10, 11, 12, 13 e 14 de novembro de 2025
ISSN 2177-3866

INSTITUTIONAL MODELING FOR INNOVATION IN THE BRAZILIAN SPACE SECTOR: AN ANALYSIS TO THE HYBRID ECONOMIC EXPLOITATION OF NATIONAL LAUNCH CENTERS

ADRIANA PAULA RODRIGUES UEDA
UNIVERSIDADE DE BRASÍLIA-UNB

THIAGO GOMES NASCIMENTO
UNIVERSIDADE DE BRASÍLIA-UNB

ROGÉRIO LUIZ VERISSIMO CRUZ
UNIVERSIDADE DE BRASÍLIA (UNB)

CARLOS ALBERTO GURGEL VERAS
UNIVERSIDADE DE BRASÍLIA-UNB

Agradecimento à orgão de fomento:
This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001.

INSTITUTIONAL MODELING FOR INNOVATION IN THE BRAZILIAN SPACE SECTOR: AN ANALYSIS TO THE HYBRID ECONOMIC EXPLOITATION OF NATIONAL LAUNCH CENTERS

1. INTRODUCTION

To a significant extent, the origins of the Brazilian Space Program can be traced back to 1961, with the establishment of the Organizing Group of the National Commission for Space Activities (CNAE). In 1963, the Executive Group for Work and Study of Space Projects (GETEPE) was created, with a focus on developing space technologies relevant to the Brazilian Air Force. As a direct outcome, the *Barreira do Inferno Launch Center* (CLBI) was inaugurated in October 1965. Institutional consolidation progressed throughout the 1970s, culminating in the creation of the Brazilian Commission for Space Activities (COBAE), which evolved into the Brazilian Space Agency (AEB) in 1994. This transition represented a major institutional milestone, establishing a centralized authority responsible for policy formulation, strategic planning, and the coordination of national space activities. In 1983 the establishment of the Alcântara Launch Center (CLA) positioned Brazil among the select group of nations possessing launch infrastructure capable of servicing nearly the full spectrum of orbital inclinations.

Globally, the space sector is undergoing significant transformations driven by the emergence of new actors, declining launch and manufacturing costs, and the expansion of commercial applications based on space-based assets. According to the ESA Space Economy Report (ESA, 2023), planned institutional space budgets are in excess of €120 billion, as of fiscal year 2024. Defense-related expenditures continue to grow at a faster rate than civilian budgets. The Indian Space Research Organisation (ISRO, 2025), although a government entity, operates with business-oriented features through its commercial arm, NewSpace India Limited (NSIL), which integrates national strategic objectives with operational and financial efficiency. As an instance, the Brazilian Amazonia-1 satellite was launched in the PSLV-C51 mission in 2021, executed by NSIL (PLSV, 2021). In the United States, the commercialization of space has been a long-standing policy priority. The Commercial Space Launch Act of 1984 was enacted to promote the development of commercial launch vehicles and associated services (Heracleous et al., 2019). Across these cases, a clear trend emerges: national governments increasingly serve as enablers of the space economy, fostering private sector participation through supportive regulatory, financial, and institutional frameworks.

To enable Brazil's effective integration into the global market for small satellite launches, it is essential to develop indigenous launch vehicles and establish institutional arrangements that facilitate the economic utilization of its launch centers. In this context, the Brazilian government is funding the development of a privately-manufactured launch vehicle MLBR (2024), with an investment exceeding US$ 35 million (Stakeholder 1). The vehicle is expected to achieve qualification and enter operational status within a three-year timeframe. The institutional framework further envisions the creation of a state-owned enterprise (Stakeholder 2) tasked with providing access to national launch infrastructure to private operators. Concurrently, the Brazilian Air Force (Stakeholder 3) remains responsible for the operation of the national launch centers. This tripartite configuration introduces a series of legal, institutional, and commercial challenges that must be addressed to ensure the successful implementation of satellite launch operations from Brazil.

Given the complexity of the proposed institutional arrangement, stakeholder theory emerges as a suitable analytical approach to understanding the dynamics among public, private, and military actors involved in the governance of strategic infrastructure. In the Brazilian space sector, government agencies, the Air Force, private companies, regulatory bodies, and international partners assume distinct roles with varying capacities and objectives. Understanding how these actors interact, assign responsibilities, and establish cooperative mechanisms is essential for designing institutional frameworks that ensure effective coordination and long-term sustainability.

The literature indicates that stakeholder theory contributes to analyzing the conditions necessary for value generation in complex organizational environments (Freeman, 1984; Bridoux & Stoelhorst, 2022). This approach emphasizes the importance of institutional coordination supported by clear governance structures, standardized contractual arrangements, and robust regulatory safeguards capable of ensuring legal certainty, economic viability, and alignment with national strategic interests. It also highlights the role of cooperative and balanced stakeholder relationships as a prerequisite for shared value creation and the long-term consolidation of institutional arrangements.

Within the framework of the 1967 Outer Space Treaty (United Nations, 1967), the concept of the 'Launching State' is central to the attribution of international legal responsibility for space activities. The treaty establishes a robust legal foundation to ensure that States exercise effective supervision and control over the space activities of their nationals or entities under their jurisdiction, thereby preventing misconduct and promoting accountability in the use of outer space. Accordingly, the legal dimensions of commercial and institutional arrangements are as critical as the launch operations themselves. Given Brazil's current stage of development in the space economy, the active participation of the State remains essential, particularly in driving technological advancement and structuring viable business models, primarily through its purchasing power. These efforts demand unprecedented levels of organizational maturity and regulatory compliance across multiple national space institutions.

