R&D Support for the Aerospace Industry

A Study of Eight countries and One Region

A Report

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Executive Summary

R&D is the major investment expense in the aerospace industry. Public support for private sector R&D in the industry is channelled through many different schemes. They include government R&D followed by technology transfer to private industry, direct non reimbursable subsidies for R&D, fiscal credits for R&D, reimbursable loans for R&D, soft government banking loans, procurement including an envelope for R&D, subsidies for aerospace cluster development.

Canada's fifth rank in the global civil aerospace industry is attributable to sound support policies implemented during the last half century. However, the rise of new competitors in China, Japan, and Russia signal the arrival of a new era. Canadian producers lack critical mass, yet they need to enter emerging country markets (host of future competitors) with advanced new products. An examination of Canada's aerospace innovation policies compared with other OECD countries finds that some areas of research (composite materials) and some policies, namely cluster policies, could be improved by adding support to cooperation among existing companies, universities and government laboratories in Canada's aerospace clusters, and by providing support to graduate studies and research within and among the same clusters.

Introduction

Putting some order in the many innovation policies designed and implemented to support aerospace technological advancement is not an easy task. The reasons are many. First, innovation-policy measures may be "concealed" within defence spending or public procurement policies, and there are many of these policies, most of them implemented at the national level, as well as regional and local policies (Hollanders et al, 2008, pp. 71/2). Second, "The aircraft industry is a multi-technology sector. Aircrafts are complex systems that rely on knowledge from many scientific disciplines and technological fields (Ibid, p. 53). Thus, studying one specific area (for example: aircraft patents through US classification code #244 or through NAICS code 3364 is not enough because additional technological areas are involved including engines, information and communication technologies (ICT), material sciences and fuel technologies, among others. Third, many national agencies are involved in the support for aeronautical R&D. For instance, the Commission for the Future of the United States Aerospace Industry (US Commission, 2003) points to thirty-four different agencies and departments in the US federal government that share some responsibility and support for R&D in the aircraft industry. They include the Departments of Defense (DOD), Energy (DoE), Transportation (DoT), Education (DoE), and Commerce (DoC). A similar pattern can be found in the European Union. France has a large R&D laboratory (ONERA), but also the French Agence Nationale de la Recherche provides support for R&D in its competitive poles, one of which is the Aerospace Valley centred in Toulouse. France also participates in several European programs including support for aerospace R&D, such as the Clean Sky Joint Technology Initiative, a component of the European Union Framework Program 7 (FP7). Fourth, some of these agencies are multi-technology organizations in themselves, such as the Defence Science and Technology Laboratory (DSTL) in the United Kingdom, which works on aerospace but also on related areas including materials and information, and communication technologies (ITC).

The countries and regions included in this report have very different trajectories in aerospace research. The United States, France, Germany and the United Kingdom are among the early leaders. Canada and Japan have been fast catchers-up since the interwar period. Israel and South Korea are post war newcomers to the industry. The European Union has been adopting aerospace policies since Framework Program 2, through the BRITE/EURAM programs in the 1980s, but European cooperation in aerospace had started earlier, when the Concorde program was signed between France and the United Kingdom in 1962. The different levels of competitiveness of these industries appear in Table 1, where trade balances and export market shares are compared.

(Table 1 here)

Finally, the aerospace industry (NAICS 3364, Aerospace products and parts manufacturing) is composed of two different subsectors: aeronautics (aircraft, engines and parts) and space (missiles, space vehicles and parts). The aeronautics industry was born in December 1903 under the initiative of the Wright Brothers. The space sector was created on October 4, 1957 after the launching of Sputnik and the immediate creation of NASA and DARPA in the United States. Even if not confined to aeronautics, this paper is mostly about aircraft and its subsystems.

1. Government support to aerospace innovation

Almost since its inception, in the first decade of the 20th century, the aerospace industry received public support. The early incumbents were France, Germany, the United Kingdom and the United States. They still are, with the United States a clear leader in terms of business expenditures on R&D.

1.1 **The United States**

According to many authors (Mowery and Rosenberg, 1989), the US leadership in aerospace comes from its many different and strong policy supports to innovation. Two of them seem to be decisive: the National Aeronautics and Space Administration (NASA) and the Air Force Research Laboratories (AFRL).

Main funding agencies and laboratories: NASA was established in 1958 to replace its predecessor NACA (1915-1958), as part of the reshuffling that followed the launching of the Sputnik. In recent years its budget has declined in nominal and current dollar terms, due to serious reductions in space research, following the Columbia Shuttle tragedy that took place in 2003. The 17.700 billion US$ of the 2012 budget is devoted to space and aeronautics research. R&D results are transferred to private corporations and/or the latter are participants in the research programs. Some recent major US programs deserve mentioning. They include:

- "High Speed" Research Program
- Advanced Subsonic Technology Program
- Aviation Safety Program
- Quiet Aircraft Technology Program
- High Performance Computing and Communications Program
- Research and Technology Base Program
- Advanced Composite Technology Program
- Vehicle System Program
- Materials and Structures Systems Programs
- Aircraft Energy Efficiency Program." (WTO, 2012, Annex A)

Without these programs, Boeing's leadership in composite materials and structures, energy efficiency, and safety would not be sustained. In addition, NASA personnel works for US private aerospace companies, allocates procurement contracts, and allows these companies to use research and test facilities, including the NASA Langley Research Center wind tunnels.

The second major research support that the US federal government provides to aerospace firms are the four different facilities of the **Air Force Research Laboratory** (AFRL). AFRL was established in 1997 to merge fourteen different laboratories into four super units. Among these, two are directly linked to aeronautics research: the Wright Laboratory (studying avionics, electronics technology, flight dynamics, materials, and Aero Propulsion), and the Rome, specialised in information and communication technologies. AFRL has 5400 employees (of which 4200 are civilian and 1200 military); government appropriations for its budget amounted to 2.2 billion US$ in 2011. Yet this amount represents over half of its total budget, as private industry annually brings additional amounts between 1.1 and 1.7 billion US$ for contract research. The AFRL conducts basic research at its Office of Scientific Research, and development in other laboratories. Among its recent projects, it is worth mentioning the ongoing Advanced Composite Cargo Aircraft (ACCA), with Lockheed Martin. The X-55 ACCA first flew in June 2009. "This has the potential to change aircraft manufacturing as we presently know it, for the better", declared B. Shenk, ACCA program manager at AFRL Air Vehicles Directorate at the Wright-Patterson lab (US Air Force Official website).[1] The budget of this ACCA prototype was set at 50 million US$.

