DISCUSSION PAPER

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ABSTRACT

National Defense requires adequately trained, prepared and equipped armed forces to perform in guaranteeing national interests and protect sovereignty. Regarding the issue of equipping – which is the main focus of the three forces' (Navy, Army, and Air Force) strategic programs – it is not restricted to investment in updated defense equipment and systems procurement, but chiefly the development of endogenous scientific-technological capacities able to provide defense needs. This makes it vital to undertake efforts and investments in the area of science, technology, and innovation, especially in research and development activities aimed at national defense. The purpose of this work is to analyze the importance of such activities in the achievement of the main strategic programs of the Brazilian Navy. For this purpose, the main aspects of the interrelation between national defense and science, technology and innovation, the general characteristics of the Navy's main strategic programs and the importance of scientific-technological enterprises in their development will be examined.

Keywords: national defense; science, technology and innovation; Brazilian Navy; naval power; military technology; strategic programs; Brazilian Armed Forces.

1 INTRODUCTION

In recent years, the importance of public policies focused on National Defense has grown, among various segments of government, private enterprise and academia in Brazil. In fact, this growing relevance can be seen by the advancement of debates on the subject and by the federal government's efforts to strengthen the political-institutional structures of Defense, as well as its material means. In terms of spending on the sector, for example, Brazil spent US$ 25.6 billion in 2015, showing a 38% variation in the amount between 2006 and 2015 – even though spending remains representing about 1.5% of the gross domestic product (GDP) (Perlo-Freeman et al., 2016).

In order to fulfill National Defense objectives, Brazil must have Armed Forces that are properly trained, prepared and equipped for action. However, training, preparation and equipping go beyond the simple acquisition of ready equipment and systems. Today, for the country's strategic interests, the capacity to design and develop them endogenously is vital. This capacity, in turn, only becomes possible through a robust science, technology and innovation (ST&I) structure that includes considerable research and development (R&D) efforts in areas of Defense interest. In this context, the adoption, by the three Armed Forces, of a model that foresees close cooperation between government, academia and industry – known as Triple Helix – stands out. Developed by Etzkowitz and Leydesdorff (1995; 1998; 2000), this model is guided by the recent transformation in the performance of these three actors in ST&I activities and by the collaborative practices among them in the innovation ecosystem, contributing directly to the effectiveness of the results achieved, as will be discussed throughout the sections of this work.

In view of the increasing importance of providing the country with appropriate means to guarantee its interests and protect its sovereignty, it is necessary to develop appropriate scientific-technological capabilities to meet the demands and achieve the highest level objectives of the Armed Forces: the Brazilian Navy, the Brazilian Army (EB) and the Brazilian Air Force (FAB). Regarding joint action, interoperability among the three Forces can be especially enhanced by the ST&I partnership established between the Navy's Directorate-General of Nuclear and Technological Development (DGDNTM), the Army's Department of Science and Technology (CDT) and the Department of Aerospace Science and Technology (DCTA). Among the results of the partnership are the Strategic Meetings for Inter-Forces Cooperation, the submission of a joint project between the Brazilian Navy and the Brazilian Army to the Organization for the Prohibition of Chemical Weapons (OPCW), the development of project proposals in areas that meet common demands, and the assignment of military personnel from the Brazilian Navy and the Brazilian Air Force to serve as instructors at the Military Institute of Engineering (IME), an EB teaching institution.[1]

Each of the three Forces currently has strategic programs that aim to guarantee the necessary material capabilities for the fulfillment of their respective missions. In the specific case of the Brazilian Navy, this means not only the demand for vessels that guarantee the Naval Force an effective performance in the protection of Brazilian Jurisdictional Waters (AJB), but also the need to develop modern surveillance systems that ensure the capacity to monitor and control these areas. Both the development and the acquisition of such instruments necessarily go through scientific research and the incorporation of technologies in the internal environment, in order to enable the military to use these means. The importance of these issues in the Brazilian Navy is such that, in April 2017, after the Force's organizational restructuring, ST&I activities were raised to the level of a general directorate: the DGDNTM. In the words of Fleet Admiral Bento Costa Lima de Albuquerque Júnior, then director of the DGDNTM:

> The Naval High Administration has improved the structure, equipment, and personnel, with the firm purpose of not only keeping up with technological evolutions, but of achieving autonomy, independence, and superiority in defense products and solutions.[2]

In addition, the Brazilian Navy has presented its ST&I projects in important events in the area, including the Annual Meeting of the Brazilian Society for the Advancement of Science (SBPC).[3]

1. Available at: <https://bit.ly/3G0SEp2> and <https://bit.ly/3DPSYVU>.

2. Speech delivered on April 25, 2018, on the celebration of the Day of Science, Technology and Innovation in the Brazilian Navy.

3. Available at: <https://bit.ly/3jbjkJW>. Accessed on: July 27, 2018.

It is also worth noting that technology is an important constituent of maritime power (a broad concept that encompasses naval power), directly affecting the distribution of capabilities of Naval Forces around the globe. It is necessary for the navies, in this context, the development of a detailed strategy for technological innovation, in order to increase the understanding of naval capabilities and optimize investments in ST&I (Till, 2009). The centralization of issues related to the theme in the DGDNTM, therefore, as well as the elaboration, by this directorate-general, of the Brazilian Navy's ST&I Strategy, launched in 2017, demonstrate an important strategic vision by this Force regarding the development of ST&I.[4]

The geographical position of Brazil, a country with more than 7,000 kilometers of coastline and a maritime territory of more than 3.5 million square kilometers, represents a key factor for its geopolitical positioning. In fact, the geographic environment constitutes the scenario in which maritime strategies are outlined (Holmes, 2014). According to Mahan (1915), regions rich in natural resources and important in terms of commercial and political aspects arouse the attention and stimulate the greed of other nations. In this context, considering the vast territory of Brazilian jurisdiction in the South Atlantic, it is essential that Brazil has the necessary capabilities for the protection of this region, which requires a suitably robust naval power and a high potential for monitoring and surveillance – skills achieved mainly through technological innovation.

Taking into account the topics covered in this introduction, the objective of this work is to analyze the importance of ST&I activities in the achievement of the Brazilian Navy's main strategic programs, demonstrating how R&D efforts are important to provide the Naval Force

4. The Brazilian Navy has presented relevant progress in the development of technologies and in the performance of ST&I activities. According to a speech given by Admiral Marcos Sampaio Olsen, current director of the DGDNTM, on May 2, 2019, on the occasion of the celebration of the Day of Science, Technology and Innovation in the Brazilian Navy, among other recent advances, the following stand out: the beginning of the operation of the pilot plant of the Power Microwave Laboratory (LaMP), the participation in research projects of sensors and systems that will serve new vessels of the Brazilian Navy Fleet, the expansion of the staff of scientists and engineers of the Naval Agency for Nuclear Safety and Quality, the implementation of the future Naval Nuclear and Radiological Emergency Response Follow-up Center, the launching of the cornerstone of the Brazilian Multipurpose Reactor (RMB), and the promotion of major events focused on new technologies and innovation – such as the International Workshop on Nuclear Safeguards, the 1st DGDNTM Seminar on Innovation and Intellectual Property, and the 1st Brazilian Navy Workshop on Artificial Intelligence.

with appropriate means for the fulfillment of its mission. This text is divided into five sections, including this introduction.

