriated and have become ghost towns used for military train-

ing and accessible only by authorized personnel, only 13,800 acres (55.847 km^2) have been available for installation use. KSC has a total area of 6,000 acres (24.281 km^2), but only 140.850 acres (0.57 km^2) of usable area. Meanwhile CLA has 22,733 acres (92 km^2) and plans to expand to 53,869 acres (218 km^2). The greatest geographical competitor, the Kourou Space Center in French Guiana, has 20,767 acres (84 km^2).

The use of the land by the current CLA presents a conflict of interest with the *quilombola* communities (the same applies to CLA's future Operational Consolidation Area). It is important for Brazil to find ways to consolidate CLA's possession of the area while considering human factors, such as those related to traditional populations, if CLA is to become one of the largest spaceports in the world.

CAIMEA also addresses the need to manage the marine areas of Brazil's territorial seas (22 km from the coast) and its Exclusive Economic Zone (approximately 370 km from the coast). Based on CLA's future strategic and economic needs, it is necessary to consider the restriction of these waters to be permanently or temporarily restricted to prioritize CLA operations. Thus, the need for close collaboration between the MB and the FAB regarding the CLA becomes even more critical.

Final Considerations

CLA, as a space center with full spaceport capabilities, can become the gateway to a billion-dollar space economy. By providing Brazil with the capability to autonomously access outer space and transport payloads, the CLA can fulfill a strategic priority for Brazil's national defense and the country's progress. The CLA has the potential to cement Brazil as a major player in current global geopolitics and future astropolitics.

CAIMEA contributes to the decentralization of the defense industrial base and training of human resources, which are currently very concentrated in Brazil's southeastern region and will help increase the Gross Domestic Product (GDP) of Maranhão, the northeast region, and Brazil's *Amazônia Legal* region.

For CAIMEA to become a reality, each of the areas discussed throughout this article need to be further studied. This article has focused on the observations made in one specific space center, but there are other models and references within the US and in other countries that can be studied to provide other insights and solutions for the future of CLA. ❑

Notes

1. National Aeronautics and Space Administration (NASA), "NASA Locations, Capabilities and Points of Contact," *NASA Partnerships*, https://www.nasa.gov/partnerships/contact.html.

2. National Aeronautics and Space Administration (NASA), NASA Earth Science, https://science.nasa.gov/earth-science/.

3. Stuart W. Leslie, *The Cold War and American science: The military-industrial-academic complex at MIT and Stanford* (Columbia University Press, 1993); Rachel N. Weber, "Military-industrial complex," *Encyclopedia Britannica*, 9 September 2005, https://www.britannica.com/topic/military-industrial-complex.

4. Dwight D. Eisenhower, "Avalon Project-Military-Industrial Complex Speech," (New Haven, CT: Yale Lillian Goldman Law Library, 1961), https://avalon.law.yale.edu/20th_century/eisenhower001.asp.

5. William Fulbright, "The War and Its Effects: The Military-Industrial-Academic Complex," In: *Super-State: Readings in the Military-Industrial Complex*, ed. Herbert I. Schiller and Joseph D. Phillips (Urbana: University of Illinois Press, 1970), 171–178.

6. Innospace, "News," http://www.innospc.com/shop_contents/myboard_read.htm?myboard_code=sub04_02&idx=301461.

7. Bruno Martini, Luis Felipe Nohra, and Maria Célia Barbosa Reis da Silva, "Counterspace Weapons - Strategic Implications for Emerging Spacepower Nations," *Journal of the Americas* 5, no. 2 (August 2023).

8. Larry Rohter, "A developing nation on the frontiers of space; equatorial location gives Brazilian station a competitive edge in launching rockets," *New York Times*, 23 May 2000, C1.

9. Brazilian Space Agency, "PDI-CEA: Programa de Desenvolvimento Integrado para o Centro Espacial de Alcântara (Integrated Development Program for the Alcântara Space Center)," (Brasília: 2022).

10. Ariovaldo Felix Palmerio, *Introdução à Tecnologia de Foguetes* (Introduction to Rocket Technology), (São José dos Campos: SindCT, 2017).

11. Brasil, Ministério da Defesa, "Estratégia Nacional de Defesa (National Defense Strategy)," 2008.

12. Thomas G. Roberts, "Spaceports of the World, a Report of the CSIS Aerospace Security Project," Center for Strategic and International Studies (CSIS), 2019.

13. Marco Aliberti, Matteo Capella, and Tomas Hrozensky, *Measuring Space Power: a theoretical and empirical investigation on Europe* (Switzerland: Springer, 2019).

14. Nilsen Aparecida Vieira Marcondes & Elisa Maria Andrade Brisola, "A Análise por triangulação de métodos: um referencial para pesquisas qualitativas (Analysis by triangulation of methods: a framework for qualitative research)," *Revista Univap* 20, no. 35 (2014): 201–208.

