A GLOBAL BENCHMARKING ANALYSIS OF PUBLIC SUPPORT FOR RTD IN CIVIL AEREONAUTICS INDUSTRY

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DRAFT INDEX OF THE STUDY

INTRODUCTION

THE ECONOMIC RATIONALE OF PUBLIC SUPPORT FOR RTD IN THE CIVIL AERONAUTICS INDUSTRY

A key motive for renewed and dedicated public support to civil aeronautics Research, Technology and Development (RTD) stems from the intrinsic and unique characteristics of the RTD process in the industry. A high level analysis of such process is therefore offered below, underlying the fundamental economic rationale for public intervention.

In the economic literature there is a widespread consensus on two main arguments for governments to take a proactive role in stimulating RTD investments in general:

- the **recognition of RTD as the main engine of long-run productivity and growth**, as new knowledge may be turned into commercially-viable innovations and, through the diffusion process of adoption and imitation, may induce long term and broad positive effect on productivity and economic growth;
- the important features which differentiate RTD from other profit-motivated investments and particularly its **public good characteristics, namely non-rivalry and non-excludability, which undermine private incentives to invest in RTD**, as a relevant part of the benefits from undertaking RTD may spillover to other firms or even across the economy and the positive externalities are not fully capturable by its “owner”. Therefore, market players tend to engage in a level of RTD activity that is too low from a societal point of view and the government’s role is to **overcome this market failure**, supporting RTD in those instances where society will benefit from the technology.

These two arguments constitute the main rationale for government support for RTD in general and explain why public authorities are generally willing to contribute to enhancing the RTD system, by providing the necessary funding, infrastructure and institutional framework in support of innovation-generating activities.[1]

The role of government in supporting RTD activities is moreover amplified in times of economic turbulence, since the public sector is called on to counterbalance the likely slowdown of private RTD investment, which tends to be pro-cyclical in the short term.

RTD in civil aeronautics represents a typical case of market failure which may be corrected by public intervention aiming to internalize its positive externalities, through financial compensation to market players in the form of direct support to their RTD process.

For instance, the knowledge and solutions generated from the RTD on new light materials and composites, on precision instruments and on electronic applications used in aeronautics, spillovers into other sectors such as automotive,

[1] A recent in-depth economic analysis of public support for research and innovation is contained in “The Economic Rationale for Public R&I Funding and its Impact”, European Commission, Directorate General for Research and Innovation, Policy Brief Series, March 2017.

energy and healthcare. Therefore the “external” costs and benefits are not comparable to the “internal” ones, since aeronautics market players cannot exploit the full RTD benefits despite the fact they bear the total RTD costs. As a result, the market mechanism is unable to provide an efficient resource allocation and aeronautics’ RTD would remain well below the optimum social level without sustained public support to compensate its players for the positive externalities enjoyed by other sectors and by the society as a whole.

Market failure could also arise because market players find it too difficult to overcome technical and market risks involved with specific RTD initiatives and therefore public support to RTD could also be justified on the basis of industry-specific dynamics and RTD process features and challenges.

And this is particularly the case for the civil aeronautics industry which is a science-led industry in continuous evolution on the technological frontier and subject — beyond the general circumstances impeding optimal investments in RTD mentioned above — to **highly-specific barriers and constraints deriving from the peculiarities of the economic dynamics of the sector and of its RTD process**.

Indeed a key distinctive civil aeronautics industry feature is the **very long RTD cycle** behind its advancements, as a civil aeronautics RTD program extends over the entire life span of a product and covers a time horizon of up to 20 years, with a range of different phases. Such programs are very technology and capital intensive and represent a **uniquely complex undertaking from a technical, financial and managerial point of view, exposed to high risks and strong public interests**.

As shown in figure 1 below, in contrast to other technology-intensive industries, product development cycles in civil aeronautics is much longer, mainly due to the severe qualification and certification requirements for every single component of aero-structures, significantly widening the timespan between TRL6 technology achievements and their introduction into final products at TRL9[2].

[2] Technology Readiness Levels (TRLs) are a type of measurement system developed by the NASA in the 70s to assess the maturity level of a particular technology prior to integrating it into a system. There are today nine technology readiness levels. A TRL6 technology has a fully functional prototype or representational model. Once a technology has been "flight proven" during a successful mission, it can be called TRL 9 and is ready for full commercial deployment.

Public support to RT&D is crucial given the length of RT&D cycles within civil aeronautics (among the longest) and high levels of uncertainty and riskiness

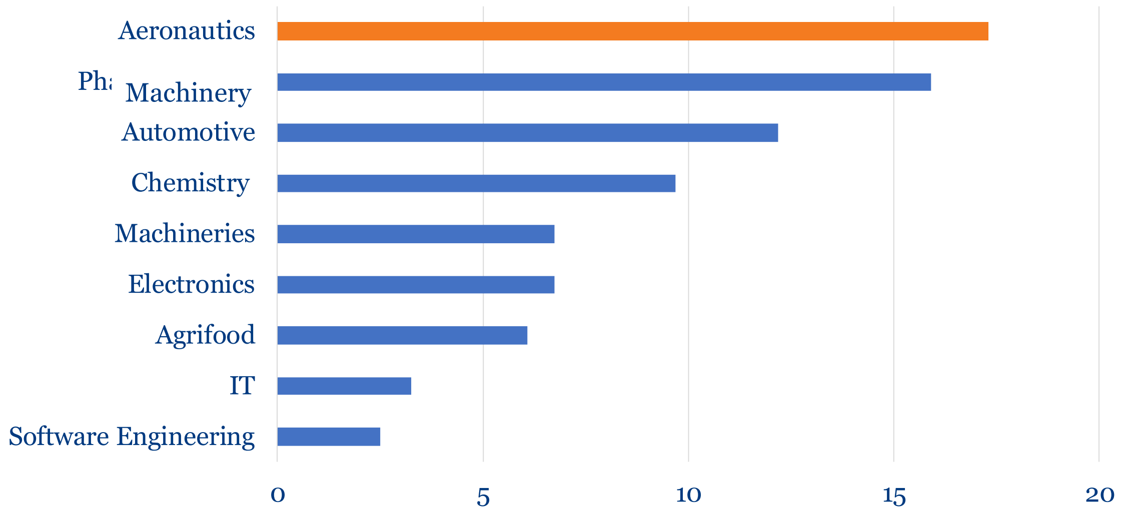

Figure 1. Time to market by industry (avg. years), 2014. Source: The European House – Ambrosetti, 2017

In addition, technological, market and financial uncertainties in the civil aeronautics business are higher than in most other manufacturing segments, as are the costs of launching a new model. In fact, RTD in civil aeronautics is distinctly different if not unique compared to most other manufacturing product RTD processes: a large part of the cost of producing an airplane is the cost of creating the technology embodied in its design and manufacturing. This cost is incurred both directly, in the form of RTD expenses and indirectly, by bearing the losses during the initial phase of the learning curve in the expectation that costs will fall as the learning curve proceeds.

Since today RTD investments are the foundations of the industry in 15 and 20 years' time, aeronautic programs require intensive long-term planning, including the years for the highly expensive RTD, before production can even begin.

A key peculiarity in the civil aeronautics product cycle is that, at intervals, fundamental breakthroughs in design are made and manufacturers introduce new families of aircraft marked by massive dynamic scale and scope economies, where a huge initial expenditure on development is followed by a steep learning curve at the firm level, lasting throughout the product cycle.

The use of state-of-the-art systems in each new generation of aircraft confronts manufacturers with significant **technological risks**: a project may be years into its development before a technical obstacle is discovered that delays or stops the endeavor. Even when technological uncertainty does not threaten the launch of a model, it decisively affects the manufacturer's decision about whether to adopt advanced subsystems and components.

In addition to technological uncertainties, **market and financial risks** are also very high. Major investment requirements have long lead times before the project reaches a positive cash flow and an even longer wait before the break-even point and the payback period (10-15 years). Since the initial development investment is essentially a sunk cost and is incurred well before revenues are generated, the size of these nonrecurring costs is a key element affecting an aircraft program's risk and expected profitability. Thus, airplane manufacturers must bear huge up-front risk and expenditures for a significant period of time, without any guarantee of future commercial success. And large financial commitments are required precisely in the early stages where the uncertainties are greatest. As showed in Figure 2 below, the early-stages of research, together with early technology development and adaptation take 50% of the RTD total costs.

Civil Aeronautics' has long lead times and cycles before technologies developed from a research project can be put into real product

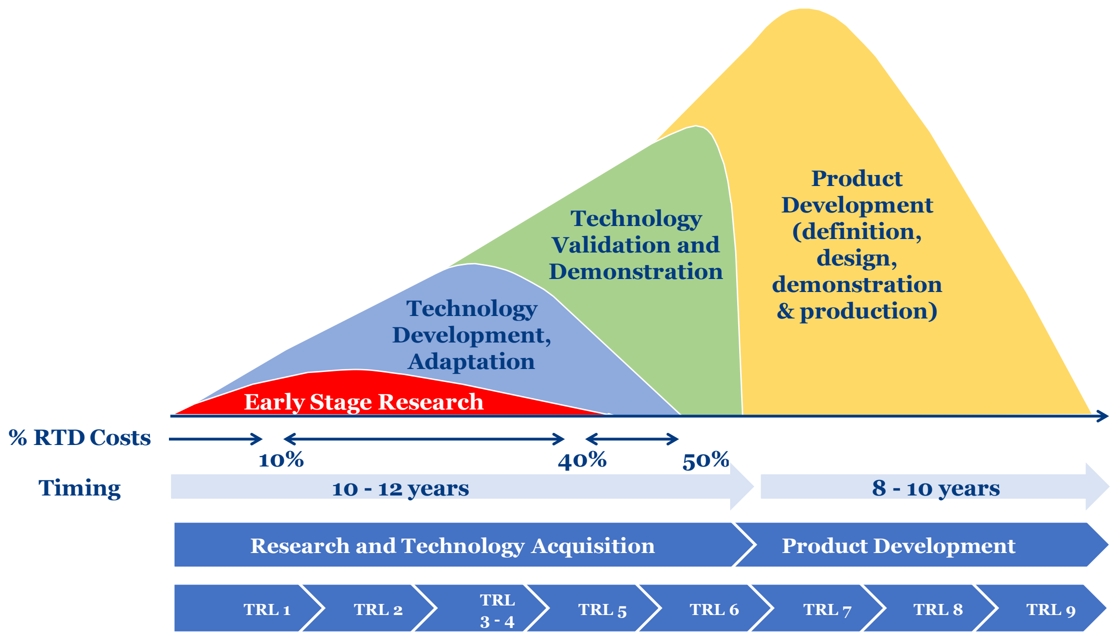

Figure 2. ***RTD cost structure in the civil aeronautics sector (illustrative).*** *Source: The European House - Ambrosetti on Thales data, 2017*

The role played by public support for RTD is particularly critical in the very early stages (red, blue and green in Figure 2 above) and make it possible to activate the subsequent product development stage (yellow).

The combination of these characteristics makes aeronautics programs uniquely risky and induces a very high concentration of the industry into an **oligopolistic market structure** in which only a few competitive firms can profitably exist.

The principal way public support may benefit is **de-risking civil aeronautics manufacturers to a point where the relation between risks and**

expected returns is favorable and a company can proceed to adopt a new technology.

Unless there is public support to co-fund and maintain these RTD efforts, aeronautics manufacturers finance these costs from four sources: retained earnings, debt and equity issues, advance payments from customers and cost-sharing with subcontractors and partners.

They rely particularly on advance orders from their customers, which typically entail substantial advance payments before delivery and therefore help fund production expenditures and recoup large RTD outlays. Moreover, international subcontractors are often used as a costs risk sharing device between the various partners along the value chain, given the significant recourse to outsourcing.

However, these sources may not be sufficient to enable a manufacturer to adopt a new technology and in some circumstances only if public support to the RTD project is available and directly assume much of the financial risk, it can go head. The opportunity to develop and prove advanced technology with government support in civil RTD projects provide the players with the necessary confidence to sustain a new endeavor.

One should be aware that the current global leadership of the European civil aeronautics industry and its relevance for the European economy and society is the result of **continuous investments** and ongoing efforts in research and development over the past decades.

Such investments have been facilitated and sustained by an attractive and supportive environment, created by both national governments and the European Union.

Indeed, long-term public investment is essential in this highly competitive and ever-changing sector, where product and technology development are of a particularly risky nature and can stretch over decades, and where both incumbent and emerging firms worldwide benefit from an array of government incentive mechanisms.

The **public and institutional commitment** in sustaining European Civil Aeronautics industry is essential, especially in its Research Technology and Development phases, in order to allow the industry facing **key contemporary challenges** like the growing and aggressive competition from new players, the increasing relevance of cybersecurity issues and the strong drive towards sustainability.

As it will be shown in the subsequent benchmarking analysis, public support for civil aeronautics RTD should also be considered as **a decisive competitive factor** for the European industry, taking into consideration that such support is widely available in other geographies directly competing with it.

BENCHMARKING ANALYSIS

PUBLICLY FUNDED INCENTIVES IN CIVIL AERONAUTICS: AN ANALYSIS OF THE COMPETITIVE LANDSCAPE BEYOND THE EUROPEAN UNION

The purpose and the perimeter of the benchmark analysis

Given the peculiar nature of the industry and its long lead times, what is not perceived as a potential menace today, could in fact become a well-established opponent in the future.

A careful screening of existing strategies and tools in place in key geographies around the world can avoid Europe to be caught off guard and to preserve its competitive edge.

Therefore a **benchmark analysis** addressing European Union's main competitors in civil aeronautics with particular focus on how the public sector supports them and helps them to innovate and to remain competitive, is particularly useful for both industry and institutional key stakeholders and decision makers.

Only through an extensive knowledge and understanding of **how civil aeronautics is supported directly and indirectly abroad**, it will be possible to conceive an appropriate industrial strategy capable to mantain European global leadership in the sector.

The perimeter of the analysis encompasses **two main clusters of countries**.

The first one refers to those countries where national civil aeronautics sector is already well developed and can currently compete with the European one. In these countries, the challenges faced by civil aeronautics' companies are similar to the ones experienced by the European industry. The value chain has a mature structure with few big original equipment manufacturers and competitive tier 1 and tier 2 producers of medium and small size, capable to generate innovative technologies and develop new products. Here, the public role is focused on supporting research and ensuring a favorable regulatory framework, also enabling and facilitating positive spillovers from the defense sector. Understanding what kind of measures and tools are in place to support national civil aeronautics industry in those countries is crucial if Europe wants to avoid the emergence of competitive gaps.