In section 2, the importance of STI&I activities in the field of National Defense will be presented, emphasizing public policies directed to the STI-Defense interrelationship and the national scientific-technological infrastructure related to the subject. In section 3, the main strategic programs of the Brazilian Navy will be presented, in general terms. In the fourth section, an analysis of the importance of STI&I activities for the achievement of these programs will be conducted. Section 5, finally, concludes the text emphasizing the importance of technological progress in Brazilian Navy programs for the achievement of public policy objectives in the field of defense in Brazil.

2 GENERAL ASPECTS OF THE RELATION BETWEEN ST&I AND NATIONAL DEFENSE IN BRAZIL

International experience shows that military demands and defense-related needs have served as an important stimulus for technological advancement in countries that prioritize innovation activities in their military spending. In fact, military superiority currently depends considerably on scientific and technological superiority (Andrade and Franco, 2016), and there is a clear correlation between a country's military capacity and its level of technical progress.[5]

Perhaps the best current example of this relationship occurs in the United States, where about 50% of federal government investments in R&D were made in the area of defense (De Negri and Squeff, 2014, p. 9), this being a "paradigmatic case in defense STI" (Squeff, 2016, p. 74). To better understand the importance of STI&I activities for the sector, it is interesting to briefly analyze two cases: the US and the UK.[6]

5. Still, there are a number of other factors (morale, mass, leadership, command, organization, intelligence, etc.) pointed out by the strategic studies literature that not only complement the scientific-technological area but can even surpass it in a conflict. Such factors, however, are not addressed in this paper due to its focus and scope.

6. Besides these two countries, Squeff (2016) analyzes in a detailed way the cases of China, Spain, France and Sweden. It is important to note, however, that the degree of development of these countries in the areas of Defense and STI is too different from Brazil, which is why they are only mentioned here as subsidies for the analysis, and not as models to be followed in their entirety.

In the United States, the relevance of defense R&D activities has enabled the "creation of a research infrastructure" and is also an "important source of civilian innovations, new companies, and training of scientists and engineers" (Squeff, 2016, p. 74). This is a "fragmented" system, in which there is no centralization of research institutes for defense under one department.[7] Briefly, this system works as follows:

> [S]S&T activities are planned and conducted by the military defense departments and agencies, with the departments being primarily engaged in applied research to give the military capabilities for its forces, and the agencies being responsible for multiservice programs and more basic and generic research. Most relevant among these is the Defense Advanced Research Projects Agency (Darpa) (Squeff, 2016, p. 76).

Recently, Defense R&D activities in the United States have become more restricted and more confidential, especially due to deepening concerns about post-9/11 terrorist threats.

In contrast to the North American model, the STI structure focused on defense in the United Kingdom is more centralized, although it has undergone important changes in recent decades. Until the early 1990s, there were five non-nuclear laboratories dedicated to defense research in the country, all government-owned, government-operated, and funded by the British Ministry of Defense. In 1991, four of these laboratories were brought together under the Defense Evaluation and Research Agency (DERA), "the largest research and technology organization of its kind in Western Europe" (Squeff, 2016, p. 73) at the time. Ten years later, DERA was separated into two distinct organizations: the QinetiQ and the Defence Science and Technology Laboratory (DSTL). The former is a publicly traded company, the result of the privatization of part of DERA, and which provides services to different governments around the globe. The second is a laboratory that has more than 90% of its revenue coming from services provided to the UK Ministry of Defense (Squeff, 2016, p. 74).

Once the importance of the inter-relationship between STI and Defense has been clarified, one must assess how this relation has been treated in the national context and, more specifically,

7. As noted by Squeff (2016, p. 75), "while most infrastructure is managed by the DoD (Department of Defense), nuclear weapons laboratories were part of the Department of Energy (DoE)".

how the federal government has given increasing importance to the theme. This is noticeable when observing both the main National Defense documents – such as the National Defense Industry Policy (NDP), the National Defense Policy (PND), the National Defense Strategy (END) and the Special Tax Regime for the Defense Industry (RETID) – and those related to scientific-technological policies – such as the National Strategy for Science, Technology and Innovation (Encti) of the Ministry of Science, Technology, Innovation and Communications (MCTIC). Another aspect that demonstrates the growing importance of this interrelationship is the significant portion of the country's scientific-technological infrastructure devoted to Defense. The next subsections will examine these two factors, respectively.

2.1 The relevance of ST&I in National Defense public policies

The relevance of STI&I activities for National Defense can be seen by the importance given to this theme in the main documents of the portfolio prepared by the federal government in recent years, especially the PND and the END, which make up the normative and operational centers of defense in the country, as well as more specific policies aimed exclusively at the defense industry, such as the PNID and the RETID.

The PND, "the highest level conditioning document of defense planning",[8] establishes as one of the National Defense Objectives (ONDs) "to promote productive and technological autonomy in the area of defense" (Brazil, 2016b, p. 13). Furthermore, the policy points out the need to "maintain and stimulate research and seek the development of indigenous technologies, especially regarding critical technologies", in addition to ensuring the qualification of human capital and the "development of the Defense Industrial Base and of dual-use products (civilian and military), as well as the generation of jobs and income" (idem, ibidem).

It is also important to highlight that the PND presents two fundamental notions for the strategic formulations made by the Armed Forces, in general, and the Brazilian Navy, in particular: Brazil's strategic environment and the Blue Amazon. The first concept refers to the area of priority interest for National Defense, which encompasses "South America, the South Atlantic,

8. Available at: <https://bit.ly/3I4s5Py>. Accessed on: Apr. 17, 2018.

the countries of the West African coast[9] and Antarctica" (Brazil, 2016b, p. 6). The second one represents a sub-area of the South Atlantic, coinciding with the AJB, being an "ecosystem of area comparable to the Brazilian Amazon and of vital relevance to the country, to the extent that it incorporates high potential living and non-living resources, among these, the largest oil and gas reserves in Brazil" (op. cit., p. 8).

Similarly to the PND, the END provides strategic direction for medium and long term actions of National Defense. Regarding the interrelationship between Defense and S&T&I, the document stresses its importance repeatedly. Firstly, science and technology constitute one of the dimensions of national power, and it is "imperative that the defense apparatus be in accordance with the most advanced practices and technologies, which requires the condition of national scientific and technological development in the state of the art" (Brazil, 2016b, p. 20-21). This, in turn, demands the permanent strengthening of the defense industry. In this sense, one of the guidelines of the END is that "the State will seek to act on the technological ceiling, in close liaison with the advanced research centers of the Armed Forces and Brazilian academic institutions" (idem, ibidem).

Secondly, when referring to "national technological competencies in the field of defense", the NDT adopts the assumption that "its improvement occurs as a function of both the development of science and technology infrastructure and the training of human resources", prioritizing "the approximation of scientific production with activities related to technological development" (Brazil, 2016b, p. 23) in the national defense industry. Thus, despite the caveats concerning the "security interests of the State regarding access to information", "joint initiatives between research organizations of the Armed Forces, national academic institutions and Brazilian private companies" (idem, ibidem) are encouraged. Therefore, it is the role of Defense to accompany "advanced research in defense technologies in the institutes of the Armed Forces or in other organizations subordinated or associated to them, aiming, above all, at the synergic performance of such initiatives" with a view to "an integration that avoids duplicity of efforts, that shares

9. Morocco, Saharawi Arab Republic, Mauritania, Senegal, Gambia, Guinea-Bissau, Guinea, Sierra Leone, Liberia, Ivory Coast, Ghana, Togo, Benin, Nigeria, Cameroon, Equatorial Guinea, Gabon, Republic of Congo, Democratic Republic of Congo, Angola, Namibia, South Africa.

staff and ideas and that rationalizes the use of resources, as well as favors the construction of links between research and production" (idem, ibidem).