The **Air Force Office of Scientific Research (AFOSR**), within the AFRL, 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 2012 budget slightly over 500 million US$, the AFOSR funded 193 M US$ of extramural research, $24 M in fellowships and support for post-doctoral fellows, and in-house AFRL research ($63 M)[2].

Other supports are also worth mentioning. The **Aeronautical Systems Center (ASC),** although more specialised in defence products for the US Air Force, also conducts research on materials, avionics, propulsion systems and other subsystems, which can be transferred to private industry. Today ASC executes an annual budget of $23 billion and employs a work force of more than 10 000 people. Its work with private industry is permanent. In April 2012, the ASC gave Boeing a 31.7 million contract to design and produce a Joint Helmet Mounted Cueing System (Military and Aerospace Electronics, May 1, 2012).

The US Defense Advanced Research Projects Agency (**DARPA**)[3] was established in 1958 as a response to the launching of Sputnik by the USSR (an event that started the space era), and it works on materials, ICT, electronics and space. DARPA is a funding agency with 240 employees and an annual budget of 3.2 billion US$. Among its projects with industry, we should mention the Boeing X-45 unmanned aircraft (first flew in 2002) and the Boeing X-47 unmanned space plane, which first flew in 2010. The US government (NASA, US Air Force, and DARPA) assumed most of the X-47 budget of 500 million US$, out of which Boeing contributed 67 million US$.

Among the many other contributing agencies, we should mention the **Jet Propulsion Laboratories (JPL)**, a NASA owned centre hosted at the California Institute of Technology. JPL was founded in the early 1930s. In 2011, JPL had 5000 employees and an annual budget of 1.6 billion US$[4]. Its work is more on the space side of the industry, but several of its

[1] www.af.mil/news/story.asp?id=123152339

[2] V. Blackwood (2012) AFOSR Overview, March 5.

[3] http://www.darpa.mil

[4] www.jpl.nasa.gov/news/fact_sheets/jpl.pdf

technologies have found applications in the civil aeronautics industry.

Funds for aerospace research also come from the Department of Defense, such as the 23 dual use research, development, test and evaluation programs worth 2.379 billion US$ programs (WTO, 2012).

Clusters: The United States has no official cluster policy, but several states including Washington, California, Texas, Connecticut, Kansas and Ohio have implemented their own. Some of them (i.e. Texas) put the accent on increasing skills in workforce, from post-secondary training in welding, machining and electronics to post-graduate engineering education. Texas also promotes networks between academia, pubic labs and private firms, in order to understand common needs and solutions.

Tax credits and deductions for R&D: The United States offers both tax deductions and tax credits for R&D. Yet the complex calculations involved in the US tax support for R&D, and its annual basis requiring continuous renewal, makes it the least desirable among OECD countries (Tassey, 2007). By 2010 the total cost of (MOT federal tax credits, all industries combined**,** was some 10 billion US$. It is impossible to calculate the share of the aerospace industry out of this total amount.

Export support: in 2011, the EXIM Bank authorised support for aerospace and avionics totalling 12.62 billion US$. Of this sum, large commercial aircraft represented 10.8 billion US$. The Bank offers four main products: working capital guarantees, export credit insurance, guarantees of 100% of principal and interest to foreign buyers, and direct loans at competitive fixed rates to foreign buyers on sums over $10 million.

In sum, each year the United States invests over 50 billion US dollars in support of its aerospace leadership, and directly employs some 20 000 people in space R&D[5]. Direct subsidies to R&D through NASA, DOD ad DARPA as well as the transfer of research results and collaborative R&D at AFRL, ASC and JPL are among the key public instruments.

1.2 The European Union

In the world aerospace industries, the European Union is catching up. Up to the 1960s, each European aerospace nation was pursuing its own program. The technically successful but commercially flawed Anglo-French Concorde Program (1962-2003) made evident the advantages of cooperation in such a risky and costly industry.

Launching support for Airbus planes between 1987 and 2002 was unveiled by the WTO in the context of a US complaint against large grants from the EU to Airbus. The WTO asserted

[5] A British government study estimates at 66 billion US$ the sums invested by the US government in space in 2005 and it argues that the US represents 81% of all space budgets in the OECD (UK BIS, 2010). Similarly, according to an OECD study, US organizations applied for 50% of all PCT space patents between 2000 and 2008 (OECD, 2011).

that loans for a total of €15 billion were granted to Airbus Industrie (WTO, 2012).

Main funding agencies and laboratories: The EU started cooperating in aerospace with the second Framework Program (FP2) through the BRITE-EURAM initiative (launched in 1989) on advanced industrial materials. A coordinating committee (ACARE) for aerospace research was created in 2001. Aerospace support continued through the following Framework Programs. In FP 6 (2002-6, with a total budget of €17 billion) and FP 7 (2007-13, with €50.5 billion) aerospace received increasing attention. FP6 has allocated €1.075 billion to aeronautics and space R&D[6]. Yet the EU figures are much smaller than the US equivalent support for aerospace R&D.

In FP7, aeronautics came under the heading of transportation. FP 7 reserved €2.3 billion for aerospace during the seven year period. These included the Clean Sky Joint Technology Initiative (with public funds worth €800 million), the SESAR JU (Single European Sky Joint Undertaking, with €350 million) and other projects worth €1.1 billion.

Clean Sky is the most relevant EU project for aerospace. Its total budget is €1.6 billion. The goal is to reduce the environmental impacts of air transportation. Within the Clean Sky Initiative there are six integrated technology demonstrators:

- Smart Fixed Wing Aircraft
- Green Regional Aircraft
- Green Rotorcraft
- Sustainable and Green Engines
- Systems for Green Operations
- Eco-Design.

All in all, 86 organizations from over 16 countries participate in the Clean Sky Initiative. They include all the largest EU firms such Airbus, Alenia Aermacchi, Liebherr, Messier-Dowty, MTU, Rolls Royce, SAFRAN, Thales Avionics and Volvo Aero Corporation. Several universities in different countries are also participating in the Initiative.

