International strategic partnerships, defense, and development: lessons from EMB-326 Xavante and AMX A-1 in Brazil

Parcerias estratégicas internacionais, defesa e desenvolvimento: lições do EMB-326 Xavante e AMX A-1 no Brasil

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INTRODUCTION

Technological advancements throughout the 20th century have profoundly reshaped the ways in which citizens, companies, and states interact. Driven primarily by breakthroughs in information and communication technologies, these changes have significantly enhanced productive interactions and exchange relations among various actors, enabling international trade to play an increasingly central role in a global landscape marked by expanding markets and the consolidation of zones of influence (Dicken 2007).

While these technological transformations have proven beneficial in many aspects, they have also underscored cultural differences and exposed power struggles. Despite the establishment of multilateral organizations

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designed to regulate inter-state relations, military power and deterrence capabilities have consistently remained genuine sources of national concern, with geopolitical interests, regional rivalries, and internal security issues playing crucial roles in shaping international politics (Kaplan 2012; Mearsheimer 2001).

In response to this reality, ongoing technological development, combined with the forces of globalization, has created strong incentives to forge alliances and strategic partnerships aimed at overcoming vulnerabilities in the defense sector (Hartley 2012). This phenomenon has manifested through investments, the fragmentation of industrial operations — from project conception to final product manufacturing and distribution — and through cooperation in productive and commercial activities related to sensitive products and inputs (Melo 2015).

In this context, Brazil faces the pressing challenge of expanding and deepening such discussions, particularly in the formulation of public policies centered on the development of productive and technological capabilities and the promotion of its Defense Industrial Base.[1] Furthermore, it is important to note that since the first edition of the National Defense Strategy in 2008, the establishment of strategic partnerships has been highlighted as a crucial tool for enabling significant developments and technological transfers in economic, commercial, and military domains — the latter element being "in no way to be neglected as a useful tool for the achievement of national interests" (Alsina 2009, 189, our translation), given the risks that a weak military structure poses to the country in potential conflicts with foreign nations.

This study, therefore, focuses on how international strategic partnerships can contribute to addressing the needs of the defense sector by fostering innovation. Such relationships are understood as the creation of bilateral or multilateral ties that promote collaboration aimed at executing joint projects, encouraging cooperation, and mitigating vulnerabilities (Ferreira 2021).

To evaluate the inherent potential of these partnerships in the defense sector, along with their commercial and productive ramifications, this article examines two strategic projects developed between Brazil and Italy: the production of the military aircraft EMB-326 Xavante (1970) and AMX A-1 (1985). The goal is to deepen the understanding of these specific partnerships, particularly in terms of their implications for Embraer's[2] efforts to foster and advance innovative technological capabilities. It is expected that a clearer understanding of their effects, combined with the empirical evidence identified, will contribute to supporting the continuity of pragmatic public policies that regard international strategic partner-

ships as a means to promote the development of the Brazilian Defense Industrial Base.

Beyond this introduction, the article is divided into four sections. Section 2 examines international partnerships as a strategy for developing the Defense Industrial Base, focusing on the role assigned to them by the Brazilian National Defense Strategy and the constraints posed by the country's fiscal and budgetary limitations. It also discusses the benefits and challenges of such partnerships, particularly regarding their operationalization and the dilemmas related to technological autonomy. Section 3 provides a historical overview of the EMB-326 Xavante and AMX A-1 projects, highlighting their productive and technological implications for the Brazilian aeronautical sector. Section 4 presents an exploratory analysis of Brazil's military aircraft exports from the 1960s through the 2010s, providing a more comprehensive understanding of how this evolution unfolded and benefited from the accumulation of technological and productive capabilities developed through the EMB-326 Xavante and AMX A-1 projects. Finally, Section 5 presents the study's concluding remarks.

INTERNATIONAL PARTNERSHIPS AS A DEVELOPMENT STRATEGY FOR THE BRAZILIAN DEFENSE INDUSTRIAL BASE

By establishing the promotion of technological and productive autonomy in the defense sector as one of its main objectives, the Brazilian National Defense Strategy outlines a series of strategic actions aimed at stimulating both the development of the country's industrial potential and the enhancement of its National Power (Brasil 2022). In this regard, the modernization of the Armed Forces emerges as an integral part of a national development strategy, with the ultimate goal of ensuring the supply of sensitive military products supported by national, preferably dual-use, technologies (Brasil 2022).

To achieve these objectives, the National Defense Strategy emphasizes two key actions: 1) ensuring the structural conditions necessary to promote defense investments by streamlining legal, regulatory, and tax frameworks; and 2) establishing strategic partnerships with other countries to consolidate and strengthen national capabilities in developing and manufacturing defense products through acquisition and technology transfer agreements (Brasil 2022).

However, the severe fiscal crisis that has affected the country since 2014[3] has imposed significant obstacles to the implementation of the first action, undermining the government's ability to drive strategic and long-term military projects through public investments (Silva 2020; Marques

2024). This situation is further exacerbated by the fact that a large portion of Brazil's defense budget is committed to mandatory expenditures, primarily personnel costs and social charges, including payments to retirees and pensioners — between 75% and 80% (Senado Federal 2025), a significantly higher level than that observed in countries such as Canada (45.5%), Spain (43.9%), France (38.6%), Germany (29.6%), the United Kingdom (28.2%), and the United States (25.2%) in 2024 (NATO 2024).

This budgetary rigidity has severely limited discretionary investments, hindering the modernization of equipment and the promotion of technological innovation, thereby aggravating the challenges faced by the Defense Industrial Base in its efforts to remain competitive on a global scale (Silva 2020). In 2024, for example, Brazil allocated only 7% of its defense budget to investment — a figure significantly lower than the amounts allocated by the aforementioned countries to equipment acquisition during the same period: Canada (18.6%), Spain (30.3%), France (28.3%), Germany (28.7%), the United Kingdom (36.1%), and the United States (29.9%).

In light of this difficult context, the inevitable postponement or cancellation of planned investments has consolidated itself as a "growing challenge to maintaining the productive capacity of the defense and security sector" (Silva 2017, p. 102, our translation), thereby weakening a critical policy instrument for the development of the Brazilian Defense Industrial Base: the consistent implementation of regular public procurement programs (Marques 2023).