Third, the END lists "three technological sectors (...) essential to National Defense", which "are considered strategic and must be strengthened" (Brazil, 2016b, p. 30-31): nuclear, cyber and space – under the responsibility of the Brazilian Navy, the Brazilian Army and the Air Force, respectively. Given their nature, these sectors "transcend the division between development and defense and between the civilian and military", seeking the "empowerment of the country as a whole" (idem, ibidem). The document presents the following directives for the nuclear sector, under the responsibility of the Brazilian Navy: "improve the development of nuclear technology"; "conclude (...) the complete nationalization and development on an industrial scale of the nuclear fuel cycle, including gasification and enrichment, and of the technology for building nuclear reactors, for exclusive use by Brazil"; "improve national technologies and capabilities in order to qualify the country to design and build nuclear thermoelectric plants", "with the purpose of diversifying the national energy matrix"; "increase the capacity to use nuclear energy in a wide range of activities for peaceful use"; and "increase the capacity to provide radiological and nuclear defenses" (Brazil, 2016b, p. 30-31).

Finally, the NDS presents Defense Strategies (EDs) and Defense Strategic Actions (AEDs) aligned with the NDP's ONDs. Thus, complementing the aforementioned OND, two EDs are presented by the END. The first one is the "promotion of the sustainability of the productive chain of the Defense Industrial Base", which aims to "provide stable conditions for research, development, production and sale of Brazilian defense products and to provide sustainable conditions for the productive chain", and is complemented by twelve AEDs.[10] The second is the "strengthening of the Defense Science and Technology Area" in search of the development and "solidity of the S&T&I area in defense matters, promoting the absorption, by the productive chain, of indispensable knowledge to gradually reduce dependence on foreign technology" (Brazil, 2016b, p. 41-42), and is complemented by nine EDAs.[11]

Regarding efforts to strengthen the national defense industry, the PNID stands out. It establishes, among its specific objectives, "the progressive reduction of external dependence on strategic defense products, developing and producing them domestically" and "the increase of competitiveness" of the national defense industry "to expand exports" (Brazil, 2005). The document also presents the existing defense industry as a priority, besides advocating the need for "inductive strategic actions" (op. cit.).

Besides the PNID, another important government action for the strengthening of the national defense industry was the approval of Law No. 12,598, of March 21, 2012, known as

10. They are: i) "seek budgetary regularity and predictability for the Defense sector"; ii) "seek budgetary and financial binding of an adequate percentage of GDP in defense expenditures"; iii) "stimulate projects of Defense interest that employ dual products and technologies"; iv) "improve the special legal, regulatory and tax regimes for the Defense Industrial Base"; v) "establish plans to meet the Defense Articulation and Equipment Plan (PAED) and to sustain the Defense Industrial Base"; vi) "favor joint government purchases of Defense interest"; vii) "improve financing mechanisms for the Defense Industrial Base"; viii) "extend the prerogatives of the Defense Industrial Base to products or systems for public security"; ix) "promote exports from the Defense Industrial Base"; x) "promote the increase of local content in Defense Industrial Base products"; xi) "stimulate the obtaining of commercial, industrial and technological compensation in acquisitions from abroad"; and xii) "promote the coordination of certification processes for defense products, services and systems – PRODE/SD [defense product/defense system], concerning the Defense Industrial Base" (Brazil, 2016b, p. 41).

11. They are: i) "promote the development of critical technologies for defense"; ii) "improve the integration model of the triad government/academia/business"; iii) "promote the development of nuclear technology"; iv) "promote the development of cybernetic technology"; v) "promote the development of space systems"; vi) "stimulate the establishment of partnerships and exchanges in the area of research of technologies of interest to Defense"; vii) "use technological orders to promote the increase of the national technological content of defense products"; viii) "promote training in basic and applied sciences, prioritizing the approximation of scientific production with activities related to the development of strategic analysis, technological development of the Defense Industrial Base and the improvement of management instruments and operational doctrines"; and ix) "promote the integration of the Defense sector in the areas of metrology, standardization and certification of Defense products, services and Systems – PRODE/SD, concerning the Defense Industrial Base" (Brazil, 2016b, p. 42).

the Law for the Promotion of the Defense Industrial Base. This is specific legislation that establishes "special rules for the procurement, contracting and development of defense products and systems" and "provides incentive rules for the strategic area of defense" (Brazil, 2012a). This law presented important definitions for the sector, such as defense product (PRODE),[12] strategic defense product (PED),[13] defense system (SD),[14] strategic defense company (EED),[15] among others. One of its main aspects is the implementation of the RETID, designed to stimulate companies in the sector by exempting them from various taxes. By exempting these national companies, the new regime facilitates both the acquisition of equipment by the Armed Forces and the export of defense products.

Regarding the inter-relationship between National Defense and STI, it is important to emphasize that the joint work dates back to the second half of the 20th century, with emphasis on the efforts of leaders such as Admiral Álvaro Alberto and Commander Renato Archer. The current stage of this interaction began in the early 2000s (therefore, prior to the defense policies presented), more specifically with the publication of the joint document Strategic

12. "All goods, services, works or information, including arms, ammunition, means of transport and communications, uniforms and materials for individual and collective use employed in defense activities, with the exception of those for administrative use" (Brazil, 2012a).

13. "All defense products (PRODE) that, due to their technological content, difficulty of obtaining or indispensability, are of strategic interest to National Defense, such as: i) naval, land and aerospace war resources; ii) specialized technical services in the area of projects, research and scientific-technological development; and iii) specialized equipment and technical services for the areas of information and intelligence" (Brazil, 2012a).

14. "Interrelated or interactive set of PRODE that serves a specific purpose" (Brazil, 2012a).

15. "All legal entities accredited by the Ministry of Defense by means of the cumulative fulfillment of the following conditions: i) have as their corporate purpose the performance or conduction of research, design, development, industrialization, services referred to in Art. 10, production, repair, conservation, revision, conversion, modernization or maintenance of PED in the country, including the sale and resale only when integrated to the industrial activities mentioned above; ii) have in the country its headquarters, administration and facilities (...); iii) have in the country proven scientific or technological knowledge of its own or complemented by partnership agreements with scientific and technological institutions to carry out joint activities of scientific and technological research and development of technology, product or process, related to the activity developed (...); iv) ensure, in its acts of incorporation or in the acts of its direct or indirect controller, that the set of partners or shareholders and groups of foreign partners or shareholders may not exercise in each general meeting a number of votes greater than 2/3 (two thirds) of the total votes that may be exercised by Brazilian shareholders present; and v) ensure the continuity of production in the country" (Brazil, 2012a).

Concept: science, technology and innovation of interest to National Defense. The document sought to enable "scientific-technological solutions and innovations, for the satisfaction of the country's needs related to defense and national development" (Brazil, 2003, p. 12-18), as the mission of the proposed System of Science, Technology and Innovation of Interest to National Defense (SisCTID). The conception presented ten strategic objectives divided into four themes: i) "mastery of technologies that meet the needs of National Defense";[16] ii) "contribution to the strengthening of national industry";[17] iii) "institutional recognition, in Brazil and abroad";[18] and iv) efficient and effective management[19] (Brazil, 2003, p. 12-18). Such strategic objectives and their implementation measures were later reaffirmed by the Policy of Science, Technology and Innovation for National Defense (PCTIDN) (Brazil, 2004).