This study seeks to contribute to the understanding of these multidimensional challenges by examining the institutional requirements for the effective operation of a hybrid model dedicated to satellite launch services from Brazilian territory. The research is motivated by a clear gap in the literature regarding innovation within state-owned enterprises in the space sector, as well as by the practical need to inform the design and implementation of such strategic initiatives. The study offers a diagnostic assessment of institutional and innovation readiness and proposes a roadmap to progressively achieve the maturity levels necessary for the economic consolidation of Brazil’s launch infrastructure, thereby generating tangible benefits for Brazilian society.

2. METHOD

The use of metrics for innovation management is a practice adopted by national funding agencies (FINEP, EMBRAPII, BNDES, FAPDF, FAPESP, CNPq) and innovation ecosystems (PCTec, 2025; KTH). The European Union utilizes the Technology Readiness Level (TRL) scale to assess the maturity of technologies and guide funding decisions for research and innovation projects. REEEM (Darmani & Jullien, 2017) also applies the innovation readiness methodology for project selection and monitoring. Projects must achieve optimal maturity across five dimensions, namely: TRL (Technology); IPRL (Intellectual Property); MRL (Market); CRL (Consumer); and SRL (Society). In Sweden, The Royal Institute of Technology (KTH) adopts a similar approach to assess, multidimensionally, the maturity of in-house innovations (Berglund & Leifer, 2018). The Innovation Readiness Level (IRL) framework developed by KTH serves as a structured tool to evaluate how prepared an innovation is to be adopted and create impact in real-world settings.

Similarly, Lee et al. (2011) proposed a framework for managing innovation across its entire lifecycle by evaluating five key dimensions: technology, market, organization, partnership, and risk. They demonstrated that this approach, supported by the metrics, allows for the strategic integration of innovation theory and practice. This enables organizations to assess their innovation readiness, thereby using it as a competitive advantage.

By integrating indicators, organizations can align innovation efforts with strategic objectives, ensure smoother implementation, and enhance the likelihood of successful market adoption. In this work, we apply relevant innovation metrics to each stakeholder as a means of identifying specific gaps (assessment) that must be addressed through targeted actions (roadmap) to enable the sustainable and profitable implementation of orbital launch services from the Brazilian territory. All the metrics used are structured in nine stages, by analogy to the TRL scale. More specifically we employed the IRL framework, with six dimensions, for technology development (Berglund & Leifer, 2018), ORL (Organizational Readiness Level and LRL (Legal Readiness Level) for the state enterprise (Bruno et al., 2020) and OPRL (Operational Readiness Level) for the launch center.

Intellectual property (IPRL) issues prevent the launch vehicle developer (Stakeholder 1) from publicly disclosing the technological details of its launch vehicle under development. Basic performance data were obtained from MLBR (2024), and detailed characteristics were calculated using a proprietary code for launch vehicle sizing (Cruz et al., 2025). Based on the detailed configuration of the vehicle, the TRANSCOST model (Koelle, 2010) was employed to estimate the efforts, in Work-Year (WY), required for development, manufacturing, site operations, and launch campaign. In the TRANSCOST model (Koelle, 2010, p. 17), a Work-Year (WYr) unit is defined as: *"The Work-Year (WYr) costs are by definition the total company annual budget (excluding subcontracts) divided by the number of productive full-time people. This means that all secondary costs like office cost, travel, material, etc. as well as taxes and profit are included, plus a certain share of administration, management and support staff costs.*"

We estimate the cost of one WY at US$ 80,000 for the Brazilian aerospace industry and US$ 25,000 for the launch centers. The technological development effort, measured in WY, defines the human resources required in all project phases (TMRL). Based on the monetary value of a WY, associated costs are estimated and translated into funding needs (FRL) and launch costs, the latter being essential for business modeling (BRL). The key parameter in this analysis is the specific transportation cost, in USD per kilogram of payload, which must remain competitive with international market standards. The overall assessment was conducted based on published literature, participation in space conferences (SGDCI, 2025), and consulting with key stakeholders.

2. PROBLEM DEFINITION

Space launch activities in Brazil face structural challenges related to institutional coordination, organizational maturity, and regulatory adequacy, all of which are essential to enabling the economic exploitation of space assets, as outlined in the National Space Activities Program (AEB, 2022). The absence of a governance arrangement centered on innovation and the creation of shared value among civilian and military actors hampers the effective utilization of strategic assets, particularly amid growing global demand for small satellite launches. In response, government authorities have been discussing the establishment of a state-owned enterprise to serve as a necessary interface between private companies, both domestic and international, and the operators of the launch centers to facilitate the commercial exploitation of these assets.

North (1991) emphasizes that institutions, understood as both formal and informal rules, are essential for reducing uncertainty and transaction costs, shaping the incentives and behavior of economic agents. In the context of the Alcântara Launch Center, the absence of specific regulations for shared commercial operations introduces legal and regulatory uncertainties to economic activity. The complexity of negotiations among actors with divergent interests, coupled with the current lack of effective conflict resolution mechanisms, increases these costs. Such challenges may be mitigated through collaborative governance supported by innovative contractual instruments and monitoring mechanisms.