EU programs bring several major benefits to companies and countries involved. They are:

- Economies of scale
- Economies of scope
- Faster achievement of objectives
- Wider diffusion of R&D results
- Upgrading poorer regions[7]
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Canadian Universities and companies can join in FP7 programs, and some of them are already participating with Canadian funds from Industry Canada, NRC, NSERC and other organizations.

On the space side of the industry, the **European Space Agency (ESA)** is an international

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[6] European Commission, The 6th Framework Program 2002-6 in brief, p. 26.
[7] European Commission, Aeronautics and Air Transport Research, 7th Framework Program, 2007-2013.

organization with 19 member states. Its total employment is 2200 and its latest annual budget is €4.400 million. Its headquarters are in Paris and its 5 operating centres are located in Germany (2), Italy, the Netherlands and Spain.

1.3 France

France hosts the largest aerospace industry in the EU. This is due to strong and continuous government support since the end of WWII. Yet, contrasts with the United States are striking. First, the first government is a co-owner of all the largest companies, including 22.6% of EADS[8], 30.2% of SAFRAN, 27% of Thales and 18.6% of Air France/KLM. Since WWII, France has been a keen supporter of aerospace projects. And because Airbus has some of its main plants located in France, the French government supports them through several national programs. Since 2008, a new national entity called CORAC (Council for Civil Aeronautics Research) coordinates French private and public aerospace research activities**,** established using ACARE as a model, CORAC was given the mission of investing € 500 million a year in aerospace research and technology in France, of which € 290 would come from industry, € 50 million from EU funds, € 20 million from French clusters programs, and € 140 million from the Ministry of Ecology, Energy, Sustainable Development and Territory (MEEDDAT) of the French government.

Main funding agencies and laboratories: public support comes from several funds for parallel projects. The FUSCOMP (Fuselage in Composites) was launched in 2007 with a budget of € 9.3 million over 4 years, to develop new composite materials and associated manufacturing technologies. The ADVITAC project (Advanced Integrated Composite Tail Cone) has a total budget of € 5.9 million of which € 4 million come from public funds. It started in 2009 and will be completed in November 2012. The project manager is the French company DAHER Aerospace; foreign companies such as EMBRAER, Honeywell and Tecnalia (Spain) are participating in the project.

Besides such projects, ONERA, the French Aerospace Laboratory is the major element of French aerospace strategy. ONERA has 2000 employees including 1500 researchers and technicians, at eight locations in France. ONERA was created in 1946 to develop aerospace research in France, transfer results to the French aerospace community and apply them eventually to other industries. ONERA conducts research projects by itself as well as under request from private firms, and is responsible for technology commercialisation. It may also advise the French government on issues related to aerospace technology. Its 2010 budget was € 227 million.[9] The Institut supérieur d'aéronautique et de l'espace (SUPAERO) was created in 1909 and was relocated in Toulouse in 1968. SUPAERO manages another large laboratory, the LAPS (Laboratoire de l'Aérodynamique et de la Propulsion, LAPS), a similar arrangement to the US CALTECH/Jet Propulsion Laboratory in the United States, but much

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[8] In 1999 the French Aérospatiale, British Aerospace, the German DASA and the Spanish CASA merged to create the European Aeronautic, Defence and Space Company (EADS). EADS is now the sole owner of Airbus and the second largest aerospace company in the world after Boeing.

[9] http://www.onera.fr/onera-offre/catalogue.php

smaller, with a €16 million of annual research turnover.

Aerospace Valley (AV) is a competitiveness pole created in 2005 in the French regions of Midi Pyrenées and Aquitaine, around the cities of Toulouse and Bordeaux respectively. Its main thematic subject is aeronautics, space and on-board systems. AV is a member of the European Aviation Clusters Partnership, a European association established in 2009. AV works on two types of projects: R&D and structural projects. The latter aim at the creation of industrial zones. Between 2005 and 2011, 480 projects with a total budget of € 725 million were invested in R&D projects in the zone[10]. Aerospace Valley receives the type of support that CORAC was proposing in its 2008 statement.

Besides help for R&D and technology, France provides repayable launch investment (RLI) for new aerospace products through its Department of Transportation. All Airbus models received such government support. The agreement stipulates that the government would advance up to 33% of the program cost, and the loan must be fully repayable if the project is successful over a 17-year period, with a 0.25% interest rate plus the cost of government borrowing.

Tax credits and tax deductions for R&D: France has both tax deductions for R&D and a tax credit for R&D programs that has been upgraded and renewed lately. In 2010, an evaluation found that in 2008 the credit had a national fiscal cost of €4.1 billion (or about C$5.1 billion). The evaluation found that French firms added 1€ to their R&D expenditures for each euro in tax credits (France, IGF 2010). No mention was made of the use of the tax credit by aerospace firms, but we may hypothesize that large R&D executants use it. Another estimation put the aerospace industry at 3% of total fiscal costs for tax credits.

Clusters: France has three main aerospace "pôles de compétitivité": Midi-Pyrénées (around Toulouse), Aquitaine (around Bordeaux) and Ile de France (around Paris). Through several inter-cluster competitions for cooperative research funds, France tries to strengthen existing "pôles de compétitivité" rather than trying to launch entirely new ones. The Agence Nationale de la Recherche (ANR) competition in 2011 chose Aerospace Valley[11] over the other two, and brought close to 400 million US$ in public funds to the Toulouse region in order to strengthen academic and industrial research, cooperation among firms, and attract high profile students to training and university education in aerospace professions. The main outcome of this support was the creation of the IRT-AESE (Institut de recherche technologique – Aéronautique et systèmes embarqués).

Export support: French export support is handled by COFACE (Compagnie Française d'Assurance pour le Commerce Extérieur). COFACE is a private sector credit insurance company that manages French exports. Privatised since 1994, the aerospace sector is its

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[10] http://fr.wikipedia.org/wiki/Aerospace_Valley and http://www.aerospace-valley.com

[11] The Aerospace Valley Cluster Association was formed in 2005, and by December 2011 it had 567 members, including such large firms as Airbus, Dassault, EADS, and Thales; 273 SMEs, universities and public labs. It works on aeronautics, space and embedded systems. Its two regional centres, Bordeaux and Toulouse, are about 250 km apart.

main client with close to 40% of all guarantees. In 2011 it extended €1.55 billion in export credits. In the aerospace sector, COFACE guarantees the French banks that finance the sales of planes or subsystems to foreign clients.