Besides laws, policies and strategies directed at National Defense in general, the Brazilian Navy in particular has given increasing attention to the issue of ST&I, the main reflection of which is the publication of the Brazilian Navy's ST&I Strategy, "which publicly signals the Scientific-Technological Areas through which the components of the Triple Helix – government, academia and industry – may contribute to the development and improvement of the Force".[20] In this sense, the Strategy has as its "most important characteristic (...) its alignment with the high level conditioning documents" (PND, END, National Defense White Paper, PCTIDN, Encti).

16. Its strategic objectives are the "expansion of the technological content of defense products and services"; the "elevation of the level of human resource training"; and the "improvement of the science and technology infrastructure to support programs and projects of interest to National Defense" (Brazil, 2003, p. 18).

17. Its strategic objectives are the "creation of a favorable environment for innovation and industrial competitiveness"; and the "implementation of financing mechanisms for ST&I activities of interest to National Defense" (Brazil, 2003, p. 18).

18. Its strategic objectives are to "broaden the interest of the various segments of society for the initiatives in the areas of ST&I focused on National Defense" and the "improvement of the image of institutional excellence" (Brazil, 2003, p. 18).

19. Its strategic objectives are the "integration of STI&I initiatives of interest to National Defense, conducted in military R&D organizations, in institutes, in civilian universities and in industry"; the "establishment of a policy for human resources valuation, based on results"; and the "implementation of a system that integrates strategic planning, the development cycle of defense products and services, and the assessment of results" (Brazil, 2003, p. 18).

20. Speech delivered by Admiral Bento Costa Lima Leite de Albuquerque Junior at the Navy Command (Brasilia, Federal District), on April 25, 2018, on the occasion of the celebration of Science, Technology and Innovation Day in the Brazilian Navy.

In addition, the document presents "the rationalization of the use of the resources of the MB [Brazilian Navy] (...), making use, when necessary, of the other members of the Triple Helix", as the "philosophy that permeates the planning and control of ST&I R&D actions" (Brazil, 2017, p. 28-29).

Thus, the Strategy is presented as an "instrument to inform military and civilian, public and private actors that participate, directly or indirectly, in the SCTMB [Brazilian Navy's Science, Technology and Innovation System]" (Brazil, 2017, p. 16), seeking three main desired effects: the "coordinated direction of the SCTMB, primarily to meet the needs of the Navy of Tomorrow and the Future";[21] the "presentation of the vision and strategy of the ST&I sector of the Brazilian Navy to decision-makers, key players, partners, clients, and executors"; and the "optimization of the application of financial resources managed by the ST&I sector for the execution of its portfolio of projects that meet the strategic programs of interest of the Force" (idem, ibidem).

The document also presents, as challenges to be faced by the SCTMB the "search for scientific and technological mastery in sensitive or strategic areas of interest to the MB [Brazilian Navy],[22] with emphasis on the design, construction and operation of nuclear-powered submarines"; the "monitoring and control of Brazilian Jurisdictional Waters and other maritime areas of interest"; "cyber security and defense"; the "continued attainment of knowledge about the different operational environments of interest to the MB [Brazilian Navy]"; the "improvement of the combatant's physical and psychological health and performance before, during and after Naval Warfare Operations"; the "training for nuclear, biological, chemical, radiological and explosive artifacts defense"; the "overcoming of barriers and limitations of access to technologies, goods and services of interest to the Navy's strategic projects"; the "uncertainties inherent to the continued provision of human and financial resources for long-term ST&I projects"; and the "guarantee of a continuous and efficient technological and knowledge management" (Brazil, 2017, p. 20-21). Thus, the SCTMB is envisioned as a "dynamic, harmonious, integrated, synergistic, interdisciplinary and adaptive" ST&I system that has "highly skilled human resources and

21. For more on the concepts of the Navy of Tomorrow and the Navy of the Future, see Brazil (2017, p. 16).

22. They are: command, control, communications, computer, intelligence, surveillance, and reconnaissance systems; cyber defense and security; operational environment; nuclear and energy; naval, aircraft, and Marine platforms; combatant performance; and nuclear, biological, chemical, radiological defense, and explosive artifact (Brazil, 2017, p. 43).

compatible infrastructure, focused on reducing external dependence to meet the technological demands" of the military organizations involved (op. cit., p. 23).

It is highlighted that its implementation must be done "through partnerships with civilian and military scientific and technological institutions, industry and academia", being imperative, also, "the cooperation and coordination with the other singular forces and other areas of government", seeking to "act at the technological frontier, seeking, whenever possible, the dual (military and civilian) utility of technology" (Brazil, 2017, p. 35). Finally, the Strategy states that the S&T&I infrastructure (within and outside the Brazilian Navy) "presents very high acquisition and ownership costs", thus requiring "close cooperation among all members of the "Triple Helix", so as to provide mutual support and obtain synergistic effects that will enable the transformation of S&T&I R&D projects into operational capabilities" (op. cit., p. 42).

Still regarding the implementation of the Triple Helix model, adopted in the development of the strategic programs of the three Forces, the purpose of enhancing the interactions between government, academia, and industry in order to develop an effective innovation strategy stands out. The focus on universities as a source of entrepreneurship and technology allows innovation to be addressed in a systematic manner, creating a dynamic ecosystem that integrates the three actors (Etzkowitz and Zhou, 2017). The evaluation of the programs of the Brazilian Navy, as will be conducted in a later section, makes evident, since its conception, the adoption of this system. The active participation of educational institutions and companies – state and private – in addition to military organizations and other government agencies, occurs in the different stages of each of the programs currently being executed by the Force.

It is not only in the area of defense that Brazil has pointed out the importance of public policies focused on ST&I. This movement can be seen by examining the Encti of the MCTIC, which, by emphasizing the importance of STI&I as a structuring axis for the country's development, determines the guidelines for national and regional actions, listing priority themes that involve the most important productive chains of the economy. In this sense, its most recent version presents the defense sector as strategic for STI in Brazil, establishing as an objective "to foster research and development of military and civilian products and systems that make scientific-technological priorities compatible with defense needs" (Brazil, 2016c, p. 89).

Encti also recognizes the contribution of National Defense in strengthening the scientific and technological base of the country, by stating that the sector "offers, through the Armed Forces, in science, technology and innovation, valuable contributions to raise the level of autonomy of the country" (Brazil, 2016c, p. 88), including through the maintenance of "centers of excellence whose production, particularly with regard to applied research, is fundamental to scientific and technological achievements" (idem, ibidem).

The development of the strategic programs of the Armed Forces provides, besides advances related to National Defense – its main function – a significant process of technological drag for civilian sectors. Through the nationalization of components and systems, technology transfer, and the training of human resources, the diffusion of knowledge to different production chains is promoted. In this sense, the dual use of technologies contributes significantly to the development of ST&I and national industry. The positive externalities that accompany such programs emphasize their relevance for the country, constituting an important contribution to the strengthening of science and national industry (Andrade et al., 2018; Andrade, Rocha and Hillebrand, 2019).

