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EUROPE INNOVA
Sectoral Innovation Watch

# Sectoral Innovation Watch

# Space and Aeronautics Sectors

Final sector report

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Enterprise and Industry

# Consortium Europe INNOVA Sectoral Innovation Watch

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# Europe INNOVA Sectoral Innovation Watch

Detailed insights into sectoral innovation performance are essential for the development of effective innovation policy at regional, national and European levels. A fundamental question is to what extent and why innovation performance differs across sectors. The second SIW project phase (2008-2010) aims to provide policy-makers and innovation professionals with a better understanding of current sectoral innovation dynamics across Europe

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Central to the work of the Sectoral Innovation Watch is **analysing trends in, and reporting on, innovation performance in nine sectors** (Task 1). For each of the nine sectors, the focus will be on identifying the innovative agents, innovation performance, necessary skills for innovation, and the relationship between innovation, labour productivity and skills availability.

| **Sector Innovation Performance:** Carlos Montalvo (TNO) | |
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| Biotechnology: Christien Enzing (Technopolis) | Space and Aeronautics: Annelieke van der Giessen (TNO) |
| Construction: Hannes Toivanen (VTT) | Textiles: Bernhard Dachs (AIT) |
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| Food and Drinks: Govert Gijsbers (TNO) | |

The **foresight of sectoral innovation challenges and opportunities** (Task 2) aims at identifying markets and technologies that may have a disruptive effect in the nine sectors in the future, as well as extracting challenges and implications for European companies and public policy.

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Task 3 will **identify and analyse current and potential bottlenecks that influence sectoral innovation performance, paying special attention to the role of markets and regulations.** Specifically, the analysis will cover the importance of the different factors in the propensity of firms to innovate.

| **Role of markets and policy/regulation on sectoral patterns of innovation:** Carlos Montalvo (TNO) | |
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Task 4 concerns **five horizontal, cross-cutting, themes related to innovation**. The analyses of these horizontal themes will be fed by the insights from the sectoral innovation studies performed in the previous tasks. The **horizontal reports will also be used for organising five thematic panels** (Task 5). The purpose of these panels is to provide the Commission services with feedback on current and proposed policy initiatives.

| **Horizontal reports** | |
|---|---|
| National specialisation and innovation performance | Fabio Montobbio (KITes) and Kay Mitusch (KIT-IWW) |
| Organisational innovation in services | Luis Rubalcaba (Alcala) and Christiane Hipp (BTU-Cottbus) |
| Emerging lead markets | Bernhard Dachs (AIT) and Hannes Toivanen (VTT) |
| Potential of eco-innovation | Carlos Montalvo and Fernando Diaz Lopez (TNO) |
| High-growth companies | Kay Mitusch (KIT-IWW) |

# Contents

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The final sector report on space and aeronautics builds on the result of the various tasks in the Europe INNOVA Sectoral Innovation Watch:



Giessen, van der A. and M. Poel (2010) Sectoral Innovation Performance in the Space and Aeronautics Sectors, Europe INNOVA Sectoral Innovation Watch, Task 1 Final Report, for DG Enterprise and Industry, European Commission, June 2010

Brandes, F. and M. Poel (2010) Sectoral Innovation Foresight – Space and Aeronautics Sectors, Task 2 Final Report, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission December 2010

Dachs, B. , I. Wanzenböck, M. Weber , J. Hyvönen, H. Toivanen (2011) Lead Markets, Task 4 Horizontal Report 3, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, March 2011

Grupp, H., D. Fornahl, C-A-. Tran, J. Stohr, T. Schubert, F. Malerba, F. Montobbio, L. Cusmano, E. Bacchiocchi, and F. Puzone (2010) National Specialisation and Innovation Performance, Task 4 Horizontal Report 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission March 2010

Montalvo, C., Diaz-Lopez, F.J. and F. Brandes (2011) 'Potential for eco-innovation in nine sectors of the European economy', Task 4 Horizontal Report 4, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Montalvo, C., A. van der Giessen and F. Brandes (2011) Analysis of market and regulatory factors influencing sector innovation patterns - Space and Aeronautics Sectors, Task 3 Report, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Rubalcaba, L., J. Gallego, C. Hipp and M. Gotsch (2010) Organisational Innovation in Services, Task 4 Horizontal Report 2, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, February 2010

# Executive Summary

The space and aeronautics sectors are high-technology sectors and belong to the most innovative sectors in Europe[1]. Analysis of CIS4 data shows that the space and aeronautics sectors continue to be very innovative. 85% of the firms is engaged in intramural R&D. Total R&D expenditures are between 21% and 11% of total turnover (depending on the countries include in the sample), which is between six and three times higher than the average of all manufacturing firms. More than 50% of the firms introduce new products, services and/or processes. This is confirmed in a survey conducted by the SIW-II consortium, which shows that aerospace firms are relatively more engaged in product, manufacturing methods and services innovation than in the other sectors.

High performance and safety are crucial in all segments. Both large and small firms are highly innovative. The R&D intensity – and the innovations that result from that – creates technology and knowledge spill overs to other sectors, such as ICT equipment and automotive sectors. The technology and product development trajectories are very expensive and take a long time. Moreover, life cycles are long and returns are only available in the long turn.

The sectors are world leader in large civil aircraft, business jets and helicopters, aero-engines, space launchers and space applications. The European space and aeronautics sectors are dominated by a small number of large firms and many more, often smaller 2nd and 3rd tier suppliers. Large system integrators such as EADS orchestrate the supply chain with complex sourcing and technology management processes and also shifting R&D activities, responsibilities and related risks to suppliers.

Within Europe, there are clear differences between countries and between regions. Based on CIS4 data, three countries - the United Kingdom, France and Germany - provide for around 80% of the sectors' added value. Reasons include scale advantages, the (tacit) knowledge that is required, collaboration in clusters, government support, linked to defence and to public research institutes. Five more countries play a substantial role in specific parts of the space and aeronautics Sectors: Italy, Spain, Sweden, Belgium and the Netherlands. In addition, Austria, Poland, Czech Republic and Hungary can be mentioned. The concentration in three countries is reflected in the export figures. 56% of turnover is export, e.g. the sales of Airbus aircrafts to a wide range of countries, and the sales of components to large assemblers in the UK, France and Germany.

International collaboration within Europe is well above the average of all manufacturing sectors. According to CIS4 data, 76% of firms in the space and aeronautics sectors cooperate with international partners, from inside or outside their own enterprise group. As mentioned above, the international structure of the sectors is also reflected in high export figures. Cooperation involves firms but also research organisations. 22% of firms cooperate with international universities, government or

[1] Two main statistical sources for this study are the Community Innovation survey (CIS) from Eurostat and the AeroSpace and Defence Industries Association of Europe (ASD). CIS does not differentiate between Aeronautics and Space, which implies that CIS figures mainly provide indications for Aeronautics, since this sector makes up over 90% of 'the' aerospace sector. Furthermore, recent CIS data on the sector does not include data from two key countries: the United Kingdom and Germany. ASD data is more comprehensive, but follow different definitions and methodology. This makes it difficult to compare data and to analyse the sector in more detail.

research institutes. Depending on the country sample, the figure for all manufacturing sectors is around 9%. Like in other high-tech sectors, regional concentration in the space and aeronautics sectors mostly depends on a research friendly environment and the availability of highly skilled workforce. According to the European Cluster Observatory, the best performing clusters in aerospace are located in Germany, France and the UK, which are also the most important countries in the sectors in terms of turnover, value added and employment.

International collaboration appears to have been stimulated by European research programmes such as the programmes by the European Defence Agency (EDA), the European Space Agency (ESA) and the Framework Programmes (e.g. FP5 and FP6). 58% of the firms in the space and aeronautics sectors receive European funding, according to CIS4 data. This percentage is higher than for national funding (50%) and local and regional government (34%). Also in categories such as small firms and/or firms from Central and East Europe, more than 50% of the firms receive public funding. The importance of public funding is in line with the general notion of high tech sectors with long term investments, with uncertain outcomes and spill overs to other sectors.

The relative importance of defence and civil markets fluctuates, and is different for aeronautics and space. In aeronautics, defence/military markets make up around 40% of total turnover. In space, defence/military markets are part of the broader category of institutional/public markets. This market is between 55 and 60% of total space revenues. Governments play a central role in the development of the sectors, as they regulate the markets, are often a major customer in these markets, and support the industry through a wide range of innovation support tools.

Historically the sector is treated as a whole and includes the sub-sectors of aeronautics and space. Between space and aeronautics sectors are linkages and parallels. All major systems assemblers are active in both sectors. Examples are EADS but also Boeing, BAE Systems and manufacturers of propulsion systems and other components (e.g. the SAFRAN group). Safety regulation and high performance criteria are crucial for commercial success in both sub-sectors with reliability of equipment being a key factor. The military and defence technology play an important role for innovation in both sub-sectors. There are however also differences. The European Space Sector is internationally structured, but with a main focus in Europe, while the Aeronautics Sector is increasingly globally oriented. In the space sector national procurement and institutional structures heavily influence the space markets, but in civilian aeronautics the share of institutional customers is much smaller. Moreover, the aeronautics sector is characterized by a small number of very large firms, a large number of medium-sized companies and a very large number of small companies. The space sector is also dominated by a few very large firms, but has a smaller number of SMEs and a large number of small space units within large companies.

**Current innovation dynamics in space and aeronautics**

*Pressure to decrease development and delivery times and costs*

The space and aeronautics sectors develop highly complex systems, which takes long development times, associated with high technological and financial risks and with cost overruns and delays in delivery schedules. This puts pressure on the sectors to improve their performance and drives the implementation of lean principles and concurrent design and engineering practices, focusing on core business, while at the same time integrating suppliers into every phase of development, production and deployment through multi-firm collaborative agreements and complex sourcing networks.

*High-tech and R&D intensive, but also conservative*

Technological advancements are essential ingredients to improve the competitiveness of the sectors, but the sectors are mainly focusing on continuous improvement of conventional configurations, which are often integrated in existing product lines. Main reasons for this are the highly interdependent systems where even small modifications can be a risky and costly undertaking, the long break even periods and small markets, but also the importance of standardisation and regulations. Despite the rather conservative culture in the sectors, radical and break-through innovation do occur, for example in the development of micro-satellites, private space activities, and the shift from aluminium to composite materials. Moreover, the sectors see the need for breakthroughs, especially to address the need for environmentally friendly aircrafts and space applications addressing major societal issues.

*Integration of services*

The combination of physical products with add-on services such as maintenance has been an important trend in the past and is expected to continue. System assemblers increasingly move to the provision of customised life cycle support services and solutions, often in partnerships. Also in space hardware is increasingly developed in combination with new applications and services in downstream markets.

*Highly concentrated in the EU and the United States, but new players are emerging*

Although the current space and aeronautics sectors are mainly concentrated in Europe and the US, other important countries in the sectors include Japan, Canada and the emerging countries Brazil, Russia, India and China. Especially in Asia the demand for air-traffic is increasing, offering new market opportunities for established players. However, at the same time competition from these emerging countries is increasing as their aeronautics industry is growing rapidly and national governments invest heavily to accelerate space programmes.

Global collaboration is getting more important. Examples are trading of technologies and patents between the US, Europe and China, global sourcing networks and Airbus and Boeing having established production facilities in emerging countries.

*Global sourcing and supply chain innovations*

Although the number of prime system integrators is limited, the industry uses a broad, deep, multi-layered and multifaceted supplier base. Prime manufacturers (‘primes’) now concentrate on product and system integration and management of the supply chain is now their core competency. They create a cooperative supply system, where suppliers are involved in the design and development of new products and responsibilities and associated risks are increasingly shifted to these suppliers. Primes force suppliers to reduce costs, improve the technological level and guarantee higher quality and service level. Open IT-platforms are used to organise competitive sourcing, while at the same time primes are seeking long term, stable and reliable relationships with fewer suppliers and outsourcing the design and manufacturing of components and entire sub-systems to external suppliers. This implies that the role of supplier in innovation had become more important, requiring new capabilities and capacities. For primes, it implies managing complex supply chain systems, also requiring new capabilities.

Another issue it the development of downstream space applications that are increasingly adopted by other sectors to develop new products and services. However, firms from these different sectors are not natural partners and new networks and platforms are needed to bring these various actors together to stimulate innovation.

*Need for eco-efficiency*

Societal concerns about the pollution by aeronautics as well as strict regulations urges the sector to develop cleaner and quieter aircrafts with a greener life cycle from design and manufacturing to dismantling and recycling. At the same time, the pressure on business performance is driving the need for fuel-efficiency. Using less fuel is a main priority for airlines and aircraft manufacturers, as fuel covers 30 to40% of an airline’s operating expenses. In this way, eco-efficiency is a main driver for innovation in the aeronautics sector. In the space sector, environmental concerns will provide opportunities in the satellite market because of an increasing need for sound data on the environment coming from earth observation and remote sensing applications.

The eco-innovation analysis carried out by SIW-II found several eco-innovation opportunities in space and aeronautics: new materials for light weight aero structures, new materials for engine performance improvements, fuel cells as alternative propulsion, bio-fuels to lower carbon footprint of air transport, and aeronautics and space coatings reducing chemical emissions in manufacturing and reducing fuel consumption of the air- and spacecraft.

*Highly-regulated sectors, is regulation a driver or barrier?*

The space and aeronautics sectors are highly-regulated and standardised sectors with regulation for safety and environment as the most important focus areas. Regulation can act as both a driver and a barrier to innovation. The survey carried out by SIW-II shows that aerospace respondents consider regulation and one of the main drivers for innovation in the sectors, similar to the respondents from the automotive sector. Safety and environmental regulation, as well as industrial standards, alternative materials regulation, waste regulation, land and labour regulation are found to have positive effects on innovation. However, environment regulation can act at the same time as an inhibitor for technology adoption, as proven technologies are preferred by customers and authorities whose prime goals is safety. Innovation, needed to realise the desired efficiency gains through for example new materials or structures is often in tension with regulation. It impacts time-to-market and development costs. The survey by SIW-II also found that price regulation, regulatory differences across Europe and public procurement regulation are considered as barriers to innovation.

**Innovation futures in space and aeronautics**

Future developments in the sector are particularly influenced by demand drivers and technology development. Demand drivers differ between aeronautics and space, with demand for aeronautics particularly shaped by expected growth in air travel, which in turn depends on economic growth and fuel prices. Space on the other hand is still a largely institutional and regulated sector, making public demand and regulation key demand drivers. Future demand for space applications is largely based on addressing societal challenges, such as monitoring and managing transport, security as well as land, water and air resources. Generally, regulation is the largest uncertainty primarily impacting future demand in aeronautics, through for example an emission trading system, but also the space sector with regulation touching on liability issues and space tourism.

Important expected technology developments are: 1) improvements in 'aviation electronics' making flying safer and unmanned aerial vehicles possible, 2) simulation and modelling technologies with positive impacts on development times and costs but also air transport management; 3) artificial intelligence promising increased autonomy of aircraft, hereby reducing failures; 4) a range of new materials on the one hand reducing the weight of aircraft but also increasing performance of for example engines, and 5) technologies for alternative propulsion systems and fuels, such as fuel cells and biofuels aiming to reduce the environmental impact of air travel.

Bringing the technology and demand drivers together results in several key emerging innovation themes for the space and aeronautics sectors as well as their requirements.

In aeronautics the most important topic for the future is the environmental impact of aeronautics and this drives the following innovation themes: 1) Air Traffic Management to increase efficiency and to accommodate more aircrafts and also personal and unmanned aircraft; 2) Improving aircraft performance to optimise the overall performance of an aircraft; 3) New airframe configurations to increase lift and reduce drag, also needed to achieve goals of zero emission aircraft; and 4) New propulsion systems and fuels. Three more innovation themes are related to increasingly distributed air travel and point-to-point connections: 1) Small aircraft and personal air transport services; 2) Personal aerial vehicles; and 3) Unmanned aerial vehicles.

In space it is expected that the future demand for space applications will come from focusing on societal challenges. The following innovation themes are considered as relevant for the space sector: 1) Global Navigation Satellite Systems; 2) Earth Observation; 3) Micro satellites, including impact on launchers and services; 3) Space travel and tourism.

The identified innovation themes will have different chances to develop in different scenarios. In an expert workshop three scenarios of future developments were developed. These three scenarios were: 1) 'Global Green Aerospace'; 2) 'Regional Aerospace'; and 3) 'Zero Sum Games'. Key differences between the scenarios are the availability and price of energy, the level of economic growth and geopolitical uncertainties. These factors were identified as posing the biggest future uncertainties for the sector.

The Global Green Aerospace scenario describes a peaceful, highly globalised world in 2040 that has successfully taken steps for an energy transition assuring a secure energy supply at reasonable but increasing prices. Business people but also private individuals enjoy the freedom of being able to travel frequently and far away. Terrorism is not a major threat obstructing air travel. This leads to a flourishing of both the aeronautics and space sector. New technologies and smart regulation lead to radical improvements in aircraft efficiency and emissions, while the space sector allows monitoring and tackling many societal issues such as climate change, environmental resources and mobility. Furthermore, free access to space and a global judicial system for space also allow the sector to flourish commercially. Important opportunities are: a) Market for efficient and environmental aircraft; b) Further growth of the personal air transport market with opportunities for both manufacturers as well as new service providers; c) Flourishing space sector particularly benefiting (small)launchers; (micro-)satellites; and space-based services. The main risks identified were: a) increasing competition from China, India and Brazil in both aeronautics and space manufacturing putting the currently dominating role of European manufacturers at risk; b) if real energy prices increase, potentially shrinking demand in air travel; c) Potential risk to free access to space from space waste and uncontrolled space activities.

The Regional Aerospace scenario describes a world in 2040 with powerful regions and limited ties between them. No global agreement on climate change has been reached, blocking a smooth transition to renewable alternatives. Access to fossil fuels hence remains important and shapes international relations. This combination of realpolitik and protectionist tendencies leads to slow economic growth and rising energy prices, with large regional differences based on access to oil/gas resources. Europe tries to lead the way but struggles with strong international competitors. While still able to travel globally, people choose to do holiday trips within Europe, largely for economic reasons. With increasing rivalry between global powers, access to space in this climate becomes more difficult.

The main opportunities include: a) market for efficient and environmental aircraft stimulated by high energy prices in Europe; b) regionalisation limits global competition and allows development of a market with regional framework conditions and policy goals. Relevant risks are: a) Slow economic growth acts as barrier for new investments; b) Markets outside the EU become more difficult to access with negative effects for exports; c) Cooperation in space and access to space become fragile due to isolation of powerful regions; d) With security relations between powerful regions deteriorating, the possibility exists of a downward spiral leading to scenario 3.

In the Zero sum games scenario, a rapid energy scarcity leads to highly fluctuating energy prices and interruptions in supply. Globalization, thriving on cheap energy and transport, comes to a halt with severe economic adjustment processes. International holiday trips are reduced sharply with people adjusting their consumption patterns to a changed economic environment. Countries seek their interests in protectionist policies leading to a downward spiral and break-down of multilateral institutions. Trade conflicts become a norm with resulting conflicts for access to natural resources. Security expenditure rises steeply at the expense of other policies such as the environment. European integration is at stake. Overall, this is an unfavourable scenario with regions competing on a zero sum basis leading to a deteriorating economic and social environment. An important opportunity stems from deteriorating security relations, when markets for military aircraft and space based systems for monitoring and control technologies are likely to flourish. Main risks include: a) Current markets for civil aircraft are stimulated by globalisation. With a reverse in globalisation this market is likely to break down; b) Capital shortages and increasing economic risks let the commercial segment of space perish; c) For the same reasons, new technologies requiring high capital investment are unlikely to be developed.

**Policy implications**

The analysis of innovation performance and dynamics of the space and aeronautics sectors point out several policy implications for stimulating innovation and competitiveness in the sectors.

*Provide long-term and stable support to risky science and R&D*

Breakthroughs and radical innovations are needed to address the pressing innovation challenges, such as eco-innovation in the space and aeronautics sectors. The space and aeronautics sectors are very R&D-intensive with very high R&D costs and long development and production times. Together with capital risks and high technical risks these factors are confirmed as market factors having a highly negative effect on innovation, and especially radical innovation. European policy efforts could focus on several approaches to overcome these barriers. First, European policy should provide stable and long-term support to risky R&D. There is some concern that European R&D programmes become more risk averse, with very high transaction costs, focusing on short-term results. This could be at the expense of long term, blue sky and radical innovation. Second, European policy could focus on introducing instruments that lower the risks on R&D and the uncertainty with capitalisation on R&D investments. Government could for example use public procurement mechanisms to take the risk of radical innovative projects in the civil market segment like they do in the military market segment. Moreover, governments could stimulate the development of different models of funding, for example through prize reward models. In addition, governments could assure that SME's are also able to join (publicly funded) long-term research projects.

*Support the creation of platforms and linkages with other sectors*

The European research system for space and aeronautics is rather fragmented and links with other sectors are hardly available. Aerospace technologies are increasingly adopted by other sectors to develop new products and services. For example, micro-electronics and other ICT clusters are highly relevant for avionics and micro-satellites, but also for downstream space-based services, sectors such as telecommunications, energy and transport are very relevant. However, firms from these different sectors are not natural partners. European policy efforts could stimulate and support platforms bringing together different actors, both large firms and small firms, infrastructure operators, service providers, venture capitalists and users. These platforms can stimulate collaboration; facilitate shared visions and standards, as well as identifying market barriers. Moreover, these platforms can support service innovation in the downstream sectors, as firms developing these downstream services and applications will get involved in the development and planning of new space infrastructures and hardware.

*Strengthen market mechanisms to support innovation*

Because of the high costs and high risks of innovation in space and aeronautics, commercial actors have many difficulties financing this type of research and establishing attractive return on investment. Hence, market adoption should be stimulated and the most effective tool is the introduction or stimulation of market mechanisms.

One example of such a mechanism is the proposed emission trading system. For successful implementation, however, a level playing field should be ensured. Another is a harmonised value added tax on kerosene that would have a similar effect as CO2 certificates. Thirdly, to reduce noise pollution from aircraft, landing fees could be based on noise emissions of aircraft. The certification process for aircraft technologies could be used to speed-up market introductions of , especially, environmental technologies. Environmental technologies could be prioritised compared to other technologies in the certification process. Another issue is the access to space data. Space data are a crucial input for many downstream services and the willingness of commercial actors to invest in service innovation is influenced by the guarantees on access to data. Data access policies should focus on this guarantee on access to data.

*Remove regulatory barriers and support smart regulation*

The space and aeronautics Sectors are highly regulated sectors, especially in relation to safety regulation. Safety is understandably the first priority in these sectors, however strict safety regulations can also limit innovation and adoption of new technologies, as proven technologies are preferred because of established certification and certainty. Nevertheless, new technologies and innovation is needed to establish efficiency gains, reach eco-efficiency and address societal challenges. Hence, innovation and safety are in tension. Creative thinking and smart regulation is needed to solve this tension. For example, procedures for certification and authorisation of environmental technologies could be speeded up. Moreover, in emerging markets stakeholders could be involved in developing smart regulation and policy makers could designate areas in which the impact of potential safety issues is limited and where exempt certificates can be used. In space, unresolved liability issues need to be resolved and regulatory frameworks in relation to safety, environmental protection, and public procurement need to be harmonised to reduce commercial risks of actors and increase legal certainty. This is needed to facilitate the commercial development of space applications and to share risks.

*Support talent and the development of new skills*

Fewer European students follow degree courses in engineering and sciences. At the same time, more and more PhD positions in the North-West European countries are filled with overseas students. These are high skilled sources of talent that cannot always be recruited by European institutions and firms due to labour market restrictions. Next to stimulating European students to follow degree courses in engineering and sciences, policy efforts should concentrate on resolving labour market barriers. This would allow Europe to profit from overseas talent that is educated in Europe and opens the doors for overseas business contacts in the future. This talent is very much needed to solve technological challenges in various fields such as new engine designs (e.g. turbo fans), airframe configurations, bio-fuels, fuel cells and new materials. Moreover, firms should be stimulated to establish a long-term view on recruitment and employability in the sectors. The cyclical nature of large scale projects also impacts the supply and demand of engineering capacity leading to a loss of talent to other sectors in downturn periods.