Moreover, limitations on overall public investment capacity further exacerbate the opportunity costs of military expenditures, especially when allocating scarce resources to socially sensitive areas (Silva 2020; Hartley 2012). These pressures make it even more urgent to explore and implement alternatives that meet national strategic defense requirements while considering fiscal and budgetary constraints in public policy formulation and implementation.

In this context, the second action — focused on establishing international strategic partnerships in the defense sector — emerges as a critical strategy for Brazil. According to Hartley (2012), collaborative projects offer significant cost-saving opportunities compared to purely national programs: participating countries share the high risks inherent in developing new technologies, and by pooling their respective consumer markets, they more easily achieve optimal levels of economies of scale and learning.

Other significant benefits include the increased technical rigor resulting from the aggregation of knowledge, experience, and competitive stimuli from interactions between partner nations, such as among teams of scientists and agencies; enhanced interoperability, allowing allied coun-

tries to design military systems that can operate jointly, providing complementary strategic advantages; and the strengthening of diplomatic and cooperative ties among the participants.

It is worth emphasizing that the potential benefits outlined above may also encounter significant barriers to their full realization, particularly depending on the number of actors involved in the development of a given project. In this context, the recent case of the F-35 Joint Strike Fighter program — a multinational initiative involving countries such as the United States, the United Kingdom, Italy, the Netherlands, Turkey, Canada, Denmark, Norway, Australia, Israel, and Singapore — has been the subject of substantial criticism, primarily due to its high production costs relative to initial expectations, as well as significant shortcomings in project development (Capaccio 2017).

Such criticisms resonate with Hartley's (2000) warnings regarding the additional layers of complexity inherent in conducting military projects through international collaboration. While acknowledging the potential benefits, Hartley also highlights the risks associated with elevated transaction costs linked to processes of specification, negotiation, agreement, and monitoring, as well as the presence of information asymmetries and opportunities for political interference — all of which may undermine productive efficiency. "Nations are expected to learn from previous collaboration experience, but these learning benefits may be reduced if new partners are added to the club" (2000, p. 14).

The challenges faced in the F-35 Joint Strike Fighter program may have contributed to the emergence of a new generation of international strategic partnerships, characterized by more modest ambitions in the design of their partnership networks, thereby rendering them less complex and more amenable to effective management. Notable examples include the Future Combat Air System program — jointly undertaken by France, Germany, and Spain, with the objective of replacing the Rafale and Eurofighter aircraft from 2040 — and the Tempest Team program — led by the United Kingdom in collaboration with Sweden and Italy, aimed at developing a sixth-generation fighter aircraft by 2035 (Marques 2024).

It is equally essential to recognize that the adoption of strategic partnerships in the defense sector requires a critical examination of the structural dilemmas between external dependence and technological autonomy. While international collaborations offer opportunities for risk-sharing, access to cutting-edge technologies, and the expansion of the national scientific and industrial base, they may also generate new forms of vulnerability — particularly when established asymmetrically or in the absence of effective mechanisms for knowledge absorption, technology transfer, and diffusion

(Dagnino 2008, Hartley 2000, Hartley 2012, Neuman 2006). The lack of state policies capable of ensuring continuity, institutional coordination, and integration across the various segments of the production chain, as well as the absence of consistent guidelines for the internalization of strategic technologies, can significantly constrain the structural effects of such partnerships on the national defense innovation system. Consequently, the country remains reliant on high value-added inputs, components, and systems sourced from abroad, thereby compromising its decision-making autonomy in scenarios involving crises, embargoes, or shifts in the international order.

In this context, the core challenge lies not merely in the establishment of agreements or partnerships, but in embedding them within a long-term strategic framework informed by the imperatives of technological development and national security.

An analysis of the Brazilian experience reveals that the country has derived substantial benefits from international strategic partnerships in the defense sector. This is particularly evident in the collaborative projects with Italy — namely, the EMB-326 Xavante (1970) and the AMX A-1 (1985) — which generated significant technological, operational, and commercial outcomes, thereby contributing to the strengthening of both the Defense Industrial Base and the national aeronautical industry. By enabling Embraer to produce the first domestically manufactured jet and achieve a higher degree of technological autonomy, equipping it with new production lines geared toward the international markets, these initiatives illustrate the positive influence of innovation on economic growth, productivity, business competitiveness, and the accumulation of technological capabilities (Bell and Figueiredo 2012; Cassiman et al. 2010; Figueiredo 2023).

The subsequent sections will examine in greater detail the specific commercial and technological benefits arising from these projects, with the objective of advancing a more comprehensive understanding of the role played by these international strategic partnerships in fostering and consolidating Brazil's Defense Industrial Base.

A BRIEF HISTORY OF THE "EMB-326 XAVANTE" AND "AMX A-1" PROJECTS: PRODUCTIVE AND TECHNOLOGICAL IMPLICATIONS

The consolidation of Brazil's military-industrial capabilities must be situated within the broader historical trajectory of national developmentalism. From the 1960s onward, the country pursued a strategy of defense industrialization that functioned less as a response to immediate external threats and more as a means of geopolitical assertion and the pursuit of technological sovereignty. This strategic orientation was informed by the

principles of import substitution industrialization, the geopolitical framework of the National Security Doctrine, and the economic nationalism intrinsic to the developmental state. Within this context, the Defense Industrial Base was conceived not only as a supplier of strategic deterrent capabilities, but also as a key driver of endogenous technological accumulation and industrial modernization (Andrade 2016, Dellagnezze 2008).

The establishment of Embraer in 1969 emerged as a cornerstone of this vision, serving as the vanguard of a dual-use aerospace industry with the potential to project Brazilian technological competencies on the global stage (Dalla Costa and Souza-Santos 2010).

Within this strategic framework, the EMB-326 Xavante and AMX A-1 programs should be understood as initiatives that extended beyond the fulfillment of specific operational requirements of the Brazilian Air Force. Rather, they constituted critical undertakings aimed at promoting the acquisition, absorption, and internalization of sensitive technologies through international partnerships. Both initiatives reflected the Brazilian state's ambitions to strengthen its strategic autonomy, reduce dependence on foreign suppliers, and consolidate a robust aerospace industrial infrastructure capable of supporting broader political, economic, and defense objectives (Amarante 2013, Francelino 2016, Poggio 2015, Souza 2012).

The EMB-326 Xavante program, implemented through a licensing agreement with the Italian firm Aermacchi, represented Embraer's first substantial foray into jet aircraft manufacturing. Initially conceived as a two-seat aircraft for pilot training, the EMB-326 Xavante was also produced under license in countries such as South Africa and Australia and would later be employed in various conflicts on the African continent, as well as during the Falklands War (Brasil 2021).