2.2 The national defense-oriented scientific-technological infrastructure

In addition to public policies aimed at STI activities within the scope of National Defense, the national scientific-technological research infrastructure relevant to the sector must also be analyzed. As noted by Squeff (2016, p. 63), "the constitution of a robust sectoral system of defense innovation that supports the national objectives for the sector cannot do without the existence of an equally robust scientific and technological infrastructure". In the current moment of "resurgence" of the country's defense industry, the search for independent technology development is of vital importance (Andrade and Franco, 2016). In this sense, it is important to highlight the scientific-technological contributions available to National Defense in the country's physical infrastructure, such as scientific and technological institutions related to the defense sector and the structures of the sectors listed as strategic by the PND and the NDS.

The three sectors of strategic importance for National Defense (nuclear, cybernetic and space) were divided among the three Forces, so that the Brazilian Navy was responsible for the first, the Brazilian Army for the second and the Air Force for the third. As far as the nuclear sector is concerned, Brazil is among the main countries that dominate its technology, with successful applications in the energy, agricultural, medical and industrial areas, besides having knowledge of the fuel cycle and enough uranium deposits for its needs. Importantly, "the Brazilian nuclear industrial park is qualified as an international reference, especially with regard to the area of safety and protection of the facilities, as well as in waste control" (Brazil, 2016a, p. 57).

Historically, the Brazilian Navy has contributed to the Brazilian Nuclear Program (PNB) since 1979, being responsible for mastering the fuel cycle and supplying uranium enrichment capacity to Indústrias Nucleares do Brasil (INB). In this context, part of the Naval Force's efforts are concentrated in the Navy Nuclear Program (PNM), whose main objective is the development of the nuclear propulsion reactor for one of the submarines foreseen under the Submarine Development Program (PROSUB), as will be explained in detail in the next section.

Regarding scientific and technological institutions in the defense sector, there are currently 44 laboratories belonging to the Armed Forces in Brazil – some of them being references in their respective areas (Squeff, 2016). Within the scope of the Brazilian Navy's partnerships in ST&I, the agreement signed in 1956 with the University of São Paulo (USP) is of special relevance. With the goal of founding the naval engineering course in the country, the partnership contributed to the consolidation of a technological culture and served as an important stimulus to national industry. As of the agreement, USP became the Brazilian Navy's higher education institution, similar to the IME (EB) and ITA (FAB). Currently, Brazilian Navy facilities are located on the institution's campus, such as the Navy Technology Center in São Paulo (CTMSP) (Brazil, 2007).

Through the DGDNTM, the Brazilian Navy has sought to expand institutional partnerships with universities. Currently, Mutual Protocols of Intent (PIM) are in effect with ten higher education institutions, based in the South and Southeast regions – Universidade Federal Fluminense (UFF) (2011), Universidade Federal do Rio de Janeiro (UFRJ) (2011), Pontifícia Universidade Católica do Rio de Janeiro (PUC-Rio) (2011), Universidade do Vale do Rio dos Sinos (Unisinos) (2014), Pontifícia Universidade Católica do Rio Grande do Sul (PUCRS) (2014), Universidade

Federal do Rio Grande do Sul (UFRGS) (2014), Universidade Federal de Santa Maria (UFSM) (2015), Universidade Federal do Rio Grande (Furg) (2015), and Universidade de Caxias do Sul (UCS) (2017), in addition to USP itself. The relationship with universities occurs especially through the Coordination Division of the ST&I Offices of the Brazilian Navy, located in São Paulo, and the Technological Innovation Center of the Brazilian Navy (NIT-MB), established in Brasilia.

Among the ongoing projects with universities and partner companies, in accordance with the Triple Helix model, we highlight work in the areas of Marine Biotechnology, Computational Fluid Dynamics, Sonar Technology, Sustainable Bioprospecting, and Climate Change. Furthermore, the projects also include training actions for officers (Master's and Doctorate). As important results of these initiatives, we can point out patent registrations and the approval of funding for the execution of the research, besides the application of the developed technologies.

Considering the institutions of the Brazilian Navy that are active in scientific-technological development, it is important to highlight the role of the DGDNTM in the integration, rationalization and dialogue with the organizational structures of ST&I management through the Navy Technology Center in Rio de Janeiro (CTMRJ) and the CTMSP, in São Paulo.[23] The Navy Research Institute (IPqM), subordinated to the CTMRJ, is responsible for the "development of technologies needed by the Navy", focusing on "research and development activities in electronic warfare, weapons, underwater acoustics, digital systems and materials" (Brazil, 2016a, p. 81). The CTMSP, in turn, is especially dedicated to the execution of activities related to the PNM, aiming to "enable the Force to achieve mastery of technological, industrial and operational processes of nuclear facilities applicable to naval propulsion" (idem, ibidem).

3 THE STRATEGIC PROGRAMS OF THE BRAZILIAN NAVY

Despite budgetary difficulties, National Defense is undergoing a transformation process, and one of its main elements is the Defense Articulation and Equipment Plan (PAED), composed of strategic programs of the Armed Forces "which aim to meet the demands of articulation and equipment necessary for the fulfillment of their constitutional missions" (Brazil, 2016a, p. 146). It is important to emphasize that the PAED is currently under review, in order to enable the

23. Available at: <https://bit.ly/3lRaCCs>.

plan's adaptation to the national situation. Before addressing the current strategic programs of the Brazilian Navy, it is necessary to emphasize that these are the most recent stage of a long historical process, and it is possible to identify, therefore, the existence of other Naval Force reequipment programs prior to 2006 (Sales, 2015). It is also important to highlight that, before the establishment of the PAED, the Brazilian Navy already had its own reequipment program, the Navy Reequipment Program (PRM).

Developed based on the strategic needs established in the National Defense Policy, the PRM is composed of the main programs which today make up the PAED.[24] The program was formally submitted to the Ministry of Defense in mid-2005 and structured in two ten-year periods: 2006-2015 and 2016-2025. Among the current strategic programs of the Brazilian Navy, three of them will be further analyzed in this paper: i) the PNM; ii) the Construction of the Naval Power Core; and iii) the SisGAAz.

3.1 PNM

In execution since 1979, the PNM emerged with the main purpose of ensuring mastery of the nuclear fuel cycle and building a nuclear power generation plant – being directly linked to the PNB. With the first efforts in the nuclear area dating from the 1930s (Leite, Assis and Côrrea, 2016), it was from the 1970s onwards that Brazil achieved significant advances in mastering this technology, thanks to national commitment and the cooperation agreement signed with the Federal Republic of Germany. This agreement, which lasted fifteen years and involved investments of around US$ 10 billion, stipulated the transfer of technical knowledge of the fuel cycle and reactor construction.

The creation and validation of the Laboratory for Generating Nuclear-Electric Energy (LABGENE), a prototype that will serve as the basis for the reactor of the first Brazilian nuclear propulsion submarine (SN-BR), to be developed under the PROSUB, are part of the PNM. The LABGENE, whose commissioning is scheduled to occur in 2021, and the Uranium Hexafluoride

24. These include the construction of vessels (nuclear submarine, conventional submarines, escort vessels, logistic support ships, ocean patrol vessels), the implementation of the Blue Amazon Management System (SisGAAz), the acquisition and development of operational systems, and the establishment of a shipyard and naval base for the construction and maintenance of submarines.

Production Unit (USEXA), inaugurated in2012, make up "the two major projects" of the program (Leite, Assis and Côrrea, 2016, p. 269).