Also in terms of skills and capabilities, there are pressing requirements. The increasingly complex value chains and networks of many suppliers and partners are difficult to coordinate and contain many risks. This requires improved skills and capabilities in supply chain management, but also sufficient in-house know-how and the ability to integrate and use new technologies from suppliers and partners. Moreover, different capabilities are required from suppliers, as they increasingly take over R&D and innovation activities and the related risks. European policy efforts should focus on supporting and stimulating the creation of new and improved skills needed in coordinating and acting in these complex innovation networks.

# 1 Patterns and performance of sectoral innovation[2]

## 1.1 Introduction to the European space and aeronautics sectors

The space and aeronautics sectors qualify as high-technology sectors (e.g. Hollanders et al., 2008) and sectors belong to the most innovative sectors in Europe. The sectors include the manufacturing of aircraft and spacecraft and related subsystems, parts and accessories that are used for transport of people or freight and for military purposes. The sectors are highly concentrated within the EU and the United States and within Europe in the United Kingdom, France and Germany. The European Space and Aeronautics Sectors are dominated by a small number of large firms (e.g. EADS, Thales, Finnmeccanica) and many more smaller 2nd and 3rd tier suppliers. Large system integrators such as EADS orchestrate the supply chain with complex sourcing and technology management processes and also shifting R&D activities, responsibilities and related risks to suppliers. R&D intensity is high and the innovations that result from that – creates technology and knowledge spill overs to other sectors, such as ICT equipment and automotive sectors. The technology and product development trajectories are very expensive and take a long time. Moreover, life cycles are long and returns are only available in the long turn.

National governments play a central role in the development of the sectors, as they regulate the markets, are often a major customer in these markets, and support the industry through a wide range of innovation support tools. Especially in the defence and space segments, public authorities are the dominant customer.

This report presents the analysis of innovation performance and dynamics of the space and aeronautics sectors. The aeronautics and space sectors are often treated as a whole, but there are substantial differences between the sub-sectors. As much as possible, both sectors will be discussed separately, but commonalities between both sectors will be addressed as well. Where relevant, linkages with developments in other sectors will be taken into account as well.

This final sector report is based on earlier tasks conducted by the consortium. It analyses and wraps up the results of the sectoral innovation performance analysis, the sectoral innovation foresight, the analysis of market and regulation factors affecting patterns of innovation and the horizontal reports, covering cross-sectoral themes such as eco-innovation and high-growth firms.

These parts will be presented in six main chapters. Chapter 1 starts with the (statistical) introduction of the sector, a general profile and a quantitative overview of the sectoral innovation performances based on an analysis of CIS4 and sector specific data. Chapter 2 discussed the carriers of innovation: who is innovating, what is the workforce and how does innovation currently takes place. Next, Chapter 3

[2] This chapter is based on the analysis performed in Task 1 of the SIW-II. The full analysis is available in Van der Giessen and Poel (2010).

provides an overview of the future developments in the space and aeronautics sectors. Both technological and societal drivers are presented and combined in innovation themes. The innovation themes are discussed in the light of three scenarios, which lead to future requirements for innovation and future policy directions. Chapter 4 describes the most important drivers and barriers in the sector today. The sectoral consequences of several horizontal themes are discussed in Chapter 5. Finally, Chapter 6 draws up conclusions based on the earlier chapters and sums up the most important policy implications.

## 1.2 Statistical definition of the sectors

The space and aeronautics sectors are statistically represented by NACE 35.3 (Rev 1.1), which includes the manufacture of aircrafts and spacecraft. Table 1.1 presents the statistical definition of the sectors according to NACE and Eurostat.

**Table 1.1 Statistical definition of the space and aeronautics sectors**

| NACE (Rev 1.1) | | Included | Not included |
|---|---|---|---|
| D | Manufacturing | | |
| D 35 | Manufacture of other transport equipment | | |
| D 35.3 | Manufacture of aircraft and spacecraft | Manufacture of:<br>– Aeroplanes for the transport of goods or passengers, for use by the defence forces, for sport or other purposes<br>– Helicopters<br>– Gliders, hang-glides<br>– Dirigibles and balloons<br>– Spacecraft and spacecraft launch vehicles, satellites, planetary probes, orbital stations, shuttles<br>– Parts and accessories of the aircraft of this class:<br>• major assemblies such as fuselages, wings, doors, control surfaces, landing gear, fuel tanks, nacelles, etc.<br>• airscrews, helicopter rotors and propelled rotor blades<br>• motors and engines of a kind typically found on aircraft<br>• parts of turbojets and turbopropellers<br>– Aircraft launching gear, deck arresters, etc.<br>– Ground flying trainers | Manufacture of:<br>- Parachutes<br>- Military ballistic missiles<br>- Ignition parts and other electrical parts for internal combustion engines<br>- Instruments used on aircraft<br>- Air navigation systems |

Source:ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=ACT_OTH_CLS_DLD&StrNom=NACE_1_1&StrFormat=HTML&StrLanguageCode=EN

The activities not included (see table 1.1) in the statistical definition of the sectors, but nevertheless relevant for the sectors, show the strong linkages between the space and aeronautics sectors and other sectors, in particular the electrical and optical equipment sector (e.g. in relation to instruments and electrical parts). Although NACE separates some activities from the space an aeronautics sectors, these activities are often included in the data and studies presented by the industry itself.

Between space and aeronautics sectors are linkages and parallels. All major systems assemblers are active in both sectors. Examples are EADS but also Boeing, BAE Systems and manufacturers of propulsion systems and other components (e.g. the SAFRAN group). Safety regulation and high performance criteria are crucial for commercial success in both sub-sectors with reliability of equipment being a key factor. The military and defence technology play an important role for innovation in both sub-sectors. There are however also differences. The European space sector is internationally structured, but with a main focus in Europe, while the aeronautics sector is increasingly globally oriented. In the space sector national procurement and institutional structures heavily influence the space markets, but in civilian aeronautics the share of institutional customers is much smaller. Moreover, the aeronautics sector is characterized by a small number of very large firms, a large number of medium-sized companies and a very large number of small companies. The space sector is also dominated by a few very large firms, but has a smaller number of SMEs and a large number of small space units within large companies. Statistically, the space and aeronautics sectors are treated as a whole, but the differences show that there are good reasons to analyse the sectors separately. This is also reflected in the new NACE 2 structure, which treats them separately. Nevertheless, the CIS4 data, which have been used in this study, still follow the NACE 1.1.

## 1.3 Characteristics of the space and aeronautics sectors

The space and aeronautics sectors (NACE 35.3) consisted of 2,312 companies in EU-27 in 2006, generating a turnover of EUR 89.1 billion. In 2006, the sectors realised EUR 29.96 billion of value added, which represents a share of 1.75% of the total value added of all manufacturing sectors. The sectors counted 382,200 employees, which is a share of 1.18% of the total employment in all manufacturing sectors (Eurostat, 2009a). The share of the sectors' employment and also value added in all manufacturing sectors is unevenly distributed in EU Member States, with much higher shares EU Member States as the United Kingdom, France and Germany (see also table 1.2). The apparent labour productivity in 2006 amounted to EUR 78,000, which is one and a half time as high as for the manufacturing sector in total (EUR 49,700).

Looking at the two sectors, space and aeronautics, data from the AeroSpace and Defence Industries Association of Europe (ASD) show that in 2008 the aeronautics sector was responsible for 92.9% of the turnover, while the space sector contributed 7.1%. Also in terms of employment, the space sector represented about 6.8%, while the aeronautics sector employed 93.2% (ASD, 2009).

The space and aeronautics sectors are dominated by three countries: United Kingdom, France and Germany. These three countries have the largest number of aerospace enterprises and are home to the largest aerospace companies. Moreover, they have a long history in aerospace research with large and important aerospace research institutes and substantial public civil and military funding for aerospace programmes. The United Kingdom represents 33% of the sector's value added in EU-27, followed by France (25.3%) and Germany (21.5%). At substantial distance follow Italy (8.2%), Spain (3.7%), Sweden (2.1%), Belgium (1.5%) and the Netherlands (1.2%). All other Member States have a substantial smaller share in the sectors' value added. Also in terms of employment, the United

Kingdom leads. In the United Kingdom, France and Germany the space and aeronautics sectors contribute to the non-financial business economy more than the EU-27 average. Although Sweden represents only 2% of the EU-27 sectors' value added and employment, this country is rather specialised with regard to employment in the sectors (see table 1.2). The dominance of a few countries in the sectors has been very stable over the past years, although the internal rankings can differ. For example, in 2004 Germany had a higher share of EU-27 value added than France (22.2% and 18.5% respectively), while in 2006 France performed better than Germany (Eurostat, 2009a). Table 1.2 presents the main results for several Member States in 2006.

The space and aeronautics sectors are relatively R&D-intensive. There is no total amount of R&D expenditures for EU-27, but table 1.2 presents some data for the countries dominating the sectors in terms of value added and employment. Five countries representing 85.6% of the sectors' value added in EU-27 spent EUR 6.7 billion on R&D in 2006. Especially in the two most specialised EU-27 Member States, United Kingdom and France, the sectors contributed significantly to the R&D of all manufacturing sectors (see table 1.2).

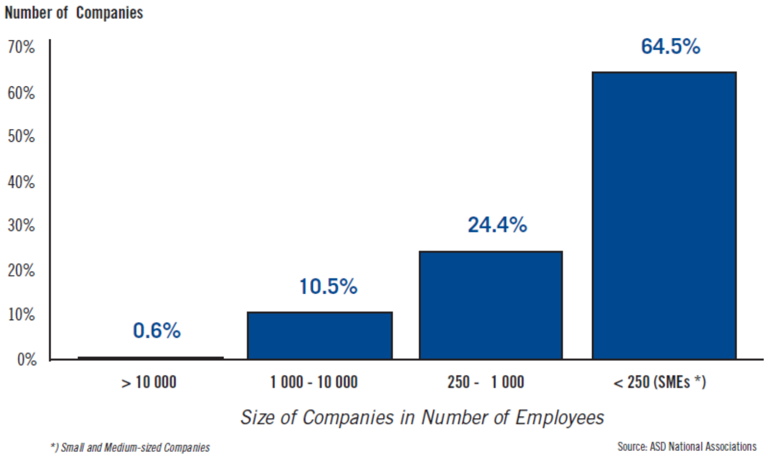
**Table 1.2 Dominance of Member States in Space and Aeronautics Sectors, 2006**

| **Country** | **Share of EU-27 sector value added (%)** | **Share of EU-27 sector employment (%)** | **Value added specialisation ratio (EU-27 = 100)[1)]** | **Employment specialisation ratio EU-27 = 100)[1)]** | **R&D expenditure (EUR million)** | **Share of manufacturing R&D expenditure (%)** |
|---|---|---|---|---|---|---|
| United Kingdom | 33% | 26.1% | 173.7% | 190.7% | 1752.1 | 23.3% |
| France | 25.3% | 24.3% | 179.5% | 214.8% | 2458.1 | 16.5% |
| Germany | 21.5% | 20.2% | 105.2% | 121.7% | 1853.7 | 4% |
| Italy | 8.2% | 8.75% | 73.4% | 74.8% | n.a. | n.a. |
| Spain | 3.7% | 4.1% | 38.6% | 38.2% | 416.6 | 12.4% |
| Sweden | 2.1% | 2.5% | 74.9% | 120.3% | 255.9 | 3.9% |
| Belgium | 1.5% | 1.6% | 56.5% | 85.9% | n.a. | n.a. |
| The Netherlands | 1.2% | 1.3% | 25.3% | 34.1% | n.a. | n.a. |

Source: Calculations based on Eurostat Structural Business Statistics Note: 1) Relative specialisation ratio is the country's share of Space and Aeronautics in its non-financial business economy in value added or employment divided by the same ration for EU-27, values above 100% indicating a relative specialisation in relation to EU-27 average.

While the aeronautics sector is characterised by a small number of very large firms and a large number of small firms, the space sector has fewer SMES, but a large number of small space units within larger firms. Figure 1.1 presents the structure of the sectors in 2007.

**Figure 1.1 Structure of the European space and aeronautics sectors in 2007**




Source: ASD (2008)

The space and aeronautics sectors are essentially assembly industries, relying on external suppliers of goods and services in manufacturing air- and spacecrafts. When looking at intermediate consumption as a percentage of production value, it is clear that the sectors depend on 2nd and 3rd tier suppliers. In the United Kingdom, France, and Germany, between 60% and 70% of the production value comes from intermediate consumption. In Belgium this share amounts even to almost 100%, while in Spain 78% of the production value comes from intermediate consumption (Eurostat, 2009b).

## 1.3.1 Pressure to decrease development and delivery times and costs

The space and aeronautics sectors develop highly complex systems including many different components and building on many different scientific disciplines and technological fields. The development of new air- and spacecrafts takes long development times and often processes are associated with high technological and financial risks. Delays in development and delivery schedules as well as cost overruns are important issues in the sectors and put much pressure on the industry to improve development and delivery schedules and to reduce costs.

**Box 1.1 Fighting delays**

Delays in developing and manufacturing new aircrafts are causing painful headaches for CEOs of aircraft manufacturers. Delays have always been there in the industry and are an important cause for disappointing profit margins. Despite all kinds of approaches, such as concurrent engineering and outsourcing to risk-sharing partners, all manufacturers face the problem of delays in their programmes. Boeing, for example, has struggled with the delivery of its new flagship 787 Dreamliner. Boeing had received record-breaking orders for this aircraft, but the production has been slowed down, mainly because of problems in the supply chain. Boeing has outsourced complete components and subsystems to global suppliers, but lost control on its supply chain as suppliers could not fulfil their contracts with Boeing. Although Boeing is still convinced that it can win competitive advantage when using a global supply chain, it also wants to reconsider its supply chain. Delays in programmes cause huge costs, not only from additional investments needed to solve technical problems, but also from penalties and compensation claims from the customers waiting for the new aircrafts.

Financial Times, 14 July 2008

Aeronautics companies have developed a broad set of approaches to improve their performance. The industry has been considerably consolidated in the past decades to improve their capacities to compete and innovate and to reduce the overcapacity. Moreover, companies implemented 'lean' principles and practices, first by just cutting costs and removing unnecessary steps, but also by developing integrated product teams, reducing inventories, coordinating procurement activities, introducing preventive maintenance practices, training employees in quality control practices, and involving suppliers earlier in the design process (Murman et al. 2002; Ecorys, 2009). A next step is the systematic approach of fully integrated product and process design teams, the integration of suppliers into every phase of development, production and deployment, multi-firm collaborative agreements with suppliers and competitors, the further application of advanced ICT systems to facilitate real-time collaboration and complex configuration management tasks, but also the focus on core business.

**Box 1.2 Top performing companies in the space and aeronautics sectors**

Each year the publication *Aviation Week and Space Technology* publishes an industry ranking for the aerospace and defence industries, based on the companies' performance in terms of revenues, return on invested capital, asset management, and financial health. The rankings allow comparison of companies' performance withinin their peer groups. Table 1.3 presents the rankings of the top performing companies in various market segments. Amongst the commercial aircraft builders, EADS ranks first in the 2009 Aerospace & Defence Industry Ranking, followed by Boeing, Bombardier and Embraer. Over the past five years, Bombardier has improved its performance stronger than its peers. Lockheed Martin leads the prime manufacturers in defence, closely followed by EADS and General Dynamics. Goodrich Corp ranks first in the group of engines and equipment manufacturers, as well as in the group of aero structures and components. Rockwell Collins leads the avionics and electronics group and United Technologies ranks first in the group of Maintenance, Repair and Overhaul. Most companies, including EADS, have been able to improve their performance over the past five years; MTU Aero Engines was able to improve its performance with 107.5% over the past five years. Nevertheless, performances of several European companies like Dassault Aviation, Finmeccanica, SAFRAN, SAAB, and Rolls-Royce have worsened in the same period.

**Table 1.3 Top performing companies in space and aeronautics sectors**

| Rank | Company | Rank | Company |
|---|---|---|---|
| *Commercial aircraft builders* | | *MRO* | |
| 1 | EADS NV (NL) | 1 | United Technologies Corp (US) |
| 2 | Boeing Co (US) | 2 | MTU Aero Engines Hldgs AG (DE) |
| 3 | Bombardier Inc (CA) | 3 | AAR Corp (US) |
| 4 | Embraer Empresa Brasileira (BR) | 4 | Rolls-Royce Group PLC (UK) |
| | | 5 | Safran SA 9FR) |
| *Defence primes* | | 6 | Rolls-Royce Group PLC (UK) |
| 1 | Lockheed Martin Corp (US) | 7 | Safran SA (FR) |
| 2 | EADS NV (NL) | | |
| 3 | General Dynamics Corp. (US) | *Aerostructures / Components* | |
| 4 | Raytheon Corp. (US) | 1 | Goodrich Corp (US) |
| 5 | Boeing Co (US) | 2 | Spirit Aerosystems Holdings Inc |
| 6 | BAE Systems PLC (UK) | 3 | Woodward Governor Co |
| 7 | Thales (FR) | 4 | Triumph Group Inc. |
| 8 | Northrop Grumman Corp (US) | 5 | Hexcel Corp |
| 9 | Dassault Avaiation SA (FR) | 6 | Zodiac Sa (FR) |
| 10 | Finmeccanica SPA (IT) | 7 | BE Aerospace Inc. UK) |
| | | 8 | Curtiss-Wright Corp |
| *Avionics / Electronics* | | 9 | Moog Inc. |
| 1 | Rockwell Collins Inc. (US) | 10 | Barnes Group |
| 2 | Raytheon Co. (US) | | |
| 3 | Honeywell International (US) | *Engines / Equipment* | |
| 4 | L-3 Communications Holdings Inc (US) | 1 | Goodrich Corp (US) |
| 5 | Thales (FR) | 2 | United Technologies Corp (US) |
| 6 | Northrop Grumman Corp (US) | 3 | Honeywell International (US) |
| 7 | Finmeccanica SPA (IT) | 4 | MTU Aero Engines Hldgs AG (DE) |
| | | 5 | Zodiac Sa (FR) |

Source: Aviation Week, 2009. Ranking based on the companies' performance in terms of revenues, return on invested capital, asset management, earnings momentum and financial health.

**Note:** In 2007, EADS realised a loss of 0.3%, while Boeing realised a profit margin of 9.5%. However, in 2008 EADS's operating profit increased substantially to EUR 1,790 million from minus EUR 881 million in 2007. In the same period, Boeing's operating profit dropped from USD 12,990 million to USD 10,600 million. While the US industry had to deal with strikes and delays, EADS delivered the largest amount of aircrafts ever. EADS's performance has been very volatile in the last decade and industry analysts wonder whether the positive results in 2008 are the result of the Power8 programme and indicate a structural improvement or not. EADS faces many challenges in several of their programmes as well as an expected downturn in demand for civil aircraft in the short term. The first results for the first half year of 2009 confirm these worries; revenue for the first six months of 2009 went up 2%, while earnings before interest and tax fell 23% and net profit went down 6%, mainly reflecting unfavourable foreign-exchange fluctuations and further delays in the military A400M programme. The second quarter of 2009 is stronger than the first quarter (http://www.dowjones.de/site/2009/07/eads-2q-profit-up-but-warns-of-future-a400-million-costs.html).

According to industry analysts, European aerospace companies suffer from high volatility in performance and poorer performance over the longer term, especially in comparison with the more consistent performance of US companies. Important causes for this include the absence of a unified European defence market and decreasing defence budgets, very complex multilateral programmes, a fragmented supply chain (especially in aero structures and electronics), strong vertical integration among larger companies, government-subsidized national champions, problematic cash flows, and high legacy costs from having been government-owned conglomerates (Gelain, 2009, in Aviation Week; Ecorys, 2009).

In the space sector, the institutional market has always been the main source of funding. However, the institutional funding level has been rather stable over the past decade and for growth the European space sector has to compete on the global commercial market. The commercial market is mainly based on the satellite communications and launch services segments, which are dependent on the health of industries using the satellites, e.g. telecommunications and which are very competitive markets. Moreover, there is increasing competition from very advanced satellites from the US and India and China are entering the lower costs satellites with lower performance. In addition, Europe is also depending on US manufacturers, as they are the sole suppliers of key components. Other influences on the competitive position of the European space sector come from countries that are further rationalising their industrial base to improve their competitiveness and from high vulnerability to exchange rate risks. The geographical contribution rule (geo-return principle) followed by ESA does not help much either. It allows Member States putting their national interests above the European interests. In addition, the geographical distribution rules makes it attractive for suppliers to be located all over Europe, getting some Member States to support their local space companies so they can offer lowest prices to the system integrators. This leads to a very competitive market for suppliers (Peter, 2008).

Also in the space sector there is pressure from both institutional and commercial markets to decrease development times and to lower costs. Especially in the launcher segment, costs need to be reduced. It is the only space segment where costs have so far not fallen over time (Poliakov et al., 2008). Several smaller launchers expected to come online over the coming years are expected to reduce these costs and lead to many smaller launches. Using more COTS (Commercial off-the-shelf) components and standardised modules could help to reduce the development times, to achieve non-dependence and to have more standardisation, which helps to lower the costs in the Space Sector (Skaar, 2007; Interviews with Boele and Blaauw, 2008 and 2009). Concurrent design and engineering contribute to decreasing development cycles and lowering costs in both the downstream and upstream parts of the Space Sector (Interviews with Boele and Blaauw, 2008 and 2009). For example, ESA has the Concurrent Design Centre, which allows experts from different disciplines to design and engineer parts and applications concurrently, by using advanced ICT tools.

### 1.3.2 High-tech and R&D-intensive, but also conservative?

As mentioned before, the space and aeronautics sectors are very R&D-intensive, with Space a bit more intensive than aeronautics. Technological developments are essential ingredients to improve the competitiveness of the sector. However, the question is whether the extensive R&D activities can also lead to truly radical and breakthrough innovations. Especially aeronautics finds itself in the specific phase of Utterback's (1996) classification of innovation life cycles. The specific phase is characterized by the existence of a dominant design (Murman et al., 2000). The aircraft configuration of present aircrafts looks rather similar to the first jet commercialized in the 1950s. This dominant design is the result of critical technology breakthroughs stemming from military investments during World War 2. Innovations in the development of an aircraft have resulted in substantial improvements of performance and a sharp decline in the costs. Developments in aerodynamics, structures and materials, control systems and propulsion technology have been the main contributors. The shift from aluminium to composite materials is already a major change and will continue with developing the functional applications of composites (e.g. structural health monitoring and repair, noise reduction and shape control). Nevertheless, the sector is a rather conservative industry, focusing on continuous improvement of conventional configurations mainly incremental and process-oriented innovations, which are often integrated in existing product lines.

There are various reasons for this orientation on incremental and process innovations. Current air- and spacecrafts are complex systems with many interdependencies and even small modifications can be a complex and costly undertaking. This means that the industry tries to reduce the huge risks as much as possible by concentrating on multi-applicable technological solutions, developing systems of relationships and by focusing on specific niches. Another reason is the long break even periods and the small markets. National markets are simply too small to reach break-even, but many governments impose direct and indirect barriers on the acquisition of aircrafts, limiting market expansion. The sector's cash flow profile is rather problematic because of heavy investments in the long development process and returns only available in the long term. Only very large firms can work under such cash flow patterns, leading to a small number of large prime contractors. Under these conditions, the need for radical innovations is seen as less urgent. Another important issue is the importance of standardisation and regulations. Driven by strict security and safety requirements, the industry has to deal with very detailed international certification procedures to meet airworthiness standards for aircrafts and components. These strict procedures can limit the possibilities for fast adoption of more radical technological solutions (Ecorys, 2009; EC, 2009a).

Although the incremental innovations are leading, the aeronautics sector also sees the need for breakthroughs in aircraft configurations and types, especially to address the need for environmentally friendly aircrafts. New technologies are developed in various sub disciplines, including aircraft configurations, aerodynamics, structures and materials, propulsion, fuels, and aviation and navigation.