1.4 Germany

The nationalised German industry was destroyed during WWII and the country was forbidden to produce aircraft until 1955, due to the Allies restrictions (Hirschel et al, 2004). Its recovery was fast and integrated in the EU programs thanks to strong public support.

Today, Germany is less government-oriented than France. State ownership is reduced to a 7.5% stake in EADS. Yet, like the French and the US governments, the German government strongly supports the aerospace industry through different schemes.

Main funding agencies and laboratories: Financial support comes through two different ministries: the Economics and Technology Department (BMWi) and Education and Research (BMBF). A major component of the German aerospace strategy is the German Aerospace Centre (DLR). DLR operates 30 institutes at eight different locations, and employs 5000 people, with an annual budget of € 450 million, plus a space budget of € 760 million. Among other facilities, it hosts a new wind tunnel, inaugurated in 2010, which is supposed to be among the best in the world. DLR is headquartered in Cologne, DLR has developed flight simulators for future aircraft; this equipment was used in the testing of the A380. DLR participates in many national and international programs in both aeronautics and space. It has the EU's largest fleet of research aircraft used, among other goals, to test aircraft components.

Most federal government support comes from the Federal Aeronautical Research Program, (FARP) launched in 2007 and run by the Federal Ministry of Economics and Technology. Its seven year budget (2007-13) is € 600 million, plus a €240 million added for the 2014-15 period. The program offers grants covering up to 50% of eligible costs and 60% of costs for SMEs. Among the main programs there is a LUFO Engine 3E project (E3E) for environmental friendliness, Efficiency and Economy in Engines with MTU and Rolls Royce Deutschland as major participants and P&WC as a member working on the P&W1000 engine with MTU. The German company now has an interest in the development of both the PW1524C intended for Bombardier's C-Series, and the PW1217G for the Mitsubishi Regional Jet. The German state also provides RLI loans for new Airbus products. For instance, it recently contributed €1.1 billion of a conditional repayable loan for the launch of A350, expected to be in the market in 2013.

Clusters: The German aerospace industry is concentrated in the states (Lände) of Lower Saxony, Bavaria, Bremen, Berlin and Brandenburg, Baden-Würtenberg, Hamburg and the Hanse and Middle Saxony. Some of these regions also host their own local aerospace research facilities. Paramount among them is the CFK Nord Research Centre for composites in Stade (Lower Saxony, near Hamburg) in a cluster known as CFK Valley Stade. The institute has a € 70 million annual budget provided by the state of Lower Saxony. The cluster hosts some 30 000 employees, almost one third of the total German aerospace employment (of 95 400). EADS and Airbus are the main employers in the cluster. The Lower Saxony state invested € 71 million in the CFK Nord research centre with an aim to developing **an** advanced manufacturing process for composite light structures[12]. The Institut für Verbundwerkstaffe in the Rhineland-Palatinate, created in 1990 is at the core of another German cluster that contributes to aerospace materials. The BavAIRia cluster hosts such firms as Diehl, Eurocopter, Liebherr, and MTU, the German leader in turbines, strongly supported by the Bavarian government. Aviabelt is the cluster around Bremen. Its strategy includes the attraction and training of qualified employees, and promoting technology transfer from R&D units to OEMs.[13]

Besides länder support for clusters, in 2007 Germany launched a cluster competition to upgrade existing clusters. In the first round, the Aviation Cluster Hamburg Metropolitan region was selected and received a €40 million grant[14]. No other aerospace cluster received federal grants in subsequent competitions[15].

Tax rebates: in Germany R&D expenditures can be deducted as business costs, but there is no tax credit for R&D, at the regional level. Yet, the introduction of tax credits for R&D is in the political either at the federal or regional levels.

Export credits: like in France, a private firm extends export credits. In the German case, it is Euler Hermes, a subsidiary of the German Allianz insurance group. Euler Hermes grants export credit guarantees on behalf of the German government. The company does not release information about clients or industrial sectors.

1.5 The United Kingdom

The UK is the third largest European aerospace nation, after France and Germany, and the EU's first aerospace defence manufacturer. In the UK, aerospace companies are privately owned, but the British state retains shares in the two largest corporations, BAE Systems and Rolls Royce.

Main funding agencies and laboratories: public support for R&D, technology and innovation comes through different channels. Direct funding is provided through FP7 as well as national and regional programs. Some of them deserve closer examination. The Next Generation Composite Wing Program (NGCW) is a £ 103 million scheme led by Airbus and partly funded by the UK Technology Strategy Board (TSB). Launched in 2008, and to be completed in 2012, it was described as "the most significant joint aircraft research program launched in the UK for decades..."

[12] http://www.aerospace-saxony.de/
[13] www.eacp-aero.eu/index.php?id=31
[14] www.hamburg-aviation.com/
[15] http://www.research-in-germany.de/research-landscape/rpo/networks-and-clusters/41830/10-2-leading-edge-cluster-competition.html

ASTRAEA is another large British program. Started in 2006 and running till 2013, its budget amounts to £ 62 million, and its project manager and prime contractor is BAE Systems. Six other companies, including Rolls Royce and Thales, are also part of the technology validation consortium aiming to produce unmanned aircraft. The UK government has supported 50% of the budget and the industrial partners the remaining share.

SAMULET (Strategic Affordable Manufacturing in the UK through Leading Environmental Technologies) is a four-year (2009-2013) collaborative program led by Rolls Royce to improve manufacturing processes and produce low energy consumption engines. Its budget is £ 90 million, out of which £ 28.5 million come from TSB and £ 11.5 million from the Engineering and Physical Sciences Research Council. The other major partner is BAE Systems.