The analysis of the PNM makes clear its importance for the PROSUB, since, as expressed in the National Defense White Paper: "[t]he feasibility of the PROSUB depends on the development of the nuclear propulsion system, the focus of the PNM" (Brazil, 2016a, p. 147). Without the development of a nuclear propulsion system, the production of the SN-BR would be unfeasible. In addition, there is great potential for technological drag in the realm of nuclear propulsion. The development of these programs brings with it a "potential duality of nuclear technology", being able to contribute "in the development of reactors that range from use in medicine and research to power generation" (Leite, Assis and Côrrea, 2016, p. 252).

Regarding specifically the dual application of technologies developed in the context of the PNM and the externalities of the program, the Brazilian Multipurpose Reactor (RMB) project stands out. This is a project under the responsibility of CNEN, supported and executed by the Financier of Studies and Projects (Finep) and by Amazônia Azul Tecnologias de Defesa S.A. (Amazul). Among its main objectives are the production of radioisotopes and radiopharmaceuticals; the irradiation and testing of nuclear fuels and structural materials; and the development of scientific and technological research using neutron beams. Thus, the RMB will bring direct benefits to areas such as nuclear medicine, industry, and the environment (Andrade et al., 2018).[25]

The participation of the Brazilian Navy is especially relevant in the RMB project – part of the applied technologies derive from those developed under the PNM. Highlighting the proximity between the RMB and the program, the enterprise will be built in Iperó (São Paulo), being adjacent to the Aramar Nuclear Industrial Center (CINA), where important stages of the PNM are developed (Andrade et al., 2018).

3.2 Building the Naval Power Core

In general, this program aims at the "expansion of the Navy's operational capacity", being "absolutely necessary, not only to modernize the Navy, but also to enable the gradual

25. Available at: <https://bit.ly/3J3kySp>.

replacement of naval, naval aviation and Marine combat platforms" (Brazil, 2016a, p. 147). This is a broad program, divided into several subprograms, highlighting: i) the PROSUB; ii) the Program for Obtaining Surface Means (PROSUPER); iii) the Program for Obtaining Amphibious Ships (PRONANF); and iv) Program for Obtaining Aircraft Ships (PRONAE).

PROSUB is divided into three main fronts: the design and construction of industrial infrastructure and support for submarine operation; the creation of four new conventional submarines (S-BR); and the design and development of the first SN-BR.[26] The transfer of naval technology by the French company Naval Group (formerly Direction des Constructions Navales – DCNS), the result of an agreement signed between Brazil and France in 2008, will make it possible to achieve the three fronts of the program. It is important to emphasize, however, that all nuclear technology on board the SN-BR is developed nationally, and the technology transferred by the French company is restricted to the submarine's resistant hull and other systems. The industrial infrastructure consists of a Steel Structures Manufacturing Unit (UFEM), two shipyards (one for construction and the other for maintenance), a naval base, a radiological complex, a ship elevator (shiplift) – with a capacity to support 8,000 tons – and an Instruction and Training Center for submarine crews (Leite, Assis and Côrrea, 2016).

Similar to PROSUB, PROSUPER provides for the acquisition of new means for the Brazilian Navy through external partnerships and national development and production. Included in the program are five scout ships, five ocean patrol ships, and one logistical support ship (Brazil, 2016a, p. 148). Currently, the Naval Force has eleven escort ships (six Niterói-class frigates, two Greenhalgh-class frigates, two Inhaúma-class corvettes, and the Barroso corvette), which are to be withdrawn from service by 2025 (with the exception of the Barroso corvette), being replaced by new multiple-use vessels of about six thousand tons, capable of operating helicopters of up to 12 t (Monteiro, 2009). Three of the five ocean patrol vessels were acquired by the Brazilian Navy from the British company BAE Systems, based on a £ 133 million (about R$ 366 million at the time) contract signed in January 2012, which included, in addition to the acquisition of the three vessels and

26. The submarine Riachuelo (S-40), the first of the four conventional units planned in the PROSUB, was launched to sea on December 14, 2018, initiating the testing stage, which precedes delivery to the operational sector of the Brazilian Navy. The first Brazilian nuclear-powered submarine, named Álvaro Alberto (SN-10), is scheduled to be launched in 2029.

respective support services, a license to manufacture vessels of the same class in Brazil (indicating the possibility that the other two ocean patrol vessels would be assembled under license in the country).[27]

Complementarily, since 2017, the Brazilian Navy has prioritized the Tamandaré Class Corvette program, which aims at the production and acquisition of four such vessels (whose design resembles the operating Barroso corvette), of about 3,400 t and at a value of over $300 million each (Rezende, 2017; 2018; Brazil, 2019). In March 2019, the Brazilian Navy concluded the process of selecting proposals for the acquisition or construction of the vessels. The Blue Waters consortium, composed of the German company Thyssenkrupp Marine Systems and the Brazilians Embraer S.A. and Atech Negócios em Tecnologias S.A. (subsidiary of the Embraer Group), was chosen to build the four ships, with delivery scheduled between 2024 and 2028. Besides ensuring the expansion and modernization of the Brazilian Fleet, the initiative contributes to job creation (more than 1 thousand direct jobs and 4 thousand indirect jobs) and the strengthening of the national defense industry. The selected project also includes technology transfer in the areas of naval engineering and a high degree of nationalization (more than 30% of local content in the first ship and more than 40% in the others) (Brazil, 2019; Galante, 2019).

Following the line of the two previous programs, PROANF foresees the procurement of an amphibious ship – a combat vehicle landing ship (NDCC) or a dock landing ship (NDD) – through the procurement of a foreign project to be built in a national shipyard (Brazil, 2012c, p. 196). Currently, a transport and support ship (NaTrAp) is being developed based on a project of the Brazilian Navy Ship Design Center, which will have a displacement capacity of about 9,000 tons, transport up to five hundred marines and operate two heavy helicopters simultaneously (Monteiro, 2009).

Finally, the PRONAE foresees the development and construction of two new air ships (popularly known as aircraft carriers): one for the First Fleet (based in Rio de Janeiro) and another for the Second Fleet (to be installed near the mouth of the Amazon River in the future). These vessels could be obtained through national projects or partnerships with other countries (Brazil, 2012c, p. 196). After the END and the National Defense White Paper, the PRONAE also began to

27. Available at: <https://bit.ly/2ISVY77>. Accessed on: Apr. 12, 2016.

assist in the Brazilian Navy's goal of a Second Fleet in the North and Northeast of the country, playing a key role in the power projection strategy (Silva, 2015, p. 153).[28]

The program was especially necessary because, until 2017, the Brazilian Navy had one airship (São Paulo), purchased from France in 2000, with 32,000 tons and the capacity to operate approximately forty aircraft. The ship was undergoing general maintenance at the Navy Arsenal in Rio de Janeiro with the goal of extending its service life until 2025. However, in 2017, the São Paulo ship was decommissioned due to high modernization costs – they would reach the R$ 1 billion mark (Monteiro, 2009). In this context, in 2018, Brazil acquired from the United Kingdom the multipurpose helicopter carrier Atlântico, a vessel of more than 200 meters in length with capacity to operate up to seven aircraft simultaneously, in addition to internal space to store up to nineteen helicopters – thus becoming the largest ship of the Brazilian fleet.

3.3 SisGAAz

Fundamental for the surveillance and protection of the Blue Amazon, the general objective of SisGAAz is to develop monitoring and control systems for Brazilian jurisdictional waters and search and rescue regions under Brazil's responsibility, contributing directly to the Brazilian maritime situational awareness.[29] The program foresees the use of satellites, radars and underwater sensing equipment to monitor Brazilian Jurisdictional Waters, integrating information and decision support networks, in order to generate benefits such as greater safety and greater efficiency of inspection and search and rescue operations – in addition to stimulating the dual use of the technologies developed (Brazil, 2012c, p. 196-197).