In Brazil, the manufacturing process was made viable through state support, particularly by securing an initial order of 112 units from the Brazilian Air Force (FAB) (Souza 2012). The agreement between Embraer and Aermacchi, formalized in 1970, stood out for the rapid adaptation of the production line and the prompt training of the personnel involved. Owing to the accelerated pace of production, the first aircraft assembled in Brazil successfully completed its maiden flight as early as September 1971 (Alamino 2021).

Following the fulfillment of the initial FAB order, additional units were requested, raising the total domestic demand to 167 aircraft. Overall, 182 units were produced, including exports to Paraguay, Togo, and Argentina. The EMB-326 Xavante remained in active service in Brazil from 1971 to 2010, being employed in various missions involving both air-to-air and air-to-surface operations (Brasil 2021, Dalla Costa and Souza-Santos 2010).

The AMX A-1, by contrast, was conceived as a bi-national program involving more extensive cooperative development with the Italian firms Aeritalia and Aermacchi, embodying a more sophisticated model of technological transfer and institutional coordination. Within the scope of this joint initiative, Embraer joined a bi-national consortium, contributing to the development of an advanced ground-attack jet that was already in progress by the Italian companies. Embraer was tasked with manufacturing key components such as the wings, engine air intakes, horizontal stabilizers, fuel tanks, and various smaller parts. This collaborative effort enabled the rapid advancement of the program, culminating in the official unveiling of the first aircraft in Italy on May 15, 1984, followed by the maiden flight of the first Brazilian-built prototype on October 16, 1985.

At the outset of the program, initial studies indicated substantial potential for the aircraft's adoption in both domestic and international markets. However, between the planning stages and the commercialization of the AMX A-1, unforeseen geopolitical shifts — most notably the end of the Cold War — profoundly altered the global landscape for conventional arms sales (Marques 2024). As a direct consequence, demand for ground-attack jets declined sharply, despite the AMX A-1's proven robustness in both simulated scenarios and real combat operations, including missions in Kosovo, Libya, and Afghanistan, as well as exercises over the United States desert and surveillance flights over Brazilian territory (Poggio 2015). This sudden contraction in international demand severely impacted Embraer's financial standing, ultimately contributing to a major crisis that brought the company "to the brink of bankruptcy just before its privatization" (Fonseca 2012, 45, our translation).

An analysis of the technological developments and implications of both projects reveals that, specifically within the EMB-326 Xavante Program, there were no significant advances in technological appropriation by the Brazilian aerospace industry. This conclusion is based on the fact that Embraer did not actively participate in the aircraft's development alongside Aermacchi but merely contracted with the Italian company to facilitate its licensed production in Brazil (Ferreira 2009; Souza 2012).

However, although the technological gains associated with the project were limited, the production of the EMB-326 Xavante paved the way for considerable productive implications for Embraer. According to Ferreira (2009), the serial production of this model on Brazilian soil, even under license, allowed Embraer to establish direct contact with the technology necessary for large-scale aircraft production, yielding significant gains in the organization of the company's production facilities, ultimately leading to solid national expertise.

In this context, Ribeiro (2017) notes that the production of the EMB-326 Xavante equipped Embraer with the necessary capabilities to mass-produce various other models, such as the EMB-110 Bandeirante, as well as other aircraft designed by the company in subsequent years. The EMB-110 Bandeirante, initially acquired only by the Brazilian Air Force, eventually became a major success in regional commercial aviation, enabling Embraer to establish a subsidiary in the United States in 1979 — Embraer Aircraft Corporation, based in Fort Lauderdale, Florida — and thereby enter the competitive North American market (Embraer 2024).

However, it was through the AMX A-1 program that the Brazilian government and the Brazilian Air Force Command (Comaer) demonstrated greater concern with the effective absorption of strategic technologies necessary to boost the country's aerospace industrial capacity. To establish the foundations for coordinating the AMX A-1 program with Embraer, Comaer initiated the creation of the Aircraft Combat Program Coordination Commission (Copac) in 1981, responsible for the systematic acquisition of materials and complex systems associated with the AMX A-1 project. The extensive experience COPAC acquired in these activities led it to later assume the coordination of several other projects, including the current development of the new generation of multimission transport aircraft: the KC-390 (Ribeiro 2017).

The AMX A-1 program, therefore, represented a hybrid model of technology acquisition, beginning with technology transfer and evolving into a cooperative agreement. To participate directly in the development of this aircraft, Embraer had to build extensive knowledge around the components manufactured by Aermacchi and Aeritalia to ensure the adequate production of the AMX A-1 (Amarante 2013).

This effort resulted in significant advances in technological expertise: before the AMX A-1 program, Embraer produced aircraft with only non-integrated electronic systems — meaning each system operated independently, with separate radios for communication and navigation. Following the development of the program, the company acquired full capacity to integrate electronic equipment into a network managed by computers overseeing various operations (Ribeiro 2017).

Another innovation of the AMX A-1 program was the creation of the Complementary Industrialization Program (PIC), established by the Brazilian Air Force Command with the goal of developing the Brazilian aerospace industry and enabling national companies in the sector to enhance their human and technological resources:

> [...] The Brazilian government's concern to directly involve national companies in the contracts for aircraft and engine pro-

> duction was evident. There were contracts for the training of Embraer and national suppliers that constituted the Complementary Industrialization Program (PIC), in which the Brazilian government explicitly promoted an industrial training program in national companies with potential for production and development. (Francelino 2016, our translation).

The principles of the Complementary Industrialization Program were clearly defined in Brazil's national strategy to strengthen its industrial base, maximizing positive technological returns and preventing capital flight from the country:

1. Maximizing the industrial production activities of equipment in Brazil, aiming for greater operational security for the aircraft and the absorption of technology applicable to other programs as well;
2. Maximizing domestic logistical support activities for the Employment Support phase of the aircraft;
3. Avoiding currency outflow;
4. Supporting a group of pre-selected national companies interested in operating independently in this industrial sector and/or in cooperation with potential foreign partners (Francelino 2016, our translation).