A major recently completed program is the Environment Friendly Engine (EFE), launched in 2006 and completed in 2010 with a budget of £ 95 million. Rolls Royce led the program and partners included Bombardier Aerospace, Goodrich, and other companies and universities. The goal was to produce an engine with 50% less CO2 emissions, 80% lower NOx emission and 50% less noise by 2020. More than 50% of the budget came from industry partners, with the UK Technology Program providing most of the remaining sums.

The British government also supports RLI. It has done so for the Bombardier Aerospace C-Series and Airbus A350XWB. In the case of C-Series, £ 155 million is being provided to Bombardier to support its Short operations in the UK and Northern Ireland.

The **Defence Science and Technology Laboratory** (DSTL) is an organization under the umbrella of the Ministry of Defence. One of its major areas of research is Air and Weapons Systems. This area supports the procurement, in-service support and operation of helicopters, large and combat aircraft across the Ministry of Defence's current and future air-based capabilities. Total current employment of the Laboratory is 3600, with a budget of £ 1.6 billion.

The **UK Space Agency** is an organization within the Department of Business, Innovation and Skills (UKBIS). Founded in 2010 to replace the British National Space Centre, its current annual budget is £230 million.

Clusters: Regional aerospace clusters are also important and they use regional funds. The Northwest is the main British aerospace cluster, where Airbus, BAE Systems and Rolls Royce have their main operations. Wales is the second aerospace cluster. The Welsh government allocated £ 28 million to create a centre for the manufacturing of Airbus composite wings. Wales has also implemented a manufacturing strategy since 2008, in order to reinforce high-value added manufacturing and skills (where aerospace has a key role). In southern Britain, the Southwest Development Agency in association with the UK Department of Business, Innovation and Skills, has launched a **New Composite Centre** in Bristol, which was inaugurated in November 2011, and received support from several aerospace companies including Agusta Westland, Airbus, Rolls Royce and Vestas. Another composite centre is built in Northern Ireland (the **Advanced Composite and Engineering Research Centre, NIACE**), funded by the UK Department of BIS and Invest Northern Ireland as well as Bombardier Aerospace. It will host 120 researchers and technicians, and encourage collaborative research.

The Engineering and Physical Science Research Council (EPSRC) used to have a Civil Aeronautics and Technology Demonstration (CARAD) research program, which expired in 2006 and was replaced by a new one. CARAD, which spent £ 23 million a year between 1996 and 2002, was evaluated in 2008, and the assessment showed great benefits for the aerospace community, by enabling leading edge research, increasing industry-university collaboration, as well as benefits to the public (UK BERR, 2008). Another similar program, more oriented towards the defence sector, replaced CARAD (ECORYS, 2009, p. 215).

Tax rebates: The UK has implemented a complex system of large tax deductions for R&D expenditures in industry. There are no figures for aerospace uses of these deductions.

Export supports: in the UK, the Exports Credit Guarantee Department (ECGD) finances British exports of goods and services. Like in Canada and the US, it is a government agency. Civilian aerospace represents typically some 46% of ECGD each year, with a peak of 90% in 2009-10[16]. In 2010-11 ECGD extended guarantees and insurances for £ 2.9 billion (4.6 C$ billion). The aerospace sector represented some 2.1 billion C$. Airbus was the main recipient of the support, followed by Rolls Royce[17].

In 2009, the UK aerospace industry spent £1.74 billion out of which 820 million were financed by industry and £580 by government; the remaining £160 million came from other governments and the rest from other sources (ADS, UK Aerospace Industry Survey 2010).

1.6 Japan

Japan's aerospace industry was mostly destroyed during WWII and the country, like Germany, was not allowed to build aircraft for ten years after the end of the conflict. But Japan could not regain its lost aerospace capability as fast as Germany did. Today the industry is mostly under the control of large conglomerates. They are Mitsubishi Heavy Industries (MHI), Kawasaki Heavy Industries (KHI), Ishikawajima-Harima Heavy Industries (IHI) and Fuji Heavy Industries (FHI). Few domestic models were designed and built. Most of the aerospace industry produces either military aircraft under licence, or subsystems and components for Boeing and other foreign prime contractors. IHI is almost exclusively the prime contractor for military projects and engines, while MHI, KHI and FHI work on airframes and components and KHI and MHI are involved in helicopter development and production (Polak and Belmondo, 2006). MHI also works on Japanese rockets, while Nissan develops satellite launchers.

Main funding agencies and laboratories: Japan supports innovation and R&D through

[16] www.ukexportfinance.gov.uk/about-us/introduction-to-ecgd/ecgd-aerospace-sector
[17] ECGD, Annual Report and Accounts 2010-11.

government laboratories. In 2003, the government merged three previously independent aerospace organizations: the Institute for Space and Astronautical Science, the National Aerospace Laboratory of Japan and the National Space Development Agency into one large organization: Japan Aerospace Exploration Agency (JAXA). JAXA has a total budget of 2.46 billion US$ and employs 1670 people. JAXA operates more on the "space side" of the industry, working on missiles, satellites and earth observation, but has some activity in the aircraft segment.

The Ministry of Defence (formerly Japan Defence Agency up to 2007) conducts research programs on military aircraft with civilian applications. The Ministry of Economy, Trade and Industry (METI) directly supported civil aerospace projects. Its most important one is the Mitsubishi Regional Jet (MRJ), a joint project with Mitsubishi Aircraft Corporation, supported equally by METI and the company **for** the amount of 500 million US$ each. The Japan Bank of International Cooperation (JBIC) supports the sales of the MRJ. However, the first flight of the regional jet has been delayed several times and it is now scheduled for the third quarter of 2013, while the first delivery is now scheduled for the summer or the latter half of 2015.

Japan offers RLI funds for the development of components, parts and the MRJ. The funding scheme is 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. No precise figures were released.

Tax support: Besides 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.

The aerospace industry turnover of Japan is small compared to the United States and the four largest European nations, but the government is determined to increase its share of this high risk, high-growth industry.