2.1 Research Context

To enable the economic exploitation of CLA and CLBI launch centers, it is necessary to establish clear formal regulations, foster informal cooperation practices, and implement coordinated public policies that promote greater institutional maturity among the involved stakeholders. The application of the Innovation Readiness Level (IRL) framework and its extended scales allows for mapping the varying degrees of stakeholder readiness to operate within a hybrid commercial exploitation model.

The launch center was granted a license to conduct launch operations by the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA, 2022). The Brazilian Air Force demonstrates relatively high levels of Operational Readiness Level and regulatory readiness, the latter from the Technology Safeguards Agreements (TSAs) signed with the United States. In contrast, the intermediary state-owned enterprise still requires institutional design and structural definition, and thus currently exhibits low levels of Organizational Readiness Level and Legal Readiness Level. Private companies, meanwhile, show both commercial interest and technological capability, as evidenced by the recent approval of funding through FINEP for the development of a satellite launch vehicle by the domestic industrial sector. The following section presents an assessment of the maturity levels associated with each stakeholder in the proposed hybrid arrangement, followed by the proposition of a roadmap aimed at facilitating the commercial viability of the country's launch centers.

2.2 Private Launch Provider (Stakeholder 1)

A Brazilian consortium is developing the Brazilian Micro-Launcher (MLBR) vehicle, led by Cenic Engenharia in partnership with Concert Space, Delsis, ETSYS, and Plasmahub (MLBR, 2024). The project is funded by the Ministry of Science, Technology and Innovation through FINEP, with support from the Brazilian Space Agency. The vehicle is designed to place a 40 kg payload into a 450 km orbit. Therefore, its commercial viability relies entirely on achieving maximum technological readiness (TRL 8). The project has just passed the preliminary design review, phase B of ESA space project planning and implementation guidelines ECSS (2009).

We apply five innovation readiness metrics to assess the current status and outline a roadmap for Stakeholder 1: Technology Readiness Level (TRL), Funding Readiness Level

(FRL), Team Readiness Level (TMRL), Customer Readiness Level (CRL), and Business Readiness Level (BRL). Upon reaching TRL 7, attention should shift to CRL, validating both strategic national and international market demand, and BRL, refining the business model based on estimated cost per launch. Early government procurement will be essential to support market entry.

Code predictions indicate the following effort levels for the launch vehicle: 153 WY for development, 47 WY for manufacturing, 19.5 WY for pre-operation, and 1.4 WY for the launch campaign. At USD 80,000 per WY for Stakeholder 1, development and manufacturing costs are USD 12.3 million and USD 3.8 million, respectively. Fixed operational costs is USD 1.6 million, assuming a WY rate of USD 52,500, averaged for Stakeholders 1 and 3. A single launch campaign would cost USD 112,800 to take place. The specific transportation cost was estimated as USD 141,000 per kg of payload, resulting in a minimum orbital insertion price of approximately USD 5.6 million.

Based on this data, Stakeholder 1 is currently assessed at TRL 6 (system/subsystem model demonstrated in relevant environment), TMRL 6 (team demonstrates execution capability and delivers milestones), considering the consortium has allocated up to 113 professionals to the project, and FRL 6 through funding from FINEP (first funding round secured and aligned with development timeline). CRL and BRL levels are estimated at CRL 3 (problem–solution fit validated with early adopters or pilot customers) and BRL 3 (initial market analysis and revenue model outlined), respectively.

2.3 State-owned Enterprise (Stakeholder 2)

A state-owned company under the Ministry of Defense will serve as the interface between the national launch centers, CLA and CLBI, and private satellite launch service providers. According to the Brazilian government's institutional model, its central role is to enable the economic exploitation of the national space infrastructure, particularly the launch centers, and the country’s aerospace navigation capabilities. The Brazilian Air Force retains responsibility for the technical operation and safety of the launch centers. In this coordinated arrangement, the company will act as a strategic link, aligning public and private interests, to foster innovation and competitiveness of the Brazilian space sector within the global market.

The application of the Organizational Readiness Level (ORL), as proposed by Bruno et al. (2020), enables the measurement of a company’s maturity level to implement innovations and operate in environments with high institutional complexity.

Table 1 lists the organizational maturity criteria applied to estimate the level of ORL of the Stakeholder 2, based on the framework proposed by Bruno et al. (2020). In ORL, the solution means: "State-owned company providing satellite launch infrastructure from CLA and CLBI”. Structured into nine levels, the ORL framework spans from the identification of needs and definition of processes to full validation and operation in real-world contexts. According to Bruno et al. (2020), any innovation, whether technical or social, must be embedded within the organizational environment to be permanently adopted. The organizational maturity assessment of Stakeholder 2 was based on documentary analysis of relevant legislation (AEB, 2022), participation in sector-specific events, and technical consultations. Simultaneously, the application of the Legal Readiness Level (LRL) is essential for the success of innovations within public organizations, especially in highly regulated sectors such as space (United Nations, 1967). When integrated with ORL, the LRL ensures compliance with the current legal framework, an indispensable requirement for institutions that cannot operate under legal uncertainty.

Table 1: Assessment of the organizational maturity of Stakeholder 2. Source: own elaboration.