While the Complementary Industrialization Program (PIC) contributed to the development of some national suppliers, Brazil has historically faced difficulties in consolidating an autonomous defense supply chain. As highlighted by Ribeiro (2017) and Souza (2012), challenges such as technological dependence, lack of continuous investment in R&D, and fragmented industrial policies have hindered the sustained integration of these suppliers into subsequent projects. These structural limitations continue to restrict the capacity of Brazil's Defense Industrial Base to reduce external dependence and ensure technological self-sufficiency.

Francelino (2016) notes that in 1981, the same year Embraer joined the AMX A-1 program, the Brazilian government signed a contract with the Italian government to increase the company's industrial capacity, particularly in planning and executing the development of its technological maturity. It was also agreed that the supply of items and subassemblies for the production of the AMX A-1 would originate from a single source for both countries. This source had to be located within the Brazilian or Italian industrial base, and if a specific item or input needed to be sourced from a third country, such acquisition would be done in mutual agreement.

Thus, in 1984, Embraer's Equipment Division (EDE) was established to produce the landing gear for the AMX A-1. This move finally brought the know-how for producing these systems to Brazil, adding crucial knowledge for the manufacturing of hydraulic components within the Brazilian aerospace industry (Francelino 2016).

In 1999, EDE became Embraer Liebherr Equipamentos do Brasil S.A. (ELEB), following a joint venture with the European company Liebherr Aerospace. After a partnership that brought significant investments and participation in various international negotiations, Embraer acquired Liebherr's stake (40%), becoming the sole owner of ELEB. In 1986, another cooperation agreement was signed between Brazil and Italy to further empower Embraer's industrial and procure equipment aimed at the production of the AMX A-1's landing gear (Francelino 2016).

According to Bernardes and Pinho (2002), in addition to Embraer, eight more national companies were trained during the Complementary Industrialization Program to supply electronic items and subassemblies covered by the AMX A-1 program, including Tecnasa, Elebra, EDE, Aeroeletrônica, Modata, ABC Dados, Engetrônic, and Pirelli. The companies ELEB and AEL Sistemas, both directly linked to the AMX A-1 program, are currently among the main suppliers for the KC-390 program. According to Silveira (2016), the levels of expertise and capability at ELEB to operate across the full landing gear supply chain were only definitively achieved through the experience obtained in the AMX A-1 program.

The electronic equipment and components related to the AMX A-1's attack and navigation systems were largely produced and developed by Aeroeletrônica Indústria de Componentes Aviónicos Ltda., the predecessor of AEL Sistemas. Within the program, the company developed and produced four domestic components and localized another nine, significantly enhancing Aeroeletrônica's capabilities in the avionics sector (Poggio 2015).

According to Bartels (2009), former president of the Brazilian Aerospace Industries Association (AIAB), the AMX A-1 program opened the door for the Brazilian aerospace industry to access cutting-edge technologies of that era. Notable advancements included Embraer's adoption of advanced digital avionics systems for navigation, transonic aerodynamics, fly-by-wire flight control systems, computerized numerical control (CNC) techniques for producing complex machined parts, and jet engine integration, among others.

Bartels also asserts that the technology transfer achieved through the AMX A-1 program was crucial for the later production of the ERJ-145

commercial jet model. The successful manufacturing of this aircraft significantly boosted Embraer's position following its privatization in 1994, positioning the Brazilian aerospace industry within the highly competitive international aircraft market and laying the groundwork for the company's financial recovery (Ferreira and Sabbatini 2014). This recovery was driven by a strategic shift toward the civil market, particularly in niches "unexplored by major industry players like Boeing and Airbus" (Dalla Costa and Souza-Santos 2010, 175, our translation), such as regional and executive aviation.

Beyond the absorption of new technologies, Bernardes (2000) agrees that the experience in managing international cooperation projects gained through the AMX A-1 program was of paramount importance for Embraer's managerial development and business operations in subsequent programs. Regarding the Brazilian Air Force Command, Francelino (2016) notes that the gains were exponential in the area of complex project management, with the experience acquired in this field — including collaboration with international partners — paving the way for the development of prominent future programs, such as the KC-390 military transport aircraft.

It is important to note, however, that by the end of the AMX A-1 program, the manufacturing costs associated with the aircraft had reached excessively high levels. As a result, the AMX A-1 struggled to find acceptance in the international markets, which increasingly favored the American-made F-16 fighter, offering a higher level of technological sophistication (Poggio 2015).

Nevertheless, although the AMX A-1's development did not translate into commercial success, Amarante (2013) emphasizes that the partnership with the Italian government, with all its implications and outcomes, proved successful for Brazil. The author also highlights that, in addition to adding a new aircraft model to its production lineup, the program allowed Embraer to apply a range of technologies absorbed during the AMX A-1's development to various subsequent projects — such as the aforementioned ERJ-145, considered the most successful model in the company's history.

It is estimated that the entire AMX A-1 program cost the Brazilian public treasury around USD 2.5 billion. Opting to purchase an off-the-shelf fighter jet might have been cheaper or even yielded a greater number of aircraft for the country. However, the Brazilian aerospace industry would have faced significant challenges in achieving its current prominent position without the AMX A-1 program (Poggio 2015).

Although significant productive and technological advances have occurred, as previously discussed, it is important to highlight that the se-

lection of the EMB-326 Xavante and AMX A-1 projects was guided by a political-strategic logic aimed not only at meeting operational demands, but also at asserting Brazil's technological sovereignty and geopolitical presence. These initiatives were being driven by the broader national-developmentalist strategy of the time, which focused on endogenous technological accumulation and industrial modernization as instruments of national power (Andrade 2016; Souza 2012). However, these ambitions were not always accompanied by coherent policies for the absorption and diffusion of technology, limiting their systemic impact on Brazil's Defense Industrial Base.

THE EVOLUTION OF BRAZIL'S MILITARY AIRCRAFT EXPORTS

As highlighted in the previous section, the international partnerships that enabled the development of the EMB-326 Xavante and AMX A-1 projects generated significant advances in manufacturing capabilities and technological learning for Brazil. Given the magnitude of these implications, this section proceeds with an exploratory data analysis of Brazilian military aircraft exports from the 1960s through the 2010s. The objective is to offer a more comprehensive understanding of how this evolution unfolded, while also providing a complementary commercial perspective to the technological and productive analysis previously developed.