15. Lisete S. Mónico et al., "Observação Participante enquanto metodologia de investigação qualitativa (Participant Observation as a qualitative research methodology)," *Atas CIAIQ 2017* 3 (2017): 724–733; Marcos Antônio da Silva, "A técnica da observação nas ciências humanas (The technique of observation in the human sciences)," *Revista Educativa-Revista de Educação* 16, no. 2 (2013): 413–423.

16. "39529 Sales Tax Rate," *Sales-Taxes.com*, 2023, https://www.sales-taxes.com/ms/39529#google_vignette.

17. John C. Stennis Space Center, *LAGNIAPPE* 7, no. 12 (December 2012), https://www.nasa.gov/centers/stennis/pdf/714383main_December_12_Lagniappe.pdf.

18. Katrina L. Wright, "John C. Stennis Space Center-A Federal City," In *Triennial Health Physics Meeting*, no. SSTI-1860-0001, September 2017.

19. National Aeronautics and Space Administration (NASA), "Stennis Space Center: Enterprise Park Special Study," *Michael Baker International Inc.*, (June 2020), https://www.nasa.gov/sites/default/files/atoms/files/enterprise_park.pdf.

20. Brazilian Space Agency, "PDI-CEA: Programa de Desenvolvimento Integrado para o Centro Espacial de Alcântara (Integrated Development Program for the Alcântara Space Center)."

21. Don Beckmeyer, "John C. Stennis Space Center: Strategic Business Development," National Aeronautics and Space Administration (NASA), 2011. https://www.nasa.gov/sites/default/files/atoms/files/business-development-ii.pdf.

22. National Aeronautics and Space Administration (NASA), "Mission Brochure 1961–2012," NASA's John C. Stennis Space Center, 2011.

23. Josevan Magalhães & Laerte Pereira Soares, "Alcântara 2030," *Instagram*, 1 November 2022, https://www.instagram.com/reel/Cw3I_Q0xpau/?igshid=MTc4MmM1YmI2Ng%3D%3D.

24. Tim Robinson, "Disperse and Survive," *Royal Aeronautical Society*, 5 May 2023, https://www.aerosociety.com/news/disperse-and-survive/.

25. DatacenterDynamics, "Conexão de alta velocidade chegará a Alcântara, no Maranhão (High-speed connection will reach Alcântara, in Maranhão)," 1 October 2021, https://www.datacenterdynamics.com/br/not%C3%ADcias/conex%C3 %A3o-de-alta-velocidade-chegar%C3%A1-a-alc%C3%A2ntara-no-maranh%C3%A3o/.

26. NASA John C. Stennis Space Center, "Environmental Assurance Program (EAP)," https://www.ssc.nasa.gov/environmental/index.html.

27. National Aeronautics and Space Administration (NASA), "Draft Environmental Assessment for Launch Complex 48," Integrated Mission Support Services, John F. Kennedy Space Center, FL, 19 February 2019, https://netspublic.grc.nasa.gov/main/LC%2048%20Environmental%20Assessment%20with%20Appendices_02.19.2019.pdf.

28. *Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis, Licença de Operação (Brazilian Institute of the Environment and Renewable Natural Resources, Operating License) No. 1653/2022 (13413478)*, https://servicos.ibama.gov.br/licenciamento/modulos/documentos.php?cod_documento=74109&donwload=.

29. Brazilian Space Agency, "Microrrede de Energia Elétrica Inteligente é inaugurada no Espaçoporto de Alcântara (Smart Electricity Microgrid is inaugurated at the Alcântara Spaceport)," 16 June 2023, https://www.gov.br/aeb/pt-br/assuntos/noticias/microrrede-de-energia-eletrica-inteligente-e-inaugurada-no-espacoporto-de-alcantara.

30. Brasil, "Política Nacional de Defesa e Estratégia Nacional de Defesa (National Defense Policy and National Defense Strategy)," Brasília: 2016, https://www.gov.br/defesa/pt-br/arquivos/estado_e_defesa/copy_of_pnd_e_end_2016.pdf.

31. National Aeronautics and Space Administration (NASA), "NASA Earth Science," https://science.nasa.gov/earth-science/.

32. NASA Stennis Space Center, "Doing Business with NASA Stennis Space Center," https://www.nasa.gov/centers/stennis/business/index.html.

33. Brazilian Space Agency, "Catálogo de Empresas Espaciais Brasileiras (Catalog of Brazilian Space Companies)," 23 December 2022, https://www.gov.br/aeb/pt-br/assuntos/noticias/catalogo-das-empresas-espaciais-brasileiras-ja-esta-disponivel-para-download.

34. Brazilian Space Agency, "INNOSPACE assina acordo tecnológico com o país para ensaios de voo (INNOSPACE signs technological agreement with the country for flight tests)," https://www.gov.br/aeb/pt-br/assuntos/noticias/innospace-assina-acordo-tecnologico-com-o-departamento-de-ciencia-e-tecnologia-aeroespacial-dcta-fab-para-ensaios-de-voo.