Also in space, current mechanisms seem to address mainly incremental innovations (Summerer, 2009). Institutional structures heavily influence the space markets, mainly because of the strategic importance of some space-based services and space assets, but also because of the importance of space activities for stimulating innovation and high technology developments, also in other sectors. Space is a risky business, leading to a risk-adverse culture, which leaves little freedom for innovation that is not strictly needed for achieving mission success. Moreover, there are very high entry barriers and the very lengthy processes between new concept and its implementation in a space mission and few flight opportunities leave little freedom for new ideas, technologies and methods. This leads to mainly incremental innovations. This effect is further strengthened by the lack of essential ingredients for a free, competition-driven, commercial market. Although institutional funding is relatively stable and defence-related space activities are publicly funded, a real market is absent. Summerer (2009) argues that during the last 25 years not a single radically new major programme has been introduced into the governmental space sector. And this, according to Summerer (2009), will likely continue in the coming years. This is because the basic assumptions are still valid: Space activities are of strategic importance and very expensive and there are not enough sufficient commercial incentives for the private sector to make the required upfront investments. Nevertheless, there are some signs that disruptive innovations can occur. A good example is the development of very small satellites. They are much simpler and cheaper to build, address a different, still marginal, market, are non-competitive in the traditional space market, offer lower profit-margins, but offer new freedom for new entrants with new business models. Another disruptive innovation area is the development of fully private space activities: space tourism and sub-orbital space flights, which are developed in a radically new approach by entrepreneurs (Summerer, 2009)

## 1.3.3 Service innovation

While it takes at least 10 years to develop a new space- or aircraft, these aircrafts are then normally produced for 25-20 years and are in service typically for another 30 years. The life-cycle of an aircraft model can be as long as 70 years (TuE, 2007). This also implies a long service and support life. As maintenance expenses during the long life-cycle of aircrafts are much higher than the acquisition price, aircraft operators are seeking for solutions to decrease the maintenance costs. They used to have in-house maintenance facilities, but aircrafts operating companies are increasingly focusing on their core activity of running aircraft fleets. Aircraft operators are increasingly transferring the maintenance and support activities to manufacturers and independent MRO providers. Manufacturers are offering now combined offerings of a product and customised services. A good example of this is Rolls-Royce which offers fixed costs maintenance, whereby operators pay for the hours they fly a plane and Rolls-Royce provides a specified level of service. Rolls-Royce uses real-time engine diagnostics allowing managing the engine on-wing and reducing the time engines to be in the workshop (Aviationtoday, 1 June 2006). Over 50% of Rolls-Royce's sales come from maintenance services (Shifrin in Aviation Week, 2007). This combination of physical products with add-on services such as maintenance has been an important trend in the past and is expected to continue. Systems assemblers, increasingly move to the provision of customised life cycle support services and solutions, often through partnerships with others. But this also means that producers retain operating risks of the products they sell. However, such business models might help customers adopt more innovative and risky products, posing a potential stimulus for innovation, as risks for customers can be managed.

**Box 1.3 Maintenance, Repair and Overhaul**

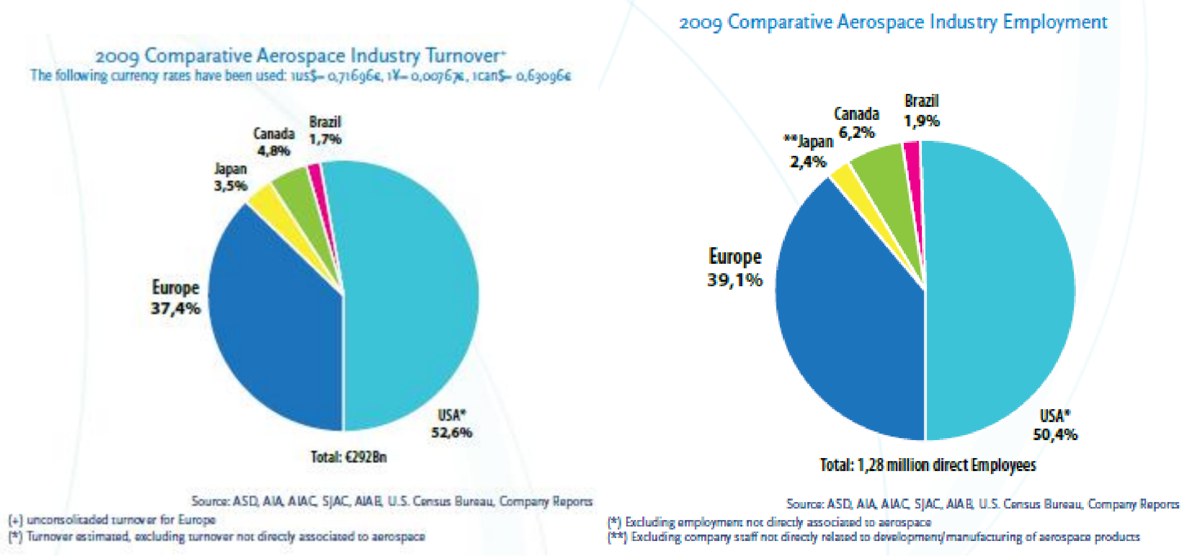
In 2007, 52% of the all MRO activities were outsourced by aircraft operators, but in engines even 75% was outsourced. Of these 75% outsourced MRO, OEMs were had the largest share with 44%, while independent MRO providers had a share of 13% and Airline Third Parties were responsible for 18% (Michaels, 2008). According to a study by the US Office of Aerospace and Automotive Industries (2008) the introduction of composite parts in new aircrafts will decrease the amount of maintenance work required. However, in the engine MRO segment, demand is expected to increase as new engine technologies are increasing the costs of maintaining the engine. Moreover, demand for MRO services of all kind will grow in Asia, due to the strong increase in air traffic in this region. This is confirmed at the North American MRO Convention in 2008 (Doan, 2008).

Another example of the further integration of products and services is the development of Space 'hardware' in combination with new applications and services in downstream markets. The European Galileo network for navigation and positioning, for example, is developed in coordination with the development of new applications using this network.

## 1.3.4 Global industry

The space and aeronautics sectors are still highly concentrated in the EU and the United States. Figure 1.2 gives an indication of the comparative industry turnover and employment for space & aeronautics as calculated by ASD (2010). Although the current space and aeronautics sectors are mainly concentrated in Europe and the US, other important countries in the sectors include Japan, Canada and the emerging BRIC countries (Brazil, Russia, India and China). In 2009, Japan had a turnover of EUR 10,220 million, employing 30,700 people and Canadian aerospace firms realised a turnover of EUR 14,016 million with 79,360 employees (ASD, 2010).

**Figure 1.2 Comparative industry turnover and employment in the space and aeronautics sectors, 2009**




Source: ASD (2010)

The Brazilian aeronautics companies realised a turnover of EUR 4,964 million in 2009, with 24,320 employees (ASD, 2010). The Brazilian aeronautics industry is dominated by Embraer and its suppliers. Embraer ranks fourth in the ranking of top-performing companies in the space and aeronautics sectors (Aviation Week, 2009). Embraer is especially strong in regional aircrafts and has 45% of the market for regional aircrafts with 30 to 60 seats (AIAB, 2009).

Public data about the size of the Russian space and aeronautics sectors are not available. In 2007, the market share of Russia in the worldwide aeronautics sector is estimated at less than 1%. The Russian aeronautics industry is transforming from a weak, fragmented industry to a strong competitor for US and the EU. In 2005, the Russian industry produced only 10 civil airplanes per year, while the demand for air traffic is growing substantial. In 2006, the Russian government started a consolidation process leading to the creation of United Aircraft Corporation (UAC). UAC wants to be the world’s third largest aircraft manufacturer by 2015. UAC and belonging Russian aeronautics companies like Sukhoi sign cooperation agreements with Western aeronautics companies for design, manufacturing and sales and marketing. Moreover, Russian companies are increasingly supplying materials, parts and engineering services for Western commercial aircraft and engine manufacturers and Western companies are opening design centres in Russia (Office of Aerospace and Automotive Industries, 2008). The first new Russian commercial aircraft is Sukhoi’s SuperJet-100, a regional aircraft with 75 to 96 seats. Some 40 global companies from Thales to Goodrich to Boeing are contributing parts to the aircraft and Italy’s Alenia owns a 25% stake in the project (Financial Times, 14 July 2008). Russia is an established space power and after the challenging period in the 1990, it started to rebuild its space capabilities. Russia plans to invest heavily in the space industry, tries to limit foreign investments and continues to consolidate the space industry (Rathgeber, 2009).

For India, public data on the size of the space and aeronautics sectors are lacking as well. The Indian aerospace industry has historically been dominated by government controlled enterprises, with the most prominent Hindustan Aeronautics Limited (HAL). Since 2001, domestic and foreign private investments have been allowed, followed by further liberalisation of the market in 2008, stimulating new players to enter the sector. The industry is growing rapidly, driven by the strong increase in demand for air traffic. India is positioning itself as a manufacturing hub, a preferred destination for manufacturing components. Western aeronautics companies are opening research, design and manufacturing centres in India and they are entering agreements with Indian companies and R&D centres. The Indian government uses offset policy to make sure that Indian procurement of aircrafts from foreign suppliers is partly compensated with foreign investments and outsourcing to the Indian aerospace industry (PricewaterhouseCoopers, 2009). India aims to develop into a major space player as well. The space programmes focus on space applications for civil and military every day uses (e.g. telecommunication), but new priorities are now on space exploration and commercially attractive space activities (Rathgeber, 2009). The Indian Space Research Organisation (ISRO) is developing and operating new satellites for earth observation, navigation and telecommunications.

National statistics about the Chinese space and aeronautics sectors are not available in the present annual Statistical Yearbook of the National Bureau of Statistics in China. The Chine Aerospace industry consists of about 200 firms, which belong to the state-owned Aviation Industry Corporation of China (AVIC). Between 1999 and 2008 AVIC I and II existed. AVIC I focused on large- and medium-sized aircrafts, leasing and general aviation aircraft, while AVIC II produced small aircrafts and helicopters. In 2008, both companies merged again to improve efficiency and being able to compete at global level. In 2008, AVIC had about 400,000 employees. In 2006, the China's Aerospace industry created a value added of USD 3,300 million and spent USD 420 million on R&D (Hollanders et al., 2008). After several decades of knowledge transfer from Western manufacturers to Chinese suppliers, China is investing heavily in its aeronautics industry to become a competitor in the worldwide market and to address the strong growth in domestic demand for air traffic. China focuses on the regional aircrafts market as well as the large civil aircrafts. Also in space, China is investing heavily to accelerate space programmes, not only for human spaceflights, but also for satellite systems and applications. China is also collaborating internationally, in particular with emerging economies and the African continent. The industrial base is undergoing a restructuring process and China plans to create a new centre for aerospace industry in the city of Shenzhen (Rathgeber, 2009)

In order to sell aircrafts to China, Western companies use offset agreements, which arrange that some part of the production is outsourced to Chinese subcontractors. These offset arrangements are a prerequisite to sell aircrafts to China, but it allows for producing components at relatively low costs as well. For example, Airbus has established a joint-venture and opened an assembling line in China to assembly A319s and A320s for Chinese and Western customers. Nevertheless, the collaborations and offset agreements have also resulted in substantial technology transfer, supporting China to become an important competitor. Western companies are becoming aware that in the future they will face competition from Chinese manufacturers when they seek to expand their share of the global aircraft market. MacPherson (2009) predicts that this will happen mid-2020s. Despite this threat, major Western aircraft manufacturers identify China as the single most important market for aircrafts in the coming 20 years, as well as a huge pool of highly skilled engineers. They acquire parts from China, open up research, design and engineering centres in China, and co-partner with Chinese manufacturers to co-produce aircrafts in China. Western companies like Airbus are convinced that their continuous efforts to innovate and focus on technological leadership will help them to compete and protect their intellectual property (Perett in Aviation Week, 2009; Financial Times, 14 July 2008; Office of Aerospace and Automotive Industries, 2008; Council on Foreign Relations, 2007).

### 1.3.5 Global sourcing and supply chain innovations

The space and aeronautics sectors have not only went through an on-going horizontal consolidation, but also the vertical relations have been reshaped (ACARE, 2009; Ecorys, 2009). Although the number of prime system integrators is limited (in civil aeronautics only two global competitors exist) the industry uses a broad, deep, multi-layered and multifaceted supplier base. About 60 to 80% of the end-product value comes from the supplier base (Murman et al., 2002).

**Box 1.4 Global sourcing and currency risks**

Global sourcing is also a way to diversity currency risks in addition to efficiency increases and financial hedging strategies. While EADS generates 70 per cent of its turnover in US Dollar, it only procures 41 per cent of its inputs in US Dollar (Mundt, 2007). With future turnover even expected to reach 80 per cent US dollars, this poses a considerable foreign currency exposure for EADS, that it aims to diversify by increasing its sourcing from firms located in countries operating with US dollars. The foreign currency exposure, but also lower labour costs, can also trigger the relocation of production activities in the sector. EADS expects by 2020 China, India, Russia and South Korea as important production locations, with Brazil, Israel and Canada as additional possible candidates (Mundt, 2007).

In order to improve their performance, the prime manufacturers now concentrate on product and system integration and the management of the supply chain is now their core competency. They increasingly become a total system integrator with a life cycle value provide role, coordinating programmes, taking care of final assembling, and interacting with the markets. According to a recent study by Ecorys (2009), the current phase in vertical evolution of the aeronautics sector is characterised as creating a cooperative supply system. EADS, for example, initiated Vision 2020, which aims for increasing global sourcing, for market access, risk management, lower production costs, and access to rare resources. EADS aims to outsource 50% of the aerostructures work to risk-sharing partners for the A350, compared to 30% with the A380 (Financial Times, 14 July 2008). Suppliers are involved in the design and development of new products. More responsibilities and associated risks are increasingly shifted to suppliers, broadening their product design responsibilities. Firms are linked together as suppliers, customers, partners, and even competitors of each other. As the primes are facing increasing financial pressure from airlines and the financial markets as well as from stronger competition from emerging countries like China, India and Russia, they will urge suppliers to reduce costs, improve the technological level and guarantee higher quality and service levels (ACARE, 2009; Ecorys, 2009). On the one hand, they source products through open IT platforms allowing suppliers to compete openly (Montalvo et al. 2006). This increases competition for suppliers stimulating innovation. On the other hand, primes are seeking long term, stable and reliable relationships with fewer suppliers and outsourcing the design and manufacturing of components and entire sub-systems to external suppliers (e.g. the wing of the Boeing 787) (ACARE, 2009; Murman et al., 2002; Ecorys, 2009). Consortia of competing suppliers are increasingly formed to share the risks of new developments. This is especially relevant for small and medium supply firms, otherwise they are simply too small to meet the prime’s requirements.

By passing on responsibilities and risks to suppliers and urging them to take over the role of sub-system integrators, the role of these suppliers to innovation has become more important. These suppliers do not only need to improve their cost-efficiency, they also need to invest in R&D and innovation. This requires from these suppliers new capabilities and capacities (Mundt, 2007). More cooperation or even consolidation at supplier level is necessary to build up these capabilities. In the development of Galileo, the difficult position of SMEs in carrying risks and making pre-investments was acknowledged (Council of the European Union, 2007).

Shifting activities to suppliers can bring efficiency advantages, but can also contain many risks. Coordinating the complex value chain of many suppliers turns out to be very difficult and prime manufacturers have already faced serious delays resulting from problematic deliveries by suppliers

(Financial Times, 14 July 2008). Supply chain management will increasingly become a crucial capability for the sectors. This is also confirmed by the respondents to the SIW-II survey as they rated in-house know-how and the ability to integrate and use new technologies as factors considerably affecting innovation.

### 1.3.6 Eco-efficiency

Society and governments in general consider aviation as very polluting sector, putting much pressure on the aeronautics sector to limit the environmental impact of aviation and to improve the eco-efficiency. On the one hand, aircrafts should become more energy-efficient, using less fuel and using alternative fuels. On the other hand, aircrafts should produce less CO2 emissions and noise. The United Nations intergovernmental Panel on Climate Change (UN IPCC) estimates that aviation is responsible for 2% of worldwide man-made CO2 emissions and this share could increase to 3% in 2050, given the expected strong increase in air traffic. Using less fuel and lowering the expenses on fuel is not only in the interest of the global climate, but is a main priority for airlines and aircraft manufacturers, as fuel covers 30 to 40% of an airline's operating expenses (Airbus, 2007). Strong business performance and strong environmental performance are two sides of the same coin. Aircraft operators and manufacturers have to work with a broad set of strict regulations and standards concerning noise and emission levels. The European Commission has extended the EU Emissions Trading Scheme (ETS, will apply from 2012 on) to aviation and this puts additional pressure on airlines to improve their eco-efficiency. The societal concerns as well as the strict regulations urges the aeronautics sector to develop cleaner and quieter aircrafts with a greener life cycle from design and manufacturing to dismantling and recycling. In this way, eco-efficiency is a main driver for innovation in the aeronautics sector. Eco-efficiency is the main priority in the Strategic Research Agenda of the Advisory Council for Aeronautics Research in Europe. European aeronautics companies are working together with universities, research organisations, airlines and other stakeholders in the major Joint Technology Initiative Clean Sky aiming at reducing emissions and noise. Another initiative, SESAR, focuses on developing a new pan-European Air Traffic Management system, which should contribute to more flight efficiency. The industry is also working on alternative fuels, like second and third generation biofuels, but also hydrogen and fuel cells. In addition, research efforts focus on, aerodynamic improvements, improved propulsion systems, next generation composite materials, and nanotechnology in devices used in aircrafts (Airbus, 2007; Boeing, 2008a).

Climate change is not only forcing manufacturers to build cleaner and quieter aircrafts, but it provides also opportunities in the satellite market. Decision makers and the public increasingly ask for sound data on the environment coming from earth observation and remote sensing applications. This will stimulate the development of new technologies and applications for earth observation and remote sensing (OECD, 2008).

# 1.4 Innovation performance: an analysis using CIS-4 survey

The sketch of the innovation performance of the space and aeronautics sectors is based on results of the CIS4 survey. The anonymous CIS4 database includes data for 20 European countries. Some relevant countries for the space and aeronautics sectors are missing in the database, including for example the United Kingdom, Germany, the Netherlands and Belgium. For confidentiality reasons, it was not possible to break-down the Space and Aeronautics Sectors in the separate sectors space and aeronautics. As the space sector is only representing about 7% of the space and aeronautics sectors in terms of employment and turnover, the CIS4 survey data will likely say more about the aeronautics sector than the space sector. Section 1.5 presents data on these sectors using other sources than CIS4.

## 1.4.1 General innovation activity

Table 1.4 presents some general indicators describing the innovation activity in the space and aeronautics sectors. The data reveal that the space and aeronautics sectors are rather innovative. About 50% of the companies are engaged in any innovation activity (introducing a new product, process or service on the market). The sectors are also very R&D intensive when compared with the average for all manufacturing sectors. Almost 85% of the companies are engaged in intramural (in-house) R&D, compared to about 22% for the average of all manufacturing sectors. Companies in the space and aeronautics sectors also spend a substantial larger share of their turnover on R&D: 20.9% in 2004 compared to only 3.7% for the average of all manufacturing sectors. Aerospace companies do not only invest relatively large amounts in R&D, but they are also very active in providing training: almost three quarter of the firms arranges training for their employees, compared to almost half of the companies on average for all manufacturing sectors.

Aerospace companies are also more than average engaged in the market introduction of innovations (43.4% compared to 33.6%). Almost 40% introduced a new or significantly improved product and 30.6% introduced a new or significantly new service. Also new or significantly improved production methods are introduced, by almost 35% of the Aerospace companies. Over 40% of the Aerospace companies are engaged in activities (e.g. market research and launch advertising) for the introduction of the new products and services.

**Table 1.4 General innovation activity in the space and aeronautics sectors, per country group**

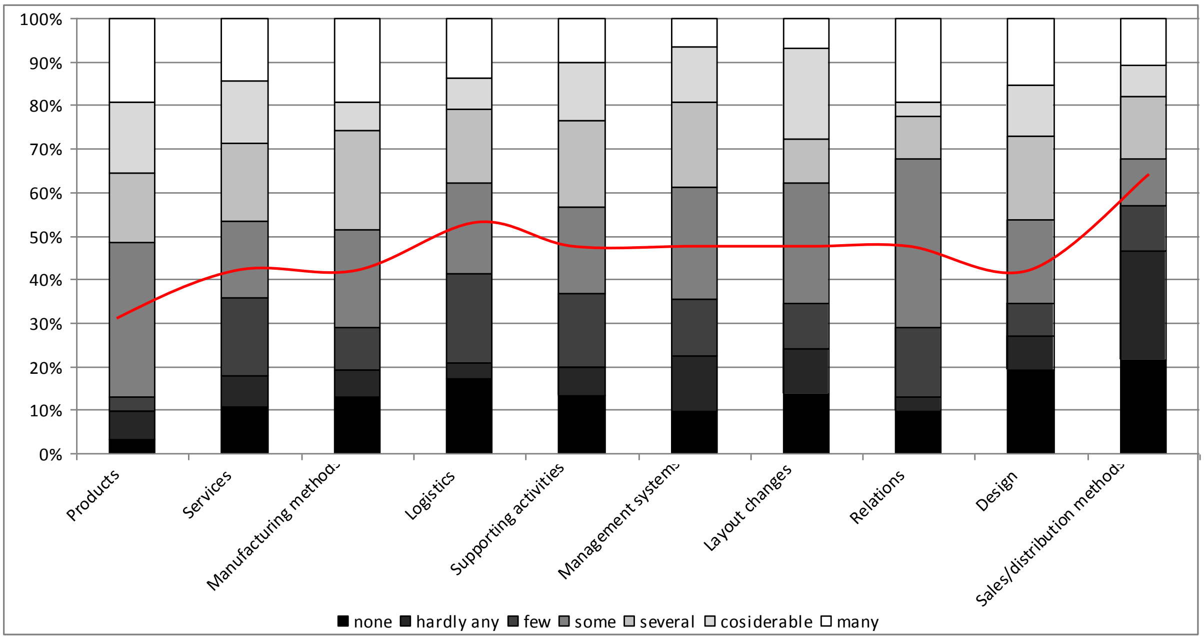
| | Country group | | | | | |
|---|---|---|---|---|---|---|
| **Indicator** | **West and North**[1)] | **Central and East**[2)] | **South**[3)] | **Country group Aerospace AVG**[4)] | **Total AVG**[5)] | **GAP**[6)] |
| General innovation activity (introducing new product, service or process) | 51.1% | 45.6% | 52.4% | 50.6% | n/a | n/a |
| Introduced onto the market a new or significantly improved good | 40.5% | 35.1% | 36.8% | 38.4% | n/a | n/a |
| Introduced onto the market a new or significantly improved service | 40.3% | 13.1% | 25.0% | 30.6% | n/a | n/a |
| Introduced onto the market a new or significantly improved method of production | 37.0% | 14.2% | 41.8% | 34.6% | n/a | n/a |
| Engagement in intramural R&D | 89.1% | 70.0% | 84.1% | 84.5% | 21.5% | 393% |
| Total R&D expenditure / Total turnover in 2004 | 16.0% | 17.1% | 30.1% | 20.9% | 3.7% | 559.5% |
| Engagement in training | 80.9% | 50.4% | 66.3% | 71.3% | 48.6% | 146.7% |
| Engagement in activities for the market introduction of innovation | 45.9% | 41.3% | 40.6% | 43.4% | 33.6% | 129.2% |
| Engagement in acquisition of machinery | 78.1% | 57.9% | 85.4% | 77.4% | 75.8% | 102.1% |
| Export (EU or outside EU) | 1.1% | 56.0% | 4.9% | 10.9% | n/a | n/a |

Notes: 1) Country group 'West and North' includes Sweden, Norway, Denmark, Luxembourg and France; 2) Country group 'Central and East' includes Czech Republic, Hungary, Romania, Bulgaria, Estonia, Latvia, Lithuania, Slovak Republic and Slovenia; 3) Country group 'South' includes Spain, Portugal, Greece and Italy; 4) Weighted average for the total Space and Aeronautics Sectors, based on weighted frequencies for the three country groups; 5) Average for all manufacturing sectors, based on a Core NACE including all countries in the sample; 6) Gap as % of the total AVG, calculated as Aerospace AVG / Total AVG.
Source: Eurostat CIS 4

In a survey conducted by the SIW-II consortium, including 441 usable cases, of which 31 aerospace, respondents were asked to indicate on a scale from one to seven to what extent their organisation engages in different types of innovation[3]. Important to note is the inverse scale, with a value of one indicating 'many' innovation activities, and at the opposite end of the scale seven indicating 'no' innovation activities. Figure 1.3 shows that aerospace firms engage more often in product, manufacturing methods and services innovation. This is in line with the focus on technological innovation, the aim of lowering development and production time and costs, the increasingly complex development and production networks and the increasing integration of services. More than the absolute results, the relative performance compared to the total survey population highlights important characteristics of the sector.