Clusters: Aichi (in Greater Nagoya) is the regional centre of the Japanese aerospace industry. The "big four" Japanese companies (MHI, FHI, IHI, and KHI) are located there together with some ten research institutes devoted to different technologies involved in aerospace, and half a dozen universities.[18] The Aichi Industrial Technology Institute provides training to company engineers and technicians on advanced fabrication technology. Aichi provides many 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.[19]

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[18] www.jetro.go.jp/en/invest/region/aichi/icinfo.html#a2

[19] http://www.pref.aichi.jp/ricchitsusho/gaikoku/pdf/incentives.pdf

1.7 South Korea

The entry of South Korea into the aerospace industry took place in the mid-1970s under the guidance of the Korean government (Texier, 2000). The main corporate entrants, like in post-war Japan, were the conglomerates. In South Korea they were Daewoo Heavy Industries, Samsung Aerospace and Hyundai Space and Aircraft. In the late 1970s, these companies started assembling fighters and helicopters under US licence. In 1999, the government decided to merge them into one large firm: Korea Aerospace Industries Ltd (KAI). The government designated KAI as the "Exclusive Business Organization for the Korea Aerospace Industries". Also, the government would provide 100% for any military project and 50% of development costs of any commercial aircraft project. KAI works in conjunction with the Korean Aerospace Research Institute (KARI), the national Agency for Defence Development and the Defence Quality Assurance Agency. KAI has also nurtured alliances with Western companies for the design and production of aircraft manufacturers. KAI is developing a new helicopter, the Surion, which first flew in 2010. The total cost of the project is 4.5 billion US$ [20]. The aircraft will have a civilian and a military version. The helicopter was developed with Eurocopter assistance, with KAI as prime contractor. Mass production would begin in June 2012. The Korean government has supported the R&D budget of 1.3 billion US$; this activity was conducted mainly by Eurocopter. GE and Samsung will co-develop the engine. A US$ 4 billion grant was signed in 2011 to support the production of the aircraft.

Also, according to the WTO, South Korea has given RLI to Airbus for the A380, but amounts were not disclosed; in March 2012, KAI received a 1.2 billion US$ contract to produce wings for its A320.

Korean aerospace products include six military aircraft under US licences. Civilian products include the co-development of two helicopters with the help of Montreal's Bell Helicopter, and more recently a small passenger plane, the KAI KC-100, a four-seat, one engine aircraft built in carbon composite materials, but not yet certified either in Korea or elsewhere. This plane, the "Naraon", first flew in July 2011; its development is to be completed in 2013, and mass production should start in 2014. The aircraft has a top speed of 389km/h and a maximum range of 1859 km. It would sell for about 600 000 US$, and would be used for commercial purposes, leisure and training.

Main funding agencies and laboratories: The Korea Aerospace Research Institute (KARI) was founded in 1989. It started producing rockets and other space technology for military purposes, but soon entered into aircraft technology, including unmanned vehicles, high altitude aircraft and is currently involved in the helicopter program[21]. The total budget is not published but its main component, the space budget, was 300 million US$ in 2008. The 2008 personnel in the space sector was 730 people. KARI has developed several satellites with the cooperation of the University of Surrey, its applications being telecommunications

[20] http://www.defenseindustrydaily.com/korea-approves-eurocopters-khp-helicopter-deal-02325/

[21] http://new.kari.re.kr/english

and broadcasting. And in 2012 Japan put into orbit a South Korean satellite (KOMPSAT-3) developed by KARI.

In summary, through massive public investment, international collaboration and audacious public and private initiative, South Korea is starting to build a major aerospace industry that will mature in the next decades. Yet it is interesting to note that business expenditures for R&D in the aerospace sector have steadily declining since 2000. One could be led to conclude that the South Korean government is accepting an increasing part of the R&D burden in the sector. (Table 2)

(Table 2 here)

Tax rebates: Korea offers both tax deductions and tax credits for R&D. No data is available about its impact on the aerospace industry. Yet, Korea has most often preferred to develop new industries and technologies through direct subsidies and well-programmed project management.

Clusters: However**,** there are no cluster policies and the industry is dispersed in seven different metropolitan areas.

1.8 Israel

In Israel, the aerospace industry was set up a few years after the establishment of the new country. Reasons for establishing this government industry included national survival, national security, and increasing the technological absorptive capacity of the country.

Main funding agencies and laboratories: The first company was Bedek Aviation (founded in 1953), a state corporation, which soon became **Israel Aerospace Industries** (IAI), the major player in the sector. IAI produces mid-sized business jets for Gulfstream, unmanned air vehicles, missiles, satellites and space launchers, military aircraft under licence and under local design, navigation systems, and other equipment. As of 2010, its total revenue was 3.15 billion US$ (3.44 billion in 2011), and it employed 16 000 people in its four divisions. IAI invests 4% of its funds in R&D but the figure increases to 20-25% (thus a minimum of US$ 700 million) when R&D funds provided by customers – mainly the state of Israel, but increasingly also foreign customers – are included.[22]

The second (state-owned) company in Israel is Raphael (Hebrew acronym for Weapons Systems Development Authority). Founded in 1948, Raphael produces the engines used for the propulsion of Israel's Shavit launchers. In addition, the company produces air-to-air and air-to surface missiles, armoured vehicles, and naval weapons, as well as electro-optic security systems.[23] Raphael invests some 10% of its revenues of 1.851 billion US$ (2010 figures) in R&D, and employs some 6000 people.

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[22] http://www.iai.co.il

[23] http://www.rafael.co.il

The third company in the Israel aerospace industry is IMI (Israel Military Industries). IMI produces armament and ammunition for Israel ground, air and naval forces. Its total turnover is 508 million US$. No data are disclosed for each division.

The Israel Space Agency (ISA) supports the work of IAI and Raphael. The ISA was established in 1988 with the launching of a domestically designed and built satellite, put into orbit with a domestically made launcher. ISA activities are aimed at both military and civilian applications of earth observation. ISA-designed satellites and launchers are manufactured at IAI plants. Yet, ISA is accountable to the Ministry of Science and Technology. ISA's annual budget is 46 million US$, plus another 6 million US$ for the Venus Project (design and development of a micro-satellite for earth observation), and 70 million US$ for the military program.

Being essentially a government-owned and –controlled industry, the Israeli state supports both its R&D and technological development. Also, Israel cooperates with the EU through the FP7 program, as well as with many agencies in the United States, the EU and India. As such**,** it profits from knowledge externalities gained in cooperative international collaboration. When all R&D expenditures of IAI, Raphael and ISA are added, one arrives at an annual Israeli R&D expenditure in aerospace of some 1 billion US$ for 2011 (including 680 million for IAI, 180 million at Raphael and 82 million US$ for ISA, plus small contributions from and to FP7 and other international cooperation agreements).