28. Foreseen in the 2012 National Defense White Paper version, PRONAE and PROANF were removed from the 2016 version of the document.

29. According to Admiral João Afonso Prado Maia de Faria (2012, p. 219-220), "maritime situational awareness is defined as the understanding of military and non-military events, activities and circumstances, within and associated with the maritime environment, that are relevant to the current and future actions of a country, where the maritime environment is the oceans, seas, bays, estuaries, rivers, coastal regions and ports". In this sense, its purpose is to "develop the capacity to identify existing threats, as soon and as far away from the country as possible, through the integration of intelligence data, surveillance, observation, and navigation systems, interacting in a single operational framework" (idem, ibidem).

Under development since 2009, this program aims to meet the "demand for resources capable of carrying out, with efficiency, the monitoring, inspection and defense activities of the Blue Amazon" (Chaves Junior, 2013, p. 12), having as pillars "the priorities established by the NDS (...); the perception of the various threats foreseen in the context of the Blue Amazon (...); and (...) the safeguarding of human life at sea" (op. cit., p. 36). SisGAAz is divided into two subsystems – the Blue Amazon Monitoring System (directed to prevention and control activities) and the Blue Amazon Protection System (directed to defense and reaction activities) – which, by means of specific sensors and equipment, will allow for "data collection (monitoring), the fusion and processing of these, the production of information to support decision making, and finally decision making so that the available means may act (protection)" (op. cit., p. 36). In its fullness, SisGAAz will enable the "collection of data, their processing, the orderly presentation of these data and (...) decision support", aiming the "control of events in the maritime environment", thus representing "the initial step for the effective control of the Blue Amazon" (op. cit., p. 43).

In addition to its main purpose, the development of SisGAAz also contributes to the strengthening of ST&I in Brazil, especially as a result of the nationalization of components and technology transfer processes foreseen in the program. In this sense, it is estimated that there will be great technological drag in its different stages, besides the creation of demands for diversified services in areas such as security, civil engineering, energy and transportation. In its original conception, the program is divided into three main phases: conceptualization, contracting, and development. The first involved operational design and specification of the system and high-level architecture design, and was closed in December 2013. The second phase, which began in January 2014, encompasses the request for proposals to be responded to by integrating companies, and subsequently the evaluation of the proposals and selection of the winner. Finally, after the contract is signed, the third phase begins.

It is important to highlight that "the SisGAAz is considered and defined by the MB [Brazilian Navy] as a defense system (...) strategic for national defense, (...), whose discontinuity will cause significant damage to the activities of the MB" (During, 2014), and should be "developed entirely in Brazil and with a strong index of nationalization" (Rossi, 2014). However, despite the importance attributed to the program, it has undergone, in recent years, an intense process of reformulation for budgetary and financial reasons (During, 2015).

Regarding other initiatives of the Brazilian Navy in the scope of monitoring and surveillance of the Blue Amazon, the Unified Situational Awareness System for the Acquisition of Maritime Information (SCUA) stands out. It is a system developed by IPqM that allows radar data acquisition and processing, enabling actions in the sphere of strategic analysis and intelligence. The SCUA was used during the 2016 Olympic Games held in Rio de Janeiro, contributing to the control of the maritime area of the Guanabara Bay and the Rio de Janeiro coast. Because it is a system that can be developed and implemented in a phased manner, SCUA was adopted by the Brazilian Navy in 2018 as the pilot project of SisGAAz.

4 THE IMPORTANCE OF ST&I TO THE STRATEGIC PROGRAMS OF THE BRAZILIAN NAVY

The examination of the strategic programs of the Brazilian Navy presented in the previous section attests to the importance of scientific-technological development for their achievement. As indicated, three stand out for their scientific-technological intensity: the PNM, PROSUB and SisGAAz. It becomes fundamental, therefore, to analyze how STI activities contribute to the development of these programs.

Firstly, the centrality given to the PNM and PROSUB reinforces the already historical importance of the nuclear sector for the Brazilian Navy (in particular) and for National Defense (in general). In this sense, one can observe the continuation and deepening of governmental efforts in the national development of nuclear technology, the most recent example of which is the creation of a new state-owned company specifically for this purpose, Amazul. Once it was realized that one of the main difficulties in the construction of a nuclear propulsion submarine is in the training of human resources, this new company was established precisely to provide these resources, which are necessary, transversally, to the accomplishment of the PNM and the PROSUB.

Created by Law No. 12.706, of August 8, 2012, Amazul, the result of the partial spin-off of the Naval Projects Management Company (EMGEPRON) and linked to the Ministry of

Defense through the General Command of the Brazilian Navy, has as its central objective the development of the nuclear sector in the country, specifically through the improvement of "technologies necessary for the nuclear activities of the Brazilian Navy and the PNM and the Brazilian naval military industry, highlighting the construction of submarines for the Brazilian Navy" (Brazil, 2012b, art. 5, I). The specific competencies of the new company include:

> the fostering of new industries in the nuclear sector and technical assistance to them; financial stimulus for research activities in the area; the elaboration of studies and engineering works; the construction of prototypes for submarine development, as well as personnel training.[30]

In 2014, Amazul had its first operational unit installed at CTMSP, becoming, since then, "the only specialized company in the national nuclear sector with an operational unit installed at the Aramar Experimental Center" (Leite, Assis and Côrrea, 2016, p. 272).

In order to fulfill its objectives, Amazul has signed important partnerships with other companies and institutions. One of them is the Foundation for the Technological Development of Engineering (FDTE), with which a cooperation agreement was signed in September 2014 aiming at "conducting research, development and implementation of the Conceptual Project of the Radiological Complex of the Shipyard and Naval Base (EBN) of the Brazilian Navy" (Amazul..., 2014). In December 2015, a technical cooperation agreement was signed between Amazul and the Naval War College (EGN), aiming at the "development of projects of common interest" (Amazul..., 2015), especially those related to the PNM and PROSUB.

While research for the development of the SN-BR nuclear propulsion system has been conducted by the Brazilian Navy itself (through its scientific-technological institutions or state-owned companies), the construction of the conventional submarines and the nuclear propulsion submarine has been made possible thanks to the partnership signed with the French company Naval Group. The importance of this partnership reflects a pattern that can be observed in other strategic programs of both the Brazilian Navy (such as PROSUPER) and other Forces. Among Brazilian Navy programs, the importance of external partnerships involving technology transfer is also observed in SisGAAz. Before undergoing reformulation, the SisGAAz had already been

30. Available at: <https://bit.ly/2MT5tpl>. Accessed on: Apr. 7, 2016.

contemplated with proposals from three consortia, all composed of Brazilian private companies in partnership with foreign companies: i) consortium Águas Brasileiras, composed by Embraer Defesa e Segurança (EDS) in partnership with the European Airbus Defence and Space; ii) consortium Nosso Mar, composed by Odebrecht Defesa e Tecnologia (ODT) in partnership with the Canadian-American MacDonald, Dettwiler and Associates (MDA), the Spanish Indra and the Swedish SAAB; and iii) consortium Mar Azul, composed by the company Orbital Engenharia in partnership with China Aerospace Science and Industry Corporation (Silveira, 2015).