[3] The survey is conducted in Task 3 of the Sectoral Innovation Watch, 'Analysis of market and regulatory factors influencing sector innovation patterns'. For the complete analysis, see the report by Montalvo et al., 2011

**Figure 1.3 Frequency distribution of survey responses by innovation type**




For the whole dataset[4]

| | Products | Services | Manuf. methods | Logistics | Sup activ | Mgt systems | Layout changes | Actor interaction | Design | Sales |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 3,1 | 3,5 | 4,0 | 4,1 | 4,0 | 4,2 | 4,2 | 4,0 | 4,4 | 4,4 |
| Std.D | 1,7 | 1,7 | 1,9 | 1,9 | 1,8 | 1,8 | 1,9 | 1,9 | 2,0 | 2,0 |

For the sector

| | Products | Services | Manuf. methods | Logistics | Sup activ | Mgt systems | Layout changes | Actor interaction | Design | Sales |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 3,2 | 3,8 | 3,7 | 4,1 | 3,9 | 4,0 | 4,0 | 3,8 | 3,9 | 4,6 |
| Std.D | 1,6 | 1,9 | 1,9 | 1,9 | 1,8 | 1,7 | 1,9 | 1,8 | 2,1 | 2,0 |

Compared with the whole dataset, firms in the space and aeronautic sectors are relatively more engaged in product, service and sales innovation. This result is in line with a sector known for focusing on developing technologically innovative products. The relative higher engagement in services reflects the increasing number of manufacturing firms providing services, and innovation trajectories for goods and services get increasingly entangled. On the other hand, one could expect higher engagement in process-oriented innovation, actors interaction, layout changes and management systems, as innovation in these areas seem to be highly important when development and production is increasingly taking place in complex global R&D and production networks. Moreover, these types of innovation are also relevant when aiming for higher competitiveness by lower development and production time and costs.

According to CIS4 data, the aerospace companies in the country group ‘West and North’ are the most active in carrying out intramural R&D; 89.1% of the companies are engaged in intramural R&D, closely followed by the companies in country group ‘South’ with 84.1%. In the country group ‘Central and

[4] The SIW-II survey results are interpreted based on three different methods. 1) The frequency graphs that show the response distribution but do not weigh the responses. 2) The mean value and standard deviation of responses that are used to identify the most important factors and compare the responses to the total survey population. 3) Correlation coefficients for significant correlations between factors and different innovation types.

East' somewhat less companies are engaged in intramural R&D (70%). While the level of engagement in intramural R&D is almost the same for companies in 'West and North' and 'South', the aerospace companies in the country group 'South' spend twice as much on R&D (30.1% of the turnover compared to 16 and 17.1% of the turnover). The companies in country group 'South' are also more engaged in the acquisition of machinery than companies in the other groups (85.4% compared to 78.1% for 'West and North' and 57.9% for 'Central and East').Training of employees is especially present in country group 'North and West'; 80.9% of the companies are engaged in training, compared to 66.3% of the companies in 'South' and 50.4% in 'Central and East'.

While the companies in the country group 'Central and East' realise about the same level of market introductions of new or significantly improved products, these companies really lag behind with regard to the introduction of new services and production methods; 13.1% and 14.2% compared to respectively 40.3% and 37% for4 the companies in the country group 'West and North'. The gap between the market introduction performance of the companies in the country groups 'West and North' and 'South' is much smaller, except for the introduction of new services. In introducing new services, the companies in the country group 'West and North' perform much better than companies in the country group 'South' (40.3% compared to 25%).

According to CIS4 data, almost 11% of the companies in the aerospace sector export. There is a big difference in exporting between the three country groups. Companies located in the country group 'West and North' hardly export, while more than 50% of the companies located in 'Central and East' export their goods and services to another country. The data present a distorted picture here, as some European countries with large, internationally operating system integrators are not included. Moreover, given the international characteristic of the aerospace markets, it is hard to think of an aerospace company that does not export. On the other hand, the substantial export activities of companies in 'Central en East' can indicate that manufacturing of components and sub-systems is increasingly done by suppliers in this area.

When considering the size of the companies in the space and aeronautics sectors, table 1.5 shows that large firms are the most active in R&D. Almost 90% of the large firms engage in intramural R&D, compared to 75.6% of the small firms and 87.7% of the medium sized companies. Medium sized firms active in intramural R&D are the most R&D intensive; they spend the largest share of their turnover on R&D (28.9%). Large firms spend 20% of their turnover on R&D, while small firms spend 16.3%. Large companies are more heavily engaged in training and in the acquisition of machinery than small and medium sized firms (13 to 14 percentage points more). Although the medium sized firms are the most R&D intensive, this does not result in more innovation activity than for the other firm sizes. Moreover, the small firms are almost equally active in introducing innovations on the market, while they are substantially less active in intramural R&D than the medium sized firms.

When looking into more detail, large firms are driving the introduction of new products, services and production methods on the market. Twice as much than companies in the other categories large companies introduced a new product or service on the market. Moreover, large firms introduced new production methods three times more than small and medium sized companies. The medium sized companies are more active in selling their products and services outside their home country; twice as much as small and large companies. Combined with their high R&D-intensity, this could indicate that medium sized firms are often highly specialised suppliers at the tier 1 or 2 level, producing components for the sub-system integrators.

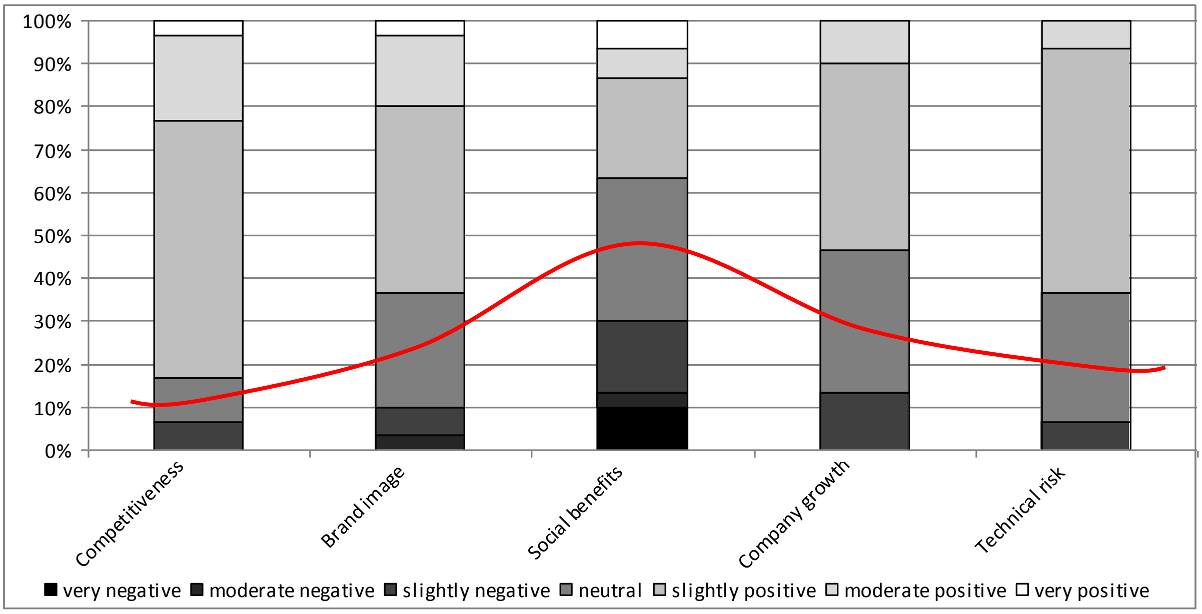
**Table 1.5 General innovation activity in the space and aeronautics sectors, per firm size**

| | **Firm size group** | | | | | |
|---|---|---|---|---|---|---|
| **Indicator** | **Small** | **Medium** | **Large** | **Firm size Aerospace AVG[1)]** | **Total AVG** | **GAP** |
| General innovation activity (introducing new product, service or process) | 35.8% | 43.1% | 89.3% | 58.3% | n/a | n/a |
| Introduced onto the market a new or significantly improved good | 28.0% | 32.9% | 65.2% | 43.6% | n/a | n/a |
| Introduced onto the market a new or significantly improved service | 19.4% | 27.3% | 57.7% | 37.0% | n/a | n/a |
| Introduced onto the market a new or significantly improved method of production | 21.5% | 27.1% | 70.7% | 41.6% | n/a | n/a |
| Engagement in intramural R&D | 75.6% | 87.7% | 89.9% | 84.5% | 21.5% | 393% |
| Total R&D expenditure / Total turnover in 2004 | 16.3% | 28.9% | 20.0% | 20.9% | 3.7% | 564.9% |
| Engagement in training | 65.8% | 65.3% | 79.6% | 71.5% | 48.6% | 147.1% |
| Engagement in activities for the market introduction of innovation | 46.4% | 36.1% | 45.4% | 43.5% | 33.6% | 129.5% |
| Engagement in acquisition of machinery | 73.4% | 71.6% | 84.6% | 77.6% | 75.8% | 102.4% |
| Export (EU or outside EU) | 8.4% | 19.3% | 8.2% | 10,9% | n/a | n/a |

Note: 1) Weighted average for the total Space and Aeronautics Sectors, based on weighted frequencies for the three firm size categories
Source: Eurostat CIS 4

To assess why firms innovate, firms in the SIW-II survey were asked to indicate on a seven point scale how innovation increased or decreased their competitiveness, improved their brand image, created large or minor social benefits, had good or bad effect on company growth and whether it was a large technical success or a large technical failure. In contrast to the preceding section, a value of seven represents the positive end of the scale, whereas a value of one represents the negative end of the scale. The graph below shows that innovation activities of most firms increase competitiveness. However, most respondents have chosen a middle value indicating that innovation is essential to stay in competition rather than gaining large advantages. Similarly the majority of respondents indicated that innovation improves their brand image. About the effect on social benefits respondents are divided. Whereas at the extremes, some see minor as well as large social benefits of innovation in the space and aeronautics sectors, the majority chooses some middle value. This might have to do with firm perspective of the respondents: whereas social benefits of innovation in regards to safety performance of aircraft is very clear, likewise for downstream space applications for Earth Observation or fuel-efficient engines, other innovation efforts in the sector might be less socially oriented.

**Figure 1.4 Frequency distribution of survey responses by outcome of innovation activity**




In regards to company growth and technical success / failure, no extremely positive or negative effects are reported. On average both show a slight positive effect of innovation on company growth and technical risk.

For the whole dataset:

| | Competitiveness | Brand image | Social benefits | Company growth | Technical risk |
|---|---|---|---|---|---|
| Mean | 4,9 | 4,7 | 4,2 | 4,7 | 4,8 |
| Std. Dev | 1,0 | 1,2 | 1,3 | 1,1 | 1,0 |

For the sector:

| | Competitiveness | Brand image | Social benefits | Company growth | Technical risk |
|---|---|---|---|---|---|
| Mean | 5,0 | 4,7 | 4,0 | 4,5 | 4,6 |
| Std. Dev | 0,9 | 1,0 | 1,5 | 0,9 | 0,7 |

Interestingly, in comparison to the total population aerospace firms report similar positive effects of innovation on competitiveness and brand image. This matches the image of an R&D-intensive and highly innovative sector. However, relatively fewer effects on social benefits, company growth and technology development are reported. This can in parts be explained with the mature structure of the sector, where it is difficult for firms to grow, where the contribution to social challenges is not evident through the whole sector and where technology development is subject to many risks as in examples such as the A400M, A380 and Dreamliner highlight.

Next to the reported results of the survey above, a correlation analysis has been conducted to identify potential relationships between the different types of innovation and the outcomes of innovation. The results for the aerospace sector show only significant correlation coefficients between innovation types on the one hand and the competitiveness and company growth of aerospace firms. Particularly, high correlation coefficients can be found between competitiveness of firms on the sector on the one hand and their innovation activities in regards to management systems, layout changes in production and interaction between actors in the sector. This is in line with the current trends in the space and aeronautics sectors such as focusing on cost-efficiency, decreasing development time and costs, consolidation of the sector and the (new) roles of the main integrators/assemblers and specialised suppliers of subsystems and components. Moreover, in both space and aeronautics, the innovation process can involve firms from upstream and downstream markets (and sectors). Examples are defence, automobile, ICT equipment, airports and air traffic systems.

### 1.4.2 Introduction of new products

As mentioned before, the CIS4 data mainly say something about the aeronautics sector and not so much about space. Two-third of the companies in the space and aeronautics sectors introduced a product that was new to the market (Table 1.6). This is substantially higher than in average for all manufacturing sectors (62.2% compared to 11.2%). The intensity of introducing products that were new to the market was almost equal in the three country groups. However, 88.3% of the aerospace companies in the country group ‘Central and East’ introduced products that were new to the firm, which is almost twice as much as the companies in the other two country groups. In addition, firms in ‘Central and East’ realised more turnover from products new to the firm (23.75%) than from new to the market (6.9%). Combined with the previous analysis that these firms introduced more new products than new processes and services, this could indicate that firms in the ‘Central and East’ countries are mainly catching up by adopting and copying industry-wide innovations.

Despite the rather high level of new product introductions, most of the turnover is still realised by unchanged or marginally modified products. In the country group ‘West and North’ 80.5% of the turnover was realised by existing products, while only 6% came from products that were new to the firm and 13.5% came from products that were new to the market. For companies in the country group ‘South’, the new products contribute a bit more to the total turnover; 13.3% of the turnover was realised by products new to the firm, while 17.4% came from products that are new to the market. A possible explanation is that the short term, market impact of innovation space and aeronautics is only part of the total impact. As mentioned above, the technology trajectories and life cycles are long. A three year time lag, which is used in CIS4, is probably too short to capture the impact of space and aeronautics innovations. Table 1.6 presents the findings for the various country groups.

**Table 1.6 Introduction of new products in the space and aeronautics sectors, per country group**

| | Country group | | | | | |
|---|---|---|---|---|---|---|
| | West and North[1)] | Central and East[2)] | South[3)] | Country group Aerospace AVG[4)] | Total AVG[5)] | GAP[6)] |
| Did the enterprise introduce a product new to the market | 62.8% | 64.9% | 60.0% | 62.2% | 11.2% | 555.4% |
| Did the enterprise introduce a product new to the firm | 46.7% | 88.3% | 48.7% | 53.8% | 12.5% | 430.4% |
| % of turnover in new or improved products introduced during 2002-2004 that were new to the market | 13.5% | 6.9% | 17.4% | 13.8% | 11.2% | 123.2% |
| % of turnover in unchanged or marginally modified products during 2002-2004 that were new to the firm | 6.0% | 23.7% | 13.3% | 11.2% | 12.5% | 89.6% |
| % of turnover in unchanged or marginally modified products during 2002-2004 | 80,5% | 50,3% | 57,3% | 68,0% | 72,9% | 93.3% |

Notes: 1) Country group 'West and North' includes Sweden, Norway, Denmark, Luxembourg and France; 2) Country group 'Central and East' includes Czech Republic, Hungary, Romania, Bulgaria, Estonia, Latvia, Lithuania, Slovak Republic and Slovenia; 3) Country group 'South' includes Spain, Portugal, Greece and Italy; 4) Weighted average for the total Space and Aeronautics Sectors, based on weighted frequencies for the three country groups; 5) Average for all manufacturing sectors, based on a Core NACE including all countries in the sample; 6) Gap as % of the total AVG, calculated as Aerospace AVG / Total AVG. Source: Eurostat CIS 4

When considering the size of the companies, almost an equal share of small, medium and large firms introduced a product which is new to the market (59.6 to 64.2%). Nevertheless, a larger share of small firms introduced a product new to the firm (66.9%), compared to medium sized firms (38.3%) and large firms (49.1%). All firm sizes realised most of their turnover by existing products; large firms a bit more than small firms (72.6% compared to 60.9%). As a relatively larger share of small firms introduced a product that is new to the firm, this size category also realises more turnover from this type of products (18.2% compared to 7.5% and 7.7% for medium and large firms). The share of turnover coming from products that are new to the market is almost equal for the three different size categories. Table 1.7 presents the finding for the various firm size categories.

**Table 1.7 Introduction of new products in the space and aeronautics sectors, per firm size**

| | Firm size | | | | | |
|---|---|---|---|---|---|---|
| | Small | Medium | Large | Firm size Aerospace AVG [1)] | Total AVG | GAP |
| Did the enterprise introduce a product new to the market | 59,6% | 62,1% | 64,2% | 62,2% | 11,2% | 466.1% |
| Did the enterprise introduce a product new to the firm | 66,9% | 38,3% | 49,1% | 52,5% | 12,5% | 420% |
| % of turnover in new or improved products introduced during 2002-2004 that were new to the market | 12,7% | 14,5% | 14,3% | 13,8% | 11,2% | 123.2% |
| % of turnover in unchanged or marginally modified products during 2002-2004 that were new to the firm | 18,2% | 7,5% | 7,7% | 11,2% | 12,5% | 89.6% |
| % of turnover in unchanged or marginally modified products during 2002-2004 | 60,9% | 69,9% | 72,6% | 68,0% | 72,9% | 93.3% |

Note: 1) Weighted average for the total Space and Aeronautics Sectors, based on weighted frequencies for the three firm size categories Source: Eurostat CIS 4

### 1.4.3 Intellectual property rights

In general, 38.2% of the companies in the space and aeronautics sectors secure their intellectual property rights; their efforts in securing intellectual property rights are much stronger than on average for all manufacturing sectors (see table 1.8). Especially in applying for a patent, Aerospace companies are more active than on average. Although the CIS4 data indicate a high patent activity for aerospace companies, representatives of the space sector in the sectoral innovation panels of the SYSTEMATIC consortium (SIW-I) mentioned that secrecy is also widely used to secure intellectual property. This cannot be found in the CIS4 data, as industrial secrets are not mentioned in the CIS survey.

Companies in the 'West and North' and the 'South' group (46.1% and 38.8% respectively) are substantially more active in securing their intellectual property rights than companies in the 'Central and East' group (11.0%). This matches the results that these companies were less active in R&D than companies in the other country groups and that they introduced more products that are new to the firm than new to the market.

Applying for a patent is chosen mostly, especially companies in 'West and North' (49.2%), followed by companies in 'South' (34.2%). Claiming copyright is the least favourite option, with 8.5% of the companies in the country group 'West and North' and '6% in 'South'. Registering an industrial design is done by 26.8% of the firms in 'West and North' and by 15.2% of the companies in 'South'. Claiming copyright and registering an industrial design appears not to be an option for companies in 'Central and East', although 7% of the companies in this country group register trademarks. However, this is far less than companies in the 'West and North' (20.8%) and 'South' (11.8%).

**Table 1.8 Securing intellectual property rights in the space and aeronautics sectors, per country group**

| | Country group | | | | | |
|---|---|---|---|---|---|---|
| **Indicator** | **West and North[1)]** | **Central and East[2)]** | **South[3)]** | **Country group Aerospace AVG[4)]** | **Total AVG[5)]** | **GAP[6)]** |
| General intellectual property rights | 46,1% | 11,0% | 38,8% | 38,2% | n/a | n/a |
| Applied for a patent | 49,2% | 3,7% | 34,2% | 37,0% | 15,9% | 232.7% |
| Claimed copyright | 8,6% | 0,0% | 6,0% | 6,4% | 4,5% | 142.2% |
| Registered an industrial design | 26,8% | 0,0% | 15,2% | 18,7% | 17,4% | 107.5% |
| Register a trademark | 20,8% | 7,4% | 11,8% | 15,7% | 16,0% | 98.1% |

Notes: 1) Country group 'West and North' includes Sweden, Norway, Denmark, Luxembourg and France; 2) Country group 'Central and East' includes Czech Republic, Hungary, Romania, Bulgaria, Estonia, Latvia, Lithuania, Slovak Republic and Slovenia; 3) Country group 'South' includes Spain, Portugal, Greece and Italy; 4) Weighted average for the total Space and Aeronautics Sectors, based on weighted frequencies for the three country groups; 5) Average for all manufacturing sectors, based on a Core NACE including all countries in the sample; 6) Gap as % of the total AVG, calculated as Aerospace AVG / Total AVG.
Source: Eurostat CIS 4

When considering the size of the companies, large firms are the most active in securing intellectual property rights; 57.7% of the large firms compared to 37.7% of the medium sized firms and 14.3% of the small firms. The differences between the three size classes are more substantial than one would expect given the almost similar share of companies introducing a new product to the market in the three size classes. Large firms are also more active in applying for a patent; 60% compared with 31.4% of the medium firms and only 10% of the small firms. A main reason for this big difference between the size categories is that applying for a patent is a very complex and costly process, which can hardly be carried by smaller companies.

Claiming a copyright is the least favourite option; 15.1% of the large companies have claimed copyright, while none of the small and medium sized firms have done this. Registering a trade mark is a bit more popular by small firms than by medium sized firms (8.5% compared to 2.5%), but again substantially more large firms have chosen this option (28.4%). About one quarter of the large firms has registered an industrial design; this is twice as much as the small and medium sized firms. Table 1.9 presents the findings for the size categories.

**Table 1.9 Securing intellectual property rights in the space and aeronautics sectors, per firm size**

| | **Firm size** | | | | | |
|---|---|---|---|---|---|---|
| **Indicator** | **Small** | **Medium** | **Large** | **Firm size Aerospace AVG**[1)] | **Total AVG** | **GAP** |
| General intellectual property rights | 14,3% | 37,7% | 57,7% | 38,2% | n/a | n/a |
| Applied for a patent | 9,8% | 31,4% | 60,0% | 36,0% | 15,9% | 226.4% |
| Claimed copyright | 0,0% | 0,0% | 15,1% | 6,3% | 4,5% | 140% |
| Registered an industrial design | 11,8% | 14,3% | 25,2% | 18,0% | 17,4% | 103.4% |
| Register a trademark | 8,5% | 2,5% | 28,4% | 15,4% | 16,0% | 96.3% |

Note: 1) Weighted average for the total Space and Aeronautics Sectors, based on weighted frequencies for the three firm size categories
Source: Eurostat CIS 4

## 1.4.4 Cooperation

Cooperating in innovation activities is important in the space and aeronautics sectors; 53% of the companies in these sectors cooperate with other companies when innovating, this is twice as high as the average for all manufacturing sectors. Companies in the country groups 'Central and East' and 'South' are more or less at the same level, while companies in the country group 'West and North' cooperate somewhat less than the sectors average (39.5%). About 95% of the Aerospace companies that cooperate collaborate with national partners, which is almost equal for the three country groups.

The aerospace companies also cooperate extensively with partners abroad; three-quarter of the collaborating firms cooperate with international partners. Collaborating firms located in the country group 'Central and East' have relatively more international partners than companies from the other country groups (90.6% compared to 69.9% for 'South' and 77.6% for 'West and North'). About 60% of the collaborating aerospace companies cooperate with other enterprises within their enterprise group. These ties are substantially stronger than in average for all manufacturing sectors (8.7%). This high percentage reflects the consolidation process of the past decade, as well as the fact that several larger aerospace companies have subsidiaries in various European countries. Especially in 'West and North', companies collaborate with their enterprise group (70.4%), compared to 30.4% in 'Central and East' and 58.8% in 'South'. Collaborations with national universities, research institutes and government institutions are also important in the aerospace sector; about 70.8% of the collaborating companies have joint projects with national universities and research organisations. In the 'South' these linkages are more frequently available than in the 'West and North' (77.1% compared to 65.4%). Aerospace companies also collaborate with international universities and research institutes, but less frequent than with national partners; 21.5% in average, with 28.3% for the companies in 'West and North' and 18.2% for 'South'. None of the companies located in 'Central and East' collaborated with international universities. Three-quarter of the collaborating aerospace firms cooperated with national suppliers, clients and competitors. This vertical and horizontal collaboration in the value chain is even a bit stronger in 'West and North' (83.8%) and 'Central and East' (81.3%). Table 1.10 presents the findings on collaboration for the three country groups.