The exploratory data analysis presented in this section is based on the database of conventional arms transfers compiled by the Stockholm International Peace Research Institute (Sipri). While the definition of conventional weapons encompasses a broad range of systems suitable for military conflict — including combat aircraft, armored vehicles, naval vessels, small arms, light weapons, and ammunition, while excluding weapons of mass destruction (Brasil 2015) — the Sipri database is limited to the most robust and technologically advanced categories. These include aircraft, air defense systems, armored vehicles, artillery, engines, missiles, naval weapons, satellites, sensors, ships, and others. Given the nature of the present investigation, the analysis focuses specifically on data related to military aircraft (Sipri 2025a, Sipri 2025b).

It is important to note that Sipri's time series are not defined in financial terms, but are instead expressed as estimates based on known unit production costs for a standardized set of weapons systems. This approach follows Sipri's own methodology, referred to as "trend-indicator values" (TIV), which enables the calculation of long-term trends in international arms transfers, indicative global shares for suppliers and recipients, and the volume of transfers to and from specific countries (Holtom, Bromley,

and Simmel 2012, 3–4). According to Sipri (2025b), "the main priority is to ensure that the TIV system remains consistent over time, and that any changes introduced are backdated".

The Sipri database is compiled from open sources — publicly available and widely disseminated information such as official government publications; United Nations registers; national notifications and reports on arms transactions; newspapers and periodicals; academic monographs and reference works; industry reports; televised broadcasts; blogs; and other relevant online publications. The potential for data inaccuracies and conflicting information among these sources is a recognized challenge, requiring Sipri to exercise careful judgment and produce cautious estimates in the compilation, organization, and maintenance of its time series (Sipri 2025b).

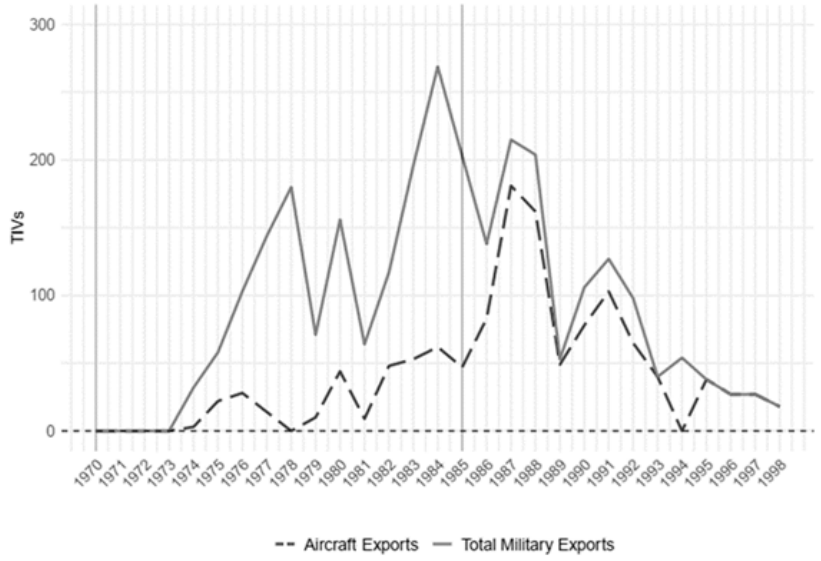
Having addressed the aforementioned considerations, we now proceed with the exploratory data analysis itself. Table 1 below presents an overview of the evolution of Brazil's capacity to export military aircraft between the 1960s and 1980s. It is noted that although the EMB-326 Xavante was launched in 1970, it wasn't until 1974 that Brazil effectively began exporting domestically produced military aircraft, starting with 18 units of the Aerotec A-122 model to Bolivia. From that point onward, military aircraft exports began gaining more traction in international markets, growing by 633% compared to the previous year — two years after Brazil's military product exports as a whole registered a 750% increase, marking the beginning of a period of intense growth for the country's Defense Industrial Base (Graph 1).

Table 1
Evolution of Brazil's capacity to export military aircraft (1960s-1980s)

Decade	Total Qty	Aircraft	Qty	Manufacturer	Buyer
1960	54	C-47	12	United States	Argentina
		T-6 Texan	14	United States	Paraguay
		PT-19	5	United States	Paraguay
		MS.760 Paris	22	France	France
		DC-4	1	United States	Colombia

1970	88	S-11 Instructor	8	Netherlands	Paraguay
		S-11 Instructor	8	Netherlands	Bolivia
		A-122	18	Brazil	Bolivia
		Universal	10	Brazil	Chile
		A-122	8	Brazil	Paraguay
		DC-6	5	United States	Paraguay
		T-6 Texan	10	United States	Paraguay
		EMB-110	6	Brazil	Uruguay
		EMB-326	6	Brazil	Togo
		EMB-110	3	Brazil	Chile
		EMB-111	6	Brazil	Chile
1980	352	EMB-110	3	Brazil	Gabon
		T-37B	30	United States	South Korea
		EMB-326	10	Brazil	Paraguay
		EMB-111	1	Brazil	Gabon
		AS-350	1	France	Argentina
		EMB-111	3	Brazil	Argentina
		EMB-326	11	Brazil	Argentina
		EMB-110	1	Brazil	Guyana
		EMB-121	43	Brazil	France
		C-47	2	United States	Paraguay
		Bell-412	1	United States/Canada	Guyana
		AS-350	2	France	Paraguay
		SA-315	6	France	Bolivia
		EMB-312	12	Brazil	Honduras
		A-132	6	Brazil	Bolivia
		AS-350	4	France	Paraguay
		A-122	6	Brazil	Paraguay
		EMB-312	20	Brazil	Peru
		EMB-312	32	Brazil	Venezuela
		EMB-312	80	Brazil	Iraq
		EMB-312	40	Brazil	Egypt
		EMB-111	2	Brazil	Angola
		EMB-312	6	Brazil	Paraguay
		EMB-312	30	Brazil	Argentina

Source: Prepared by the authors based on Sipri data (2024).



Graph 1 — Brazil's military exports (1970-1998).
*Vertical lines in 1970 and 1985 correspond to the years of the launch of the EMB-326 Xavante and AMX A-1.
Source: Prepared by the authors based on Sipri data (2024).

By the end of the 1970s, Brazil had exported a total of 88 military aircraft, including the first exports of the EMB-110 Bandeirante, EMB-111 Bandeirante Patrulha, and the EMB-326 Xavante. Domestically manufactured aircraft accounted for 65% of all exported aircraft, with the remaining 35% being second-hand foreign aircraft. South American countries were the destination for 93% of all Brazilian exports, with Togo accounting for the remaining 7%.