ORL	Success Criteria	Assessment
1	Has the organization identified a specific need in terms of infrastructure, capabilities, or skills, and recognized the key aspects that determine its organizational readiness?	Yes: The company has its responsibilities legally defined. AEB Public Call 02/2020 (AEB, 2020) confirms the organizational need for the solution.
2	Has the organization formulated a proposed solution concept, assessed its potential impacts, and identified the necessary roles, processes, functions, and structures?	Yes: The proposed solution was agreed upon by AEB and the Air Force Command.
3	Has the organization described in detail how the proposed solution will impact internal roles, competencies, skills, and physical infrastructure?	Yes: The stakeholder has a basic description of its role, the necessary competences/skills. Physical infrastructure is also in place.
4	Has the organization validated the solution through simulation of significant organizational changes and started to acquire the necessary roles, skills, and infrastructures?	Yes.: Considering foreign companies signed contracts with the Brazilian Government for satellite launches from CLA (AEB, 2020).

The LRL is also a 9-level metric designed to assess whether legal, regulatory, and even ethical norms are consolidated. When applied to Stakeholder 2, the LRL is estimated to be at maturity level 4, highlighting the urgent need to strengthen the legal framework for the commercial use of launch centers. Table 2 presents the LRL diagnostic as applied to Stakeholder 2. In LRL, solution means “State-owned company with all the legal compliances”

Table 2: Assessment of the legal maturity of Stakeholder 2. Source: own elaboration.

LRL	Success Criteria	Assessment
1	Has the organization considered legal and ethical compliance aspects without taking concrete steps toward legal development of the solution?	Yes: The stakeholders are aware of the regulations described in Law 14,946/2024 (Brasil, 2024). The regulation for the use of the Alcântara Launch Center (CLA) is in effect, and Brazil is a signatory to the Outer Space Treaty.
2	Has the organization formulated the need to enhance legal norms, laws, regulations, and guidelines, and begun assessing legal and ethical compliance issues for the solution?	Yes: Discussions on the legal framework have been undertaken. The Law 14,946/2024, which affects the solution under analysis, has been proposed by the Institutional Security Office of the Presidency of the Republic (GSI-PR), through Resolution CDPEB No. 32, dated July 1, 2025.

Table 2: Assessment of the legal maturity of Stakeholder 2. (continue).

LRL	Success Criteria	Assessment
3	Has the organization provided an abstract or initial description of how the proposed solution addresses legal and ethical compliance?	Yes: As stated in the public call (AEB, 2020), which outlines basic aspects of the solution, although, there is still a lack of a consolidated legal framework for a state-owned managing enterprise.
4	Has the organization validated the legal and ethical compliance prospects of the solution against the required or recommended changes in the legal and/or regulatory system?	Yes: The applicable regulations include the State-Owned Companies Law, Law 14,946/2024, the 1967 Outer Space Treaty (United Nations, 1967), and Decree No. 1,332/94 (Brasil, 1994).

2.4 Alcântara Launch Center (Stakeholder 3)

The Alcântara Launch Center (Fig 1) is a strategic pillar of Brazil's space infrastructure. Its primary mission is to carry out and support the launch and tracking of aerospace vehicles. Modeled after the Kourou Launch Center, the Alcântara Launch Center maintains regular contact with that European space facility to exchange operational and safety-related best practices for space launch operations. Launch operations at CLA involve interaction with multiple organizations and entities. To coordinate this complex articulation, the launch process begins with the approval of the Launch Operation by the Director-General of the Department of Aerospace Science and Technology (DCTA), a branch of the Brazilian Air Force to which CLA is subordinate. The systematic monitoring of launch interfaces, covering both operational and technical aspects, is carried out through the Launch Interface Group (Brasil, 2022).

Regarding infrastructure, the Brazilian Air Force Command has established an implementation plan for the Alcântara Space Center (Brasil, 2023). This plan outlines the necessary actions to ensure the full operational capacity of assets and services offered to private companies through public calls for proposals. Budgetary resources are allocated annually under the Multi-Year Federal Plan (2024–2027) through the budgetary action designated as 7F40.

With respect to the safety of space launch operations, the Alcântara Launch Center has consolidated its experience from previous national launches into its Operational Safety Manual (CLA, 2008). This manual has been applied in various suborbital launch operations, including the launch of the Hanbit-TLV vehicle developed by the South Korean company Innospace. This launch was conducted within a research framework and served as a test flight during the vehicle's development phase. Innospace, is a South Korean startup specializing in developing hybrid space rockets. The 8.4 ton single-stage hybrid rocket was launched from the Alcantara Space Center on March 19th, 2023. Innospace's launch was the first rocket blastoff by Korea's private sector. According to the company, the Hanbit-TLV was also the world's first launch of a hybrid rocket using an electric pump, The Korean Herald (2023).

Figure 1: Relevant infrastructures of the CLA. Source: FAB

Table 3 outlines the success criteria used to characterize the Center's operational maturity level (Bruno et al., 2020). In OPRL, solution means "CLA meets the operational requirements for executing orbital launch campaigns". Based on the OPRL framework, the operational maturity of CLA was estimated at OPRL 6, reflecting its demonstrated capability in real launch operations and cooperation with multiple stakeholders.

Table 3: ORL scale to assess operations readiness of the CLA. Source: own elaboration.

OPRL	**Success Criteria**	**Assessment**
1	Has the need for establishing or enhancing the operational capabilities of the launch center been formally recognized, including identification of infrastructure, personnel, and process gaps?	Yes: It was defined in the 1960s with support from the French and based on the experience of the CLBI.
2	Has a concept of operations (ConOps) been developed for the launch center, addressing required capabilities, infrastructure, safety protocols, and institutional responsibilities?	Yes: ConOps listed in RICA 21-91, Internal Regulations of the Alcântara Launch Center, (CLA,1991).
3	Has the impact of launching operations been described in terms of changes or demands on physical infrastructure, workforce qualifications, environmental safeguards, and institutional coordination?	Yes: As described in RICA 21-9 (CLA,1991).