**Table 1.10 Cooperation arrangements in innovation in the space and aeronautics sectors, per country group**

| | Country group | | | | | |
|---|---|---|---|---|---|---|
| | **West and North[1)]** | **Central and East[2)]** | **South[3)]** | **Country group Aerospace AVG[4)]** | **Total AVG[5)]** | **GAP[6)]** |
| Cooperation arrangements on innovation activities | 39,5% | 56,0% | 54,6% | 53,0% | 25,1% | 211.2% |
| Cooperation with national partners | 97,9% | 90,7% | 93,0% | 95,4% | 23,0% | 414.8% |
| Cooperation with international partners | 77,6% | 90,6% | 69,9% | 76,4% | 11,8% | 647.5% |
| Cooperation with international partners outside own enterprise group | 75,4% | 90,6% | 69,9% | 75,3% | 5,1% | 1441.2% |
| Cooperation with other enterprises within enterprise group | 70,4% | 30,4% | 58,8% | 61,7% | 8,7% | 709.2% |
| Cooperation with National Universities / Government or research institutes | 65,4% | 76,8% | 77,1% | 70,8% | n/a | n/a |
| Cooperation with International Universities / Government or research institutes | 28,3% | 0,0% | 18,2% | 21,5% | n/a | n/a |
| Cooperation with national suppliers, clients or competitors | 83,8% | 81,3% | 63,2% | 76,4% | n/a | n/a |

Notes: 1) Country group 'West and North' includes Sweden, Norway, Denmark, Luxembourg and France; 2) Country group 'Central and East' includes Czech Republic, Hungary, Romania, Bulgaria, Estonia, Latvia, Lithuania, Slovak Republic and Slovenia; 3) Country group 'South' includes Spain, Portugal, Greece and Italy; 4) Weighted average for the total Space and Aeronautics Sectors, based on weighted frequencies for the three country groups; 5) Average for all manufacturing sectors, based on a Core NACE including all countries in the sample; 6) Gap as % of the total AVG, calculated as Aerospace AVG / Total AVG.
Source: Eurostat CIS 4

When taking into account the different sizes of the firms in the sectors, table 1.11 shows that large firms cooperate in innovation almost twice as much than medium sized and small firms. National collaborations are important to all size categories, but especially to the medium sized firms (100%). Almost an equal share of collaborating small, medium sized and large firms have international partners. Ties between enterprises within the same enterprise group are mainly relevant for large firms (76% compared to about 40% for medium sized and small firms), which is logical taking into account that these large firms are often groups consisting of several subsidiaries. This holds also for collaborations with national universities and research organisations. Moreover, one third of the collaborating large firms cooperate with international universities and research organisations, while this is not practice for the small and medium sized firms. Horizontal and vertical collaboration in the value chain is also very relevant for the large firms, but even more for medium sized firms (82.5%).

**Table 1.11 Cooperation arrangements in innovation in the space and aeronautics sectors, per firm size**

| | Firm size | | | | | |
|---|---|---|---|---|---|---|
| | **Small** | **Medium** | **Large** | **Aerospace AVG[1)]** | **Total AVG** | **GAP** |
| Cooperation arrangements on innovation activities | 34,8% | 40,6% | 74,8% | 53,0% | 25,1% | 211.2% |
| Cooperation with national partners | 84,0% | 100,0% | 98,2% | 95,4% | 23,0% | 415.7% |
| Cooperation with international partners | 71,9% | 70,7% | 79,9% | 76,4% | 11,8% | 647.5% |
| Cooperation with international partners outside own enterprise group | 71,9% | 70,7% | 78,0% | 75,3% | 5,1% | 1441.2% |
| Cooperation with other enterprises within enterprise group | 39,6% | 42,8% | 76,0% | 61,7% | 8,7% | 709.2% |
| Cooperation with National Universities / Government or research institutes | 43,4% | 54,5% | 86,3% | 70,8% | n/a | n/a |
| Cooperation with International Universities / Government or research institutes | 0,0% | 0,0% | 36,3% | 21,5% | n/a | n/a |
| Cooperation with national suppliers, clients or competitors | 62,2% | 82,5% | 79,8% | 76,4% | n/a | n/a |

Note: 1) Weighted average for the total Space and Aeronautics Sectors, based on weighted frequencies for the three firm size categories
Source: Eurostat CIS 4

### 1.4.5 Public funding

Public funding is widely used by aerospace companies. Again, the CIS4 data give indications about the aeronautics sector more than the space sector. Over 80% of the firms use public funding, compared to 28.9% for the average of all manufacturing sectors. The importance of public funding is in line with the general notion of high tech sectors with long term investments, with uncertain outcomes and spill overs to other sectors.

Public funding is especially used by companies in ‘West and North (97.8%), followed by companies in ‘South’ (75.1%) and substantially less by companies in ‘Central and East’ (51.3%). Most funding comes from the central government, reflecting the fact that aerospace is in many countries considered as a national priority because of its role in national security and its contribution to societal challenges. Over 50% of the companies in ‘West and North’ and ‘South’ use national funding, while only 32.2% of the firms in ‘Central and East’ use national funding. Regional funding is used by about 40% of the firms in ‘West and North’ and ‘South’, while only by 5.5% of the companies in ‘Central and East’. Public funding coming from the EU is also used; 29.7% of the firms in ‘South’, while only 7.3% of the firms in ‘Central and East’. Funding from the European Framework Programmes is also relevant; over 80% of the companies located in ‘West and North’ use this type of funding, followed by 42.3% of the companies in ‘South’ and 11.4% of the companies in ‘Central and East’. Table 1.12 presents the findings for the country groups.

Public funding is heavily used by large firms (95.2%) and medium sized firms (86.9%), but less by small firms (53.5%), although still substantially more on average for all manufacturing sectors. Public funding is often available for larger research and development programmes, which will be more difficult for smaller companies to participate in. Funding from the central government is mainly important for large firms (68.6% compared to 26.2% for small firms), more than regional funding, which is more important for medium sized firms (44.5%, compared to 27.9% for large firms). Large firms are also able to use public funding from the EU (44.25), which appears of minor relevance to the other size categories. Moreover, funding from European Framework Programmes is also mainly used by large firms (69.1%), followed by medium sized firms (36.8%) and small firms (4.7%). Table 1.13 presents the findings per firm size.

**Table 1.12 Public funding in the space and aeronautics sectors, per country group**

| | **Country group** | | | | | |
|---|---|---|---|---|---|---|
| | **West and North[1)]** | **Central and East[2)]** | **South[3)]** | **Country group Aerospace AVG[4)]** | **Total AVG[5)]** | **GAP[6)]** |
| Any public funding | 97,8% | 51,3% | 75,1% | 82,9% | 28,9% | 286.9% |
| Public funding from local or regional authorities | 40,2% | 5,5% | 37,3% | 33,8% | 15,5% | 218.1% |
| Public funding from central government | 55,2% | 32,2% | 51,3% | 50,3% | 15,4% | 326.6% |
| Public funding from the EU | 22,7% | 7,3% | 29,7% | 22,6% | 5,8% | 389.7% |
| Funding from EU's 5th or 6th RTD | 82,2% | 11,4% | 42,3% | 57,7% | 2,6% | 2219.2% |

Notes: 1) Country group 'West and North' includes Sweden, Norway, Denmark, Luxembourg and France; 2) Country group 'Central and East' includes Czech Republic, Hungary, Romania, Bulgaria, Estonia, Latvia, Lithuania, Slovak Republic and Slovenia; 3) Country group 'South' includes Spain, Portugal, Greece and Italy; 4) Weighted average for the total Space and Aeronautics Sectors, based on weighted frequencies for the three country groups; 5) Average for all manufacturing sectors, based on a Core NACE including all countries in the sample; 6) Gap as % of the total AVG, calculated as Aerospace AVG / Total AVG.
Source: Eurostat CIS 4

**Table 1.13 Public funding in the space and aeronautics sectors, per firm size**

| | **Firm size** | | | | | |
|---|---|---|---|---|---|---|
| **Indicator** | **Small** | **Medium** | **Large** | **Aerospace AVG[1)]** | **Total AVG** | **GAP** |
| Any public funding | 53,5% | 86,9% | 95,2% | 79,1% | 28,9% | 273.7% |
| Public funding from local or regional authorities | 31,2% | 44,5% | 27,9% | 33,1% | 15,5% | 213.5% |
| Public funding from central government | 26,2% | 50,8% | 68,6% | 49,9% | 15,4% | 324% |
| Public funding from the EU | 1,9% | 15,1% | 44,2% | 22,8% | 5,8% | 393.1% |
| Funding from EU's 5th or 6th RTD | 4,7% | 36,8% | 69,1% | 39,5% | 2,6% | 1519.2% |

Note: 1) Weighted average for the total Space and Aeronautics Sectors, based on weighted frequencies for the three firm size categories
Source: Eurostat CIS 4

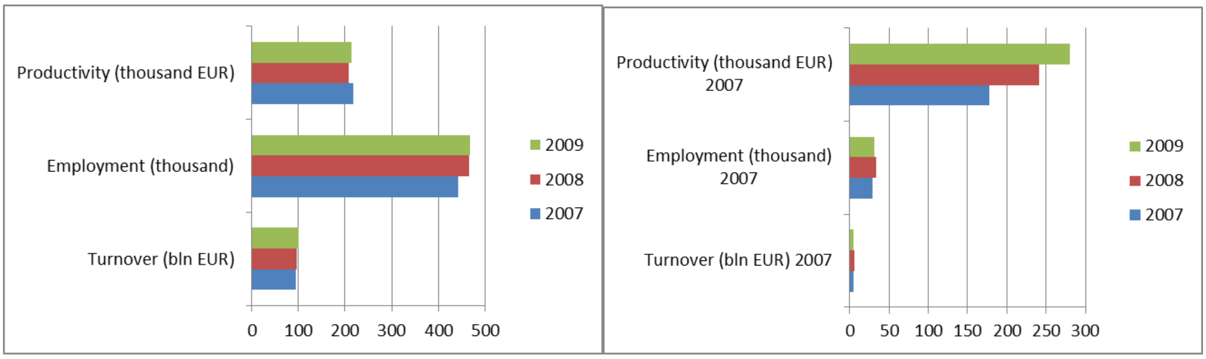
# 1.5 Economic and innovation performance: analysis of additional data sources

This section analyses other statistical data that complements the analysis above. These statistics will be used to distinguish between aeronautics and space, bring more detail to the analysis of the economic and innovation performance in the sectors, and cover additional European countries. An important source of data on the space and aeronautics sectors comes from the AeroSpace and Defence Industries Association of Europe (ASD). The ASD addresses both sectors in its annual facts and figures. In addition, ASD-Eurospace (the space group of ASD) publishes it each year facts and figures dedicated to the space sector. The latest Eurospace Facts & Figures covers the year 2009 and includes statistics of member companies in 20 countries. The Facts & Figures of ASD include data on aeronautics, space and land and naval. This last category includes military land and naval systems and is not included in the data presented in this section. ASD collects the data by using a survey amongst the member companies. The ASD statistics do not include the suppliers to aeronautics, space and defence sectors, whose main interest is not one of these sectors. The Facts & Figures by ASD-Eurospace mainly include turnover and employment data, while the Facts & Figures by ASD also include data on R&D. There are differences in several indicators when comparing the data from Eurostat (Structural Business Statistics) and from ASD. This is mainly because of differences in definition of the sectors, different countries included and different reference years. In general, the figures from ASD are somewhat larger than from Eurostat.

## 1.5.1 Economic and innovation performance in the space and aeronautics sectors

In 2009, the space and aeronautics sectors realised a turnover of EUR 105,860 million and employed 499,728 people in Europe. In terms of turnover and employment, the aeronautics sector is substantially larger than the space sector. The difference between both sectors in productivity is much smaller. Figure 1.5 shows the main data of aeronautics and space in 2007, 2008 and 2009. In both sectors the turnover increased slightly in the past three years. Also the employment increased in the same period. In 2007, the labour productivity in aeronautics was somewhat higher than in space, but in 2008 and 2009 the labour productivity improved substantially in the space sector and passed aeronautics. The increase in labour productivity is a longer term trend already since the 1980s.This reflects companies' efforts to improve productivity, which is under pressure from, amongst others, global competition and the euro-dollar volatility. The labour productivity in aerospace is higher than the average rate for the non-financial business economy, but the average personnel costs in aerospace are also higher. This results in a wage adjusted labour productivity of 131.4% which is below the average rate for the non-financial business economy (151.1%) in 2006 (Eurostat, 2009a).

**Figure 1.5 Main indicators for space and aeronautics in 2007 and 2008**

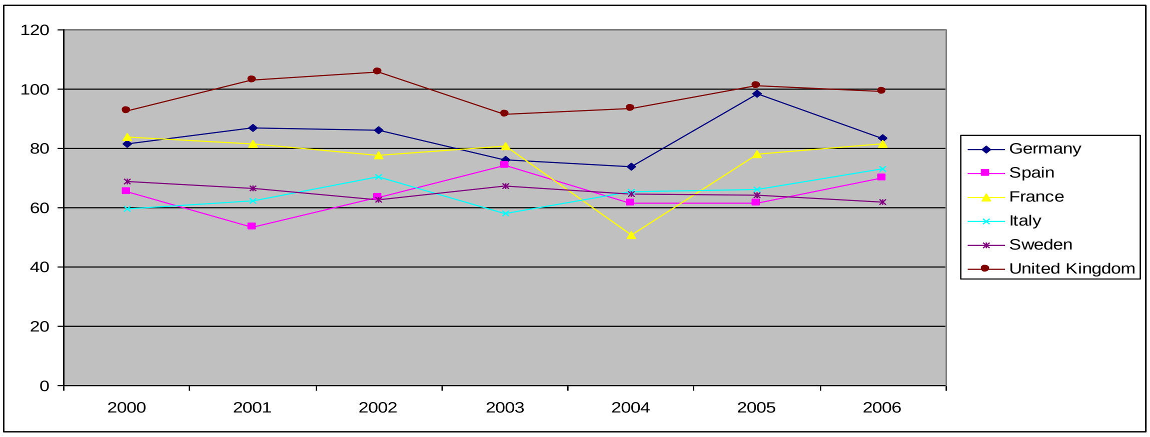



Aeronautics Space

Source: ASD (2008, 2009, 2010)

Figure 1.6 shows the apparent labour productivity in the space and aeronautics sectors for six European Member States. Over the past six years, the United Kingdom had the highest labour productivity, although the sectors experienced a small decrease in 2003. Italy followed more or less the same pattern, but at a lower level. France and Spain experienced a sharp decrease in 2004, but in France this decrease was made up again already in 2005. In Spain, the recovery is much slower. Also Germany experienced a small decrease in 2004 and improved its labour productivity substantially in 2005, but the growth was almost lost again in 2006.

**Figure 1.6 Apparent labour productivity in the space and aeronautics sectors**




Source: Eurostat Structural Business Statistics

According to Eurostat figures (2009a), the space and aeronautics sectors realised a gross operating profit of 8.2% in 2006 (EU-27), which is below the average rate for the non-financial business economy (10.8%). An important reason is the high average personnel costs. According to the ASD data (2010), the operating profit margin reached 5,7% in 2009, which is a substantial decrease from 7.1% in 2008, but a bit higher than the 5.3% in 2007.

In 2007, the sectors had a trade surplus with Extra-EU exports valued ad EUR 41,450 million, while the Extra-EU imports were smaller with a value of EUR 30,267 million (Eurostat, 2009a). In 2006, France, Germany and United Kingdom dominated, accounting together for 84.1% of the exports in EU-27 and 78.5% of the imports. Without surprise, France had the largest trade surplus of EUR

12,100 million, followed by the UK with EUR 5,800 million (Eurostat, 2009a). According to the ASD (2010), the Aeronautics Sector realised 59.5% of its turnover outside the EU, mainly from civil products. In space the picture is not different: France, Germany and United Kingdom account for almost 50% of the space exports from OECD countries in 2004, while the US is responsible for 32% (OECD, 2007a).

The space and aeronautics sectors are relatively R&D-intensive. The Eurostat Structural Business Statistics present data, but not for all EU Member States. The total amount of R&D expenditures for the EU is only available for 17 countries, representing 88% of the sectors' value added in EU-27; the companies in these countries spent EUR 6,800 million R&D in 2006 (table 1.14). These countries together had 49,040 R&D employees in 2006. The three countries that have the largest Space and Aeronautics Sectors in terms of value added and employment (United Kingdom, Germany and France), are also the most important in terms of R&D activities. Other countries that are rather R&D intensive (R&D expenditure as share of value added) include Spain, Sweden and some new Member States such as the Czech Republic, Slovenia and Poland.

The ASD also presents data on R&D expenditures, but for both sectors only data for the year 2006 are available. In 2006, the space and aeronautics sectors spent EUR 11,520 million on R&D. This includes data from companies in 20 countries. The aeronautics sector accounted for about 95% and the space sector for almost 5% of the R&D expenditures. The R&D/turnover ratio has been rather stable over the years and amounted to 11.3% in 2006. The small and medium sized companies seem to be as R&D intensive as in average for both sectors in total. In 2006, SMEs in the sectors spent 12.9% of their turnover on R&D and this ratio has been stable over the last five years (ASD, 2007a).

**Table 1.14 R&D activities in European Member States, space and aeronautics sectors, 2006**

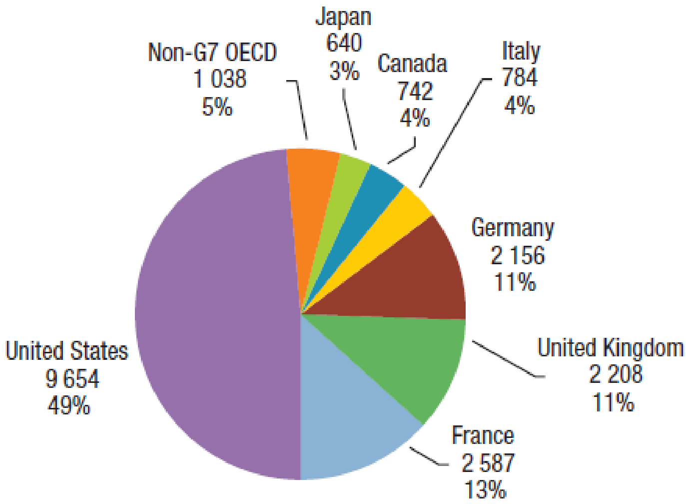
| | **Share of EU-27 sector value added (%)** | **R&D expenditure** | **R&D employees** | **Share of R&D employment in number of persons employed (%)** | **Share of R&D expenditure in value added (%)** |
|---|---|---|---|---|---|
| Austria | 0.21% | 3.7 | 60 | 8.6% | 5.9% |
| Belgium | 1.54% | | | | |
| Bulgaria | 0.00% | 0 | 0 | | |
| Cyprus | 0.00% | 0 | 0 | | |
| Czech Republic | 0.32% | 26.7 | 699 | 9.2% | 28.1% |
| Germany | 21.46% | 1853.7 | 12812 | 16.6% | 28.8% |
| Denmark | 0.32% | 0 | 0 | 0% | 0% |
| Spain | 3.66% | 416.6 | 3071 | 19.5% | 37.9% |
| Finland | 0.15% | | | | |
| France | 25.27% | 2458.1 | 16502 | 17.8% | 32.5% |
| Greece | 0.66% | 0 | 0 | 0% | 0% |
| Hungary | 0.15% | 0 | 0 | 0% | 0% |
| Ireland | 0.49% | | | | |
| Italy | 8.20% | | | | |
| Lithuania | 0.01% | 0.1 | 7 | 1.6% | 1.6% |
| Latvia | | 0 | 0 | 0% | |
| Netherlands | 1.16% | | | | |
| Poland | 0.79% | 14.8 | 809 | 5.6% | 6.3% |
| Portugal1) | 0.16% | | | | |
| Romania | 0.27% | 0.3 | 65 | 1.1% | 0.3% |
| Sweden | 2.14% | 255.9 | 1473 | 14.2% | 39.9% |

| | Share of EU-27 sector value added (%) | R&D expenditure | R&D employees | Share of R&D employment in number of persons employed (%) | Share of R&D expenditure in value added (%) |
|---|---|---|---|---|---|
| Slovenia | 0.01% | | | 13.6% | 17.7% |
| Slovakia1) | 0.04% | 0 | 2 | | |
| United Kingdom | 32.97% | 1752.1 | 13540 | | |

Source: Eurostat Structural Business Statistics; data for the year 2006. Note: 1) data for the year 2005

When comparing various OECD countries, the US aerospace industry spends by far the largest amount on R&D. Figure 1.7 presents the R&D expenditures in the aerospace industry by OECD country in 2002.

**Figure 1.7 R&D expenditures in aerospace industry by OECD country, 2002 in millions of US dollars using PPP and percentage of OECD aerospace R&D total.**

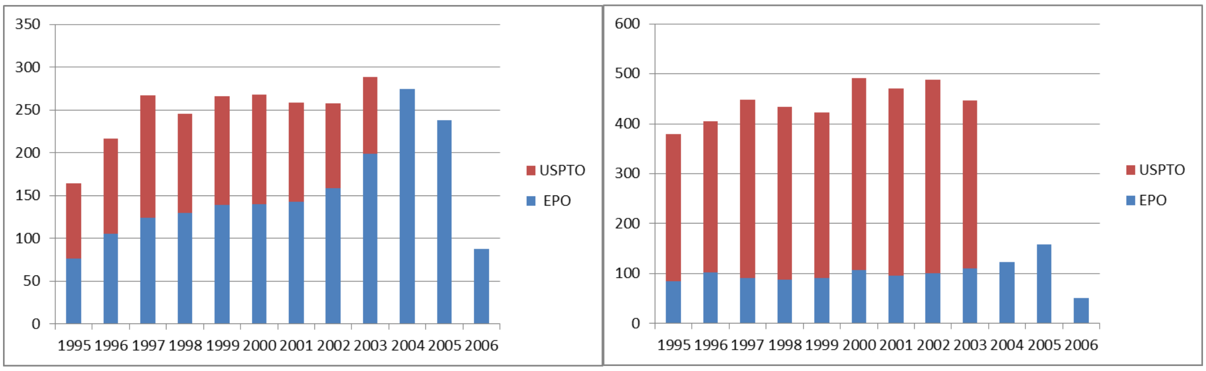



Source: OECD, 2007a

The OECD STAN database containing data on R&D expenditures presents R&D expenditures by Aerospace industry in the United States. In 2006, the US R&D expenditures by the US Aerospace industry amounted to USD 16,367 million, which is an increase of 69.5% compared with 2002.

Patents can give an indication of the innovation output of a sector. As revealed by the Community Innovation Survey, 38% of the companies in the space and aeronautics sectors (see section 1.4.3) secure their intellectual property rights in a formal way. However, representatives of the space sector in the Sectoral Innovation Panel in the SYSTEMATIC consortium (SIW-I) mentioned that often secrecy is used to protect intellectual property. Nevertheless, this category is not included in the CIS survey. Patents are therefore not the best indicator for measuring the innovation performance in the sector. Nevertheless, there is no other indicator available and patent activity by companies in the sectors can give a first indication of the innovation in the sectors. Figure 1.8 presents for EU-27 and for the United States the patent applications in EPO and the patents granted by USPTO. The data cover the IPC class ‘Aircraft, aviation, cosmonautics’.

**Figure 1.8 Patent performance, 1995-2006 for EU-27 and for US**




EU-27 United States

Source: Eurostat Patent Statistics, IPC class B64 Aircraft, aviation, cosmonautics. USPTO patent numbers only available for the period 1995-2003.

Overall, European firms file less patents than American firms. Where European firms file less than 300 patents (EPO and USPTO together) in 2003, US-based firms file almost 450 patents in the same year. Since 1995, European firms have increasingly filed patents with EPO, with a sharp decline in 2006. The number of USPTO patents filed by European firms has decreased over the years.