During the 1980s, the volume of aircraft sold by Brazil grew by an impressive 300%, reaching a total of 352 aircraft, of which 87% were domestically produced. In addition to the previously exported models — EMB-110 Bandeirante, EMB-111 Bandeirante Patrulha, and EMB-326 Xavante — two other aircraft gained important markets: the EMB-121 Xingu, with 43 units sold to France, and the EMB-312 Tucano, with a total of 220 units sold to countries such as Honduras, Peru, Venezuela, Paraguay, Argentina, Iraq, and Egypt, making it Brazil's top export aircraft of the decade.

This underscores the fact that the production of the EMB-326 Xavante preceded, by a few years, the beginning of Embraer's trajectory as an ex-

porter of military aircraft. As noted in Section 3, the serial production of the EMB-326 Xavante played a foundational role in the maturation of Embraer's productive capabilities, providing the company with essential experience and the capacity required for large-scale aircraft manufacturing (Ferreira 2009). It facilitated the internalization of complex production routines, the establishment of quality assurance protocols aligned with international standards, and the development of logistical and managerial competencies indispensable to sustaining advanced aeronautical production. These structural advances not only enabled the subsequent diversification of Embraer's portfolio but also enhanced its credibility in international markets. In this regard, the EMB-326 Xavante can be seen as a critical enabler of Embraer's future export-oriented engagements and as a catalyst in the process through which the company evolved from a domestically oriented, state-owned enterprise into a globally competitive aerospace manufacturer.

Following the analysis, Table 2 compiles data on Brazilian aircraft exports from the 1990s to the 2010s. During the 1990s, Brazil experienced a 23% decline in aircraft export volume, with a total of 272 units delivered, 92% of which were EMB-312 Tucano. Notably, 180 units of the EMB-312 Tucano were requested by countries with advanced Defense Industrial Bases, such as the United Kingdom and France. The percentage of aircraft manufactured in Brazil during this period reached 100%.

Table 2
Evolution of Brazil's capacity to export military aircraft (1990s-2010s)

Decade	Total Qty	Aircraft	Qty	Manufacturer	Buyer
1990	272	EMB-312	14	Brazil	Egypt
		EMB-312	25	Brazil	Iran
		EMB-312	10	Brazil	Peru
		A-122	15	Brazil	Bolivia
		EMB-110	2	Brazil	Colombia
		EMB-312	130	Brazil	United Kingdom
		EMB-312	14	Brazil	Colombia
		EMB-110	3	Brazil	Peru
		EMB-312	50	Brazil	France
		EMB-110	1	Brazil	Cape Verde
		EMB-312	8	Brazil	Angola

2000	57	EMB-145/MP	2	Brazil	Mexico
		EMB-145/AEW	1	Brazil	Mexico
		Universal	6	Brazil	Bolivia
		Universal	6	Brazil	Paraguay
		AS-355	1	France	Uruguay
		AS-565	3	France	Uruguay
		HS-748	5	United Kingdom	Ecuador
		AS-565	1	France	Chile
		EMB-120	1	Brazil	Angola
		Bell-212	1	United States/Canada	Argentina
		EMB-145/AEW	4	Brazil	Greece
		EMB-314	25	Brazil	Colombia
		EMB-120	1	Brazil	Uruguay
2010	134	EMB-314	18	Brazil	Chile
		EMB-314	8	Brazil	Dominican Republic
		EMB-312	3	Brazil	Paraguay
		EMB-314	18	Brazil	Ecuador
		EMB-314	3	Brazil	Burkina Faso
		UH-1H	4	United States/Canada	Bolivia
		EMB-314	2	Brazil	Mauritania
		L-410 Turbolet	1	Czechia	Cameroon
		EMB-314	6	Brazil	Angola
		EMB-314	8	Brazil	Indonesia
		EMB-312	3	Brazil	Mozambique
		EMB-314	26	Brazil	Afghanistan
		EMB-314	6	Brazil	Lebanon
		EMB-314	4	Brazil	Mali
		Phenom-100	5	Brazil	United Kingdom
		ERJ	3	Brazil	India
		EMB-314	6	Brazil	Filipinas
		BN-2 Islander	2	United Kingdom	Guyana

Source: Prepared by the authors based on Sipri data (2024).

The 2000s continued the declining trend observed in the 1990s, with only 57 units exported. However, new Brazilian-made models appeared in the commercial portfolio: the EMB-145 from the ERJ family, used for both maritime (EMB-145/MP) and airspace (EMB-145/AEW) surveillance; the EMB-120 Brasília for transport; and notably, the EMB-314 Super Tucano, which accounted for 44% of all exports during this period. In total, domestically manufactured aircraft represented 81% of all exported aircraft throughout this decade.

As seen in Graph 1, the decline in military aircraft exports during the 1990s fits into a broader context of a downturn in international arms trade and Brazilian military product exports, largely due to the geopolitical and economic shifts following the end of the Cold War (Marques 2024). In this context, as detailed in Section 3, the development of the AMX A-1 aircraft did not lead to direct exports, but the technological advancements gained through this project were essential for the later development of civilian aircraft, which played a key role in the company's financial recovery during the 1990s. Additionally, the experience gained in managing complex projects proved crucial for future strategic programs, particularly the KC-390, further validating the success of the partnership with the Italian government (Amarante 2013).

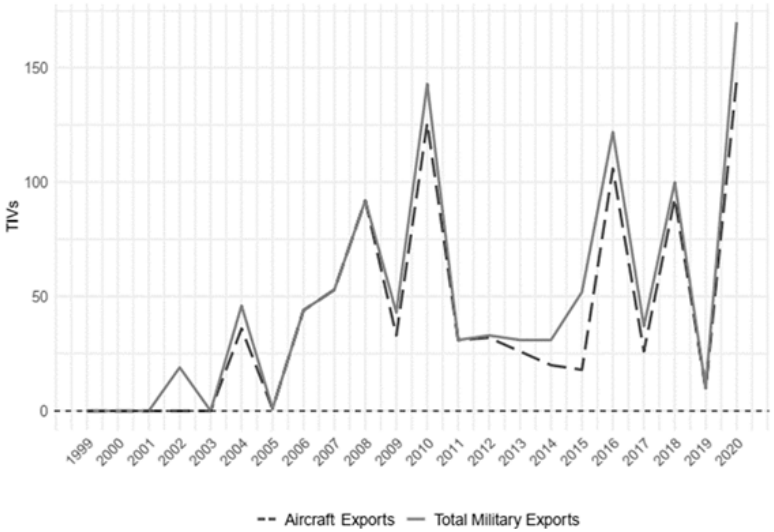
Concluding the exploratory analysis of the data in Table 2, the 2010s marked a reversal of the decline seen in the previous two decades, with a total of 134 military aircraft sold, 95% of which were manufactured in Brazil, with 84% corresponding to the EMB-314 Super Tucano. It is also noted that Latin American, African, and Asian countries remain important markets for Brazilian military production, particularly for high-tech products.