Table 3: ORL scale to assess operations readiness of the CLA. (Continue).

OPRL	**Success Criteria**	**Assessment**
5	Has the launch center conducted pilot or test launch campaigns in realistic environments, validating the effectiveness of personnel, systems, and procedures?	Yes: Already established based on more than 500 space artifacts launched. Proven by the capability to prepare larger-scale launches, such as the case of the VLS-1.
6	Has the launch center executed operational launch campaigns involving real missions and gathered structured feedback from regulatory agencies, private users, and military partners to improve readiness?	Yes: Evidenced by the variety of types of space vehicles launched. Proven by the capability to prepare larger-scale launches, such as the VLS and, more recently, operations with the South Korean company Innospace.

Figure 2 summarizes the different maturity levels relevant to the stakeholders involved in the hybrid arrangement. Stakeholder 1 shows high levels of technological, funding, and team maturity, but low levels of market and business maturity, these latter aspects being entirely dependent on achieving launch vehicle qualification (TRL 8). The estimated organizational and legal readiness levels of Stakeholder 2, the state-owned intermediary company, were assessed at ORL 4 (solution validated through simulation of major induced changes to substantiate proposed impacts and organisational readiness: the organisation which is developing the solution starts to acquire roles, competencies and skills, physical infrastructures required) and LRL 4 (solution's legal and ethical compliance prospects validated against any required or recommended changes in the legal and/or regulatory system). Stakeholder 3 (CLA) demonstrates a high level of organizational maturity, at OPRL 6, as discussed.

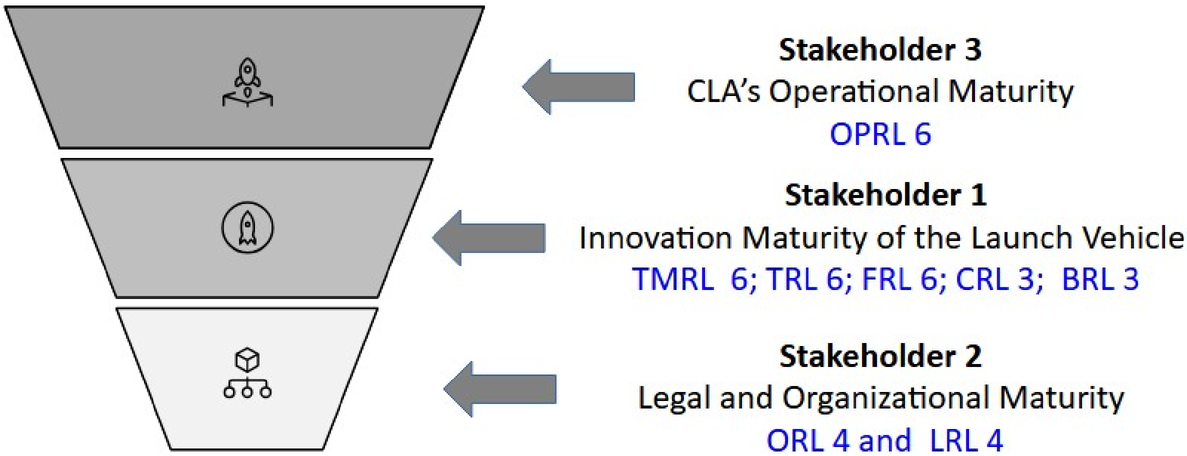

Figure 2: Current maturities of the Stakeholders. Source: own elaboration.

3. RESULTS AND DISCUSSIONS

To position Brazil in the global space launch market, a coordinated intervention is proposed to progressively raise the institutional, legal, technological, and operational maturity of the three main stakeholders. Given that funding is critical for the development of the launch vehicle and that it depends on government financing, the roadmap of Stakeholder 1 is directly linked to the disbursement schedule of the funding agency. Total investment from FINEP amounts to USD 35.1 million (exchange rate as of 07/04/2025), with the disbursement schedule detailed in Table 4 following the contract signing.

Funding was estimated at FRL 6. To reach FRL 7 additional funding or investments should be secured for continuation or scale-up. Notwithstandingly, the required additional funding is already secured, as detailed in Table 4. The funding should reach maturity level FRL 8 by month 31, meaning full funding secured to complete the development and deployment phases. However, the release of fund parcels is conditional upon the progress in the technological development of the launch vehicle.

Table 4: Disbursement schedule for the launch vehicle development funding (FINEP). Source: own elaboration.

Month	1st	7th	13th	19th	25th	31st
Parcel (%)	22.6	19.1	18.7	17.7	12.5	9.4

The satisfactory operation of a prototype of the vehicle, or of its main subsystems, corresponds to Technology Readiness Level (TRL) 7, which is expected to occur around month 19, when approximately 80% of the financial resources will have been invested. TRL 8 is projected to be achieved between months 31 and 36, at which point the final product, built to operational specifications, will have been qualified through testing and demonstration. Considering the manufacturing cost of one launch vehicle to be approximately USD 3.8 million, the project would have sufficient resources to carry out up to two qualification launches.