The second cluster encompasses those emerging countries where civil aeronautics sector is nascent or not yet fully developed and competitive at international level, but where public commitment is today very strong and decisively contributing to foster its growth.

The situation and the challenges experienced by civil aeronautics' sector in these geographies are different from those affecting the European industry and the public contribution and support is more pervasive. Despite the low degree of comparability between measures and tools here in place and the European situation, extending the scope of our analysis including these countries can provide useful insights anyway.

Main purpose of the following benchmark analysis is to provide a comprehensive overview of the tools and schemes today in place to support civil aeronautics RTD in major EU competing geographies

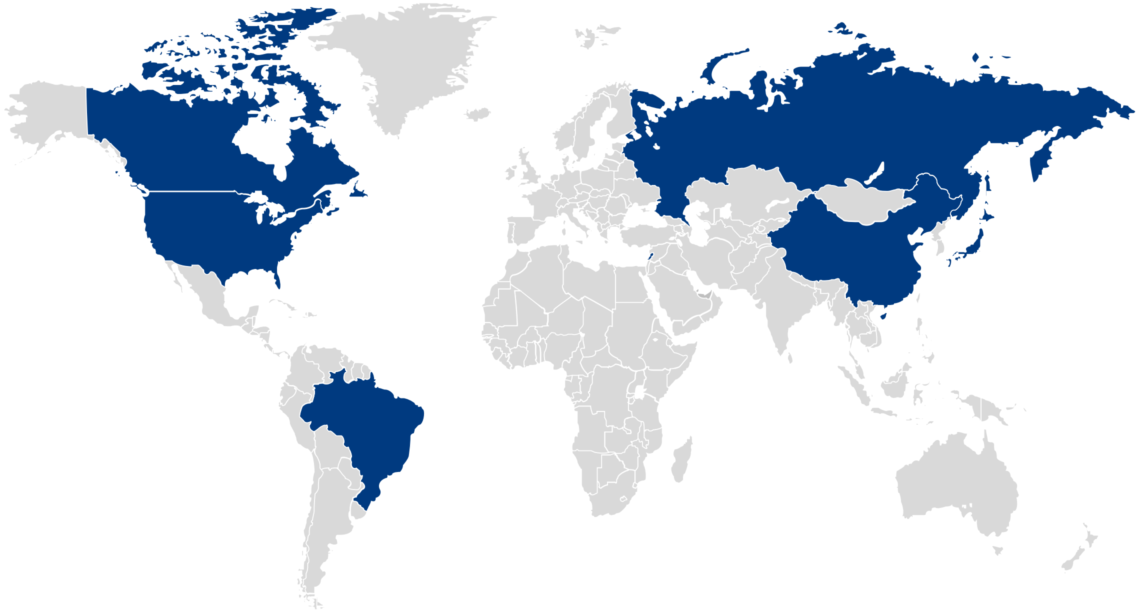

Figure 3. The geographical scope of the Benchmarking analysis. Source: The European House - Ambrosetti elaboration, 2017

The main purpose of the analysis is to **provide a comprehensive overview of the tools, policy measures and supporting schemes** today in place in the main civil aeronautics manufacturing countries, together with a consistent framework illustrating the strategies put in place by European competitors to sustain national civil aeronautics industries.

How established players in civil aeronautics manufacturing are keeping their national industry competitive

The countries with the most significant civil aeronautics industry today are: **European Union, United States, Canada and Brazil, together accounting for over 80% of global market share**. This is due to historical conditions and investments, coming from both private and public sector.

In each of these countries the development of a competitive civil aeronautics sector has been seen as **a priority by the respective government and represents an important element of national pride, industrial policy and strategic autonomy**. The benefits to the countries involved include positive mutual spillovers, synergies with defense sector and benefits to non-aerospace manufacturing industries, especially those that are by nature less technology-intensive.

United States

The United States are clearly a leading player, together with the European Union. The overall industry in the US contributes to over $120 billion exports, attracting **almost $30 billion in Foreign Direct Investments** and providing 500,000 direct jobs. The Unites States is a global leader in Large Civil Aircrafts, Rotorcrafts, and Engines and has strong capability in ATM technologies.

United States aeronautics' industry keeps growing, with export value of almost $120 bln. and Value Added of $100 bln. in 2014

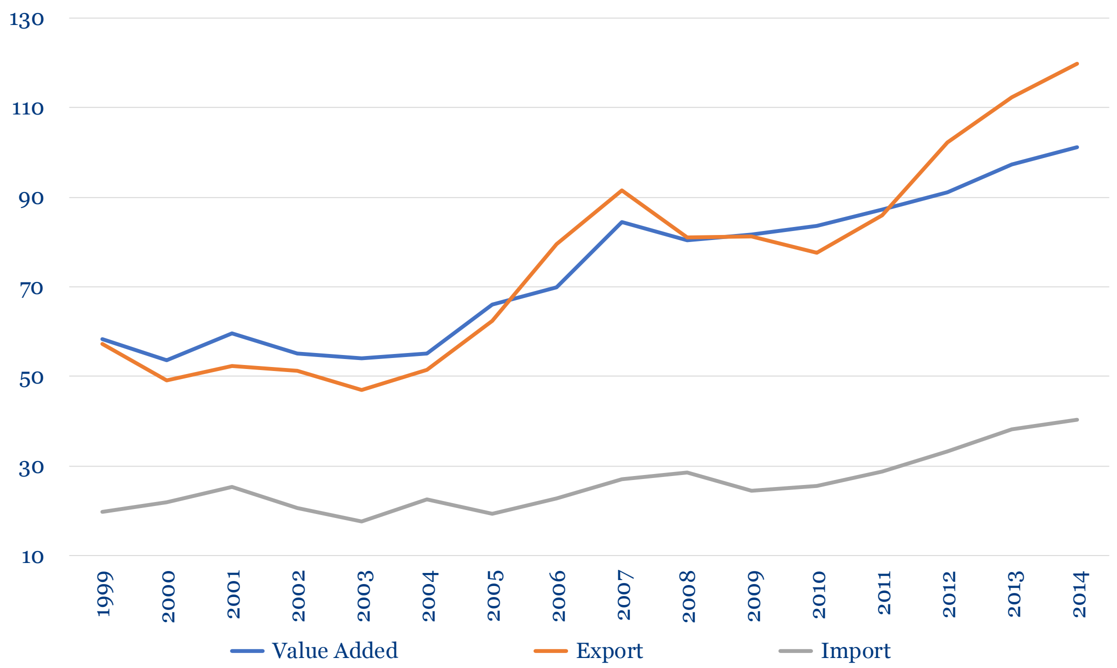

Figure 4. United States aircraft production, value added, export and import (bln. $), 1999-2014. Source: The European House – Ambrosetti elaboration on NSF data, 2017

This leadership comes from both investments in the past decades and a strong public commitment.

Public commitment in particular has been continuous, benefiting from clear strategies and the explicit support of the Executive. Regardless of the alternation of Presidents and Governments, the development and success of US aeronautics sector has always been a priority for American federal administrations.

The set of regulations, policies and tools put in place during the years by American administrations to support its civil aeronautics industry is extensive and **leverages the defense sector very** effectively, especially for research, technology and development. In 2002 the Commission for the Future of the United States Aerospace Industry pointed to **34 different agencies and departments** in the United States federal government that share some responsibility and support for R&D in the aircraft industry. The public commitment remained unchanged in subsequent years. The main instrument to support the industry has been federal budget allocations for research programs.[3] Considering total federal funds in Fiscal Year 2016 allocated for R&D,[4] they totaled an estimated **$149 billion (+7.5% compared to 2015).** In 2017 the projected increase is for a further 3.3%.[5]

Federal budget allocation for research programs, surpassed 150 bln. in 2016 and is expected to further increase in 2017

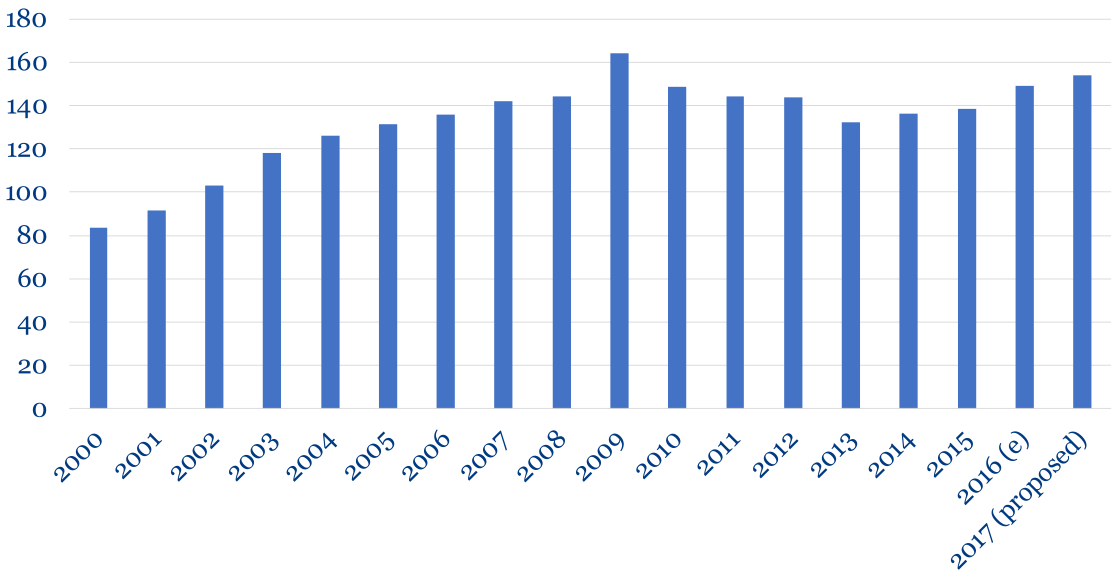

Figure 5. Federal budget for R&D and R&D plants (bln. dollars, current). Source: The European House - Ambrosetti on NSF, 2017

Civil aeronautics is one of the industrial sectors in the US to benefit directly and to a very significant extent from this federal budget spend in RTD. Furthermore, US civil aeronautics companies have **indirectly benefitted from research programs and grants issued by the US Department of Defence** (DOD) due to technological spillovers. For example, technology such as night vision is of use in both military and civilian aircraft. According to the European Commission, the DOD has transferred dual-use technology at no cost and worth up to US$1.2bn, for direct use by national industry in the production of Boeing Commercial Aircraft.

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[3] These programs encompass several areas: Advanced Air Vehicles, Airspace Operations and Safety, Integration of Aviation Systems, New Materials and Composites, Innovative Concepts in Aeronautics, Subsonic Technology, Sound Reduction, Base Research, New Computing and Efficiency technologies.

[4] Considering total industry.

[5] Source: National Science Foundation, 2017.

An example of the spillover existing between civil and military research is provided by the **role of the Air Force Research Laboratory (AFRL)**, established in 1997 to merge fourteen different laboratories into four comprehensive research units. AFRL's mission is to lead the discovery, development, and integration of warfighting technologies for US air, space and cyberspace forces. Still, such research has often **produced technologies later used in civil aeronautics' products**.

The laboratory employs approximately 10,000 military and civilian personnel. It is responsible for managing an annual $4.4 billion science and technology program. This budget, however, is only in part funded by Air Force budget, while a share comes from private customers in the industry. **AFRL investment includes basic research, applied research and advanced technology development**.

Top contractors of US Department of Defense are US players in the Aeronautics' sector

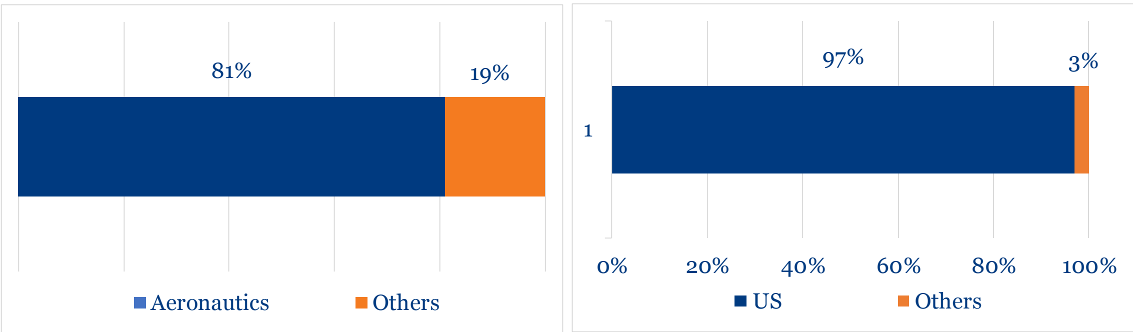

Figure 6. Analysis by sector and region of DoD top-20 contractors (comprising 50% of 2016 budget), % of total $ awarded, 2016 Cluster analysis. Source: The European House - Ambrosetti on Federal Procurement Data System, 2017

Among other examples, an experimental twinjet transport aircraft project, intended to demonstrate new air cargo-carrier capabilities using advanced composite material, was included in the ten-year research and development investment known as the composite affordability initiative, led by the AFRL and involving private players from the commercial and military aircraft business on a 50-50 cost share base.[6]

Within AFRL, **The Air Force Office of Scientific Research (AFOSR)**, identifies research opportunities, distributes research grants and graduate fellowships at US research universities and participates in the **Small Business Technology Transfer Research program (STTR)**. With an annual 2015 budget of approximately 500 million Dollars, AFOSR funded over 340 intramural

[6] Total Budget of $152 million. Source: AFRL "COMPOSITES AFFORDABILITY INITIATIVE (Preprint) CANCOM 2007", 15 August 2007.

research projects, 320 international grants, and 1,350 U.S. research grants at more than 200 American universities.

Further support comes from the **US Defense Advanced Research Projects Agency (DARPA)** working on materials, ICT, electronics and space. DARPA is a funding agency with 240 employees and an annual budget of $3 billion.

The Joint Unmanned Combat Air System (J-UCAS) is an example of the programs that DARPA has previously managed, granting significant funding to US industry (over $500 million). The Boeing X 45 and the Northrop Grumman X 47 were the two systems developed under the first phase of this program which was handed over to a joint US Navy and Air Force office in October 2005.

The Department of Defense also has a **Deputy Under Secretary for Industrial Policy**. His mission is to ensure that the industrial base on which the DoD depends is reliable, cost-effective, and sufficient to meet Department's requirements. It should be noted, in this respect, that US authorities are not constrained by multilateral agreements, which typically do not apply to defense matters.