The development and achievement of such programs attest to the "proven capacity for innovation and technological absorption of national firms" (Andrade et al., 2016, p. 46) in the defense sector, "coupled with the opportunities opened by strategic partnerships with other countries", which consequently "provides a promising scenario for the consolidation and future development of the defense industry in Brazil" (idem, ibidem). To get the most out of the scientific-technological capabilities available both in the national industry and in the scope of external partnerships, it is necessary to integrate R&D efforts at all levels and scales, involving the actors (academia, research institutes, government entities, and private companies) throughout the product development cycle – from basic scientific research, through project execution, to the final construction of platforms and systems. In this sense, it is of utmost importance to seek maximum integration among all parties involved, in a long-term and continuous perspective, in order to achieve success not only in providing means to the Naval Force (and other Forces), but also in providing the country with material capabilities to reduce its foreign dependence on equipment and systems vital to its defense.

However, as emphasized by Squeff (2016, p. 106), "the national aspiration for the endogenous development of technologically competitive defense products may find in the scientific and technological infrastructure a barrier to its realization". In this sense, the comparison with the existing structure in leading countries in the defense market (especially those that excel in scientific-technological research focused on this sector) makes clear the Brazilian gap, since "national laboratories dedicated to defense activities still present a very small scale in relation to the infrastructures dedicated to the same area abroad", and the "governance structure of its infrastructure is not very centralized" (Squeff, 2016, p. 104) can be attributed to this delay in the country.

Furthermore, the strategic programs of the Brazilian Navy (and the other Forces) face a serious problem arising from the current Brazilian reality: the risk of discontinuity due to lack of funds. The budgetary constraints faced by several portfolios of the federal government have been especially harsh for Defense, bringing serious consequences in the short, medium and long term not only for the Armed Forces but also for the national defense industry. In this sense, the Brazilian Navy has prioritized its nuclear and submarine development programs, while other strategic programs such as SisGAAz and PROSUPER are out of step with the original schedule.

In the short and medium term, the effects of such contingencies compromise the capacity of the Armed Forces to act by depriving them of their means of action. However, in the long term, the discontinuity of investments may seriously affect R&D activities in S&T&I focused on defense, and may cause technological capabilities developed domestically over decades to be lost to foreign countries – the so-called "denationalization" (Andrade and Franco, 2016). This is just one of the risks that the country faces when it discontinues R&D efforts aimed at improving its defense structure, and may ultimately compromise its own sovereignty due to the lack of means to ensure it.

In the long term, however, cooperation between different sectors may be a mechanism to circumvent the reduction of resources for the area. Recently, the Ministry of Defense has already demonstrated some possibilities for the future. In 2017, for example, it was announced that the National Bank for Economic and Social Development (BNDES) will also offer credit lines to governments that are interested in acquiring defense products from Brazil – a Ministry of Defense project carried out in partnership with the ministries of Finance; Foreign Affairs; Science, Technology, Innovations, and Communications; and the Chamber of Foreign Trade (CAMEX). Even without specific incentives for ST&I, initiatives of this nature can generate new funding possibilities. Another example of a partnership was the one created to develop products in the aerospace, defense, public safety and special materials sectors, known as Inova Aerodefense, launched in 2013.

Innovation is fundamental to any society, government or company, and is one of the goals indicated in the highest level strategies of the ST&I sectors of the Brazilian Armed Forces. Innovation, in the economic view, consists of inserting new products or processes in the productive environment, in order to generate value. Regarding innovation practices in the national context, it can be observed that

> The analysis of global data and information on competitiveness and innovation indicates that Brazil's performance leaves much to be desired when compared to countries such as Germany, China and the United States. Despite the efforts and resources invested in innovation in the country, the results are still shy in terms of what is effectively generated through innovation in social benefits, especially in industrial sectors (Pavanelli and Dostler, 2016).

The United States Armed Forces can be cited as a reference in the development of technologies that become innovation, i.e., those that, when ready, due to their dual character, are transferred to the civilian environment (spin-off), such as: the jet airplane, the transistor, fiber optics, nuclear energy, the electronic computer, the global positioning system (GPS), satellites, microwaves, and unmanned aerial vehicles (UAVs) (popularly known in the civilian market as drones).

In this sense, the Brazilian Navy has been restructuring itself in order to allow, in the molds of the main innovative world Armed Forces, the application of technologies already developed in its Science and Technology Institutions (ICTs) and the transfer of those of dual use to the civilian sector. The business model adopted is based on the Triple Helix, summarizing itself in developing projects of interest, in partnership with Brazilian universities (basic and applied research), and, when it reaches a sufficient level of maturity to be prototyped, the project is presented to the business community as a business opportunity, to be produced and marketed in Brazil and abroad. As the product gains market scalability, the Brazilian Navy will be compensated by means of royalties, due to the intellectual property, which will enable financial feedback for the ICTs' own ST&I system and may generate resources to finance new projects of interest to Brazilian society.

5 FINAL CONSIDERATIONS AND RECOMMENDATIONS

The Armed Forces' activities in the development of strategic programs essentially fulfill their constitutional functions of protecting the country's citizens and assets and defending national interests. In terms of guaranteeing the nation's sovereignty, which is also the mission of the Armed Forces, the importance of scientific-technological mastery and the search for the country's autonomy stand out. In this context, the application of knowledge becomes an important vector for national progress, so that programs of high technological content contribute directly to obtaining and improving this domain.

Even though political and economic instabilities affect Brazil's investment capacity and mean budget contingencies in many different spheres, national strategic objectives must be considered when defining priority public policies for the country. Thus, it is indicated that issues related to the fields of National Defense and STI be associated with long-term policies, with a permanent and continuous character. Programs that unite the two areas, such as those presented in this work, contribute significantly to national development and bring direct and indirect benefits to Brazilian society.

Keeping the Armed Forces adequately prepared and equipped is as important as ensuring that they have the necessary means for their actions. For this purpose, it is vital to continue and strengthen National Defense ST&I actions, especially R&D activities that enable the endogenous development of new defense equipment and systems, with the purpose of achieving autonomy. In this context, it is verified that bringing the Armed Forces closer to the state of the art in ST&I enables the increase of efficiency and effectiveness in the fulfillment of their missions.

The analysis of the strategic programs of the Brazilian Navy presented in this work attests to this importance. Furthermore, besides strengthening ST&I actions, it is essential to strengthen the necessary infrastructure for the development of these actions. It is recommended, in this sense, to strengthen interoperability between the Forces and to favor the Triple Helix model in the execution of these programs. Thus, it will be possible to expand the positive externalities and technological drag resulting from their development, benefiting not only the defense industry, but also different productive chains in the civilian sphere. The direct benefits to the population are observed from projects such as the RMB, an example of the spill-over of nuclear technology to areas such as medicine.

In the specific case of the strategic programs of the Brazilian Navy evaluated in this paper, it can be seen that the need to prioritize investments, even if dealt with in a partially effective way, causes direct effects on the Force's planning, requiring adjustments and changes during the course of the program and sometimes jeopardizing steps already taken.

The guarantee of resources for the continuity of programs, as well as the stability regarding the funds destined to their execution, is a fundamental element to achieve greater predictability throughout their different stages, an indispensable component in highly complex scientific-technological projects. In this sense, treating public policies and investments in the scope of National Defense and ST&I as long-term issues is essential in the scope of federal planning, justified by the benefits that reach the economic, industrial and social spheres.

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