The Team Maturity Readiness Level (TMRL) evaluates the capability and maturity of the project team to execute the mission. Predictions from the TRANSCOST model estimate a total development effort of 153 Work Years (WY). The consortium has allocated 113 professionals for this phase. Assuming that, on average, each professional will dedicate 50% of their time to the project, this results in a total contribution of 56 WY for each year during three years. Thus, the total workforce effort dedicated to the project adds up to 168 WY, slightly exceeding the estimated requirement of 153 WY. Therefore, TMRL 7 can be readily achieved, indicating that team scalability is ensured and additional experts and partners will be integrated as needed. The same logic applies to TMRL 8, where the team is fully operational, with clearly defined governance structures, decision-making processes, and continuity plans, all of which must be consolidated throughout the development process. Progress in Customer Readiness Level (CRL) and Business Readiness Level (BRL) is entirely dependent on achieving TRL 8. Once this level is reached, potential clients will have the assurance that orbital launch operations are within the institutional arrangement's capabilities.

Stakeholder 2, in turn, must advance in both organizational and legal maturities as detailed in Fig. 4. The process should start in ORL 5 and advance to ORL 8. The same holds to LRL, which must advance, in parallel to the ORL, from LRL 5 to LRL 8.

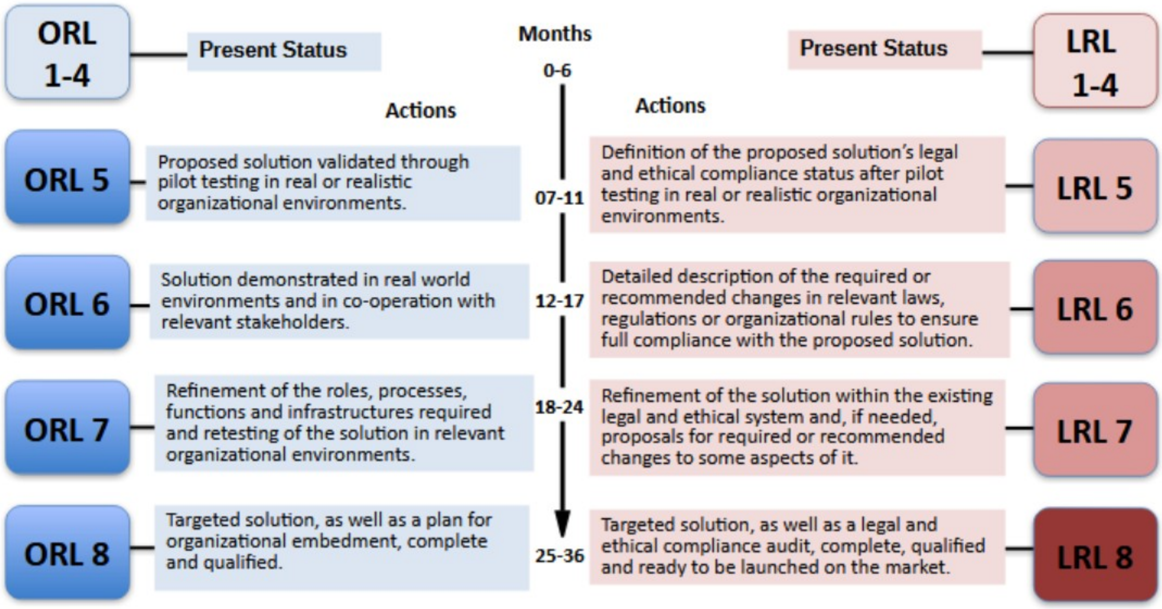

Figure 4: ORL and LRL roadmap for Stakeholder 2. Source: Own elaboration

Stakeholder 2, in combination with CLA, must complete an independent legal and ethical compliance audit, secure its operator license, formalize insurance mechanisms, and document adherence to standards such as ISO 24113, Outer Space Treaty, Liability Convention, and Registration Convention, while also complying with Brazil's nº 14,946/2024 Law, frequency coordination (ITU), and export control regimes (such as MTCR). Meeting these requirements ensures that the state enterprise can operate lawfully and reliably within the international space economy, reinforcing its institutional credibility and legal readiness.

Finally, among the various enterprise models considered, the CDPEB Commission recommended the establishment of a state-owned, non-dependent company as the most appropriate option. This recommendation was based on key criteria, including the preservation of national sovereignty, exemption from annual fiscal budget constraints, and the ability to engage in profitable economic activities. However, it is important to emphasize that this freedom to operate is necessarily subject to strict legal, regulatory, and ethical compliance, as the entity remains a state-owned enterprise bound by public governance principles and oversight mechanisms.

Regarding the Alcântara Launch Center (CLA – Stakeholder 3), the focus lies on consolidating its Operational Readiness Level (OPRL), aiming to transform it from an institutionally oriented center into infrastructure fully capable of serving multiple commercial operators. The recommended actions include: (i) updating technical, operational, and safety protocols based on ISO standards and practices adopted by the FAA and ESA (targeting OPRL 6–8); (ii) Additional investment in civil-military infrastructure, including payload integration centers, telecommunications terminals, and redundant telemetry and tracking systems (targeting OPRL 7); (iii) continuous staff training and operational integration with temporary civilian teams through exchange programs and joint operations (targeting OPRL 7); and (iv) formalization of operational qualification and certification processes, through independent audits and international cooperation, in partnership with Stakeholder 2 (targeting OPRL 8). Late in 2025, South Korean company Innospace plans to launch its Hanbit-Nano rocket from the Alcântara Space Center (CLA), aiming to achieve a Technology Readiness

Level of 8 (TRL 8) for its vehicle. The two-stage rocket, which uses hybrid propellant engines, is designed to carry a 90 kg payload to a 500 km Sun-Synchronous Orbit (SSO). A successful combined mission would also elevate the Alcântara Launch Center to an Operational Readiness Level of 8 (OPRL 8).