Between 2000 and 2006, the EU-27 applied in total for 1240 EPO patents (see table 1.15). Germany and France have the highest shares, followed at some distance by the United Kingdom. Germany and France also have the highest share in the patents granted by USPTO in the period 1997-2003. In 2006, the highest number of EPO patent applications per million euro spent in R&D can be found in Austria, followed by Germany and France.

**Table 1.14 Patents by country in the space and aeronautics sectors**

| **EPO patent applications (2000-2006)** | | | **USPTO patent grants (1997-2003)** | | |
|---|---|---|---|---|---|
| | | % share | | | % share |
| EU-27 | 1240 | | EU-27 | 819 | |
| Germany | 464 | 37.4% | Germany | 290 | 35.4% |
| France | 419 | 33.8% | France | 289 | 35.3% |
| United Kingdom | 157 | 12.7% | United Kingdom | 133 | 16.3% |
| Italy | 42 | 3.4% | Italy | 29 | 3.6% |
| Spain | 40 | 3.3% | Sweden | 19 | 2.3% |
| Sweden | 33 | 2.7% | Spain | 18 | 2.1% |
| Belgium | 20 | 1.6% | Austria | 13 | 1.6% |
| Netherlands | 19 | 1.6% | Netherlands | 8 | 1% |
| Austria | 13 | 1.1% | | | |

Source: Eurostat Patent Statistics, IPC class B64 Aircraft, aviation, cosmonautics. Only countries with a share of 1% or higher are shown.

## 1.5.2 Economic and innovation performance in the aeronautics sector

Turnover in aeronautics has increased with approximately 6% annually in the past three years. Employment has also increased in the same period, although there was small decrease between 2006 and 2007. According to ASD, this small decrease is due to restructuring and outsourcing of production to improve profitability and increase flexibility in production. Since 1980, the turnover per employee in the aeronautics sector has increased in average by 4% per year. According to ASD, this is due to restructuring and outsourcing of production to improve profitability and increase flexibility in production. Since 1980, the turnover per employee in the aeronautics sector has increased in average by approximately 3% per year. The aeronautics' labour productivity has increased by almost 90% from EUR 115,000 per employee in 1991 to EUR 214,000 per employee in 2009 (ASD, 2010). Although the turnover and the labour productivity have increased over the years, the operating profit dropped substantially after 2005. An important reason for this could be the problematic euro-dollar volatility during 2008, especially for companies that do not own assets in US dollar markets. Other causes could be increasing costs of commodities and the increasing development times for complex new programmes (ASD, 2008). ASD reports an organic growth in the operating profit margin from 4.16% in 2007 to 7.1% in 2008, but with a sharp decline to 5.7% in 2009. According to ASD the initial growth was mainly based on the significant improvement of EADS's performance, which represents an important share of the European aeronautics sector. The decline in 2009 was due to the fact that large aircraft development programmes moved from development to full production and faced delays and additional costs (ASD, 2010).

In 2009, 59.2% of the turnover came from civil markets and 40.8% came from military markets. In 2009, 72.8% of the turnover came from customers other than governments and government agencies. The Aeronautics Sector sells 59.9% outside Europe and 40.5% at domestic markets (ASD, 2010). In 2009, 44% of the turnover of the European aeronautics sector was realised by aircraft final products. Commercial aircrafts account for 57% of the aircraft final products, followed by military aircrafts (27%) (ASD, 2010).

The companies in the aeronautics sector spent 12.1% of their turnover on R&D activities, which equalled EUR 12.2 billion in 2009 (ASD, 2010). The share of turnover spent on R&D remained stable over the past few years. Two third of these R&D expenditures is financed by the industry itself, while one third came from government funding. Table 1.16 presents the main indicators for the aeronautics sector.

**Table 1.16 Economic and innovation performance in the aeronautics sector**

| | 2005[1)] | 2006[2)] | 2007[3)] | 2008[4)] | 2009[5)] |
|---|---|---|---|---|---|
| Turnover (in EUR M) | 81,600 | 90,500[6)] | 94,500 | 97,300 | 100,400 |
| - % of Civil in turnover | | 69.2% | 57.9% | 60.1% | 59.2% |
| - % of Military in turnover | | 30.8% | 42.1% | 39.9% | 40.8% |
| - % of domestic in turnover | | 48% | 44% | 41.2% | 40.5% |
| - % of export in turnover | | 52% | 56% | 58.8% | 59.5% |
| - % of governments in turnover | | | 22.4% | 19.3% | 27.2% |
| - % of other customers in turnover | | | 77.6% | 80.7% | 72.8% |
| Operating Profit | 6.9% | 4.5% | 4.16% | 7.1% | 5.7% |
| Employment | 430,000 | 448,000 | 442,100 | 446,900 | 468,300 |
| Labour productivity (turnover / employees)[9)] | 189,767 | 202,009 | 217,753 | 214,000 | 214,000 |
| R&D Expenditures (in EUR M) | 10,037[7)] | 10,430[7)] | 11,700 | 11,300 | 12.200 |
| % of R&D of turnover | 12.3% | 11.83%[8)] | 12.4% | 12% | 12,1% |
| % of R&D financed by companies | | 55% | 71% | 68.3% | 65.3% |
| % of R&D financed by (national and European) governments | | 45% | 29% | 31.7% | 34.7% |

Sources: 1) ASD (2007c) Facts & Figures 2006, Belgium (based on 20 countries: EU15, Czech Republic, Poland, Bulgaria Norway, Switzerland and Turkey); Edelstenne, C. (2007) ASD Press Conference on Key Figures for 2006, Brussels, 4 June 2007; 2) ASD (2007c) Facts & Figures 2006, Belgium; 3) ASD (2008) Facts & Figures 2007, Belgium (based on 21 countries: EU 15, Czech Republic, Poland, Bulgaria, Norway, Switzerland and Turkey); 4) ASD (2009) Facts & Figures 2008, Belgium (based on 20 countries: EU 15 minus Luxembourg, Bulgaria, Czech Republic, Poland, Norway, Switzerland and Turkey); 5) ASD (2010) Fact & Figures 2009, Belgium (based on 20 countries: EU15 minus Luxembourg, Czech Republic, Bulgaria, Poland, Norway, Switzerland and Turkey; 6) The turnover for 2006 was adjusted from EUR 88,200 million in the Facts & Figures of 2006 to EUR 90,500 million in ASD (2008) Facts & Figures 2007, Belgium; 7) own calculation using publicly available data on turnover and share of R&D of turnover; 8) as included in: ASD (2007c) Facts & Figures 2006, Belgium, does not take into account the adjusted figure for turnover in: ASD (2008) Facts & Figures 2007, Belgium; 9) own calculations by dividing turnover by employment.

**Box 1.6 Impact of the financial and economic crisis on the aeronautics sector**

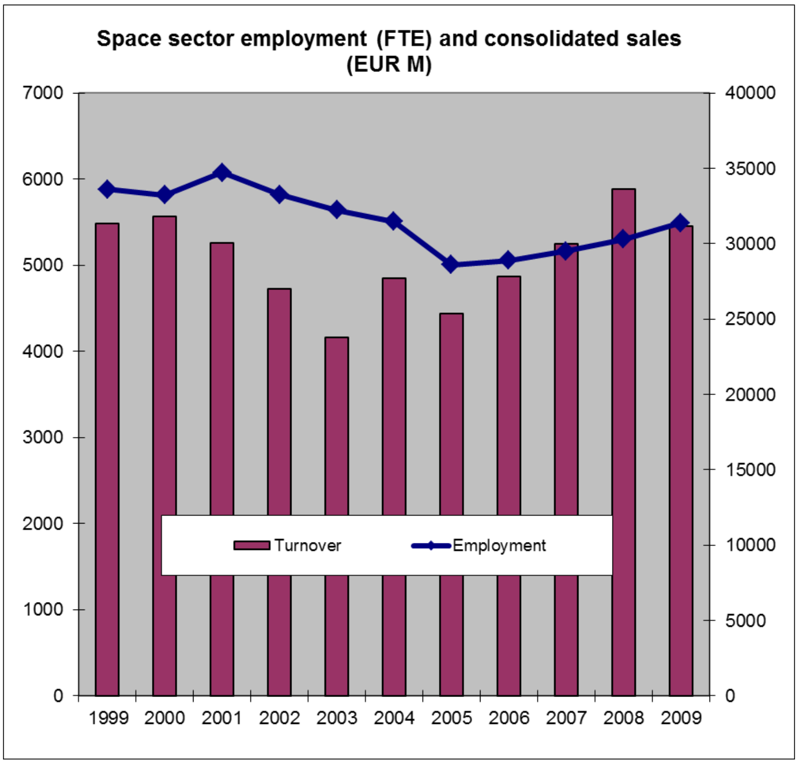
In 2008, the International Air Transport Association (IATA) expected that global passenger traffic will fall by 3% in 2009 and a return to traffic growth above 4% was not expected until 2011. Indeed, during the first half of 2009, the demand for traffic dropped sharply 2009, mainly in the European and US markets (IATA, 2009). In emerging markets, demand for air traffic will continue growing. According to IATA (2008), the fall in air traffic is the biggest since 1991, when air traffic dropped with 2.6% due to recession and after the 9-11 terrorist attack. In general, the aerospace industry is in a better situation compared to other manufacturing sectors like the automotive industries. This is mainly because of a considerable backlog following from the many orders made during the last years. Aircraft operators seem to be optimistic about their markets in the long term and they will need to replace significant numbers of older, less fuel efficient aircraft. Another positive factor is that the military demand has largely been unaffected by the crisis so far, although governments will cut budgets here as well and this will have effects. Financing the aircrafts will mainly come from financiers focused on asset and lending institutions, but these want to see convincing answers from the industry to the threat of the crisis and high fuel prices. Despite the relatively optimistic trends in demand, both Airbus and Boeing experienced more aircraft cancellations than orders in the beginning of January 2009, reducing their backlog. Programmes for new aircrafts to be delivered by 2020 seem to be not affected by the crisis so far. According to industry analysts the aeronautics industry can survive the crisis, but they have to do better in meeting costs and schedule objectives in their programmes. Customers are much under pressure themselves to control costs. In addition, the aeronautics industry will have to pursue more actively new markets and customers in India and the Middle East in order to realise growth (Captain and Coykendall, 2009). Also IATA (2010) considers these emerging markets as the main driver for growth. Although the major primes seem to be able to handle the crisis so far, the suppliers are really hit, mainly because they have very limited access to long term credits (needed to participate in large programmes) as well as to short term credits needed for their day to day operations. An additional complicating factor is that many suppliers are also active in other manufacturing sectors, like automotive, where the crisis is very present, and further threatening their financial situation. Without surprise, the business jet industry is hit hard as well (ACARE, 2009).

Although the economic crisis is still present, especially in Europe and the United States, the current (spring 2011) major issue is the strong increase in fuel prizes. IATA (2010) forecasts a stable increase in the demand for air traffic, but also states that high fuel prices will substantially affect the profitability of airliners, both in terms of operating costs and demand for air traffic, as higher energy prices also affect the economic recovery of main clients.

### 1.5.3 Economic and innovation performance in the space sector

The space sector is the smallest sector in the space and aeronautics sectors. Turnover increased steadily from EUR 4,400 million to 5,457 million in 2009. Figure 1.9 shows a decline in the period 2001-2003. An important reason for the decrease in turnover in the period 2001 – 2003 is the telecommunications market downturn, resulting in fewer satellites ordered. Since 2005, direct employment in the space sector has increased slowly, from 28,584 FTE to 31,369 FTE in 2009. This increase comes after several years of decreasing employment figures, caused by industry restructuring (vertical and horizontal integration) and less favourable market conditions at the beginning of the century (ASD-Eurospace, 2009).

**Figure 1.9 Employment and turnover in the EU space sector, 1999-2008**

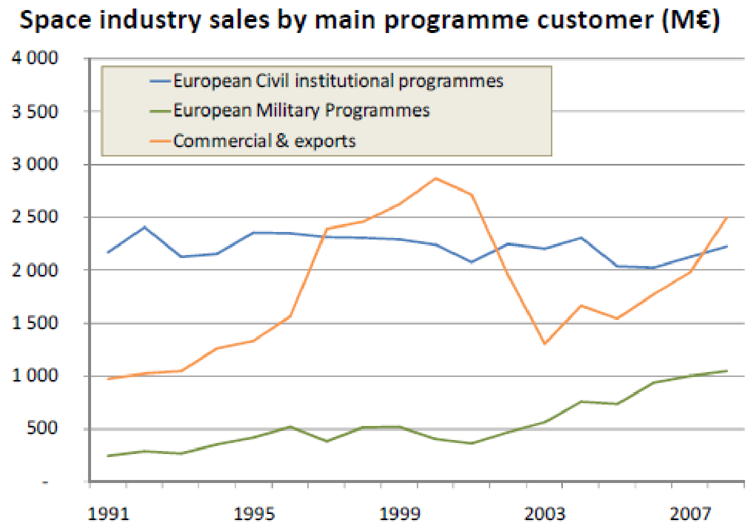



Source: ASD-Eurospace (2009 and 2010)

More than 70% of the sector's employment is concentrated in four large industrial holdings (EADS, Finmeccanica, Safran and Thales). Less than 5% of the companies in the sector are SMEs, but small space units within larger companies represent 20% (ASD-Eurospace, 2009).

The turnover in the space sector comes from two main types of customers: institutional customers and commercial programmes & exports. Institutional customers include the European Space Agency, national space agencies, public satellite operators and military procurement agencies. In 2009, institutional customers represented 59% of the turnover and commercial customers represented 41%. The contribution of the European civil institutional programmes (from ESA, national space agencies, Eumetsat and EC) remained relatively stable over the period 1999-2009, while the size of the European military programmes (e.g. Sicral, SAR-Lupe) have grown steadily since 2001. The commercial markets, the commercial satellites in particular, appear to be far more cyclical. In the 1990s the commercial satellite sector grew significantly, but since 2001 this market has declined sharply. Only since 2006, the turnover from commercial satellites has been increasing again, but is still behind the levels of 2000. Figure 1.10 presents the trends in turnover in the space sector.

**Figure 1.10 Trends in turnover in the space sector, by main programme customer, 1991 – 2008**




Source: ASD-Eurospace (2009)

The space sector designs, develops and produces three main categories of products: launchers, satellites (and space crafts) and ground systems. The satellites and spacecraft segment is the biggest, representing almost two third of the sector's sales and workforce. The satellite segment in Europe has two large system integrators: Thales Alenia Space and EADS Astrium. The satellite segment covers a broad spectrum of space activities: telecommunications, science, Earth observation, navigation, and space infrastructures. Medium and small system integrators have been established in Germany, the UK, Belgium and Sweden, but the share of SMEs is in general very small, mainly because of high risks and high entry barriers.

The launchers segment represents 20% of the total turnover and workforce. For the Ariane programme there is one single prime contractor (EADS Astrium), one reference motorist (Safran) and about 40 European subsystem and equipment suppliers, of which 25 are highly specialised in Ariane subsystems and components. There is almost no possibility that newcomers can enter the market, mainly because of long development cycles and exploitation phases and the difficulty to implement any change in the qualified definition of the launcher systems.

The ground systems sector represents less than 10% of the sector's employment and turnover. Companies in this sub-sector focus on the design, development, manufacturing and operations of ground systems (e.g. control systems) (ASD-Eurospace, 2010).

**Table 1.17 Economic and innovation performance in the space sector, 2005-2008**

| | **2005** | **2006** | **2007** | **2008** | **2009** |
|---|---|---|---|---|---|
| Turnover (in EUR M)[1)] | 4,432 | 4,867 | 5,242 | 5,885 | 5,457 |
| - % of institutional markets (civil and military) in turnover | 60.3% | 60.5% | 59.6% | 55.5% | 59% |
| - % of commercial and exports in turnover | 37.2% | 37% | 37.7% | 42.4% | 41% |
| Employment (direct) | 28,584 | 28,872 | 29,506 | 30,301 | 31,369 |
| Labour productivity (turnover / employees)[2)] | 155,052 | 168,571 | 177,658 | 194,218 | 173,962 |
| R&D expenditures (in EUR M)[3)] | | 548 | | | |
| % of R&D of turnover[3)] | | 14.43% | | | |

Sources: ASD-Eurospace (2009) *The European Space Industry in 2008 – facts & figures*, 13th edition, rev. 1, July 2009, Paris; ASD-Eurospace (2010) The European Space Industry in 2009 – fact & figures, 14th edition, September 2010, Paris
1) The division between in institutional and commercial markets does not sum up to 100%, because a small part of the turnover cannot be allocated to one of these two categories; 2) Own calculations, dividing turnover by employees; 3) ASD (2007c) Facts & Figures 2006, Belgium

There are hardly any data available on the business R&D expenditures in the space sector; data are only available for the aeronautics sector. Only for 2006, there are data about the expenditures on R&D and share of turnover spent on R&D in Space (see table 1.17). While the R&D-intensity rate in the space sector is higher than in the aeronautics sector (14.43% compared with 11.83% in 2006), the size of the total R&D expenditures in space is much smaller than in aeronautics and has a share of only 4.8% in the R&D expenditures of the total space and aeronautics sectors.

The OECD provides data on the public space research and development budgets (GBOARD), but this also includes government funding for R&D performed at higher education institutes, non-profit institutions and governments and it does not separate the public funding available to business enterprises in space. According to the OECD (2007a), the total government budgets of OECD countries for space-related R&D amounted to USD 16,400 million in 2004. Table 1.18 provides an overview of the public space R&D budgets in available European countries.

**Table 1.18 Public space R&D budgets in Europe**

| Country (latest year) | Public space R&D budgets (GBOARD) in millions of current US dollars using PPP |
|---|---|
| Austria (2006) | 15 |
| Belgium (2005) | 172 |
| Czech Republic (2005) | 10 |
| Denmark (2006) | 28 |
| Finland (2006) | 31 |
| France (2004) | 1,567 |
| Germany (2005) | 924 |
| Greece (2005) | 16 |
| Hungary (2005) | 17 |
| Ireland (2005) | 12 |
| Italy (2005) | 902 |
| Netherlands (2006) | 98 |
| Portugal (2006) | 3 |
| Romania (2006) | 10 |
| Spain (2005) | 322 |
| Sweden (2006) | 25 |
| United Kingdom (2004) | 206 |

Source: OECD, 2007a

# 2 Carriers of innovation

## 2.1 Workforce and talent

The ASD (2008) presents a breakdown of the employment in the European aeronautics industry by activity. 57% of the employees in the aeronautics industry work in production and 20% work in R&D. Taking into account the breakdown by qualification; data show that highly skilled jobs including graduates, engineers and managers represent 35% of all jobs in the aeronautics sector, followed by manual workers who account for 33% of all employees. Another 32% of the employees has an education below university level and includes technicians, draughtsmen, craftsmen, secretaries, etc. Employees in the Space Sector in general have higher qualification levels than in the aeronautics sector. According to ASD-Eurospace (2009), 53% of all employees in the space sector have at least a master’s degree, while 22% have a bachelor’s degree from university. 13% of the employees received an education at a Higher Vocational School. The workforce in the space sector is dominated by older men; 77% of the employees are male and two-third of the men are older than 40 years, while 32% are over 50.

The data from ASD and ASD-Eurospace show that knowledge is of key importance to the space and aeronautics sectors. According to Hollanders et al. (2008), the sectors are characterised by strong knowledge accumulation and knowledge capital is an important driver of innovation in these sectors. Based on the Revealed Technological Advantage (based on patents), European countries including Austria, Italy, Spain, Germany, France and Sweden have technological leadership in the space and aeronautics sectors (Hollanders et al., 2008). Moreover, human capital and high skilled employees contribute to the improved total factor productivity growth through innovation.

Despite this strong knowledge accumulation and technological leadership, the space and aeronautics sectors face some important challenges with regard to the workforce. The main worry is about skill shortages, especially in relation to engineers (Ecorys, 2009). The UK Sector Skills Council for Science, Engineering and Manufacturing Technologies (SEMTA) prepared a Sector Skills Agreement for the UK aerospace industry in 2006, which describes the current state of the UK aerospace industry and analyses the workforce development and skills requirement in the sectors. The analysis shows that the present workforce is ageing and many employees will retire within five to ten years’ time. At the same time, replacement by younger engineers is problematic because the supply of newly educated engineers is decreasing and the younger and more experienced engineers are in high demand in all manufacturing sectors. In the United Kingdom, the study reports hard-to-fill vacancies for professional engineers, skilled trades (craft) and machine operatives. There is especially a lack of good qualified applicants with work experience. The industry reports skills gaps, especially in management, professional, craft and operator/assembler levels. Skills gaps for technical engineering skills are the most significant. The supply of young people will be insufficient to meet the necessary skills requirements, which implies that it is also needed to focus on up skilling and effective redeployment of the adult workforce. The insufficient supply of highly skilled and experienced staff will be further accentuated by the move of higher value added workload from first tier companies and OEMs to Tier 2 companies. Leading first tier aerospace companies and OEMS are reducing the proportion of operators in their workforce mainly through changes in technology and working practices. The trend towards high performance and lean working will put pressure on Tier 2 companies and below to deal with more higher value added workload, which will require more high-grade technicians and graduate skills.

Technical skills are essential to the sectors, especially the following technical skills are considered as important by the UK space and aeronautics sectors:

- Software systems, modelling and simulation, especially for navigation, flight, weapons and radar;
- Systems design and modelling, advanced manufacturing design and simulation, advanced electrical systems design;
- Systems and systems integration including more complex high integrity systems;
- Advanced materials engineering and assembly techniques;
- Diagnostic and prognostic techniques;
- Skills to support emerging technologies, particular in relation to regulatory requirements for fuel efficiency, safety and emissions.

With regard to the more personal and generic skills; the sectors foresee the following skills requirements:

- Communication skills;
- IT skills;
- Customer handling skills;
- Team working skills;
- Supply chain management skills;
- Project management skills;
- Process excellence skills and lean manufacturing skills.

The industry also acknowledges that the sectors might be not so attractive to prospective employees. Employment in the sectors is often considered as insecure, mainly because of the highly cyclical nature of the sectors and the dependency on external events (e.g. government spending, security and safety incidents) (SEMTA, 2006; AIA, 2008; Ecorys, 2009). Labour costs are high in the sector and are an important instrument in lowering the productions costs. Especially relevant is labour flexibility. Although, national labour policies in Europe can make it difficult to adapt the workforce size to the production levels, European firms have increased the number of temporary contracts and systems for exchanging employees between firms. In addition, firms have automated substantial parts of their operations. Another attempt to reduce costs and the vulnerability to exchange rates is to offshore work to cheaper locations, resulting in a loss of medium and low-skilled employment (Ecorys, 2009).

To address the skills gaps and lack of engineers, several actions are needed. The Aerospace Innovation and Growth Team (AeIGT) in the UK has identified the following actions to address the skills gaps in the UK space and aeronautics sectors:

- Enhance continuous learning practises throughout the industry;
- Communication with universities to supply undergraduates with an appropriate foundation of skills;
- Adoption of an aerospace-oriented technician apprentices programme to supply appropriately trained technicians;
- Establishment and enhancement of Teaching Centres of Excellence to provide specialised post-graduate training and continual professional development to industry personnel;
- The fostering of a certified high standard of engineering through Professional Registration of appropriate technical personnel.

To support the match between supply and demand, to attract workforce and to strengthen the motivation of young academics, more cooperation between various stakeholders is needed. Aerospace clusters offer opportunities to develop and expand cooperation in cross-sectoral and transnational education and training programmes, in programmes to exchange trainees, and in cross-sectoral and transnational workforce recruitment.

**Box 2.1 Hamburg Qualification Initiative**

In 2000, the Hamburg aviation cluster established the Qualification Initiative Aviation Industry, which aims to develop the supply of a skilled workforce to the Aeronautics industry in short, medium and long term. In this initiative, universities, vocational training institutes and industry collaborate to develop new ways of recruiting and new, international programmes for education and training and to create a large number of apprenticeships for aeronautics engineers. The Qualification Initiative is also focusing on transnational cooperation. It established an exchange of training programmes and trainees between the aeronautics clusters of Hamburg and the French Aerospace Valley of the Midi-Pyrénées and Aquitaine (http://www.luftfahrtstandort-hamburg.de/index.php?id=67&L=1).