Tax rebates: Israel has tax deductions for R&D inasmuch as firms locate in priority geographical areas.

Cluster: Aerospace industries are located in the Tel Aviv metropolitan area, which is not in the priority areas of the country.

2. Conclusion and policy implications

After WWII**,** Canada has been able to build a strong civil aerospace industry at a reasonable cost. Yet, compared to other OECD countries, ***Canada appears different mainly in two related areas: the absence of an aerospace defence industry, and relatively small government support for space activities.*** At the other extreme, the United States maintains its global leadership with very generous support aimed mainly at the research, development and technology side of the spectrum, and leaves it to its national champions (Boeing, GE, Lockheed Martin, P&W, Sikorsky, Textron, and others) to commercialize their products. Israel has a very strong military aerospace sector and very small commercial aircraft and space sectors. In the meantime, Japan and South Korea are playing catching up through provisions of public funds, and strong links between their conglomerates and the state.

(Table 3 and Figure 1 here)

The very different relative size of the public institutes in the countries under study is obvious. US laboratories are the largest, followed by European and Japanese laboratories. Canadian laboratories seem modest in comparison. Up to a certain point, the smaller size, the reduced space budgets and the absence of a defence industry are related. Canada produces satellites, but not rockets to put them in orbit, and no defence aircraft.

Like most OECD and emerging countries, Canada has developed two major clusters, located in Montreal and Toronto. Within the EU one finds increasing attention paid to major aerospace regional clusters such as Aerospace Valley (France), CFK Valley in Germany, Bristol and Wales in the UK (ECORYS, 2009). Several Canadian companies are supporting research centres in the European Union, such as Bombardier in the UK and Northern Ireland, and P&WC in Germany, most probably intending to be close to customers, gain research support and create critical masses.

2.1 Best practices in policy support

Policy support in the industry can be grouped into two classes: export support and R&D support.

Export support

Canada's export support is comarable to that provided by France, the United Kingdom and the United States, particularly when one takes into consideration the size of their economies. When normalised by population, EDC Canada's aerospace budget of 3 billion C$ is larger than the US EXIM Bank aerospace support of 12.62 billion US$, British ECGD support of 2.1 billion C$, or COFACE's 800 million C$. The reason may be the nature of their products (large commercial aircraft, military aircraft and engines). American, British and French firms are more protected from competition, while Canadian aerospace exporters need more support to compete with foreign firms based in Brazil, France, EU, Israel, Italy and the United States.

R&D support: Tax credits

All OECD countries have been concentrating their support in the R&D activities of aerospace firms. Within the OECD, Canada is the country that has relied more on tax credits for RE&D than on any other direct instrument (OECD, 2010). Canada is now reconsidering its indirect support of R&D through tax credits, and trying to rely more on direct support for R&D, as Germany, Japan, the United States and other more innovative countries do.

It is almost impossible to compare the tax deductions and tax credit systems of OECD countries in the aerospace industry based on the limited figures that are published, and the major differences between them. Canada's tax incentive for R&D system could be improved, yet it has often been presented as one of the most performing in the world (Warda, 1999). Also, a reform of this incentive is now taking place in Canada. In aerospace, public direct funding of R&D has been the norm and tax incentives occupy a less central position. Yet, according to Statistics Canada (2012), the Canadian aerospace industry spent 1.356 billion

C$ in intramural R&D; one may infer that the federal level alone handed out 272 million C$ in tax credits (or 20% of total BERD, which reflects the federal legislation). In addition, at a conservative estimate, Quebec[24] should have granted tax credits for at least 82 M C$ (or 10% of the C$ 821 million fiscal credit granted in the province) and Ontario another 27.5 M C$ out of the 275 M spent in aerospace R&D in that province. Combined, federal and provincial tax credits for R&D should represent at least about 381 M C$ in annual tax breaks for the Canadian aerospace industry.

2.2 Policy implications: improving Canada's R&D support

While it would be difficult to argue that Canada needs more export guarantees or tax credits for R&D, there may be an argument in favour of increasing ***direct support to R&D*** in space budgets, industry-university collaborative R&D in aerospace, and cluster innovation in the aerospace industry.

Increasing space budgets

Space makes use of several general-purpose technologies with multiple applications (new materials, global navigation systems and other information and communication technologies, earth observation for economic, security and social benefits) in different sectors, particularly in aeronautics. Canada may be interested in increasing space budgets up to the G-7 levels, from present day 0.025 to 0.084% of GDP (Figure 2) by concentrating on new materials, telecommunications and earth observation technologies. All these technologies have applications in the civil aerospace industry.

Increasing aerospace industry-university R&D

NSERC investment in aerospace (20 M C$ or 2% of its considerable annual 2010-1 budget of 1 billion C$, compared to UK EPSRC annual budget of 1.3 billion C$) is fairly low when compared to the importance of the aerospace industry in Canada in terms of industrial R&D, employment and exports. Aerospace represents 6% of BERD in Canada, and is one of the most active R&D sectors in industry. ECORYS et al (2009: 247) also underline the fact that the Canadian aerospace community did not make much use of aerospace grants until the appearance of the Consortium for Research on Innovation in Aerospace in Quebec (CRIAQ). Canada may be interested in increasing its collaborative industry/academia research funding on aerospace, following UK EPSRC patterns, eventually reallocating existing NSERC budgets.

Rethinking cluster policies

In OECD countries, the aerospace industry is geographically concentrated in a few metropolitan areas (Table 3). The United States boast six of them, with some 54% of all OECD aerospace employees. France has three. Germany has six and Japan has one.

[24] Quebec allows tax credits only on R&D salaries; Ontario accepts a larger list of costs.

(Table 3 here)

France supports actual innovative regions, rather than trying to create new ones or diluting existing ones in a "whole-nation cluster". In 2011, the ANR (Agence Nationale de la recherche) chose Aerospace Valley and invested € 400 million (520 million C$) in this particular region after a multi-cluster national competition. Competitions were organized for existing clusters, and many regions competed including two in aerospace: Aquitaine and Midi-Pyrénées, the one that finally appeared among the few winners. Yet Aerospace Valley now hosts both Toulouse and Bordeaux as its regional metropolitan centres.