Considering the part of budget devoted to civil sector, **NASA** (National Aeronautics and Space Administration) is the agency playing the key role in supporting aeronautics research through its **Aeronautics Research Mission Directorate**. Its mandate is to focus on research and technology development that is beyond the current grasp of industry, with emphasis on technologies to achieve societal benefits such as safety assurance and environmental protection.

In the past decades NASA has very effectively contributed to the development of technologies that apply to today's commercial aircrafts

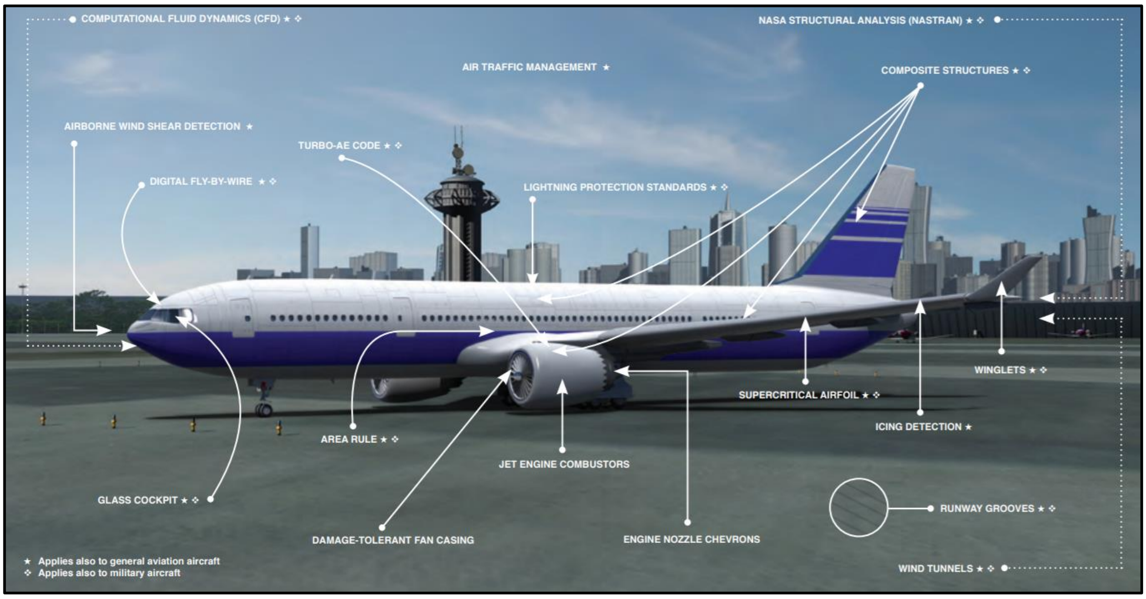

Figure 7. Applications of NASA research results in a modern commercial airliner (illustrative). Source: The European House - Ambrosetti elaboration on NASA, 2017

In the past decades, however, it has effectively contributed to the development of **technologies that apply to today's commercial aircrafts**, providing significant support to the US civil aeronautics industry and providing an incentive to relocate or retain operations in the US.

For example, during the 1990s, NASA focused on the following programs: development of Future Flight Central full-scale airport operations simulator, simulations of the National Airspace System (NAS), development of air traffic control and air traffic management tools, exploration of air vehicle and propulsion concepts for energy efficient aircraft, initiation of research into electric propulsion technology, integration of human factors, guidance, displays, and intelligent flight controls into safety research, research in aircraft structures, composites, high-temperature materials, demonstrators to reduce sonic boom intensity and development of physics-based and multidisciplinary tools for aircraft design and analysis.[7]

To sustain future programs, the **President's Fiscal Year 2017 budget provides a further $790 million to NASA's Aeronautics Research Mission Directorate** with the mandate to accelerate aviation energy efficiency, advance propulsion system transformation and enable major improvements in aviation safety and mobility.

NASA Aeronautics' Budget is expected to grow steadily until 2023 under the so called "10-year American Aviation Plan"

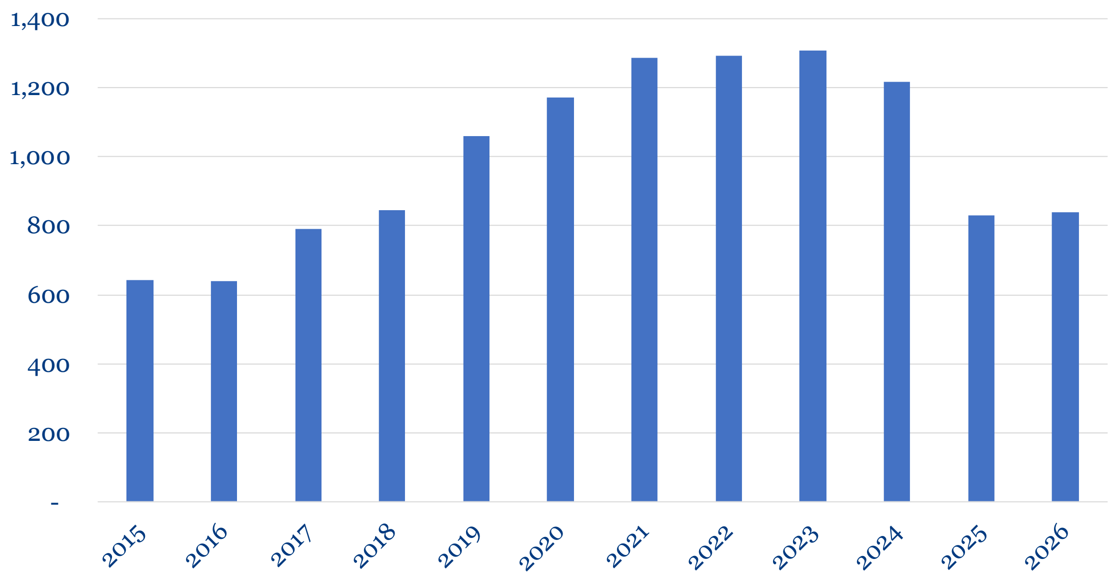

Figure 8. NASA Aeronautics 10-year American Aviation Plan, Budget Request, ($ mln.), 2015-2026 (planned). Source: The European House - Ambrosetti elaboration on NASA data, 2017

[7] Source: NASA, 2017.

This figure represents a significant increase to the budget requested in 2015 and 2016 ($640 million) and is part of **NASA's Aeronautics long term vision and strategy**, a 10-year plan developed to let NASA achieve critical outcomes, including a bold series of new experimental aircraft or "X-plane" and technology systems demonstrations, that would benefit greatly US civil aeronautics' players.[8]

NASA's Aeronautics long term vision and strategy in particular focuses on the following **six technology areas**:

- Safe, Efficient Growth with the aim to enable a NextGen air transportation system in the US by 2035 and safely expand capability of the global airspace system to accommodate growth in air traffic.
- Innovation in Commercial Supersonic Aircraft with the objective to provide low-boom standard, efficiency and noise reduction technologies that could lead to commercial supersonic flight overland.
- Ultra-Efficient Commercial Vehicles to pioneer technologies for future generations of commercial transports that simultaneously reduce noise, fuel usage and emissions.
- Transition to low-carbon Propulsion to enable transition of industry to low-carbon fuels and alternative propulsion systems.
- Real-Time System-Wide Safety Assurance aimed to develop tools for use in a prototype of an integrated safety monitoring and assurance system that detects, predicts and prevents safety problems in real time.
- Enabled Assured Machine Autonomy for Aviation with the goal to enable the utilization of higher levels of automation and autonomy across the aviation system including routine Unmanned Aircraft System presence in the National Air Space.

ARMD collaborates closely with the industry and the Federal Aviation Administration (FAA), as well as with the Department of Defense (DOD) and other government agencies to leverage technology investments.

Industry partnerships in particular allow rapid insertion of ARMD research results into air vehicles and subsystems. Furthermore, partnerships with domestic academic institutions support cutting-edge research on emerging aviation technologies and on the education of new researchers in various fields of study.

In addition, both NASA and Department of Defence allow own **personnel** to work for US private aerospace companies. They also allow these companies to use

[8] Thanks, in large measure, to technology features attributable to ARMD research, commercial aircraft now entering service are 20% more energy efficient and have a noise footprint 60% smaller than the aircraft they will replace. Source: NASA ARMD strategic implementation plan, 2017.

research and test facilities, including the NASA Langley Research Center wind tunnels.

Free technology transfer, transfer of patents (and other vital knowledge) and cession of intellectual property rights are also used. The exploitation of the transferred technology is often restricted by the US authorities as a result of Export Control. Other tools to support the national civil aeronautics' industry include **reimbursement of private own R&D expenses**.

Of course, although the focus of this analysis is on public support to industrial RTD, there are many other public incentive mechanisms used by the US government to attract and retain private aeronautics investment.

NASA Aeronautics' "10-year American Aviation Plan" identify a well-structured long-term strategy with specific goals and measurable objectives

	2015	2025	2035
Strategic Thrust 1: Safe, Efficient Growth in Global Operations	Improved NextGen Operational Performance in Individual Domains, with Some Integration Between Domains (ATM+1)	Full NextGen Integrated Terminal, En Route, Surface, and Arrivals/ Departures Operations to Realize Trajectory-based Operations (ATM+2)	Beyond Next-Gen Dynamic Fully Autonomous Trajectory Services (ATM+3)
Strategic Thrust 2: Innovation in Commercial Supersonic Aircraft	Supersonic Overland Certification Standard Based on Acceptable Sonic Boom Noise	Introduction of Affordable, Low-boom, Low-noise, and Low-emission Supersonic Transports	*(Outcomes beyond 2035 will depend on market needs and technology solutions)*
Strategic Thrust 3: Ultra-Efficient Commercial Vehicles	New Transport-class Aircraft that Achieve N+1* Levels of Efficiency	Technology and Potentially New Configuration Concepts that Achieve N+2** and N+3*** Levels of Efficiency and Environmental Performance	Technology and Configuration Concepts, Including Low-carbon Propulsion and Autonomy, that Stretch Beyond N+3 Levels of Efficiency and Environmental Performance
Strategic Thrust 4: Transition to Low-Carbon Propulsion	Introduction of Low-carbon Fuels for Conventional Engines and Exploration of Alternative Propulsion Systems	Initial Introduction of Alternative Propulsion Systems	Introduction of Alternative Propulsion Systems to Aircraft of All Sizes
Strategic Thrust 5: Real-Time System-Wide Safety Assurance	Introduction of Advanced Safety Assurance Tools	An Integrated Safety Assurance System Enabling Continuous System-wide Safety Monitoring	Automated Safety Assurance Integrated with Real-time Operations Enabling a Self protecting Aviation System
Strategic Thrust 6: Unmanned Aircraft System(s) (UAS) integration in National Airspace System (NAS)	Initial Autonomy Applications Human-machine	Teaming in Key Applications	Ability to Fully Certify and Trust Autonomous Systems for NAS Operations

**N+1: -32dB Noise (Cumulative margin relative to ICAO 8.4.2/ FAA Stage 4 noise limit), -60% NOx emissions in landing/takeoff cycle (Relative to ICAO CAEP/6 standard), -55% Cruise NOx Emissions (Relative to 2005 best in class), -33% (Aircraft Fuel/Energy Consumption (Relative to 2005 best in class). **N+2: -42dB, -75% NOx emissions in takeoff/landing, -70% cruise NOx emissions, -50% fuel consumption. ***N+3: -52dB, -80% NOx emissions takeoff/landing, -80% Cruise NOx emissions, -60% fuel consumption*

Figure 9. NASA ARMD long term vision and strategy (illustrative). Source: The European House – Ambrosetti on NASA data. 2017

The **Export-Import Bank of the United States**, known as EXIM, provides strong financing support to aeronautics manufacturers. During Fiscal Year 2009 only, EXIM Bank provided financing of approximately $8.6 billion to support the export of 150 large commercial aircraft, a greater than 50% increase relative to the previous year. Today's Bank exposure to support the export of aviation-related products amounts to $42 billion; 48.2% of its total exposure.[9]

Less easy to calculate is the important and influential role played by the US **Federal Aviation Administration** (the FAA) in buoying US exports. The FAA does have a budget allocated to Research, Engineering & Development (RE&D), amounting to $167.5 million (requested) in 2017, equal to a $1.5 million (+1%) increase from 2016. However, the Agency reach surpasses research budgetary spending, since it exerts significant influence internationally, for instance within the ICAO in terms of determining international industry standards and rules and also bilaterally with third countries. The **Aviation Cooperation programs** that it has established in important aviation markets such as Brazil, China, India and Indonesia, designate significant budgets to augmenting the reach of US aviation standards and companies worldwide in areas such as manufacturing and airworthiness and safety and flight standards.

The **US-China Aviation Cooperation Program** (ACP), for example, is Co-Chaired by John Bruns, President of Boeing China, and Chris Collins, the Federal Aviation Administration (FAA) Senior Foreign Affairs Officer in Beijing and channels annually millions of dollars of assistance into the Chinese market.[10]

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[9] Source: EXIM Annual Report, 2016.
[10] Source: ACP Introduction on the US-China Aviation Cooperation Program website, 2107.

WTO cases opposing the US and Europe in large civil aircraft.

Two cases opposing US and Europe over alleged government subsidies to the aeronautics industry were opened in 2004. The US accuses Airbus of receiving illegal loans in the form of reimbursable launch investment; the EU accuses Boeing of having received grants and tax breaks from federal and local government sources.

The WTO's Appellate Body confirmed that the EU and US each violated some aspects of global trade rules in their support to their respective aerospace sectors and these cases subsequently entered the compliance phase, where the global trade arbiter was asked to review whether the EU's and US' changes to their policies were sufficient to bring them in line with WTO rules.

A ruling on 15 May 2018 handed the US a partial victory over the EU, putting at test Europe's efforts to defend global trade rules from Trump administration criticism. According to the WTO the EU and members states France, Germany, Spain and UK failed to comply with an earlier WTO panel ruling by maintaining illegal subsidies for the European aircraft manufacturer Airbus. The US could now take steps to establish the level of sanctions it can impose on European exports under WTO rules, unless the EU comply with the required amendments in its support policy. The ruling came at a tense time for trans-Atlantic trade relations, while US President Trump levied tariffs on EU exports of steel and aluminium and pulled the US out of the 2015 Iran nuclear deal, despite European allies who are parties to the accord. However, the WTO is expected in the coming months to issue a ruling on an EU case against the US over subsidies provided to Boeing and that could rebalance the case and plunge the two sides into a tit-for-tat sanctions battle or prompt what some trade experts have long expected, that is a trans-Atlantic deal on financing big civil aircraft.