**Box 2.2 European Student Aerospace Challenge**

In 2006, the European Student Aerospace Challenge was initiated by Dassault Aviation and student associations and was soon joined by Astronaute Club Europeen (ACE), EADS, ESA, Safran, Thales, GIFAS, as well as the International Astronautical Federation (IAF). The European Student Aerospace Challenge started as an answer to the problem of attracting highly skilled young engineers to the sectors. It aims to bring students and the industry together, to train students in team-working and project-leading skills, and to offer students the experience of working on an ambitious large scale project. The subject of the Challenge was initiated by the ACE and focuses on designing and developing a new suborbital craft. The Challenge is basically a contest among students and their universities and schools, working on various parts of the suborbital crafts. The best projects win awards. In 2006-2007, 15 teams with 82 students participated, while in 2007-2008 16 teams participated with 103 students. In 2008-2009, 15 teams with 80 students are involved (http://www.studentaerospacechallenge.eu/).

## 2.2 Organisations

### 2.2.1 The largest R&D spending firms

As mentioned in section 1.2, the space and aeronautics sectors consists of a few very large firms and a large number of small companies. While the aeronautics sector has many SMEs, the space sector has a large number of small space units within larger firms. The space and aeronautics sectors are in general rather R&D-intensive. Analysis of the CIS4 data showed (see section 1.4.2) that large firms are the most active in R&D and are also driving the introduction of new products, services and production methods on the market.

The EU Industrial R&D Investment Scoreboard present annually R&D spending data for 2000 companies from EU and non-EU countries reporting major R&D investments. EU companies include the parents companies that have registered offices in an EU country. This scoreboard includes data on the R&D financed by the company's own funds and excludes government funding for industry R&D activities. Table 2.1 presents the top 10 EU and non-EU companies in aerospace and defence. The European Aeronautics Defence and Space Company (EADS) is by far the largest R&D performing company in Europe and invests also more in R&D than Boeing, the largest R&D spending company outside Europe. Although EADS has its registered office in the Netherlands, the R&D activities take place in other European countries. Finmeccanica is ranked second in the EU list of companies and spends EUR 800 million more than the number two on the non-EU list, the US company United Technologies. Both EADS and Finmeccanica belong to the top 20 largest R&D spending companies in the EU; seven European Space and Aeronautics companies belong to the top 100 of largest European R&D performing companies (see also Table 2.1). Finmeccanica is by far the most R&D intensive organisation, with regards to the R&D/Net Sales ratio and the amount of R&D per employee.

Eight of the ten largest R&D spending companies outside Europe are registered in the United States of America. The other two companies are located in Canada and Brazil. The Brazilian company EMBRAER was not included in the ranking of the 2005 Scoreboard. The positions of the other companies in the ranking have not changed that much compared with 2004. The largest R&D spending companies in the USA are less R&D intensive than their European counterparts. They spent a smaller share of the net sales on R&D and their R&D expenditures per employee are also lower.

**Table 2.1 Largest R&D performing companies**

| | | | | R&D Investment | Net Sales | Employees | R&D/ Net Sales Ratio | R&D per Employee |
|---|---|---|---|---|---|---|---|---|
| **Rank (2004)** | **Company** | **Rank in top 1000 list EU** | **Country** | **2007** | **2007** | **2007** | **2007** | **2007** |
| **European companies** | | | | | | | | |
| | | | | **EUR M** | **EUR M** | **#** | **%** | **EUR thousand** |
| | | | | **8.093.89** | **126,391** | **519,148** | **6.4** | **15.6** |
| 1 (1) | EADS | 12 | The Netherlands | 2,701.00 | 39,123 | 116,493 | 6.9 | 23.2 |
| 2 (3) | Finmeccanica | 16 | Italy | 1,955.00 | 11,916 | 58,700 | 16.4 | 33.3 |
| 3 (4) | SAFRAN | 30 | France | 887.00 | 11,494 | 52,515 | 7.7 | 16.9 |
| 4 (6) | Rolls-Royce | 40 | UK | 618.12 | 10,123 | 38,600 | 6.1 | 16.0 |
| 5 (5) | Thales | 43 | France | 584.00 | 12,296 | 61,195 | 4.7 | 9.5 |
| 6 (na) | Dassault Aviation | 72 | France | 265.03 | 4,085 | 12,136 | 6.5 | 21.8 |
| 7 (2) | BAE Systems | 78 | UK | 239.62 | 19,482 | 83,000 | 1.2 | 2.9 |
| 8 (8) | SAAB | 110 | Sweden | 147.73 | 2,436 | 13,337 | 6.1 | 11.1 |
| 9 (na) | Zodiac | 113 | France | 145.19 | 2,478 | 17,402 | 5.9 | 8.3 |
| 10 (na) | MTU Aero Engines | 180 | Germany | 88.80 | 2,576 | 7,092 | 3.4 | 12.5 |
| **Non-European companies** | | | | | | | | |
| | | **Rank in top 1000 list non-EU** | | **R&D investment 2007** | **Net sales 2006** | **Employees 2007** | **R&D / Net sales ratio 2007** | **R&D per employee** |
| 1 (1) | Boeing | 19 | USA | 2,633.26 | 45,406 | 159,300 | 5.8 | 16.5 |
| 2 (na) | United Technologies | 49 | USA | 1,147.69 | 36,879 | 225,600 | 3.1 | 5.1 |
| 3 (2) | Lockheed Martin | 61 | USA | 824.86 | 28,632 | 140,000 | 2.9 | 5.9 |
| 4 (4) | Northrop Grumman | 125 | USA | 367.29 | 21,909 | 122,600 | 1.7 | 3.0 |
| 5 (5) | Raytheon | 133 | USA | 343.35 | 15,339 | 72,100 | 2.2 | 4.8 |
| 6 (6) | General Dynamics | 154 | USA | 294.11 | 18,668 | 83,500 | 1.6 | 3.5 |
| 7 (8) | Rockwell Collins | 188 | USA | 237.34 | 3,020 | 19,500 | 7.9 | 12.2 |
| 8 (7) | Goodrich | 225 | USA | 191.51 | 4,470 | 23,400 | 4.3 | 8.2 |
| 9 (na) | EMBRAER | 237 | Brazil | 177.64 | 3,588 | 23,734 | 5.0 | 7.5 |
| 10 (9) | Bombardier | 377 | Canada | 95.07 | 11,973 | 59,385 | 0.8 | 1.6 |

Source: EC (2008) EU Industrial R&D Investment Scoreboard 2008

## 2.2.2 Clusters in the space and aeronautics sectors

The space and aeronautics sectors are high-tech sectors depending on research and highly skilled human resources. Therefore, regional concentration mostly depends on a research friendly environment and the availability of a highly skilled workforce. Organisations participating in a cluster enjoy several economic benefits, including access to specialised human resources and suppliers, knowledge spill overs, pressure for higher performance in head-to-head competition and learning from the close interaction with specialised customers and suppliers.

The European Cluster Observatory (www.clusterobservatory.eu) contains a database with 259 regions, containing 10.000 clusters: intersections of sectors and regions from 32 countries. The clusters are assessed on three dimensions:

- *Size:* if employment reaches a sufficient share of total European employment, it is more likely that meaningful economic effects of clusters will be present.
- *Specialisation:* if a region is more presented in a certain cluster than in the overall economy, this will indicate the economic importance of the regional cluster.
- *Focus:* if a cluster accounts for a larger share of a region's overall employment, it is more likely that spill-over effects and linkages will actually occur instead of being drowned in the economic interaction of other parts of the regional economy.

Based on these three dimensions, clusters are rated with one to three stars (with tree stars being most important). For the ‘Aerospace, Vehicles and Defence, Engines’ sector, the European Cluster Observatory contains 34 clusters. Table 2.2 presents the clusters and the main characteristics of these clusters. The best performing clusters are located in Germany, France and the UK, which are also the most important countries in the sectors in terms of turnover, value added and employment.

**Table 2.2 European clusters in space and aeronautics**

| Cluster | Employees | Stars | Innovation[1)] | Export[2)] |
|---|---|---|---|---|
| Hamburg, DE | 19 411 | *** | High | Strong |
| Île de France (Paris), FR | 23 232 | ** | High | Very strong |
| Midi-Pyrénées (Toulouse), FR | 18 656 | ** | High | Very strong |
| Lancashire (Blackburn), UK | 14 806 | ** | High | Weak |
| Oberbayern (München), DE | 13 957 | ** | High | Strong |
| Derbs and Notts (Nottingham), UK | 12 639 | ** | High | Weak |
| Gloucs, Wilts and N Som (Bristol), UK | 10 740 | ** | High | Weak |
| Aquitaine (Bordeaux), FR | 10 244 | ** | Medium | Very strong |
| Schwaben (Augsburg), DE | 8 966 | ** | High | Strong |
| E Wales (Cardiff), UK | 8 557 | ** | Medium | Weak |
| Campania (Naples), IT | 8 023 | ** | Low | Weak |
| Provence-Alpes-Côte d´Azur (Marseille), FR | 7 659 | ** | Medium | Very strong |
| Podkarpackie (Rzeszów), PL 3) | 6 936 | ** | Low | Weak |
| Dorset and Somerset (Bournemouth), UK | 6 933 | ** | High | Weak |
| Hants and Isle of Wight (Southampton), UK | 6 002 | ** | High | Weak |
| Northern Ireland (Belfast), UK | 5 879 | ** | Medium | Weak |
| Pays de la Loire (Nantes), FR | 5 432 | ** | Medium | Very strong |
| SW Scotland (Glasgow), UK | 5 151 | ** | Medium | Weak |
| Bremen, DE | 4 503 | ** | Medium | Strong |
| Bucuresti - Ilfov, RO | 4 444 | ** | N/A | Weak |
| Östra Mellansverige (Uppsala), SE | 4 284 | ** | High | Weak |
| Madrid, ES | 10 241 | * | High | Weak |
| Piemonte (Turin), IT | 6 444 | * | Medium | Weak |
| Andalucía (Sevilla), ES | 5 227 | * | Low | Weak |
| Darmstadt (Frankfurt am Main), DE | 4 890 | * | High | Strong |
| Lombardia (Milan), IT | 4 251 | * | Medium | Weak |
| Weser-Ems (Oldenburg), DE | 4 242 | * | Low | Strong |
| Tübingen, DE | 4 098 | * | High | Strong |
| Région Wallonne, BE | 3 704 | * | Medium | Weak |
| Zürich, CH | 3 451 | * | N/A | Weak |
| Zentralschweiz (Luzern), CH | 2 914 | * | N/A | Weak |
| Stredni Morava (Olomouc), CZ | 2 019 | * | Low | Weak |
| Poitou-Charentes (Poitiers), FR | 1 932 | * | Low | Very strong |
| Lüneburg, DE | 1 519 | * | Low | Strong |

Source: European Cluster Observatory:
http://www.clusterobservatory.eu/index.php?id=&cluster_ID=2&presentationselect=table

Notes: 1) Innovation: Data is for region, regardless of cluster category. Based on 2006 European Regional Innovation Scoreboard, MERIT; 2) Exports: Data is national export data for the cluster category, regardless of region. Based on International Cluster Competitiveness Project, ISC at HBS; 3) year of data is more than 3 years older than reference year (2006).

**Box 2.3 Aerospace Valley Midi-Pyrenees & Aquitaine, France**

One of the largest European clusters in aerospace is located in the Midi-Pyrenees and Aquitaine, France. The cluster is active in space, aeronautics and embedded systems and consists of 1,300 partners, employing 8,500 people in research and 94,000 people in industry and services, of which 40,000 jobs are with the manufactures and main equipment suppliers and 50,000 in the subcontracting network. This cluster represents one third to the French employment in aerospace.


The cluster hosts six universities and 12 aeronautics engineering schools (Grandes Ecoles) as well as the Aerospace Campus in Toulouse. This Aerospace Campus aims to be the largest European university campus in the field of aerospace and brings together the main institutes in the field of aerospace training and research. The Aerospace Valley association was created on July 13, 2005 and was one of 67 selected Pôles de Compétitivité (competitiveness poles). At present the association has 500 members representing companies, research centres, education and training centres and authorities involved in the sectors. The association aims to crate 40,000 to 45,000 jobs in the next 20 years. The association wants to develop the cluster into a worldwide leading network in aerospace, based on excellence in aerospace research and innovation. The Aerospace Valley association initiates and supports two different types of projects contributing to the development of the cluster. Cooperation projects support R&D collaboration between firms and research organizations in specific business sectors, such as embedded systems, aero-mechanics, and navigation. Structuring projects support the development of education and training initiatives, the development of new R&D centres and other initiatives aimed at the economic development of the cluster. The cluster hosts the global leaders in aeronautics, space and embedded systems, such as Airbus, Zodiac, Safran, Siemens, and Rockwell, as well as network of SMEs working for the major global prime contractors

Source: http://www.aerospace-valley.com/

## 2.2.3 Industry organisations

The space and aeronautics sectors are international sectors, with global sourcing networks and strong international competition. The public sector plays an important role, as customer, regulator and financer. Moreover, activities in the space and aeronautics sectors are concentrated in a few European Member States and regions, around large system integrators with many smaller supplying enterprises. Cooperation between the various actors in the sectors is crucial for innovation, for example with respect to certification and standardisation, education and training, R&D activities, or financing. This section and the following sections present several organisations and platforms for coordination, collaboration and representing the interests of the stakeholders.

The AeroSpace and Defence Industries Association of Europe (ASD) is the main representative organisation for the aeronautics, space, defence and security industries in Europe. This also includes the defence and security sectors for land and naval systems. ASD has 30 member organisations in 20 European countries. Members include major aerospace companies in Europe, as well as national industry associations. ASD was established in 2004, from a merger between three different industry organisations, including AECMA, Eurospace and EDIG. The ASD represents the interests of the aerospace industry in Europe and European public policy and acts as a single point of contact between the industry and relevant stakeholders and institutions. The ASD also coordinates initiatives related to environment, standardisation, skills and training, quality standards, social impact, international trade and cooperation, and the development of SMEs in the sectors. ASD offers quality related services through four affiliated associations: STAN (standards), EASE (supplier evaluation), PRO (quality assessment of special processes and CERT (certification). ASD participates and collaborates in several European programmes and initiatives in research, safety and quality. The ASD, for example, collaborates with the European Commission and institutions from non-European (mainly Asian) countries in international programmes on air safety and operational safety awareness. The Aerospace Performance Improvement (API) is an initiative of the European Aerospace Quality Group (EAQG, part of ASD) and the International Aerospace Quality Group (IAQG) and offers the industry best practices on supply chain performance improvement. Other initiatives include ACARE, Clean Sky, SESAR, SETRAS, AeroPortal and Staccato, some of which will be described in more detail in the section on networks. The ASD also represents the European aerospace industry and national associations in the International Civil Aviation Organisation (ICAO), which is part of the United Nations and deals with issues in civil aviation related to safety, security, environment, continuity, operational efficiency, and regulations. The ASD-IMG4 is the aeronautics industry network for research and technology and represents larger manufacturers of aircrafts, aero engines, equipment, and air traffic management systems. The ASD-IMG4 represents the aeronautics industry in the EU civil aeronautics framework programmes and the strategic research agenda. In doing this, it collaborates with AeroPortal as well as with the representative organisations of aeronautics research organisations.

The interests of the Space Sector are specifically represented by Eurospace, which is the space group of ASD. Like ASD, Eurospace offers information and advice, acts as a liaison between industry and institutional clients, and coordinates various initiatives related to safety, quality, environment, research, and trade.

## 2.2.4 Institutional clients

The European Space Agency (ESA) was established in 1975, as a follow-up of the European Space Research Organisation (ESRO) and the European Launcher Development Organisation (ELDO). ESA includes 18 European countries (and Canada as a cooperating state) and is responsible for developing and executing the European space programme. It aims to provide for European collaboration in space research and technology and space applications for both scientific purposes and operational space applications (e.g. telecommunications, earth observation). ESA’s budget for 2009 amounted to EUR 3,592 million and is the main customer for the European Space Sector. In 2007, the European Commission together with ESA initiated the European Space Policy, aiming at unifying the approach of the ESA with national space programmes. The European Space Policy is the first common political framework for space activities in Europe.

For the military part of the space and aeronautics sectors, the European Defence Agency (EDA) is the main governmental agency in Europe. The EDA was established in 2004 and includes 25 European Member States. The EDA sustains the European Security and Defence Policy and aims to develop defence capabilities, promote defence research and technology, promote armament collaboration, and create a competitive European Defence Equipment Market as well as a strong Defence Technological and Industrial Base. In 2009, the EDA had a budget of EUR 20.7 million, of which EUR 2.5 million was spent on operational projects and studies.

The European Civil Aviation Conference (ECAC) was established in 1955 as an intergovernmental organisation that seeks to harmonise civil aviation policies and practices among its member states. The ECAC is closely related to the International Civil Aviation Organisation (ICAO), which is the global organisation for civil aviation issues.

The European Aviation Safety Agency (EASA) is responsible for the common safety and environmental rules in aviation at the European level. In close cooperation with the national authorities, the EASA monitors the implementation of standards and rules through inspections in the Member States and offers technical expertise, training and research. EASA is the counterpart of the US Federal Aviation Administration (FAA).

Eurocontrol is the European organisation than plans, develops and coordinates the pan-European strategies for air traffic management for civil and military users. Eurocontrol manages the transnational air traffic control centre, offers training for air traffic management officers, and works on developing future air traffic management, in particular the Single European Sky initiative.

### 2.2.5 R&D organisations and platforms

The EREA, the Association of European Research Establishments in Aeronautics was established in 1999. Members of EREA are national research organisations active in aeronautics research. EREA has two permanent working groups, one on aeronautical research and one on security research, as well as one ad-hoc working group on human resources and skills. EREA is participating in several European initiatives in aeronautics research, including ACARE.

The EASN, the European Aeronautics Science Networks is the European platform for European universities active in aeronautics research. EASN was established in 2008 and includes research groups at universities in 31 European countries. EASN aims to encourage and support research collaborations, mobility of researchers and knowledge and technology transfer, as well as contributing to the development of European research programmes in aeronautics. Another representative group of European universities active in aeronautics and space is Pegasus, which started in 1998. Pegasus aims to encourage collaboration between universities in the field of aerospace engineering and is especially focused on promoting the quality of education and research programmes in space and aeronautics. It has, for example, developed a certificate for graduated engineers in space and aeronautics. Members of Pegasus include 23 universities from eight European countries.

GARTEUR is the Group of Aeronautical Research and Technology in Europe and is based on a Memorandum of Understanding between seven European countries with major research and testing facilities in aeronautics. GARTEUR was established in 1973 and focuses on collaborative research topics mainly for the longer term, both civil and military. GARTEUR brings together industry, research organisations and universities collaborate R&D projects (over 120 projects since its establishment (http://www.garteur.org/index.html).

## 2.2.6 Support for SMEs and entrepreneurs in aerospace

AeroPortal is the main initiative to support SMEs and entrepreneurs active in the Aeronautics Sector. AeroPortal is a joint initiative by ASD and the European Commission and aims at encouraging and supporting the participation of SMEs in the EU's Seventh Framework Programme of Research. AeroPortal provides information about funding opportunities and activities related to aeronautics research in FP7. AeroPortal offers information and support to SMEs and entrepreneurs, provides training and coaching, and acts as an intermediary between aeronautics SMEs, research organisations and other stakeholders (http://www.aeroportal.eu).

INVESAT is an initiative of Europe INNOVA which aims to bridge the gap between SMEs and financial investors in the emerging markets of satellite-based earth observation, navigation, geo-positioning, and telecommunications. INVESAT acts as a mediator between SMES and financing organisations by providing SMEs and entrepreneurs with knowledge required for the development of successful business models, by coaching entrepreneurs, by overcoming barriers for capital investment to invest in new, innovative satellite applications, and by catalysing innovation financing through entrepreneurs' networks.

Another Europe INNOVA initiative in promoting the availability of finance for SMEs and entrepreneurs in Space is FINANCE Space. FINANCE Space stands for Finance Innovation Network Addressing New Commercial Enterprise using Space. FINANCE Space aims to encourage and facilitate linkages between the funding sources of the European space sector and innovative enterprises. New space applications offer opportunities for new business services, but finance is often an obstacle. FINANCE Space wants to contribute to the further commercialisation and privatisation of space applications in Europe. While INVESAT is trying to link entrepreneurs to investors and to coach entrepreneurs in attracting investors, FINANCE Space is more dedicated to analysing and identifying the conditions of innovation financing in space and the specific problems related to this. FINANCE Space aims to assist policy makers by formulating policy recommendations on innovation financing in the Space Sector (http://www.europe-innova.org).

The European Space Incubators Network (ESINET) was launched in 2002 and serves as a network of European incubators in space technologies and applications. ESINET aims to support regional incubators in stimulating entrepreneurship and SMEs in space technologies and applications. ESINET includes 27 members from various European countries (http://www.esinet.eu).

KIS4SAT is also funded by the Europe INNOVA initiative and aims to support SMEs and entrepreneurs in downstream satellite applications by providing innovation business support services, networking services, as well as training (http://www.esinet.eu/DisplayPage.aspx?pid=211).

Support to SMEs in the space sector is also provided by the NAVOBS Plus programme. The NAVOBS Plus programme aims to improve the participation of SMEs in R&D activities in space applications, in particular related to GALILEO, GMES and satellite telecommunication services. The NAVOBS Plus programme is an initiative of the European Space Incubator Network (ESINET), supported by the European Business and Innovation Centre Network, the European Space Agency and the Space Research & Applications Unit of the EC DG Enterprise and Industry (http://www.navobs.com).

### 2.2.7 Access to finance

Despite the various schemes and initiatives available to SMEs in the space and aeronautics sectors, access to finance is in general a major challenge in these sectors. Especially since the start of the financial and economic crisis at the end of the first decennium, the capital intensive space and aeronautics industry suffers from restricted access to finance. On the one hand, airlines are suffering from the economic crisis with declining passenger numbers, lower freight volumes, decreasing flying activity of corporate personnel and very restricted credit possibilities. This directly impacts the orders for new aircrafts as well as the possibility for customer financing. Also the aircraft leasing companies run into trouble. On the other hand, suppliers get more risk handed over from prime and first tier manufacturers requiring larger investments, while at the same time the smaller companies have more difficulties getting loans or credits. This directly impacts the delivery of parts and components, delaying the delivering of aircrafts. The financial and economic crisis seems to hit smaller firms in particular; often the important suppliers to the prime manufacturers. The prime manufacturers need to safeguard their supply chain by expanding their network of suppliers or by direct financial support to their suppliers.

## 2.3 Clusters and networks

The long, complex and expensive product development trajectories in the Space and Aeronautics Sectors are in most cases joint initiatives of several aerospace firms, suppliers, and research organisations. Large R&D projects are increasingly carried out by international consortia.

This section presents several research networks, programmes and collaborations at the European level.

## 2.3.1 European Technology Platforms

In Europe, but also worldwide, companies, universities and other research organisations collaborate in dedicated R&D collaborations and networks. European Technology platforms (ETPs) are important examples of collaborative networks in the European space and aeronautics sectors. ETPs provide a framework for stakeholders, led by industry, to define research and development priorities and action plans, needed for Europe's future growth, competitiveness and sustainability. All ETPs set up a common strategy, a Strategic Research Agenda (SRA), and aim to build partnerships to share risk, pools of resources and team up to compete worldwide. Accordingly, they play a key role in ensuring an adequate focus of research funding on areas highly relevant to the industry. They provide important input for the Framework Programme 7 (FP7).