After applying the relevant maturity metrics to the different stakeholders, a discrepancy among them becomes apparent. The arrangement depends on the technological development led by Stakeholder 1, whose relevant metric, FRL, is at a high level and its maturity is secured by the funding agency (FINEP). The levels of TRL and TMRL are consistent with the proposed challenges and the funding guarantees in place. CRL and BRL, currently at level 3, must have their roadmaps further detailed once the launch vehicle reaches TRL 8. Although Stakeholder 2 currently presents low maturity levels (ORL 4 and LRL 4), it does not appear to face major obstacles in reaching higher levels of institutional maturity. The same applies to Stakeholder 3, whose OPRL needs to advance toward levels 7 and 8.

5. CONCLUSIONS

This study investigated the organizational and legal challenges associated with the commercial operation of Brazilian launch centers, in light of Law No. 14,946/2024. The launch centers are federal assets under the operational responsibility of the Brazilian Air Force and, therefore, are not legally permitted to enter into direct commercial agreements for the economic exploitation of their infrastructure with private companies. Consequently, it is necessary to structure an institutional arrangement in which a state-owned enterprise intermediates between the launch centers and the private sector, enabling the commercial launch of satellites from national territory.

The problem assessment revealed varying maturity levels among the stakeholders. The results indicate low maturity for Stakeholder 2, medium maturity for Stakeholder 1, and high maturity for Stakeholder 3. As a social-technological contribution, the study proposes a roadmap to raise the maturity levels pertinent to each stakeholder. For Stakeholder 1, it is necessary to reach Technology Readiness Level (TRL) 8 within 30 months. The funding, provided by FINEP, ensures Funding Readiness Level (FRL) 8 as long as the development of the launch vehicle proceeds according to the contractual terms. The Team Maturity Readiness Level (TMRL) assessment indicates that the project team is adequately structured, with the capacity to allocate human resources in both quantity and quality required for the development phases (TRL 6 to TRL 8). Currently at TRL 6, it is recommended that detailed application of the Customer Readiness Level (CRL) and Business Readiness Level (BRL), each assessed at level 3, be carried out once TRL 8 is achieved.

The state-owned enterprise (Stakeholder 2) must advance in both Organizational Readiness Level (ORL) and Legal Readiness Level (LRL), with particular emphasis on the latter, which could potentially hinder the commercial use of the launch centers. From a legal standpoint, Stakeholder 2 must ensure compliance with key national regulatory frameworks (e.g., Law No. 14,946/2024, the State-Owned Companies Law, and Decree No. 1,332/1994) and international agreements (e.g., the 1967 Outer Space Treaty, and the ITU and UN COPUOS standards), in coordination with Stakeholder 3. The AEB Public Call 02/2020, currently in force, may serve as a reference for the roadmap proposed for Stakeholder 2.

Stakeholder 3, assessed at OPRL 6, must continue progressing toward OPRL 8. This requires actions such as continuous personnel training, operational integration with civilian teams, and the formalization of operational qualification and certification processes to achieve full maturity.

This study presented both a detailed assessment and a set of actionable recommendations for structuring a hybrid arrangement, which is essential to enable the commercial exploitation of Brazil's launch centers. The research addresses a gap in the literature concerning innovation within state-owned enterprises in the space sector. A successful and sustainable implementation of this hybrid model for at least one year of economic activity would allow all maturity metrics to reach level 9. Beyond the technical roadmap, the findings underscore the importance of fostering institutional coordination and trust among stakeholders (military, public, and private). As shown through stakeholder theory, effective governance arrangements require more than legal compliance; they depend on shared objectives, transparent communication, and mechanisms that promote sustained collaboration. By integrating legal, organizational, and technological perspectives, the study contributes to the development of a strategic vision for the Brazilian space sector. As Brazil seeks to consolidate its position in the global space economy, the ability to structure responsive and mature institutions will be decisive. The long-term success of this endeavor will rest not only on hardware development, but on the collective capacity of its institutions to operate in synergy, adapt to regulatory demands, and deliver public value.

For future research, it is recommended to monitor the ongoing development of the launch vehicle technology, the institutional structuring of the state-owned enterprise, and the modernization of infrastructure and processes at the Alcântara Launch Center, with the goal of proposing solutions to reach the targeted maturity levels.