In addition to these proceedings before the WTO in February 2015 the EU filed a new WTO case against the US, claiming tax breaks had been paid to Boeing by Washington State in exchange for the company locating its 777X wing and fuselage production as well as final assembly in Washington State territory.[1] The tax breaks granted by Washington State to Boeing total more than 9 billion dollars, but the WTO did not find these subsidies prohibited so far, even though they are dependent on locally produced parts, discriminating against foreign suppliers. However, the will likely be found to be actionable in the same way as previous aids received by Boeing, because of the resulting lost sales suffered by Airbus.

Brazil

The country is a major player in civil and defense aeronautics and one of the few countries in the world that holds nationally the competences and capability to fully manufacture commercial jets. **Aeronautics manufacturing accounts for 4% of total Brazilian GDP**, while aircraft production generates a value added of almost $5 billion. in 2014.[11] The country also exported almost $7 billion in aircrafts, with the overall industry positively contributes €1.3 billion to the national trade balance in 2014.[12]

Brazilian aeronautics' industry generated almost $5 bln. in Value Added in 2014. Export value reached $7 bln. recording a +40% growth between 2011 and 2014, but still below value of import

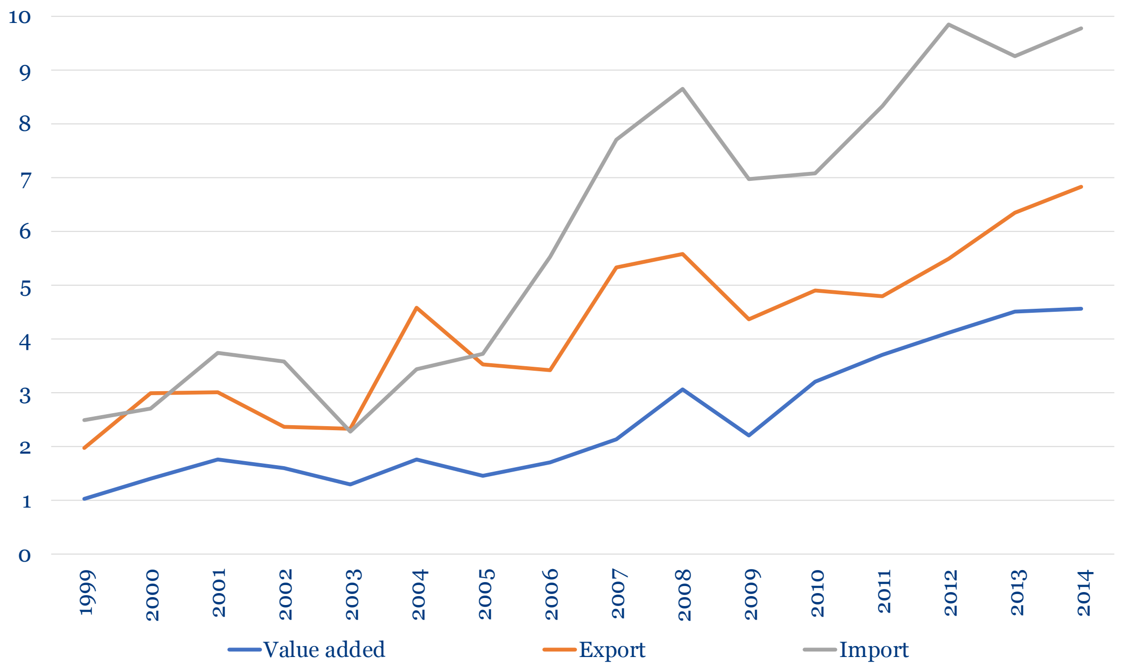

Figure 10. Brazil aircraft production, value added, export and import (bln. $), 1999-2014. Source: The European House – Ambrosetti elaboration on NSF data, 2017

The pillar of national industry is **EMBRAER**, the Brazilian aerospace conglomerate producing commercial and military aircrafts. The company, which delivered 240 aircrafts[13] in 2016, generating €4 billion revenues, is today among the largest commercial jet manufacturer globally. It employs almost 20,000 people, while R&D activities alone employed 4,000 people and accounted for over €160 million investments in 2015. The company is also atop of a comprehensive

[11] Sources: AIAB/FIPE and NSF, 2014.
[12] Including defence activities.
[13] Of these, 49% were executive jets, 45% served commercial aviation. The remaining were related to defence and security.

and diversified aeronautics' value chain that has Sao Jose dos Campos cluster at its core.

To achieve these results and support growth and competitiveness of the sector, over the past decades Brazilian government has put in place a set of systemic measures involving local government and financial institutions. Since the 1950s the Brazilian Government has supported its aeronautics industry with the aim of achieving independent capability in a sector considered strategic. Important steps towards this goal were the creation of the **Aeronautics Technical Centre and the Research and Development Institute** in 1953.

Brazilian Government ordered one third of all aircrafts produced by Embraer between 1969 and 1980s. Brazilian Government also put in place a set of policies to support the Brazilian industry, with a 50% tariff on commuter-type aircraft and **"law of similar"** which prevented the public sector from purchasing any aircraft when a locally equivalent was available for less than 15% above the import price.

Military offset policies – whereby any procurement above a $1 million – necessitated a transfer of production by the contractor to Brazil.[14] A further major source of Government support was the **PDTI** (Industrial Technology Development Program) system of tax breaks for private investment in R&D. This benefited significantly the Brazilian aeronautics industry.

The Brazilian interest rate equalization program (**Proex-Equalization**), managed by Banco do Brasil, acts as a financing scheme for Brazilian exported aircrafts.[15]

In addition to Proex program, current support scheme involves **BNDES, the Brazilian development bank**, which Together with **FINEP (Finance Fund for Studies and Projects)**, a public fund, brought very significant contribution to the financing of Brazilian aircraft.[16]

Since 2008, BNDES support to Brazilian aviation sector has steadily increased, growing from €840 million in the period 2009-2012 to €5 billion in the period 2014-2017. It has been the greatest increase compared to all other Brazilian industrial sectors.

In addition, aeronautics is also among the industries beneficiating from so-called **"sectoral funding" from the Brazilian government**.

The main R&D umbrella public body is the **CTA** (military/civilian Aeronautics Technological Center) managed by Aeronautics Ministry (a division of the Brazilian Ministry of Defense). It provides technical support services to the

[14] Source: Harvard Business School, "Brasil – Aeronautics Cluster", 2011.
[15] Due to WTO sentence, PROEX has been modified in early 2000s. So called PROEX III is currently in place.
[16] Source: Harvard Business School, "Brasil – Aeronautics Cluster", 2011.

industry and has created large number of specialist institutions, which collectively employ thousands of technical experts in Sao Jose dos Campos.[17]

BNDES support to the Brazilian aviation sector has steadily increased, with a growth rate that outpaced the one related to any other sector

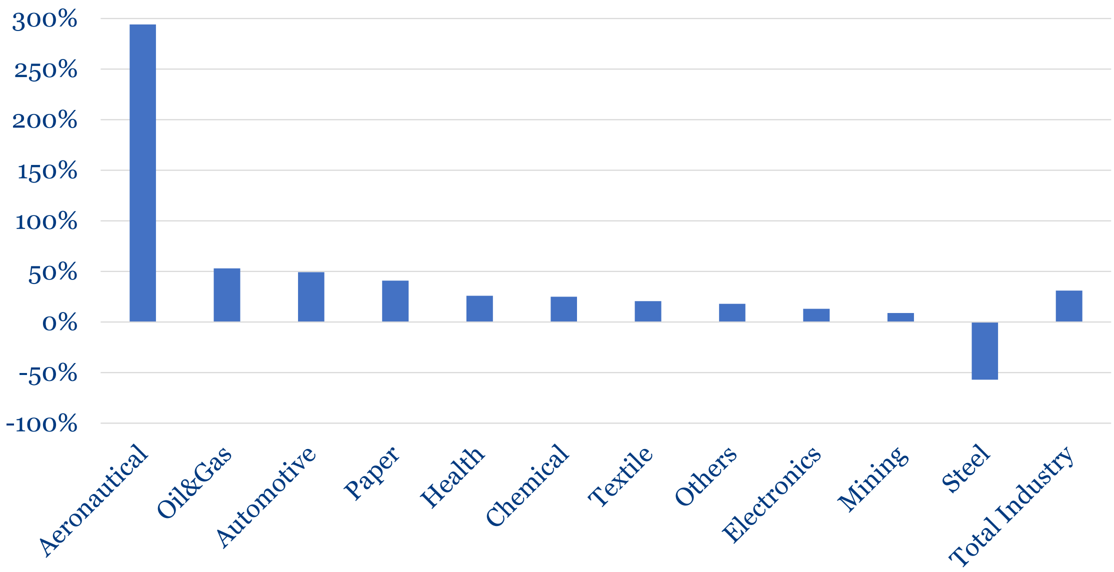

Figure 11. Brazil aircraft production, value added, export and import (bln. $), 1999-2014. Source: The European House – Ambrosetti elaboration on NSF data, 2017

FAPESP (São Paulo Research Foundation), is also a public foundation funded by the taxpayer in the State of São Paulo, is a key R&D funder for SMEs in the sector. FAPESP's expenditures in 2013 were R$1.085 billion (approximately US$500 million).[18] This adds to several programs that during the past decades have been put in place to sustain R&D, either with specific focus on aeronautics industry or addressing the whole Brazilian industry.[19]

In addition, Brazilian Government has established the so called **"Strategic Defense Companies" (EED)**. Defense companies can be considered EEDs if they comply with the following requirements: are technology intensive and have High-Technology qualification, are suppliers of strategic defense products to the

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[17] These include: the Institute of Advanced Studies (IEA – responsible for basic research), Institute of Aeronautics and Space (focused on research and development), Aeronautic Technology Institute (ITA – an educational institute which has to date trained some 5,000 aeronautical engineers, including most of Embraer's CEOs; and, the Industrial Foment Institute (IFI – which plays a major role in providing consultancy and encouraging industry networking). Source: Harvard Business School, "BRASIL – Aeronautics Cluster", 2011.

[18] Of these, 37% of the expenditures supported basic research; 10% supported research infrastructure; and 53% supported application-oriented research.

[19] Source: DOU, Brazilian Legislation, 2017.

Brazilian Armed Forces, have their Headquarters and production within Brazilian territory, and have two thirds of their capital under Brazilian control.

Public measure supporting aeronautics' manufacturing in Brazil are several and intertwined, providing both financial and non-financial support

Support Mechanism	Amount
Innovation Act (Law 10.973/2004)	Non-financial
Lei do Ben (Law 11.196/2005)	Non-financial
Act 10.332/2001	Non-financial
Act 4.179/2002	Non-financial
RETAERO (2011)	Non-financial
IEAV	Non-financial
PROAERONAUTICA	Specific for SMEs, Min. funding of R$1M for company, R$200,000 for export
Inova Aerodefesa	R$ 2,9 billion
FUNTEC	Vary
PROSOFT-company	Min. funding of R$1M or subscription of securities
PROSOFT-commercialization	Limited to 200% of product value
CT-AERO	7,5% of CIDE (fuel tax)

Figure 12. Brazil support to R&D in aeronautics: main federal measures. Source: The European House - Ambrosetti elaboration on Duarte, Gaviria, 2017.

Brazilian EEDs have several benefits. They can have access to the "**Special Tax Regime for the Defense Industry" (RETID),** a program that aims to "establish special provisions for the procurement and contracting of the national defense industry's concerns, beyond providing for the special tax regime and financing able to allow for the empowerment of the base of the defense industry, stimulating it to acquire the technologies indispensable to the country".[20]

Within this context, the benefits of the program include suspension of the Tax on Manufactured Products (IPI) and Social Insurance Contributions (PIS/COFINS) due on domestic sales. The RETID also allows beneficiaries to import goods into Brazil with the suspension of IPI, PIS and COFINS-Importação taxes.

EED companies also have **special treatment in general public biddings and exclusive public biddings**. In particular public bidding, foreign companies or companies other than EEDs can participate only in association with Brazil Strategic Defence Companies or create a consortium with it. In case of Joint Ventures, leadership should be taken by Strategic Defense Company. EEDs also benefit from preferred financing programs, projects and public initiatives.[21]

[20] Law nr. 12.598, Brazilian Official Gazette (March 23, 2012).

[21] Source: "An Introduction to the Aerospace and Defense Industry in Brazil", Business Sweden, December 2015.

In case of strategic defense products imports, Brazilian Ministry of Defense can require that foreign suppliers get associated with Brazilian Strategic Defense Company at least for one phase of product development.

An explanatory example is provided by the 2014 Brazilian acquisition of military aircrafts from a European manufacturer. The deal has been possible only after the participation of Brazilian aeronautics' companies in the production of parts of the aircraft, as envisioned by the abovementioned legislation. These parts include Infrared sensor, Display systems, Data link, Landing gear, Navigation system, Aircraft body, and Weaponry.

The transaction also included technology transfer to Brazilian companies: Brazilian companies will produce 40% of parts and up to 80% of the aircraft structure. Further on, it is expected that certain foreign components, could be substituted by locally produced parts.[22]

[22] Business Sweden, December 2015.

Canada

Canada is currently ranked **third globally in terms of aircraft and engine production.** In 2016, the Canadian aerospace industry created directly 87,000 jobs and $13 billion value added[23], while $1.64 billion were dedicated to aerospace manufacturing R&D.[24] These results were possible thanks to continued public support channeled through many different schemes and programs.