35. Tecnologia & Defesa, "FAB assina contrato com C6 Launch Systems para lançamentos em Alcântara (Brazilian Air Force signs contract with C6 Launch Systems for launches in Alcântara)," https://tecnodefesa.com.br/fab-assina-contrato-com-c6-launch-systems-para-lancamentos-em-alcantara/.

36. Gabriel Aguiar, "Entenda como a Virgin Orbit poderá lançar foguetes desde o Brasil (Understand how Virgin Orbit will be able to launch rockets from Brazil)," *Revista Exame*, 2021, https://exame.com/negocios/entenda-como-a-virgin-orbit-podera-lancar-foguetes-desde-o-brasil/.

37. National Aeronautics and Space Administration (NASA), "National Aeronautics and Space Act of 1958 (Unamended)," https://www.nasa.gov/history/national-aeronautics-and-space-act-of-1958-unamended/.

38. Infinity Science Center, https://visitinfinity.com/.

39. Michael Cabbage, "Promoting NASA," NASA Office of Communications, Presentation to the NASA Advisory Council, 20 September 2010, https://www.nasa.gov/sites/default/files/512594main_10-09_PromotingNASAforSeptember2010.pdf.

40. Instituto do Patrimônio Histórico e Artístico Nacional (Institute of National Historical and Artistic Heritage—IPHAN), http://portal.iphan.gov.br/pagina/detalhes/548/.

41. Darciléa Ferreira Castro et al, "Novas ocorrências de Asiatoceratodus (Osteichthyes, Dipnoiformes) na Formação Alcântara, Eocenomaniano da bacia de São Luís, MA, Brasil (New occurrences of Asiat Ceratodus (Osteichthyes, Dipnoi Formes) in the Alcântara Formation, Cenomanian of the São Luís basin, MA, Brazil)," *Revista Brasileira de Paleontologia* 7, no. 2 (2004): 245–248.

42. Luciana Luisa Chaves Castro, Gabriela Silva Noronha and Manoel Alfredo Araújo Medeiros, "Ecoturismo como alternativa de Desenvolvimento Socioeconômico na Ilha de Cajual, Alcântara (Ecotourism as an alternative for Socioeconomic Development on Cajual Island, Alcântara)," *Revista Brasileira de Ecoturismo (RBEcotur)* 9, no. 3 (2016).

43. Bruno Martini & Maria Célia Barbosa Reis da Silva, "A Inteligência Geoespacial por Satélites de Interesse Nacional do Brasil (Geospatial Intelligence via Satellites of National Interest in Brazil)," *Revista da Escola Superior de Guerra* 32, no. 64 (January/April 2017), https://revista.esg.br/index.php/revistadaesg/article/view/945/826.

44. André Trindade and Carlos Nina, "A Segunda Esquadra da Marinha (The Second Navy Squadron)," Ordem dos Advogados do Brasil do Maranhão (Brazilian Bar Association of Maranhão), 24 Jan 2018, https://www.oabma.org.br/agora/artigo/a-segunda-esquadra-da-marinha-202.

45. Brazilian Army Project Office, "Liberdade de Ação no Espaço Cibernético (Freedom of Action in Cyberspace)," http://www.epex.eb.mil.br/index.php/defesa-cibernetica.

46. Filipe Ferreira da Veiga & Humberto Lourenção, "Analysis of the Use of Armored Vehicles for the Defense of Brazilian Military Aerodromes in Urban Zones: Application and Relevance to the Brazilian Air Force (FAB)," *Revista da Escola Superior de Guerra* 36, no. 77 (May/August 2021): 29–50.

47. The Center of Higher Learning, Stennis Space Center, https://www.chl.state.ms.us/.

48. Brasil, CTA, "Portaria no. 149/SDE, 17 December 2007," *Diário Oficial da União*, (Brasília: 09 January 2008), https://www.normasbrasil.com.br/norma/portaria-149-2007_200352.html.

49. National Aeronautics and Space Administration (NASA), "Small Business 'Boot Camp' Project," Stennis Space Center Release S22-041, https://www.nasa.gov/centers/stennis/news/releases/2022/Stennis-Space-Center-Collaborates-on-Small-Business-Boot-Camp-Project.

50. United States Space Force (USSF), "Space Domain Awareness and Combat Power," https://www.ssc.spaceforce.mil/Program-Executive-Offices/Space-Domain-Awareness-Combat-Power.

51. Eun-Jung Choi et al., "Performance analysis of sensor systems for space situational awareness," *Journal of Astronomy and Space Sciences* 34, no. 4 (2017): 303–314.

52. Kennedy Space Center, https://www.nasa.gov/kennedy/.

53. Aparecido Camazano Alamino, *Centro de Lançamento de Alcântara - Uma Janela Brasileira para o Futuro (Alcântara Launch Center - A Brazilian Window to the Future)* (Rio de Janeiro: Adler, 2014).

54. Brazilian Air Force, "Confira os bastidores da Operação Astrolábio (Go behind the scenes of Operation Astrolabe)," 19 March 2023, https://www.youtube.com/watch?v=dDYk6CUFDqI.

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