6. REFERENCES

Agência Espacial Brasileira. (2020). Edital nº 02/2020: Public call – Processo nº 01350.000919/2020-48 (SEI nº 0072186). Brasília, DF: AEB. https://www.gov.br/aeb/pt-br/programa-espacial-brasileiro/chamamento-publico-public-call/SEI_AEB0072186EditalPTBR.pdf

Agência Espacial Brasileira. (2022). *PNAE: Programa Nacional de Atividades Espaciais 2022–2031* (2ª ed.). Brasília: AEB. https://www.gov.br/aeb/pt-br

Berglund, H., & Leifer, L. (2018). *KTH Innovation Readiness Level Model: A tool for assessing innovation maturity*. KTH Royal Institute of Technology. https://www.kth.se/innovation

Brasil. (1994). *Decreto nº 1.332, de 8 de dezembro de 1994*. Aprova a atualização da Política Nacional de Desenvolvimento das Atividades Espaciais (PNDAE). https://www.planalto.gov.br/ccivil_03/decreto/1990-1994/d1332.htm

Brasil. (2023). Ministério da Defesa. Comando da Aeronáutica. Departamento de Ciência e Tecnologia Aeroespacial. *Portaria nº 15/CEMAER, de 2 de março de 2021*. Aprova o Plano de Implantação do Centro Espacial de Alcântara. Brasília. (PCA 11-317)

Brasil. (2022). Ministério da Defesa. Comando da Aeronáutica. Departamento de Ciência e Tecnologia Aeroespacial. *Portaria DCTA nº 72/DCI, de 11 de fevereiro de 2022*. Aprova a reedição da Instrução que trata do Grupo de Interfaces de Lançamento (ICA 60-1).

Brasil. (2024). *Lei nº 14.946, de 26 de julho de 2024*. Lei Geral das Atividades Espaciais. *Diário Oficial da União*, Brasília, DF.

Bridoux, F., & Stoelhorst, J. W. (2022). Stakeholder theory, strategy, and organization: Past, present, and future. *Strategic Organization, 20*(4), 797–809. https://doi.org/10.1177/14761270221127628

Bruno, I., Lobo, G., Covino, B. V., Donarelli, A., Marchetti, V., Panni, A. S., & Molinari, F. (2020). Technology readiness revisited: A proposal for extending the scope of impact assessment of European public services. In *Proceedings of the 13th International Conference on Theory and Practice of Electronic Governance* (pp. 369–380).

Centro de Lançamento de Alcântara. (2008). *Manual de Segurança Operacional do CLA*. Alcântara. https://cla.dcta.mil.br/images//pdf/Manual_do_CLA_20_2024-04-11_signed.pdf

CLA. (1991). *Centro de Lançamento de Alcântara, RICA 21-91: Regimento Interno do Centro de Lançamento de Alcântara*. Alcântara, MA.

Cruz, R. L. V., Ueda, A. P. R., & Veras, C. A. G. (2025). Development, manufacturing, and operational costs of a three-stage solid-propellant launch vehicle. 3rd Brazilian Aerospace Congress, 22-2th Sep. 2025, Brasilia-DF, Brasil. To be presented. https://cab.unb.br/.

Darmani, A., & Jullien, C. (2017). *Innovation Readiness Level Report – Energy Storage Technologies (D2.2a)*. REEEM Consortium. https://www.reeem.org/uploads/REEEM-D2.2a.pdf

ECSS. (2009). European Cooperation for Space Standardization. *ECSS-M-ST-10C Rev. 1: Project planning and implementation*. European Space Agency–ESTEC. https://ecss.nl/standard/ecss-m-st-10c-rev-1-project-planning-and-implementation/

ESA. (2023). *European space economy 2023*. Retrieved from https://space-economy.esa.int/documents/b61btvmeaf6Tz2osXPu712bL0dwO3uqdOrFAwNTQ.pdf

Freeman, R. E. (1984). *Strategic management: A stakeholder approach*. Boston: Pitman.

Heracleous, L., Terrier, D., & Gonzalez, S. (2019). NASA's capability evolution toward commercial space. *Space Policy, 50*, 101330. https://doi.org/10.1016/j.spacepol.2019.07.004

IBAMA. (2022). *Licença de Operação (LO) Nº 1653/2022 (13413478)*. https://servicos.ibama.gov.br/licenciamento/modulos/documentos.php?cod_documento=74109&donwload=

Indian Space Research Organisation. (2025). *Industry Engagement*. https://www.isro.gov.in/Industry.html

Koelle, D. E. (2010). *TRANSCOST 7.3: Statistical-analytical model for cost estimation and economical optimization of launch vehicles* (Rev. 3). In *Handbook of Cost Engineering for Space Transportation Systems*. TCS-TransCostSystems.

Lee, M. C., Chang, T., & Chien, W. T. (2011). An approach for developing the concept of Innovation Readiness Levels. *International Journal of Managing Information Technology*.

MLBR. (2024). *Retrospectiva 2024*. Private Communication.

North, D. C. (1991). *Institutions, Institutional Change and Economic Performance*. Cambridge: Cambridge University Press.

PLSV-C51. (2021). *Brochure PSLV-C51 – Amazonia-1*. https://web.archive.org/web/20210223104252/https://www.isro.gov.in/pslv-c51-amazonia-1/pslv-c51-amazonia-1-brochure

Science and Technology Park of the University of Brasília – PCTec/UnB. (n.d.). *Home page*. University of Brasília. Retrieved June, 2025, from https://www.pctec.unb.br/

SGDCI. (2025). *1st Seminar on Security, Development and Defense in the Space Environment*, 24–26 June 2025, Brasília-DF. https://sgdci.aeb.gov.br/

The Korea Herald. (2023). Innospace launches world's 1st hybrid rocket with electric pump. https://www.koreaherald.com/article/3083932

United Nations. (1967). *Treaty on principles governing the activities of states in the exploration and use of outer space, including the Moon and other celestial bodies (Outer Space Treaty)*. United Nations Office for Outer Space Affairs. https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introouterspacetreaty.html