Canadian Aeronautics' industry is growing with Value Added of almost $8 billion and a positive trade balance

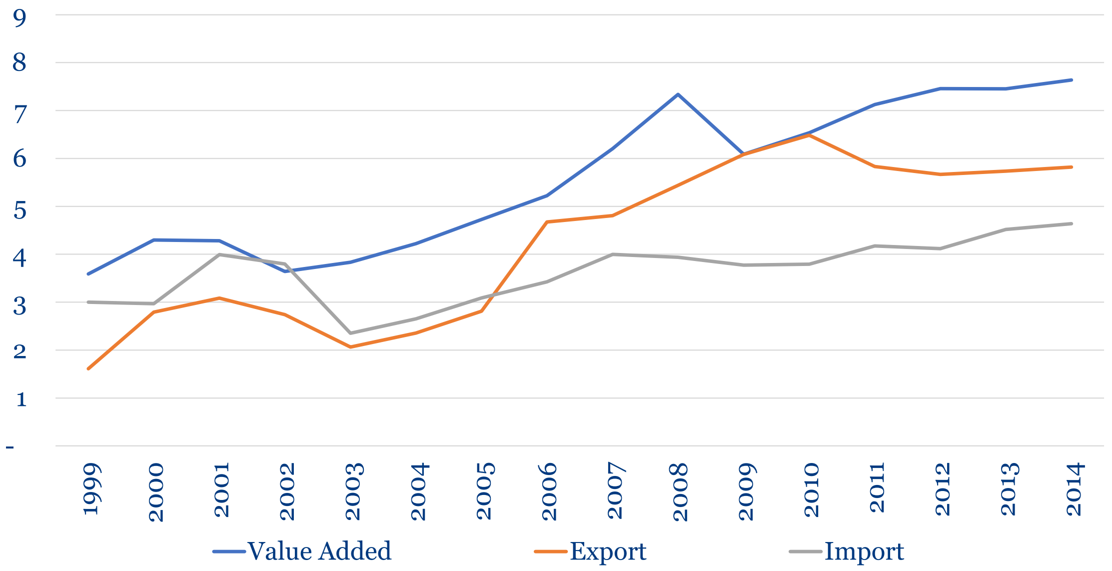

Figure 13. Canadian aircraft production, value added, export and import (bln. $), 1999-2014. Source: The European House – Ambrosetti elaboration on NSF data, 2017

Supporting the development and competitiveness of national aeronautics industry is a key declared priority of Canadian Government, which sustained the sector since late 1940s through the involvement of the Canadian National Research Council.

Today, the **Strategic Aerospace and Defense Initiative (SADI)** program is in place and has a specific focus on R&D activities within the sector. It supports strategic industrial research and pre-competitive development projects in the aerospace, defense, space and security industries. Launched in 2007, its key priorities are to encourage strategic R&D, capable to result in innovation and excellence in new products and services and fostering collaboration among research institutes, universities, colleges and the private sector. Since its

[23] In this chapter $ is referred to USD.
[24] Source: State of Canada's Aerospace Industry 2017 Report.

inception, **$1.6 billion in authorized assistance has been approved for 41 projects under SADI.** Of these, 88% has been devoted to large companies.[25]

Research is also supported through **dedicated funds allotted by Canadian Federal Budget**. In 2016 it deferred for four years the more than $3.7 billion allocated in 2015 for large-scale capital defense projects. It also made available $800 million - over four years from 2017 on - in order to strengthen innovation clusters. The budget also committed $50 million to the **Industrial Research Assistance Program (IRAP)** so that more organizations across Canada can take part in it, and promised $30 million a year starting in 2017 to the Natural Sciences and Engineering Research Council (NSERC), to further support university-based research.[26]

In addition, indirect federal government support has been provided through tax credits for eligible R&D activities, procurement for dual use technologies and companies involved in both civil and defense activities, specific support for SMEs and programs to support skills' creation. Overall, Government of Canada resources and programs stimulate innovation by substantially reducing the associated costs across the supply chain and the technology-readiness spectrum. Provincial support customized to regional needs complements these federal initiatives.

The **Technology Demonstration Program (TDP)**, launched in 2013, offered non-repayable contributions in support of large-scale technology-demonstration projects in the aerospace, defense, space and security sectors. It was worth $110 million over its first four years and $55 million per year thereafter. It has been replaced in 2016 by the **Strategic Innovation Fund**. It allocates repayable and non-repayable contributions for R&D activities. The program has a budget of $1.26 billion over five years. It consolidates and simplifies the Strategic Aerospace and Defense Initiative, Technology Demonstration Program, Automotive Innovation Fund and Automotive Supplier Innovation Program.

Canadian National Research Council - the Government of Canada's premier research organization - plays an important role too. It has an Aerospace dedicated program - **NRC aerospace** – that has annual budget of $58 million (59% of which is provided through federal funding; the remainder comes from industry partners). It works in concert with NRC's Industrial Research Assistance Program, which provides $24 million in funding for aerospace projects conducted by Canadian small and medium-sized enterprises.[27]

NRC Aerospace offers innovation assistance to SMEs, including advisory services, funding for innovation, networking and youth employment. It also

[25] Source: Gouvernement du Canada, 2017.
[26] Source: AeroMontreal, 2017.
[27] Source: National Research Council Canada, 2017.

conducts research and technology development (R&TD) across the full spectrum of issues related to the design, manufacture, qualification, performance, use and maintenance of air and space vehicles. It offers technical and advisory services, fee-for-service testing, calibration and consulting support. It also develops and transfers technologies through consortia, collaborative research agreements and licensing arrangements.

NRC Aerospace program also maintains national research and technology development facilities in Ottawa, Montreal and Thompson, Manitoba. These facilities include a state-of-the-art manufacturing center; six wind tunnels; engine test cells with customizable capabilities and the **Global Aerospace Centre for Icing and Environmental Research (GLACIER)**.

In addition, world-class post-secondary institutions - sustained by Public financing - provide the industry both research expertise and research facilities and help develop the skilled and knowledge workers critical to R&D-intensive industries such as the aerospace industry. In 2017, **$10 million funding for CATT (Centre for Aerospace Technology and Training)** in Winnipeg has been announced by the Ministry for Innovation.[28]

Established in 2009 as an Industrial Campus for Red River College, the Centre for Aerospace Technology & Training is today a 'technology validation' site where industry can test new processes and materials within their existing production flow. Access to equipment and expert operators allows for the development of process-knowledge and the integration of new processes prior to an organization making a significant capital investment. Other industry-research partnerships are the **Scientific Research and Experimental Development (SR&ED)** - which benefits from income tax credits and refunds for expenditures on eligible R&D activity - and the **Natural Sciences and Engineering Research Council (NSERC)**, receiving funding for university researches.

Canada also facilitates collaborative R&D and initiatives supported by the federal and provincial governments. The **Green Aviation Research and Development Network (GARDN)** - launched in 2008 and renewed in 2014 with GARDN II - funds collaborative projects that can reduce the environmental footprint of aircraft, engines and avionics systems developed in Canada. Considering GARDN II alone, as of 2015, $20M in investments were earmarked for projects.

In 2016, four newly launched research projects have been added to the GARDN II portfolio, which now includes a total of 16 projects, all aimed at a cleaner, quieter, more sustainable aviation industry. Since GARDN's inception, 33 research projects have been brought to life, developing more than 50 key

[28] Source: Red River College, 2017.

technologies and 19 prototypes, fostering collaboration between members of the aerospace community in the supply chain and investing in training and research.

At **regional level,** The Consortium for Research and Innovation in Aerospace in Québec (CRIAQ), established in 2002 with the financial support of the Government of Québec, supports collaborative industry-led research involving 63 industrial members and 22 universities and research centers. The consortium has provided over $1.8 million additional funding to researchers and students through programs aimed to promote collaboration between industry and research specialists. The purpose is to identify and implement precompetitive projects that meet industry requirements.

Such Regional entities work together with **The Consortium for Aerospace Research and Innovation in Canada (CARIC)**, a non-profit organization created in 2014 with the federal government's financial support and a yearly budget of approximately $3.8 million per year. Its goal is to facilitate the dialogue between all the stakeholders in the Aeronautics and Aerospace Value Chain, from industry, academia and research institutions, fostering collaboration and providing financial support to launch R&D projects in partnership with these players.

To the above-mentioned Aeronautics-focused programs, one should add as well the **Composites Research network,** based in British Columbia and the **Composites Innovation Centre (CIC)**, managing composites manufacturing R&D.

Canadian industry has also been able to benefit from international programs, such as **CANNAPE (Canadian Networking Aeronautics Project for Europe)**, published by European Commission under the 4th call of the FP7 competition for Aeronautics in order to explore opportunities and stimulate research cooperation between Canada and the EU also promoting the participation of Canadian stakeholders with their European counterparts in common activities.

How emerging players are supporting their nascent civil aeronautics industry

In addition to well established players in civil aeronautics, several emerging countries are also strengthening their commitment to support the development of national competitive aeronautics industries in the upcoming years.

China

The most comprehensive support strategy to civil aeronautics has been put in place by China through a framework that includes a mix of centralized planning and industry concentration around state-owned enterprises.

The Chinese government has identified the development of a national civil aeronautics industry as a key priority in several official documents, including those developed at top executive level. In particular, there are **six key government plans** relevant to commercial aviation development:

- Five-Year Plans;
- 12th Five-Year Plan for Chinese Civil Aviation Development;
- Strategic Emerging Industries (SEIs) documents;
- National Civil Aviation Medium- to Long-Term Plan (2013–2020);
- National Medium- and Long-Term Program for Science and Technology Development (2012–2030);
- Made in China 2025 initiative.

First of all, the sector is highlighted as crucial for the Chinese economy in all the latest **Five-Years Plans**, the strategic documents elaborated by the Chinese leadership that provide guidance for the mid-term development of the national economy and society as a whole. These documents also drive all other policy or regulatory instruments and provide a broad outline of the priorities to be met by various ministries.

In detail, the commercial-aviation manufacturing industry has been featured as a development priority since the 10th Five-Year Plan of China in 2001. This document set the goal to develop a twin-engine regional jet (the ARJ21) by 2005. The following 11th Five-Year Plan awarded the civil aerospace sector with $29 billion in the period 2005-2010. The "12th Five-Year Plan for Chinese Civil Aviation Development" covering the period 2011–2015 and issued by the Civil Aviation Administration of China (CAAC) in 2011, also calls for the implementation of strategy to enhance the "safety, popularity, and globalization of China's civilian aviation industry".

CAAC is China's largest government agency in charge of regulating air-traffic control, air safety and air-transportation services for commercial aircraft.

Arguably the most important function of the CAAC is its ability to approve all purchases of aircraft by Chinese airlines. This role gives CAAC significant influence over China's commercial airline industry by encouraging purchase of domestically produced jetliners such as the C919.

The current Five-Year Plan of China, the 13th (covering the 2015-2020 period), calls for "breakthroughs in civilian aviation engine technology" and the "acceleration of research in large-body aircraft, helicopters, regional jets and general aviation". FYPs do not provide specific directives or details on how China seeks to execute such goals. Rather, they provide a **broad outline of priorities for China's various ministries to implement**.[29]

Furthermore, in 2010 and 2013, China's State Council released two documents defining the so called **Strategic Emerging Industries (SEIs)**. The 2010 document laid out the general strategy and rationale behind seven SEIs, without touching on specific development policies, rather presenting the goals and aspirations of SEI policy in general. The 2013 document details the development goals of the seven SEIs that Chinese policymakers have identified as drivers of Chinese innovation and development through 2020. Both documents identify the "advanced equipment manufacturing" sector as one of the seven key industries and this included civil aeronautics with the following objectives and priorities identified: R&D of aviation technology, developing and industrializing aviation products, development of large passenger planes, advanced planes for regional airlines, new-model regional planes and new-model planes and helicopters for general use. Another stated priority relates to the achievement of breakthroughs in developing core technologies pivotal to plane engines and advance in services for maintaining aviation equipment and systems. Furthermore, **specific goals** (called "Major Engineering Projects") **are set for civil aeronautics**, comprising the development of the C919 (a single-aisle, 150-seat large-capacity jet) and the AJ21 (already mentioned in the 10th Five-Year Plan). The overall goal is to produce significant growth in China's capabilities to develop aviation equipment by 2020.

In the beginning of 2017, the National Development and Reform Commission (NDRC) formulated the latest SEI Catalog together with the Ministries of Science and Technology, Industry and Information Technology, and Finance. The document identifies **nine strategic emerging industries** regarded as drivers of Chinese innovation and development as part of implementing China's 13th Five-Year Plan, which extends through 2020. Among the nine SEIs, the "high-end equipment manufacturing" industry remains among the top priorities and **specifically addresses civil aeronautics**, once again highlighted as a key development area.

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[29] Source: RAND, "Chinese Investment in U.S. Aviation", 2017.

The Chinese government has not limited itself to identify the SEIs, but has also set a target for these Strategic Emerging Industries to increase their **contribution to China's GDP from 2% in 2010 to 8% by 2015 and 15% by 2020**,[30] for which it allotted about $640 billion in state funds between 2011 and 2015[31].

Chinese Aeronautics' industry is still very reliant on imports, but both Value Added and export are steadily growing

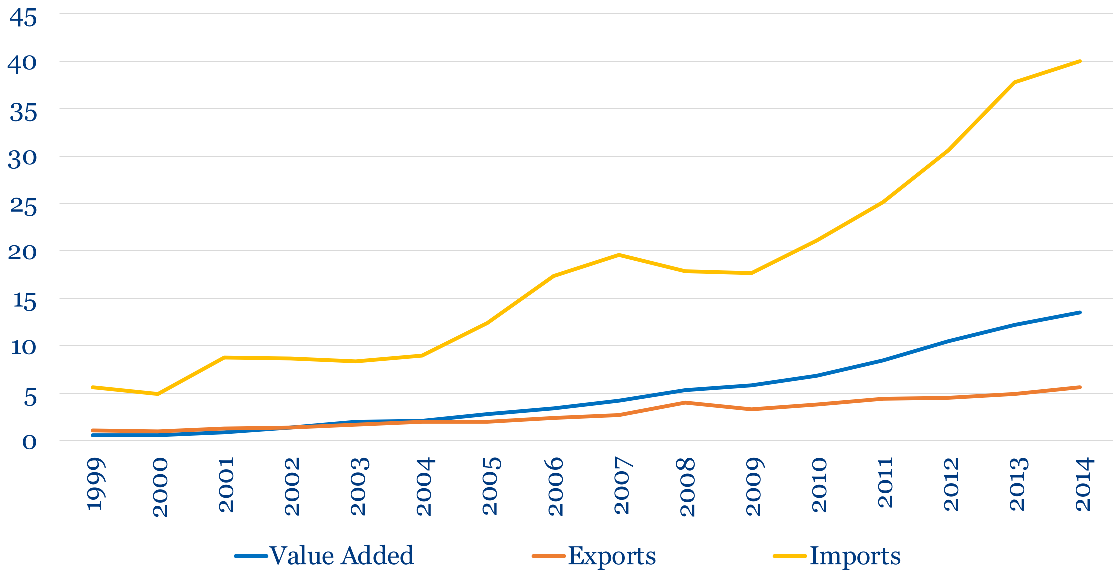

Figure 14. China aerospace industry, value added, exports and imports ($ bln.), 1999-2014. Source: The European House - Ambrosetti elaboration on NSF data, 2017

Aside from the 2010 and 2012 SEIs documents, the most important guidelines document for China's civil aeronautics industry is the "**National Civil Aviation Medium-to Long-Term Program for Scientific and Technological Development (2006-2020)",** issued in 2012 by the Chinese State Council and Ministry of Science and Technology, which represents the only long-term plan that specifically targets the domestic aviation industry in China, providing strategic guidelines for the 2013-2020 period. It calls for domestically manufactured civilian aircraft to account for **no less than 5%** of China's total civilian aviation market share by 2020. The National Civil Aviation Medium-to Long-Term also sets the goal for China to become a technological innovator in regional jet development, as well as an innovator in general aviation, multipurpose aircraft and helicopters for domestic and international markets. Finally, it also offers a detailed blueprint for creating a system of aviation production, R&D and "innovation hubs" across different regions and cities in

[30] According to government sources, as of today, SEIs account together for 10% of Chinese GDP.
[31] It is unclear what fraction of SEI resources was devoted to aviation.