One noteworthy finding that emerges from this analysis is the increasing dominance of military aircraft within Brazil's conventional weapons export portfolio over time. As shown in Graph 1 above, in 1973, military aircraft exports accounted for 12% of total military exports, but by 1975 this category had reached 37%, the highest value observed during the latter half of the decade. By 1979, military aircraft exports had lost some relevance, returning to around 12%, with an average of 23% for this five-year period. The first half of the 1980s saw a modest improvement, with military aircraft exports accounting for an average of 26% of total military exports.

From the late 1970s to the early 1980s, the military product category that dominated Brazil's export portfolio was armored vehicles. This dominance lasted until 1985 when it began to lose ground to the rising military aircraft category, culminating in the bankruptcy of Engesa, Brazil's

largest producer of armored vehicles, in 1993 (Marques 2024).[4] From this point onward, the disparity between the growth of total military exports and the performance of military aircraft exports began to narrow, driven both by the robust growth in military aircraft exports — which jumped from an average of 26% of total military exports between 1980 and 1984 to 66% between 1985 and 1989 — and by the declining competitiveness of the armored vehicle sector (Graph 1).

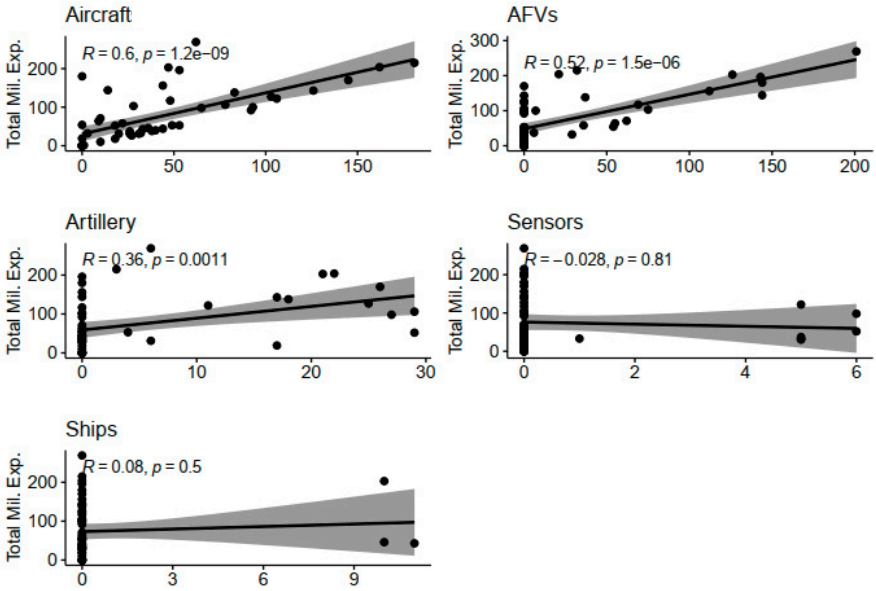
From 1989 onward, Brazilian military product exports entered a steep decline (Graph 1). Although military aircraft exports also experienced a decline, regressing by 37% in the first half of the 1990s, the category rose to account for an average of 75% of the military export portfolio — paving the way for military aircraft to become the leading sector of Brazil's Defense Industrial Base in terms of international competitiveness in the following years (Graph 2 below).



Graph 2 — Brazil's military exports (1999-2020).
Source: Prepared by the authors based on Sipri data (2024).

The aerospace sector's significant role in promoting Brazil's military export capacity between the 1970s and 2010s can be clearly seen in the Kendall[5] correlation analysis (Graph 3). Using the time series data from Sipri on conventional arms transfers, the results indicate a 60% correlation (p-value = 1.2e-09) between military aircraft exports and total military

exports, closely followed by armored fighting vehicles (AFVs), with a 52% correlation (p-value = 1.5e-06) throughout the period analyzed. This result is explained, as noted above, by the fact that AFVs dominated the military export portfolio from the late 1970s to the early 1980s, although they experienced a sharp decline from 1985 onward, losing ground to the growing military aircraft category (Graph 1). A statistically significant correlation (p-value = 0.0011) can also be observed for the artillery category, albeit with a lower correlation degree of 36%.



Graph 3 — Correlation charts by product categories and military exports.
Source: Prepared by the authors based on Sipri data (2024).

FINAL CONSIDERATIONS

Alliances and strategic partnerships play a fundamental role in Brazil's National Defense Strategy, contributing to economic, commercial, technological, and military development. As such, they serve as key instruments for advancing and promoting the Brazilian Defense Industrial Base, facilitating the creation of new products and the internalization of sensitive technologies.

As demonstrated, the international partnerships established between Brazil and Italy — particularly those involving the development of the

EMB-326 Xavante and AMX A-1 military combat aircraft — were crucial to the advancement of Brazil's aerospace sector. These collaborations enabled Embraer to produce the country's first domestically manufactured jet and attain greater technological autonomy, positioning the company to launch new production lines geared toward international markets.

Despite having taken place in politically and economically challenging environments, these experiences were fundamental for building critical capabilities, especially in the management of defense product development projects involving high value-added technologies. Over time, this contributed to a significant shift: from a model focused primarily on technology absorption to one in which Brazil increasingly acts as a disseminator of advanced technological solutions. A notable example of this evolution is the EMB-314 Super Tucano program — developed in partnership with Sierra Nevada Corporation (SNC) in the United States and OGMA in Portugal — which represents a more mature and balanced cooperation model, marked by broader international presence and heightened prominence of Brazil's defense industry.