A similar good cluster practice is the Italian policy to form inter-regional clusters or to develop cooperation among close geographical clusters (i.e. Puglia-Campania-Lombardy) to better organize the national division of labour and attract international investment and national and regional support. Germany also applied a similar policy in its Leading Edge Cluster Competition.

Since 2001, NRC cluster policies have aimed at launching new regional innovation systems (RIS) from scratch. Such policy runs against those of most OECD countries, that tend to support existing innovative regions. In addition, Canada claims to have ten aerospace clusters, one per province (Invest in Canada, 2011). In fact, there are just two aerospace clusters: Montreal and Toronto. According to Statistics Canada's latest figures, the province of Quebec concentrates 74.4% of Canada's aerospace R&D and Ontario another 24.9% for a total of 99.3% (Statistics Canada, 2012); similar figures at the Census Metropolitan Area level show that Montreal and Toronto are Canada's industrial aerospace RIS (Niosi, 2005; Niosi and Bourassa, 2008). In addition, most aerospace public laboratories are located in Ottawa. It may thus be advisable to implement a cluster policy based on ***actual*** regional innovation systems, and eventually support aerospace academic and industrial research cooperation in the Montreal-Ottawa-Toronto corridor.

Within aerospace clusters, organizations are not naturally prone to cooperation. A prime contractor will probably enrol customers and suppliers from different countries in order to secure demand and foreign government RLI or other public supports. Such global strategies tend to decrease intra-regional collaboration. Several countries have tried different approaches in order to increase intra-cluster cooperation. The French "pôles de compétitivité » competition for collaborative R&D experience, organized by the ANR in 2010-1, may be worth considering to strengthen cooperation in Canada's aerospace industry.

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Tables and Figures

Table 1: Aerospace trade balance and export market share 2009, selected countries

Country	Trade balance (current US$ million)	Export market share (Percentage)
Canada	4016	4.88
France	19338	16.22
Germany	6057	15.41
Israel	1042	0.73
Japan	-4482	1.55
Korea, South	-861	0.38
UK	-1232	9.36
USA	54223	32.68
Total OECD	71193	91.48

Sources: OECD: Main Science and Technology Indicators, 2011/2, Paris.

Table 2: BERD performed in the aerospace industry at current prices and millions USD (PPP)

Country	2000	2005	2009
USA	10.319	15.005	27.572**
France	2.093	3.026	2.995*
UK	1.716	3.391	2.244
Germany	2.166	2.292	2.446*
Canada***	899	857	1.103
Japan	555	379	503
Korea	405	166	86

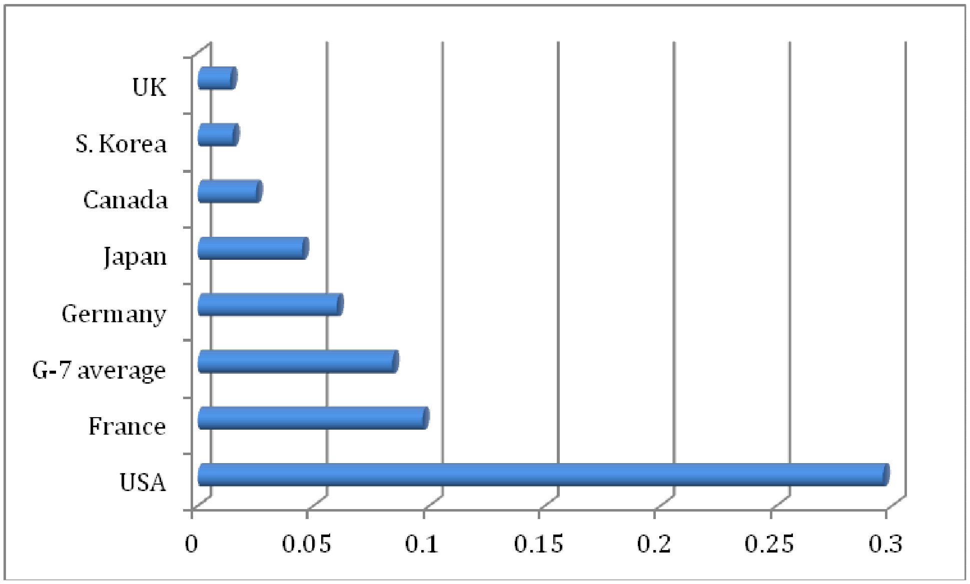
Source: OECD: Main Science and Technology Indicators 2011/2, Paris

Notes: * Most recent data are for 2007 ** Most recent data are for 2008.
*** Canadian data are from Statistics Canada in current millions C$.
OECD did not publish data for Canada, Israel, the EU27, or the OECD as a whole.

Table 3: Clusters in some OECD aerospace nations

Country	Nb. of clusters	Location of aerospace clusters
USA	6	Washington state, California, Texas, Kansas, Connecticut, Ohio
France	3	Midi-Pyrénées, Aquitaine, Ile-de-France
Germany	6	Bremen, Hamburg, Bavaria, Berlin, Hanover, Dresden
UK	3	North West, Wales, Midlands
Canada	2-3	Montreal (QC), Toronto and Ottawa (ON)
Italy	5	Piedmont, Lombardy, Latium, Campania, Puglia
Spain	3	Madrid, Andalusia, and Basque region
Japan	1	Greater Nagoya
Korea	None	Aerospace industry dispersed in seven regions

Figure 1: Public Space Budgets as a percentage of National GDP, 2005, selected countries



Source: UK BIS (2010)

Table 4: Public space agency budgets, selected countries, 2012 (millions US$)

Country	Agency	Budget 2012
USA	NASA	17.700
EU	ESA	5.430
Russia	ROSCOSMOS	3.800
France	CNES	2.822
Japan	JAXA	2.460
Germany	DLR	2.000
India	ISRO	1.320
China	CNSA	1.300
Italy	ASI	1.000
Iran	ISA	500
UK	UKSA	414
Brazil	AEB	343
Canada	CSA	300
South Korea	KARI	300
Israel*	ISA	46

*Data provided by the spokesperson of the ISA.