China. The research and building of a long-haul commercial airplane has also been set as one of the sixteen priorities within the Medium/Long term.

The **"Made in China 2025" initiative** also addresses civil aeronautics. The document serves as the first ten-year program for China's manufacturing industry providing industrial policy guidelines aimed to upgrade Chinese industry. The final goal is to enable China to occupy the highest parts of global production chains, transforming China into one of the world's great powers in manufacturing through new technologies and innovation by 2021. Among the program's priorities are aviation and aerospace technologies, which is evidence of continuing support from the State Council.[32] Aircraft engines manufacturing in particular is identified as one of the 10 crucial manufacturing sectors of importance.

Specific goals are included in the **"Made in China 2025 Key Technology Roadmap"**: the CJ-1000A turbofan jet engine model has to be completed by 2020 and prepared for commercial use by 2025. Moreover, domestically produced regional aircraft components and general-purpose aircraft components aim to capture 30% and 50% of the market share in 2025, respectively.

From these documents emerges how the development of Chinese commercial-aircraft manufacturing industry is regarded as a top priority in order to reduce Chinese dependency on foreign suppliers, as the country is expected to require about 6,000 new aircraft in the next 20 years, accounting for 18% of global demand of new aircrafts.

Moreover, the development of a national civil aeronautics' industry is clearly perceived by Chinese Government as a matter of national prestige and civil aeronautics industry is regarded with paramount importance by public authorities for its capability to generate hi-tech spillover capable to benefit the overall Chinese manufacturing industry.

China had an astonishing emergence as a manufacturing powerhouse in the past decades. However, Chinese government is today well aware that a strategic shift from the production of low-value added commodities to high-value added products is crucial to sustain Country's future growth. To do so, Chinese government is thus strongly committed to increase the relevance of high-technology industries in its economy, building up its global competitiveness in knowledge-intensive sectors such as aeronautics manufacturing and nurturing the ambition to be a global leader in science and innovation by 2050.

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[32] Source: RAND, "Chinese Investment in U.S. Aviation", 2017.

This goal seems within reach, given that China already outperforms the European Union in terms of expenditure on research and development as a share of its GDP. China is also the second-largest performer of public R&D[33], on a country basis, accounts for 20% of total world R&D expenditures,[34] and produces about the same number of scientific publications—and more PhDs in natural sciences and engineering—than the United States.[35]

Chinese Government is committed in making the country a leader in high-tech and knowledge intensive sectors, as public R&D expenditures show

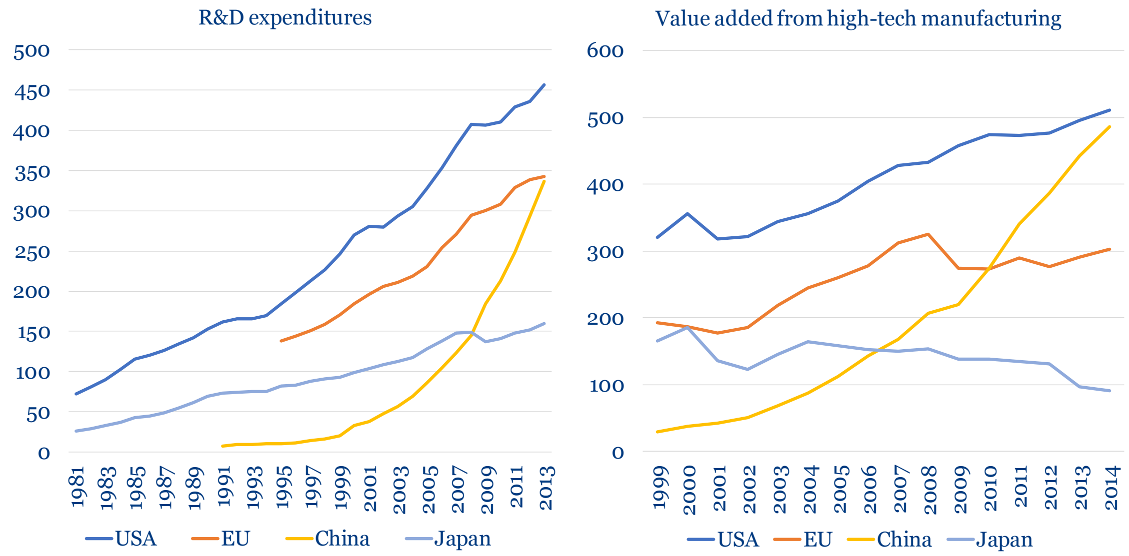

Figure 15. GERD and value added from high-tech manufacturing, growth in selected countries (bln. $ current), 1999-2014 or latest available year. Source: The European House - Ambrosetti elaboration on NSF data, 2017

Above-mentioned plans and documents fall within this broader strategy. One of the most important functions that sets Chinese government policies apart from policies in other developed countries is the ability to **direct China's ministries** to pool resources and offer financial incentives and direct investments to state-owned enterprises.

These ministries also work with local governments to create talent-incubator centers—such as R&D hubs, training facilities and research labs within universities—to develop the domestic aviation industry. Furthermore, Chinese state development banks offer a mix of preferential financial loans, tax incentives, and investments in infrastructure. Finally, favorable policies that allow domestic aeronautics companies to enter into joint ventures with foreign partners are put

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33 Considering Gross domestic expenditure on R&D (GERD).

34 Source: NSF, "Science and Engineering Indicators 2016", 2017.

35 Source: Reinhilde Veugelers, "The challenge of China's rise as a science and technology powerhouse", July 2017.

in place. An early example of this was provided from the 1985 partnership with McDonnell Douglas, which accelerated the Chinese industry's learning process through the joint manufacturing of the MD-82.

The third element in such broader civil aeronautics strategy (in addition to State Council documents and implementation at Ministry-level) are the **State-Owned Enterprises** in the aeronautics sector. During the '90s, the Chinese government undertook a process of consolidation of national industrial capabilities around state-owned enterprises, creating the two **Aviation Industry Corporations of China** (AVIC I and AVIC II), later merged into a single entity in 2008.

This new company (AVIC) is today the major Chinese **state-owned aerospace and defense player**, with over 530,000 employees and a turnover of over $60 billion as of 2016. It has also established itself as a global leader in the aero-structures market, where AVIC has developed into a leading tier-1 supplier to all major OEMs at global level. The company stands at the top of a highly vertically integrated structure that includes over 100 subsidiaries and nearly 27 listed companies, where a significant amount of activity is controlled at **provincial and local level**.

A well-defined strategy is in place, involving both State Council, ministries and local government, also leveraging on State Owned

Figure 16. Chinese government policy coordination process supporting the civil aeronautics industry (illustrative). Source: The European House – Ambrosetti elaboration on RAND, 2017

In parallel, the state-owned **Commercial Aircraft Corporation of China (COMAC)** has been created as the domestic Original Equipment Manufacturer. AVIC has about 25% ownership of COMAC, which focuses on the development of civil aircraft. COMAC has been defined, analyzing its complex shareholder structure, as a joint venture between China's central government and Shanghai local government[36]. COMAC and AVIC have been deliberately separated, so that **foreign companies can collaborate more easily** with COMAC thanks to the absence of defense-related branches and activities.

COMAC, reference State Owned Enterprise manufacturing civil aircrafts, has been separated by AVIC to ease collaboration with foreign companies

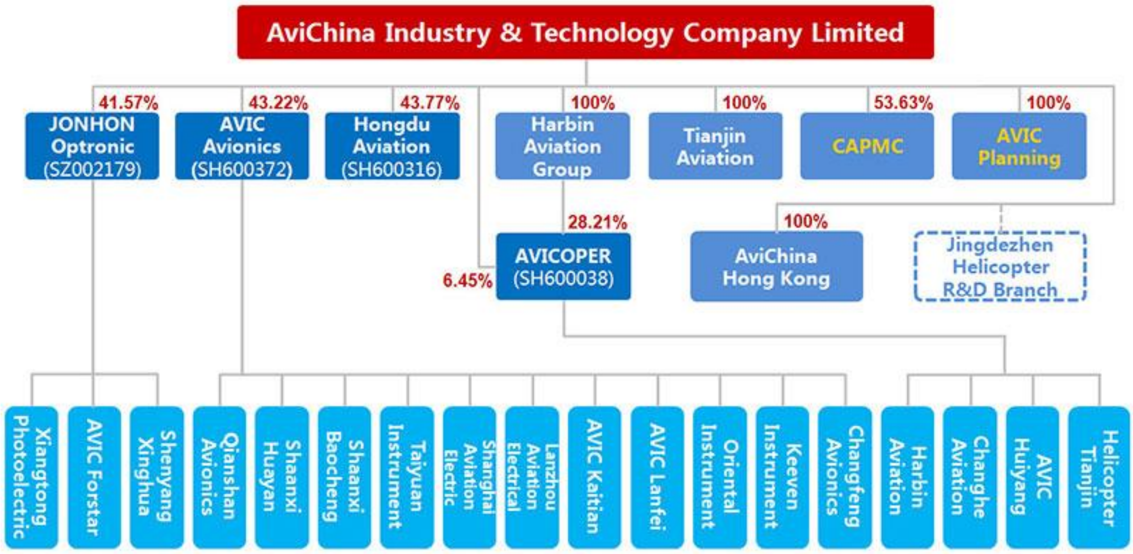

Figure 17. AviChina company structure (illustrative). Source: AviChina, 2017

COMAC inherited the completion of the ARJ21 RJ, a twin-engine regional jet and kicked off the development of the C919 (single-aisle, 150-seat large-capacity jet). The development of the ARJ21, started in 2002 as a key project in the "10th Five-Year Plan" (2001-2005) of China. This project experienced significant delays compared to the initial plan: the first commercial flight took place in June 2016, six years later than planned and only two ARJ21 aircraft had been delivered as of February 2017, both to Chengdu Airlines, a company owned by COMAC).

Public support for the C919 project alone has been estimated at $7 billion.[37]

Furthermore, COMAC recently initiated the development of **two long-haul aircraft** to further extend its product range: the C929, wide-body, twin-engine aircraft with 280 seats and a range of 12,000 km, to be jointly developed by COMAC and Russia's United Aircraft Corporation and the C939, a long-range, wide-body aircraft with 400 seats.

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36 Source: RAND, 2017.

37 Source: https://www.bloomberg.com/news/articles/2017-05-04/china-s-first-jet-to-rival-boeing-is-helped-by-u-s-technology.

Following the 2015 "Made in China 2025" industrial policy, that identifies aircraft engines as a key manufacturing sector of importance, a third new state-owned entity was created in 2016 with the objective of building a world-class jet engine. This new entity, called the **Aero Engine Corp. of China (AECC)**, consolidates all existing Chinese engine manufacturers.

Defense budget of the People's Republic of China is a further source of support for the indigenous civil aviation industry. Even if clear data are not available total budget is steadily rowing

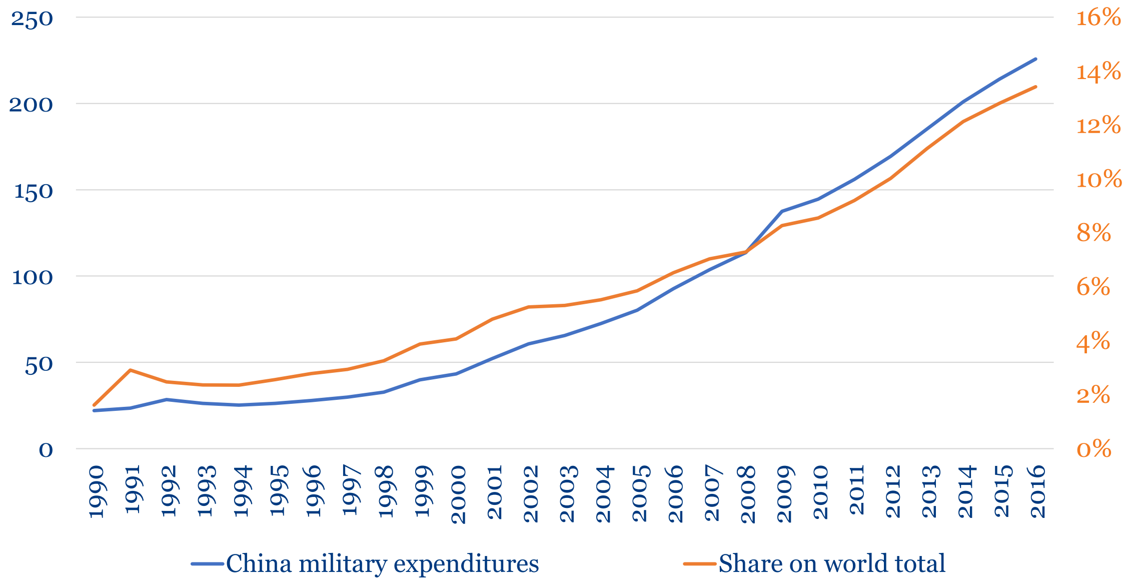

Figure 18. China military expenditures growth (Left axis: total in $ mln. 2015 constant prices. Right axis: %, share of world total), 1990-2016. Source: The European House – Ambrosetti elaboration on SIPRI data, 2017

With its 46 subsidiaries and 96,000 employees, AECC is responsible for the R&D and manufacturing of aircraft engines and gas turbines. This strategic move aims at strengthening the Chinese aviation industry by reducing its reliance on foreign suppliers. AECC plans to build engines that can replace foreign-made engines on the ARJ21 and the C919. To a lesser extent, the Chinese government has also invested in the joint venture between AVIC and GE (AVIAGE Systems) to develop **avionics systems**.