In this context, the positive outcomes for Brazil's aerospace industrial capacity demonstrate that, while international partnerships must be pursued with due caution, they should not be dismissed out of excessive apprehension. Global initiatives such as the Future Combat Air System (FCAS) — a collaboration between France, Germany, and Spain aimed at replacing the Rafale and Eurofighter aircraft by 2040 — , the Tempest Team program — involving the United Kingdom, Sweden, and Italy to develop a sixth-generation fighter by 2035 — , the F-35 Joint Strike Fighter program — launched in 2006 and expected to remain in service until 2070, with participation from countries including the United States, United Kingdom, Italy, Netherlands, Canada, Denmark, Norway, Australia, Israel, and Singapore — , and the KC-390 program — involving Brazil, Argentina, Portugal, the Czech Republic, and the British multinational BAE Systems — all underscore the relevance, viability, and strategic value of such partnerships.

One of the main conclusions of this research is that Embraer has played a central role in Brazil's technological modernization, fulfilling the vision of its founders to strengthen the national aerospace industry. By occupying market niches both domestically and internationally, and by leveraging in-house expertise as well as knowledge acquired through technology transfer agreements, the company has achieved remarkable production success.

As this study has shown, Embraer also benefited significantly from support by the Brazilian government, highlighting how public-private

collaboration can foster technological innovation through complex, multinational defense projects with allied nations.

Ultimately, deepening the understanding of the specificities and outcomes of strategic partnerships, such as those examined here, provides valuable insights for the future. Expanding this type of analysis to encompass other case studies in international cooperation is a necessary step toward better understanding the potential benefits, limitations, risks, and nuances of such initiatives — thereby generating critical knowledge to inform evidence-based public policy in the defense sector, fully aligned with the country's economic development goals and the accumulation of technological capabilities.

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NOTAS

1. Understood as the "set of public and private, civil and military bodies and entities, governed by Brazilian legal regulations, that conduct or manage research, projects, development, industrialization, production, repair, conservation, overhaul, conversion, modernization, maintenance, integration, decommissioning, or termination of defense goods and services" (Brasil 2022, our translation).
2. Founded in 1969 as a state-owned company with mixed capital, Embraer emerged as the fulfillment of a "national project for the development and mastery of aerospace technology, which originated in the 1930s and was considered essential from a military perspective" (Dalla Costa and Souza-Santos 2010, 175, our translation).
3. This fiscal crisis is rooted in the "explosive trajectory of [public] debt since 2014 [...] clearly associated with the intense growth of [public] spending (though it was exacerbated by the recession)" (Pastore 2017, 433, our translation and emphasis added).
4. Engesa's bankruptcy can be attributed primarily to two interrelated factors: the high-risk investment in the development of the EE-T1 Osório tracked main battle tank and the structural downturn in the global market for conventional weaponry that began in the late 1980s. Concerning the first factor, several challenges proved decisive: fierce international competition from well-established and combat-proven manufacturers; the powerful lobbying efforts of U.S. and European defense firms, often backed by diplomatic leverage and favorable financing mechanisms; persistent skepticism over Engesa's lack of experience in producing tracked vehicles; and the company's mounting financial difficulties, reflected in halted production lines and shortages of key components. Unable to reap the benefits of its investments, Engesa saw its financial situation rapidly deteriorate, ultimately leading to its bankruptcy in 1993 (Marques 2024).
5. The choice of Kendall's correlation is due to the fact that this technique does not assume any specific assumptions regarding the data distribution — in contrast to Pearson's correlation technique, for example, where the assumption of a normal distribution is a requirement.

INTERNATIONAL STRATEGIC PARTNERSHIPS, DEFENSE, AND DEVELOPMENT: LESSONS FROM EMB-326 XAVANTE AND AMX A-1 IN BRAZIL

ABSTRACT

This article examines two emblematic military aircraft projects jointly developed by Brazil and Italy — the EMB-326 Xavante (1970) and the AMX A-1 (1985) — to assess how the international strategic partnerships forged through these initiatives enabled Embraer to accumulate both productive and technological capabilities. These collaborations not only led to the production of Brazil's first domestically manufactured jet but also provided access to critical technologies and laid the foundation for the company's expansion into new production lines targeting international markets. The analysis is organized into the following sections: a discussion of international partnerships in the context of Brazil's National Defense Strategy and the country's fiscal and budgetary constraints; a historical review of the EMB-326 Xavante and AMX A-1 programs and their impact on the national aerospace sector; and an exploratory data analysis of military aircraft exports from the 1960s to the 2010s, offering a complementary commercial perspective on how the capabilities developed through these programs helped position military aircraft as the leading category of Brazil's defense exports. The findings reaffirm the role of international partnerships in strengthening Brazil's aerospace industry and offer valuable insights — particularly for public policy formulation — into how international collaborations can advance the development of the Defense Industrial Base.

Keywords: Defense Industrial Base; Combat Aircraft; R&D; International Arms Trade.

RESUMO

Este artigo analisa dois projetos emblemáticos de aeronaves militares desenvolvidos conjuntamente por Brasil e Itália — o EMB-326 Xavante (1970) e o AMX A-1 (1985) — com o objetivo de avaliar de que maneira as parcerias estratégicas internacionais estabelecidas em torno dessas iniciativas permitiram à Embraer acumular capacidades produtivas e tecnológicas. Essas colaborações não apenas viabilizaram a produção do primeiro jato fabricado no país, como também proporcionaram acesso a tecnologias críticas, e lançaram as bases para a expansão de novas linhas de produção voltadas ao mercado internacional. A análise está estruturada em três seções principais: uma discussão sobre as parcerias internacionais no contexto da Estratégia Nacional de Defesa e das restrições fiscais e orçamentárias enfrentadas pelo Brasil; uma revisão histórica dos programas EMB-326 Xavante e AMX A-1 e de seus impactos sobre o setor aeroespacial nacional; e uma análise exploratória dos dados de exportação de aeronaves militares entre as décadas de 1960 e 2010, oferecendo uma perspectiva comercial complementar sobre como as capacidades desenvolvidas no âmbito desses programas ajudaram a posicionar a categoria de aeronaves como o principal produto de exportação militar do país. Os resultados reafirmam o papel das parcerias internacionais no fortalecimento da indústria aeroespacial brasileira e oferecem subsídios valiosos — especialmente para a formulação de políticas públicas — sobre como as parcerias internacionais podem contribuir para o avanço da Base Industrial de Defesa.

Palavras-chave: Base Industrial de Defesa; Aeronaves de combate; P&D; Comércio Internacional de Armas.

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