Another source of support for the civil aviation industry comes from the **defense budget** of the People's Republic of China. Even if military expenditure data are not publicly available, several estimates exist and the most reliable ones signal a steady growth of the Chinese defense budget, which has increased with a CAGR of 9.3% between 2006 and 2016. As of today, 22.5% of total Defense Budget is devoted to RT&D and procurement, a share that is also expected to grow, with a strong involvement of Chinese industrial players, in particular AVIC.

Japan

Another Asian country that is committed to supporting the growth of an indigenous aeronautics industry is Japan. In the past decades, the country has developed a competitive cluster of international players, **contributing to major OEM value chains**.

Japanese suppliers have played an increasingly bigger role in building Boeing aircraft, supplying 15 percent of the 767 jet, 21 percent of the 777, and 35 percent of the 787.

The development of Japanese aeronautics' industry has leveraged the participation to international programs eased by Government support

Aircraft	Parts	Scope
Boeing 767	Fuselage, landing gear, doors	15% program partner
Boeing 777 777X	Center section, fuselage	21% program partenr
Boeing 787	Wings, fuselage	35% program partner
Challenger 300	Wings, landing gear	RSP
CRJ 700/900	Fuselage, landing gear and systems	RSP
Embraer 170/190	Wings	RSP
Hawker 4000	Wings	RSP
Gulfstream	Flaps, landing gear, operation devices	Supplier
Airbus A380	Cargo doors, vertical stabilizer, carbon fiber and titanium parts	Supplier
Helicopter		
MD902	Production of the transmission	-
AW139	High-speed gearbox (RSP)	-
Engine		
PW1100G-JM	Fans, low-pressure compressors modules, combustor, low-pressure shafts	Program Partner 23%
Trent1000	Mid-pressure modules, combustor modules, low-pressure turbine vanes	RSP 16%
Genx	Low-pressure turbines, high-pressure compressors, shafts and combustor cases	RSP 15% and subcontract
GP7200	Coupling shaft	Subcontract
Trent900	Low-pressure turbine blade	Subcontract
Trent500	Mid- & low-pressure turbine vanes, compressor cases, turbine cases, etc.	RSP 20%
CF34-8/10	Low-pressure turbine module, highpressure compressor rear stages, fan rotors, gearboxes, etc.	RSP 30%
PW4000	Low-pressure turbine vanes, disk, combustor, active clearance control, etc	RSP 11% and subcontractor
GE90	Low-pressure turbine rotor vanes disks, long shafts, etc.	RSP 10%
Trent700/800	Low-pressure turbine vanes, disks, long shafts, low-pressure turbine disks, turbine cases, etc.	RSP 8 to 9%
V2500	Fans, low-pressure compressors, fan cases, etc.	Program Partner 23%

Figure 19. Japan aeronautics company participation in international programs (illustrative). Source: The European House - Ambrosetti on SJAC, 2017.

Japan civil aeronautics production is currently on the rise, with market size increasing by 15% between 2013 and 2015 and local aeronautics output rising by 20%. In the same period, export of aeronautics products has also grown by 15%, while revenues from aeronautics manufacturing are as high as $15 billion.[38] This positive trend is expected to continue, as the Society of Japanese Aerospace Companies (SJAC) has forecast a 5% annual increase in market size for the next

[38] Source: Society of Japanese Aerospace Companies, 2016.

5-6 years and the Japanese government is determined to increase its share in this strategic industry.

As a result, Japan civil aeronautics production is currently on the rise, with a strong export vocation

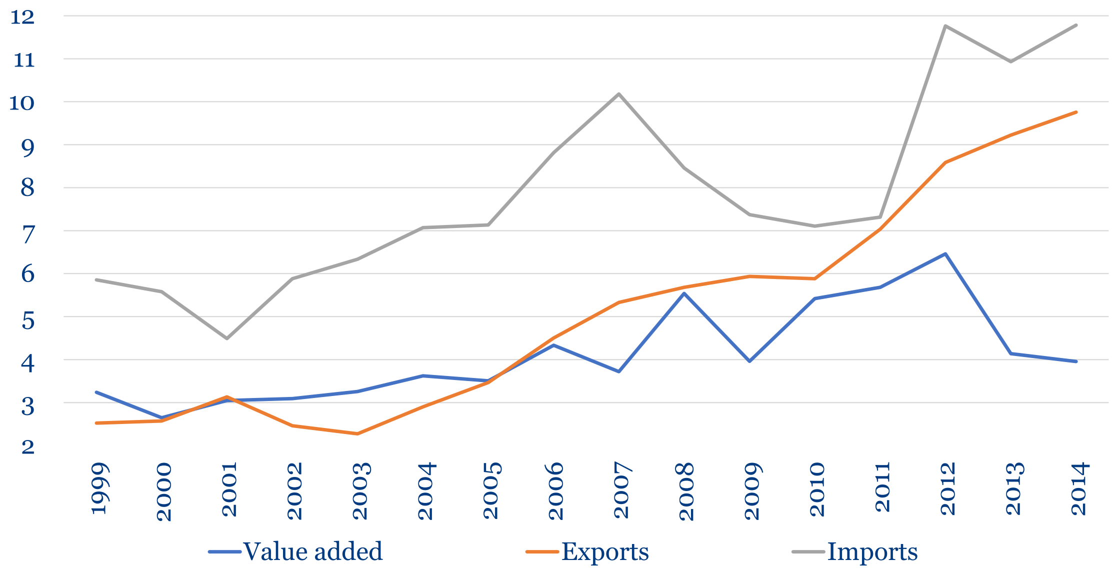

Figure 20. Japanese aircraft products ($ bln.), 1999 - 2014. Source: The European House - Ambrosetti elaboration on NSB data, 2017

Support from Japanese government certainly played an important role in shaping such positive picture. The state currently offers Reimbursable Launch Investment (RLI) funds for the development of components, parts and airframes.

The funding scheme is organized as follows: the Development Bank of Japan lends funds to the Japan Development Aircraft Corporation (JADC), a non-profit consortium of private firms working on the development of commercial airplanes, and JADC redistributes the funds among its members.

The Ministry of Defense conducts research programs on military aircraft with civilian applications, while synergies between military and commercial aircraft companies are encouraged. Ministry of Defense also allows the Japanese aircraft manufacturers it contracts to apply research results obtained during military projects in commercial products at their discretion.

The Ministry of Economy, Trade and Industry (METI) directly supported civil aerospace projects.

Considering tax incentives, R&D&T direct subsidies, Japan provides both tax credits and tax deductions for R&D up to 40% of eligible costs and a higher rate for SMEs in the aerospace industry.

At local level, Aichi Prefecture, where major aeronautics players are located, offers incentives to industrial investors such as direct subsidies for new plants (up to 10% of costs) and R&D laboratories (up to 20% of costs) with 20 employees or more, indirect subsidies (tax rebates up to 10%), fund loan programs and other incentives. The Aichi Industrial Technology Institute provides training to company engineers and technicians on advanced fabrication technology. Small-business companies are also offered consultancies explaining the certification and grant process in the sector.

Russia

Civil aeronautics manufacturing is today an increasingly important industrial sector in Russia, consisting of 248 enterprises and employing around 400,000 people.

A consolidation program launched by the Russian government in 2005 led to the creation of the United Aircraft Corporation (UAC) holding company, which now holds majority ownership of the domestic industry's key companies.[39]

Russian aeronautics' shows today some capability in developing and manufacturing civil aircrafts

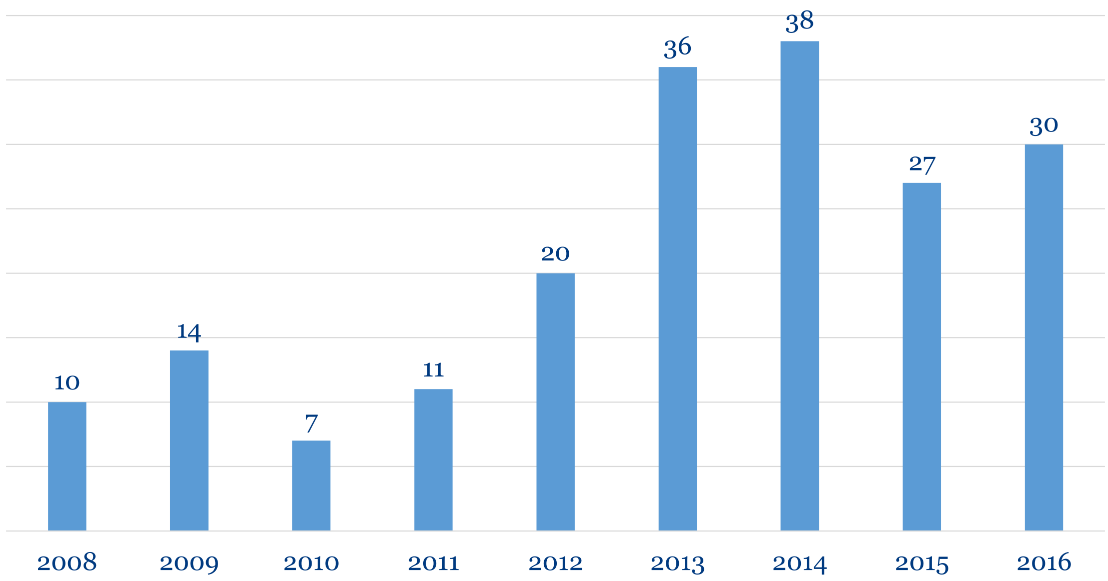

Figure 21. Civil aircraft manufactured in Russia (units), 2008 - 2016. Source: The European House - Ambrosetti elaboration on AviationVoice, 2017

Both imports and value added are steadily growing, while exports are still lagging behind. Value added, in particular, surpassed $7.7 billion in 2017. The future outlook is positive: the development of the Russian civil aeronautics industry resulted in the presentation, in May 2017, of the MC-21-300 single-aisle twinjet airliner by Irkut Corporation, itself owned by the state-controlled United Aircraft Corporation.

The Russian government continues to support the industry through a special state program and plans to allocate $28 billion in order to make Russia one of the world's top three aircraft manufacturers by 2025. In fact, the Russian government

[39] Source: U.S. Department of Commerce's International Trade Administration, 2017.

had planned to allocate more than 40 billion rubles (approximately $702 million) for the support of the national aircraft industry in 2017.[40]

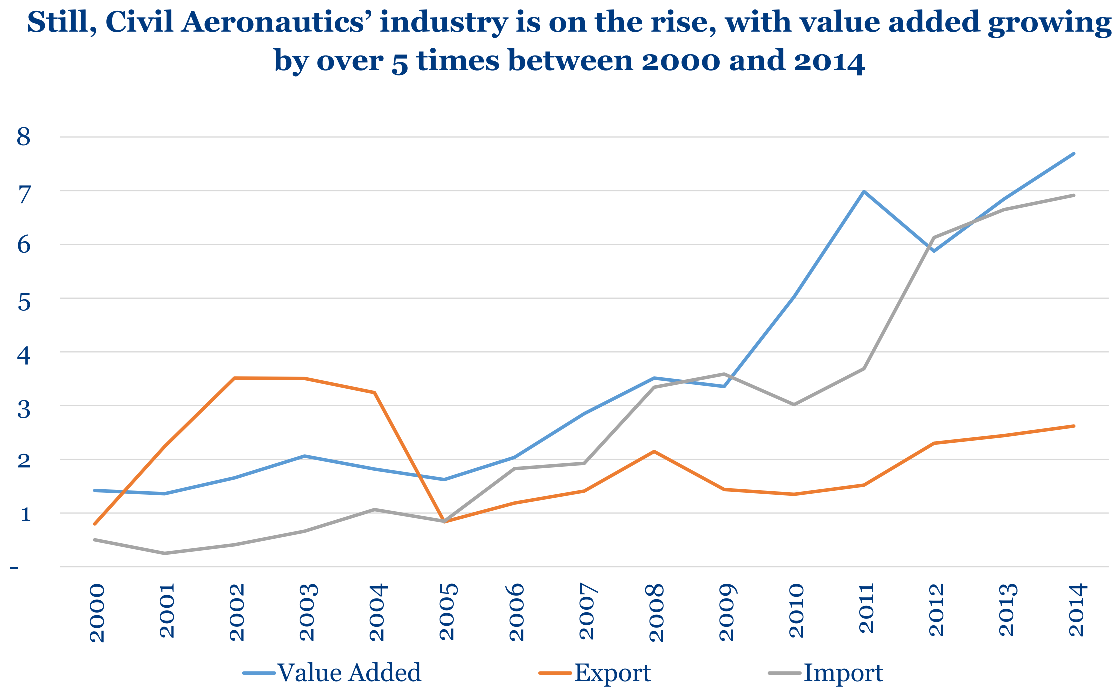

Figure 22. Russian aircraft products ($ bln.), 2000 - 2014. Source: The European House - Ambrosetti elaboration on NSB data, 2017

According to the 2014 "Aviation industry development within the period 2013-2025", designed plan drawn up by the Industry and Trade Ministry and approved by the cabinet, the government will invest 714 billion rubles **($20.5 billion)** of state funds into the aviation industry through 2025, while a further 277 billion rubles ($7.9 billion) are to come from private pockets. Research, innovation and technology will be almost entirely financed by state funds.

The plan updates the 2006 aviation strategy that was aimed at carrying out R&D, and technical and technological re-equipment of aviation enterprises. With the 2014 plan, state support shifted towards **promotion of production** of the aviation industry on domestic and foreign markets and the creation of advanced scientific and technological potential.

[40] Source: Russian Federation State Program "Aviation industry development within the period 2013-2025", 2014.

“Aviation industry development within the period 2013-2025” channel $20.5 billion of state funds into the aviation industry through 2025

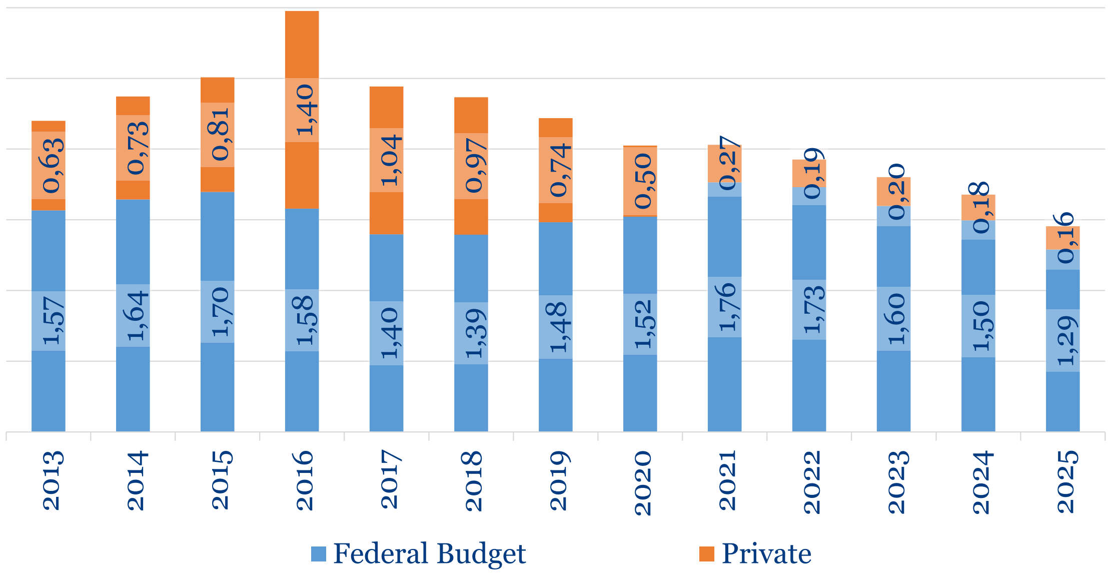

Figure 23. Support for the aircraft manufacturing industry by source of funding ($ bln.), 2013-2025. Source: The European House - Ambrosetti elaboration on Russian Federation State Program data, 2017

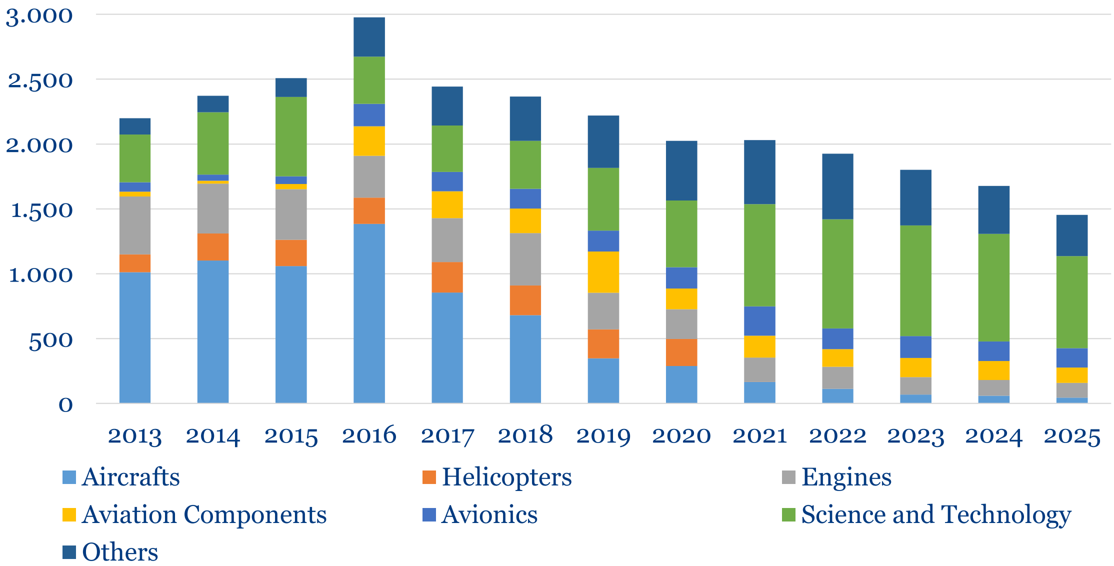

Figure 24. Support for aircraft manufacturing industry by area ($ bln.), 2013-2025. Source: The European House - Ambrosetti elaboration on Russian Federation State Program data, 2017

The **Central Aerohydrodynamic Institute** participates in several joint research programs involving the development of next-generation aircraft. Some of its most significant recent accomplishments are in the areas of structural strength, finite element method analysis and optimization of structural weight.

VIAM is the leading scientific research organization of the defense industry complex, including 32 research-technological complexes in the development of new-generation materials, testing facilities and specialized departments. It cooperates with 16 universities and over 70 enterprises providing technical support and coordinating joint programs. It also provides access to 19 scientific and technological complexes that are centers for transfer of technologies and carries out research and tests of materials.

Southeast Asia Countries

In addition to China, other major Asian countries are committed to grow in the civil aeronautics sector, leveraging the current success and competences in MRO sector and attracting international investments, competences and know-how, to **develop competitive Tier 1, Tier 2 and Original Equipment Manufacturers** in the longer term.

Southeast Asia Aeronautics' industry is still largely reliant on Import, while Value Added was still below $5 bln. in 2014

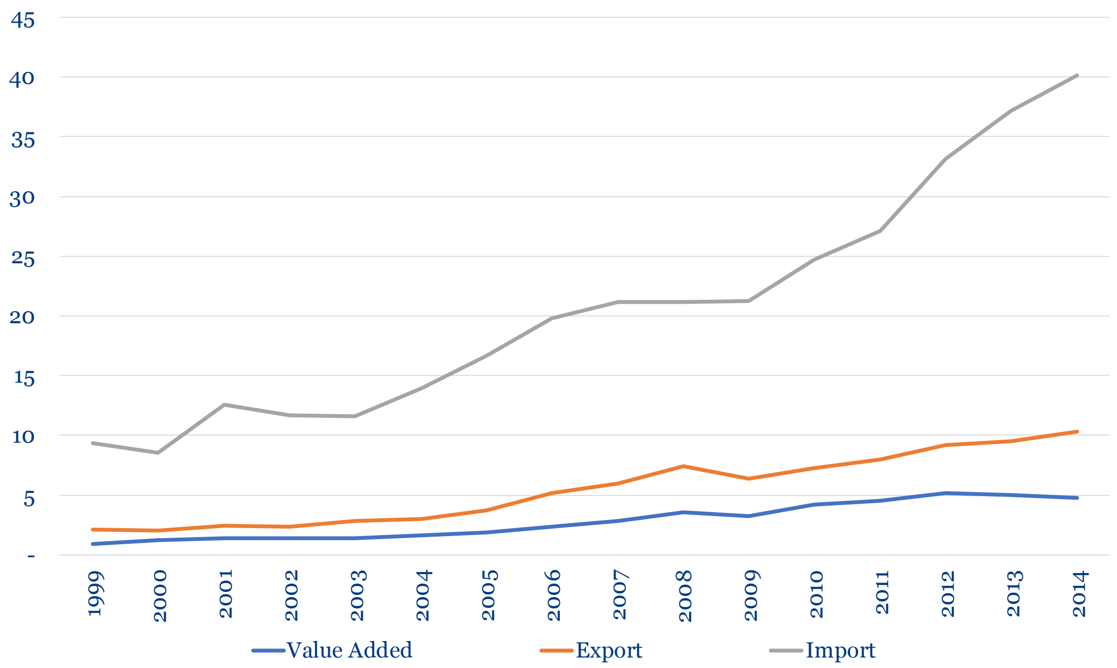

Figure 25. Southeast Asia aircraft products ($ bln.), 2000 - 2014. Source: The European House - Ambrosetti elaboration on NSB data, 2017

Among the others, the Philippine government, is acting to position the country as a major hub within the global aeronautics industry by playing a role in the manufacture of original equipment parts (OEMs). Currently the local aeronautics manufacturing industry[41] accounts only for 0.15% of national GDP and hosts three tier-1 manufacturers. However, this share is expected to increase up to 0.6% by 2022, with a turnover exceeding 380 million dollars and generating an additional 8,300 jobs in the period (from the current 2,200).[42]

The **Philippine Aerospace Development Corporation** (PADC), operating under the supervision of the Department of Transportation and

[41] The aggregate considers also space products that account for less than 10% of the overall turnover and both the civil and military component.

[42] Source: Aerospace Industries Association of the Philippines (AIAP), 2017.

Communications, is mandated to undertake all development projects for the establishment of a reliable aeronautics industry. The country's leverage points include its strategic location together with a skilled and cost-competitive local labor force trained by a well-established network of good-quality aerospace engineering programs. At the same time, the Philippines occupies a strategic location, potentially serving as a vital link in the aerospace industry value chain.

The manufacture of aeronautics parts and components and support activities (e.g., R&D activities, research/testing laboratories, and technical vocational education and training institutions) are also among the preferred activities listed in the Investment Priorities Plan (IPP). Here, the role of the industry in generating positive spillovers for the entire national economy is clearly indicated.[43]

Indonesia also aims to develop a regionally-competitive aeronautics sector. The aerospace cluster in Bintan Island already produces avionic radio systems, communication and navigation equipment and other cockpit components for aircraft used in commercial aircraft at a global level. The state-owned company, **Dirgantara Indonesia**, has recently developed a locally built twin-engine plane, the N-219. The project, which required less than US$100 million, is sponsored by the State-Owned Enterprises Ministry, the Research, Technology and Higher Education Ministry as well as the National Institute of Aeronautics and Space (LAPAN).

Moreover, the Indonesian Ministry of Industry will support exports from Dirgantara by providing its prospective customers with access to credit from the Indonesian Export Financing Agency worth more than 30 million dollars to procure aircraft from the company.

Singapore is experiencing a growing number of aerospace design and manufacturing operations, with leading engine manufacturers already having a manufacturing presence in the country. The government's aim is to increase Singapore's production capacity and intellectual property by partnering with global OEMs and providing RT&D financing through grant-based research programmes.[44]

The **Economic Development Board (EDB) of Singapore** — the lead government agency that plans and executes economic development strategies for Singapore — has selected aerospace as one of eight target industries to develop in upcoming years. Advanced manufacturing and engineering have been identified as a key technological focus area, which is why US$13.3 billion will be invested in R&D in these ambits over the next five years, under the Research, Innovation and

[43] Source: BOI, "2017 Investment Priorities Plan", 2017.
[44] Source: ASD Europe, "Position for the Preservation of Grants for EU AeroSpace and Security Research", 2016.

Enterprise 2020 plan. In addition, The Singapore Agency for Science, Technology and Research runs a Research Consortium for Aerospace-focused R&D while locations such as **Seletar Aerospace Park (SAP)** have enabled an aeronautics ecosystem to emerge, attracting to-date leading industry players. SAP in particular has already established into a world class integrated aerospace hub hosting a wide range of aerospace-related activities.[45]

The country also has over 1,700 aerospace-trained graduates every year. Rolls-Royce has collaborated with Nanyang Technological University (NTU) by making a $53 million investment in R&D. NTU also has a S$5 million (US$3.5 million) partnership with Leonardo for helicopter aerodynamics.

Aeronautics' manufacturing in Southeast Asia countries is still negligible, but precise strategies are leveraging on a well-developed and competitive MRO sector

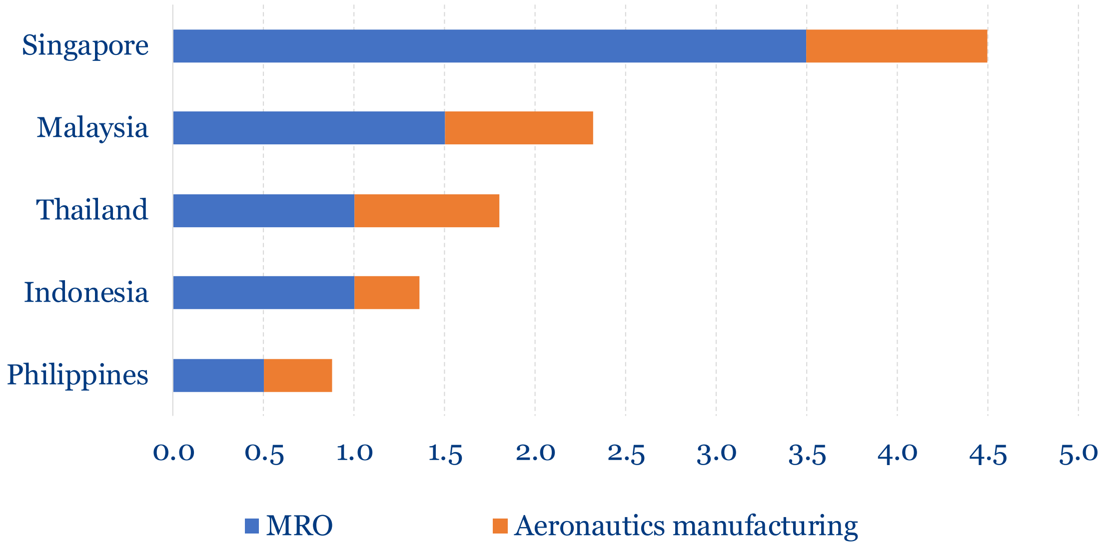

Figure 26. Turnover from MRO and aeronautics manufacturing in selected countries, ($ bln.), 2015. *Source: The European House – Ambrosetti elaboration on Malaysian Industry-Government Group for High Technology, 2017*

Strong public commitment also comes from the Malaysian government, which has recently launched the "**Malaysian Aerospace Industry Blueprint 2030**", highlighting the aerospace sector as a strategic industry.[46] Since 1997,

45 Airbus has selected Seletar Aerospace Park to engineer and program the development of the A330 Passenger-to-Freighter (PTF) conversion.

46 The program updates the first blueprint launched in 1997 that managed to activate 0.9 billion dollars in investment between 2010 and 2014.

turnover from the industry has grown steadily[47] **13-fold** reaching 2.3 billion dollars to place it right behind Singapore.[48]

Currently in the country there are 8 companies involved in aircraft assembly, 28 companies in the manufacture of aircraft parts and components (including ground support equipment), while more than 50 companies are involved in MRO activities. Currently, most Malaysian companies are Tier-2 suppliers. Aero-structure manufacturing in particular is expected to continue its growth trend over the next several years, thanks to Malaysian involvement in narrow-body programs.

The Malaysian government has granted the aeronautics industry "pioneer status", providing it with investment tax allowances, reinvestment allowances, and exemption from duty and import taxes on machinery and raw materials. The **mandatory offset program** requires foreign firms that complete major equipment sales to invest a specific amount[49] of capital in Malaysia as support for technology transfer and innovation. The government has also allocated $61.9 million to develop a second campus for the Kuala Lumpur Institute of Aviation Technology, expected to supply 4,000 highly-skilled engineers annually once it is inaugurated.

47 2017 projections indicate a 7% growth. Source: Malaysian Investment Development Authority, 2017

48 Source: Malaysian Industry-Government Group for High Technology, 2017

49 In most cases it amounts to 100%, so for every dollar spent on aerospace purchases, the vendor must invest one dollar in domestic aerospace programs.