There are three Technology Platforms active in the field of space and aeronautics: ACARE, ESTP, and ISI. ACARE is the Advisory Council for Aeronautics Research in Europe, established in 2001. ACARE was set up to develop and maintain a Strategic Research Agenda for aeronautics in Europe. ACARE comprises about 40 members, including national research agencies, national aeronautics research organisations, ministries and directorates-general, manufacturers, airports, representative organisations of airlines, as well as regulators and Eurocontrol. The Strategic Research Agenda materialises the vision from the 2001 report 'European Aeronautics: a Vision for 2020'. The first edition of the Strategic Research Agenda was published in 2002; the second edition was published in 2004. In 2008, an Addendum to the SRA was published. Beginning of 2011, a new vision, 'Flightpath 2050' was presented. Flightpath 2050 continues the work of ACARE beyond 2020 towards 2050 and will also develop Strategic Research Agendas, starting with SRA-3. The SRAs is converted into research programmes by the stakeholders who contribute funds, resources and capability to execute the research guided by the SRA. Since the start of the agenda, over 200 projects have been launched from the EU Framework Programmes, worth EUR 2,000 million. In addition two large Joint Undertakings have been started since: the Clean Sky and SESAR.

The first edition of the SRA identified five areas of research: Noise and Emissions, Quality and Affordability, Safety and Security, and Air Transport System Efficiency. The second edition further developed the first edition by introducing possible future scenarios in order to identify areas of uncertainty, variance and choice. In the Addendum in 2008, three areas have been chosen for increased priority: the Environment, Alternative Fuels, and Security (website ACARE). These three areas are also mentioned in Flightpath 2050, as well as maintaining and extending industrial leadership.

The European Space Technology Platform (ESTP) started in 2005 to develop the Strategic Research Agenda for space technology in Europe. ESTP has members from 19 Member States, Norway, Switzerland, and Canada. It includes 110 space companies, Eurospace, ESA, national space agencies as well as R&D organisations and universities. The Strategic Research Agenda was published in 2006 and called for increased attention for and investments in space technology. According to the ESTP, the space sector is losing ground, mainly because of insufficient and fragmented funding and Europe's limited commitment to security-related space activities. The Strategic Research Agenda proposes three main pillars: 1) non-dependence: development of strategic space technologies, needed for Europe's independence; 2) multiple-use and spin-in: creating synergies with non-space sectors in areas of mutual interest; 3) enabling technologies: developing technologies needed for new space services and applications addressing EU policy objectives, e.g. in security, Galileo and GMES (European Space Technology Platform, 2006).

The Integral Satcom Initiative (ISI) is the Technology Platform related to satellite communications, including broadcasting, broadband, mobile satellite communications, but also other satellite based applications like navigation and earth observation. Presently, ISI had 174 participants from 27 countries, also including the US, South Korea, and Israel. ISI brings together industry, ESA, national space agencies, and research organisations and universities. ISI published its first version of the Strategic Research Agenda end 2005. ISI identified several research themes. Research objectives deal with spectrum availability and higher frequency bands and ISI wants to stimulate and support the development of new satellite technologies in less time and at lower costs which allow more flexible satellite missions, with higher performance and at lower costs. Moreover, ISI works towards the convergence and integration of satellite and terrestrial network, including all internetworking and interoperability aspects. ISI also wants to contribute to the development of urban and in-building coverage and addresses the integration of satellite communications with navigation, earth observation and air traffic management systems. Specific attention is given to Galileo and GMES. ISI promotes harmonisation of the international regulatory framework as well as the development of open standards and international standardisation (ISI, 2006).

While these three European Technology Platforms are dedicated the space and aeronautics sectors, also other Technology Platforms focus on technologies relevant for the space and aeronautics sectors. These Technology Platforms include, for example, Artemis (embedded computing systems), eMobility (mobile and wireless communications), EUROP (robotics), EUMAT (advanced materials), ENIAC (nanoelectronics), and Photovoltaics (European Space Technology Platform, 2006).

The functioning of the ETPs was evaluated in August 2008 by Ideaconsult. The results of an extensive online survey, case studies and interviews among all relevant stakeholders revealed that the ETPs are successful in mobilising industry and academia and creating a momentum on industrial and political level. The study concludes that ETPs are generally considered to be sufficiently open and transparent and successfully involve and represent a broad range of EU-wide stakeholders in their activities. Most stakeholders are satisfied with the strategic work of the ETPs and the coordination role they have resulting in significant synergy effects between industry and academia. Concerning the goal of mobilisation of resources stakeholders indicate positive effects in relation to the increase of EU funding, national funding and also industrial (private) funding in certain R&D areas. Concerning effects on the improvement of framework conditions and the enhancement of a high-skilled workforce, there are positive effects as well. However, the study reveals that ETPs have difficulties in providing evidence about their activities and the results achieved. Despite of this, it seems that innovation performance benefits from these platforms.

## 2.3.2 Networks

Single European Sky ATM Research (SESAR) is the technological dimension of the Single European Sky (SES), which was initiated in 1999 by the European Commission to reform the architecture of the European traffic management. A reformed European Air Traffic Management (ATM) network will enable sustainable, efficient, safe, fully integrated and cost-efficient air traffic in Europe and will be able to manage the expected strong increase in air traffic. In 2007, the SESAR Joint Undertaking was started and it will last until 2020, from defining and developing a new European ATM to implementing the new system. In 2009, agreements were made with 16 partners for a total amount of EUR 1,900 million for the next seven years. Partners include air navigation service providers, ground and aerospace manufacturing industry, aircraft manufacturers, airports and airborne equipment manufacturers (http://www.sesarju.eu/public/subsite_homepage/homepage.html).

The Joint Technology Initiative Clean Sky aims to develop breakthrough technologies to improve the impact of air transport on the environment. Clean Sky is a large EU initiative with a budget of EUR 1,600 million, equally shared by industry and the European Commission for the period 2008-2013. Clean Sky aims to involve the whole supply chain and encourages the participation of SMEs. Members of Clean Sky come from 16 countries with 54 industries, including 20 SMEs, 17 research centres and 17 universities. The research and development in Clean Sky focuses on six themes or demonstrators: green regional aircraft, SMART fixed-wing aircraft, green rotorcraft, sustainable and green engines, systems for green operation, and eco-design.

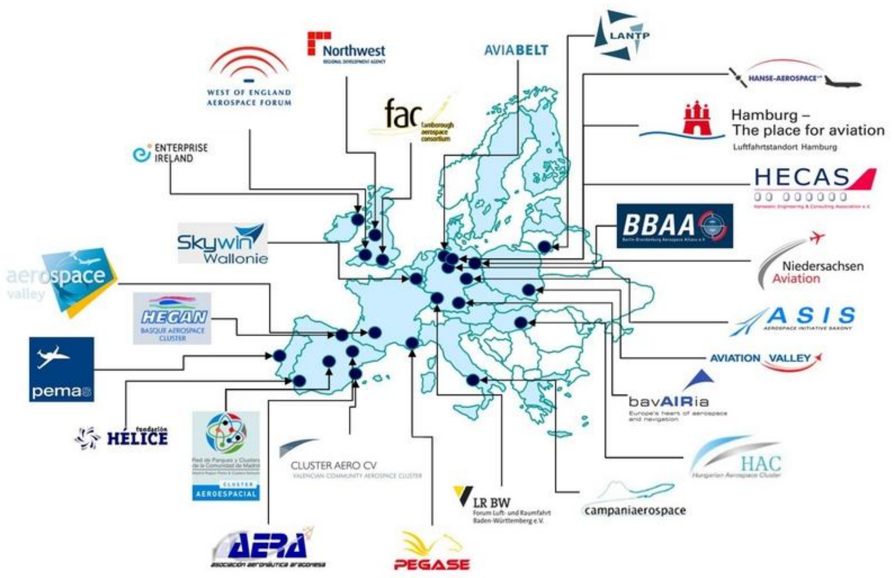
The Air Transport Net is an ERA-Net covering aeronautical research and air traffic management issues. It includes 26 public research institutes and governmental organisations from 17 European states and Eurocontrol. Air Transport Net was initiated by GARTEUR and aims to coordinate aeronautical research at the national and European level.

There are also several networks focusing on the safety and security market segments, which are addressed by the Aerospace Sector as well as other by other sectors (e.g. Electrical and Optical Equipment, Defence Industries). In 2007, the Stakeholders platform for supply Chain mapping, market Condition Analysis and Technologies Opportunities (STACCATO) was established, funded by the EU Preparatory Action for Security Research. STACCATO focuses on the methods and solutions for the creation of a security market and a structured supply chain in Europe. It aims to contribute to the development of a common European Security Equipment Market by identifying common needs and coordinating security research programmes. Another example is SETRAS, which is also focused on the security market and aims to enhance the critical infrastructure protection measures and security standards.

## 2.3.3 Clusters

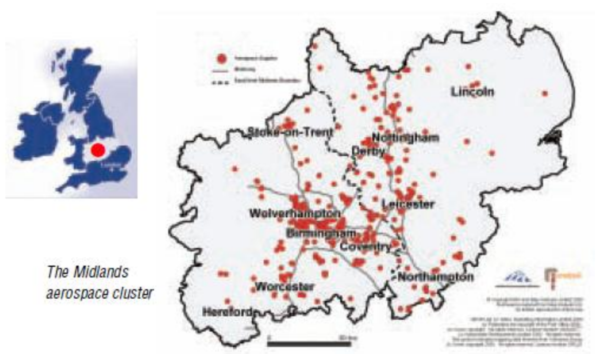
The European Aerospace Cluster Partnership (EACP) is a network of European aerospace clusters and provides a platform for mutual exchange, policy learning and collaboration among these clusters. The EACP has 26 members from 11 countries. Figure 2.1 presents the participating aerospace clusters.

**Figure 2.1 Aerospace clusters participating in EACP**




Source: http://www.eacp-aero.eu/index.php?id=4

**Box 2.4 Midlands Aerospace Alliance, United Kingdom**




In 2003, the Midlands Aerospace Alliance was set up to improve wealth creation and employment for companies and people involved in the aerospace industry across the Midlands in the United Kingdom. The Midlands aerospace cluster is located at the centre of England with at the heart of the cluster Rolls-Royce, the world's number 2 manufacturer of aircraft engines. Rolls-Royce accounts for 25% of the 45,000 jobs in the cluster. A second hub in the cluster is concentrated around the companies Goodrich, GE Aviation and Meggit, which supply electro-mechanical systems that control the aircraft's moving parts. A third hub is concentrated around specialist aerospace materials producers including Alcoa, Timet, Advanced Composites and Special Metals Wiggin. In total, about 300 companies are in the cluster making flying parts. In addition, there are many companies that generate their turnover from non-flying parts and services to the aerospace industry, such as specialist design and manufacturing equipment. The cluster does not produce complete aircrafts, but includes all kinds of subsystem integrators and suppliers of components, as well as research organisations, suppliers of equipment for design, engineering, testing and manufacturing. In this way, the aerospace cluster is linked to other sectors, such as automotive, electronics and telecommunications.

The cluster supports the development of a successful, competitive and innovative regional aerospace industry. Important elements in the cluster are geographical proximity, repeated transactions with competitors and collaborators, mobility of human resources among companies and research organisations, but also operating at a great scale without full-scale vertical integrations or mergers. Especially in aerospace cooperation is essential. The long development times and high risks in developing aircraft systems are a too heavy burden on one company alone. Even rivals join forces to win a new project and offer better service, each specialising in a different part of the work. The cluster also stimulates the creation of new companies, providing a network of established relationships and hence lowering entry barriers in this rather closed industry. The Midlands aerospace cluster has developed since the war-time years, building on the development of engines at several engine manufacturing companies, including Rolls-Royce. The Midland Aerospace Alliance supports the cluster by organising networking and knowledge exchange activities, providing expertise and advice for companies, as well as by organising seed funding for new technology development projects. The MAA collaborates with other regional initiatives and helps filter national aerospace initiatives and policy to increase the impact and benefit for the Midlands aerospace cluster. The MAA is supported by Advantage West Midlands and the East Midlands Development Agency (Mair, 2008).

**Box 2.5 The Aviation Valley Association, Poland**


The Aviation Valley Association was created in 2003 in Podkarpackie in Poland. The Aviation Valley aims to build a strong regional cluster in aeronautics, stimulating the regional development and exploitation of regional potential. The association was established by a group of leading regional enterprises, Rzeszow Technical University and Rzeszow Regional Development Agency. Podkarpackie is located in south-east Poland and has long history of aviation. About 90% of the production in the Polish aeronautics industry originates from this region. The region is also home to some aviation-related R&D institutions. During the 1990s the large state-owned companies in aeronautics had to size down, while at the same time new SMEs were established, which became sub-contractors to large manufacturers in Poland and worldwide. The cluster currently represents 76 companies and employs 22,000 people. The Aviation Valley Association aims to develop a network of subcontractors and a low-cost supply chain, support collaboration between firms and technical universities to stimulate knowledge transfer and innovation in the sectors, to develop relationships with other European aerospace clusters, to attract foreign investments, as well as to act as an intermediary between national, regional and European governments and the industry.

The cluster received funding from the international engine manufacturer Pratt & Whitney, which was already active in that region. Furthermore, the initiative has been supported through INTERREG IIIC ADEP and collaborated with the Oulu region in Finland and the Border, Midland and Western region in Ireland. The Aviation Valley is included in the Regional Innovation Strategy, which aims to support and initiate actions for professional training and conducting research. The Aviation Valley was one of the first clusters in Poland and implemented some basic cluster-building methods and best practices from clusters abroad. It now also transfers experiences with other clusters in Poland and other Central and Eastern European countries. In a case study description for Inforegio, the main success factors of the cluster are discussed. Important success factors for the cluster, according to a case study description for Inforegio, are the active participation of local leaders from private companies and research organisation, the close links with local companies to identify real needs, the good relationships based on trust among the members of cluster, as well as the useful interaction with two clusters abroad which have similar characteristics and the strong link with regional strategic planning and policies. (http://ec.europa.eu/regional_policy/cooperation/interregional/ecochange/goodpractice/1knowledge/1cluster/pl_aviation.pdf ; http://www.dolinalotnicza.pl/pl/)

CASTLE is a trans-national aerospace technologies cluster encompassing three European regional clusters with a strong focus on satellite navigation applications. CASTLE stands for Cluster sin Aerospace and Satellite Navigation Technology Applications Linked to Entrepreneurial Innovation. CASTLE aims to support the three clusters to become competitive in Europe for innovation in satellite navigation applications. The three regional clusters are situated around Munich (Germany), Leiden (The Netherlands) and Prague (Czech Republic). CASTLE is supported by Europe INNOVA (http://www.europe-innova.org).

Another Europe INNOVA cluster initiative focused on space applications is ENCADRE. ENCADRE brings together 16 existing space clusters and operates as an informal platform to support the creation of a market strategy in the field of satellite communication, satellite navigation and earth observation applications, in particular Galileo derived applications. ENCADRE stands for European Network of Clusters for Satellite Applications Development (http://www.europe-innova.org).

# 3 Sectoral innovation futures[5]

## 3.1 Emerging and future drivers of innovation between S&T and (market) demand

The following paragraphs will discuss the main drivers of innovation in the space and aeronautics sectors from the perspectives of science and technology and of demand.

### 3.1.1 Science and technology drivers

This section presents major, generic developments in science and technology that are relevant for aeronautics and/or space. It presents technological developments independent of their specific application in the sector. Of key importance are the long technology and product development times which make technology adoption of the sector relatively slow. Furthermore, the Advisory Council for Aeronautics Research in Europe (ACARE) highlights that the technical agenda should remain unchanged for incremental improvements but accelerated towards breakthrough technologies. Otherwise future targets in emission and noise reductions cannot be achieved (ACARE, 2008). In the foresight analysis, the following main categories of science and technology drivers have been identified:

- IT developments and avionics;
- artificial intelligence;
- new materials and nanotechnology;
- alternative propulsions and fuels, and
- communication technologies.

There is substantial consensus between the various forward looking studies, partly because of the long development times and life-cycles in aeronautics making developments in the coming 20-30 years fairly predictable. In this sector, there is no 'driver of the year' or 'innovation of the year'. Still, drivers may become less or more important.

#### 3.1.1.1 IT development and avionics

Avionics, meaning 'aviation electronics', comprise electronic systems for use on aircraft, artificial satellites and spacecraft, including communications, navigation and the display and management of multiple systems. It also includes the hundreds of sub-systems that are fitted to aircraft to meet individual roles. These can be as simple as a search light for a police helicopter or as complicated as the tactical system for an Airborne Early Warning platform (NLR, no date). Technological advances in IT and electronics (e.g. miniaturisation) have been on-going for several decades but promise further advances in flight control, air traffic management, simulating and modelling of new products and manufacturing processes (aeronautics) as well as communication technologies and satellite

[5] This chapter is based on the foresight analysis performed in Task 2 of the SIW-II. The full results of this analysis are available in Brandes and Poel, 2010.

applications (space). Miniaturisation is driven by further advances in nano-technology, and electronics are increasingly embedded driven by the convergence of ICT and nano-technology. Miniaturisation leads to falling real costs and widespread integrated use. Related to this trend is the increase in computing power allowing for managing and controlling complex systems that were previously not manageable (important for air traffic management; design development, and control of new aircraft designs).

Furthermore, simulation and modelling technologies are advancing enormously providing large opportunities in the design and manufacture of new products as well as the training of pilots and users. Modelling technologies can be applied in the design, not only of the overall product but in all product and system components, leading to shorter development times and cost savings. These technologies are therefore expected to have a high impact on the innovation cycle of the sector as well as productivity.

#### 3.1.1.2 Artificial intelligence

Equipment is expected to become more intelligent in the near future with advancements in artificial intelligence (AI) increasing autonomy (ISTAG, 2006). In short, AI is the branch of computer science dealing with the reproduction or mimicking of human-level thought in computers, so that these can solve problems creatively. Intelligent systems are expected to use an array of cognitive functions: 1) Cognitive vision 2) Speech recognition, 3) Learning and self-reflection and 4) Context-sensitivity and affective computing (understanding emotions) making them adaptive to impulses from their environment (FMER, 2007). Artificial intelligence has the potential to enable robust, secure and reliable systems that are capable of self-organizing. Self-organizing means that they can configure, test, maintain, repair and even dispose themselves, while keeping out any human factor (IPTS 2003, 2008; ISTAG, 2006). This is of high interest also for space applications where continuous communications with Earth is impossible and products need to self-diagnose technical failures, and if possible find a solution. However, advancements in this area are likely to take some time before widespread commercial impacts can be expected.

#### 3.1.1.3 New materials and nano-technology

Developments in (new) materials play a crucial role in airframe structures, engine components and in related systems and devices (DTI, 2001, p.9). For example, while for the Boeing 777 aluminium was the dominant material, the A380 is already made of 22 per cent composites, while the Boeing 787 is planned to use 50 per cent composites, similarly to the planned A350-900 (BmVit, 2008). This trend towards lightweight materials in airframe structures is on-going. But new materials are much broader. These aim at manipulating the physical properties of materials (nano-technology) to enhance performance, to be able to reach set goals to increase fuel efficiency, reduce emissions and noise levels. Examples in addition to lightweight materials (composites but also metallic cellular structures) are high performance alloys for jet engines (refractory metal alloys) etc. (BmVit, 2007). At the same time there are few fundamental material changes observed in industry (DTI, 2001). The adoption takes time and will happen step by step to manage and control technological risks as the new models of Boeing and Airbus show.

#### 3.1.1.4. Alternative propulsions and fuels

Another technology driver to achieve environmental goals in aeronautics, relates to alternative fuels and radical alternative propulsions. While alternative fuels are already in adoption in other transport modes, aeronautics relies on kerosene with different properties than standard fuels (energy density / freezing point). ACARE (2008) therefore calls for research activities to analyse aviation specific implications of alternative fuels including a detailed well-to-wake analysis for all potential fuels to be considered. Furthermore, to prevent technology lock-in two parallel research efforts should be pursued at the same time:

- drop-in alternatives of kerosene - renewable fuels that can be added / used in the current kerosene infrastructure.
- revolutionary aircraft power systems - fuel cell / hydrogen that require a new infrastructure and hence pose considerable barriers.

#### 3.1.1.5 Communication technologies

Communication technologies one day could become full substitutes for face-to-face contact making travelling less important. However, electronic communications seem to have increased the demand for international business travel, as companies operate on an increasingly international scale and therefore have a far larger customer and supplier base spread over a wider area (UK DfT, 2002, p.15). It rather seems that demand for air travel is closely related to global economic integration and hence increases with widespread use of global communication services.

### 3.1.2 Demand drivers

Demand drivers differ between aeronautics and space, with demand for aeronautics particularly shaped by expected growth in air travel, which in turn depends on economic growth and fuel prices. Space on the other hand is still a largely institutional and regulated sector, making public demand and regulation key demand drivers. Generally, politics and regulation are seen as key uncertainties impacting demand in both segments.

The role of the military and public agencies as procurers of leading edge technology has an important impact on innovation in the sector. The military in the past has often been a lead user as it is most interested in obtaining a performance advantage. Super-sonic aircraft, satellites, composite materials, etc. have first been applied in military research or procurement. While military spending after the collapse of the iron curtain has decreased – with focus away from large technology projects to distributed warfare - public institutions still play a key role for financing and using new technologies. The drivers shaping innovation differ substantially between the different segments. Table 3.1 highlights the needs of customers for the two main market segments ‘aeronautics’ and ‘space’ by key customer group, the institutional/military and the commercial market. With the focus on leading edge and high performance technology the institutional/military segment provides the most opportunities for radically new innovations to originate.

**Table 3.1 Key clients by sub-sectors and potential for lead market**

| | Aeronautics (aircraft) | Space (launchers / spacecraft) |
|---|---|---|
| Commercial | Airlines / leasing firms main customers: main focus, safety, comfort and life-cycle cost reductions<br>• low lead user potential | Telecom firms main customers for satellite launches: main focus cost reductions and reliability<br>• little potential as lead user |
| Institutional / Military | National military: main focus high performance, technical lead, national procurement<br>• lead user | Government institutions and military: main focus leading edge technology, national procurement to preserve national security<br>• lead lead-user |

Source: Brandes and Poel (2010)

Furthermore, the institutional and space segment is willing to take higher risks to push out technology boundaries, providing a lead user role (e.g. small air vehicles, unmanned aircraft, space robots etc.). On the other hand the commercial aircraft segment has low lead user potential as customers are risk averse. The exception could be 'green technology' with commercial pressures in the sector acting as a very strong driver to realise efficiency gains.

Key demand drivers for innovation:

- With growing income, people spend more time on holidays and travel further. Furthermore, large shares of world population reach income levels where they demand air travel.
- Strong competition caused by de-regulation and privatisation in air travel and air traffic management has led to falling real prices driving growth in air travel.
- Globalisation requires increasing levels of mobility by firms to manage international production networks and goods.
- Capacity issues and low cost carriers result in more and more point-to-point connections challenging the traditional hub-and-spoke model driving small scale, distributed air travel.
- Safety regulation is a key factor shaping technology choices in aircraft manufacturing, being in tension with new technology adoption.
- Societal challenges – referring to environmental degradation including natural resources such as water, forestry, but also climate change, the mobility challenge, and a perceived need to improve security (terrorism, rouge states). These are expected to be a key demand driver for governments to invest in space applications to monitor and measure environmental effects, and increase effectiveness of policies (OECD, 2005).
- Public procurement for civil as well as military applications is an important driver for the institutional segments of the sector, space and military aircraft.

- With the end of the Cold War cuts in military budget have slowed demand and make dual-use of technologies between civil and military applications important.
- The level of international cooperation is a key future determinant for developing space infrastructure, access to space and a judicial framework fostering commercialisation of space activities.

The following sections describe in more detail what these drivers mean for the different segments of the sector.

### 3.1.2.1 Aeronautics - civil

**Growth in air travel - mobility challenge**

Air traffic has grown over the last decades despite external crisis, such as the Gulf crisis, Asian Crisis, attack on WTC and SARS. Since 1970s the world annual traffic increased from 500 billion to 4,200 billion revenue passenger kilometres in 2006 (Airbus, 2006). Forecasts from ICAO, Boeing and Airbus predict an annual average passenger traffic growth of 4 to 5% per annum. Airbus (2007), for example, predicts world traffic to reach 11,528 billion RPKs in 2026.

The dominant system of air travel in the last decades is a centralized hub system, where large national carriers guide international traffic via a small number of large airports (hubs). However, with deregulation and increased demand for air travel, traffic has also become more de-centralised with the regional jet market having emerged as a robust segment (PwC, 2006). Alenia Aeronautics, a European manufacturer of regional aircrafts expects that in the near future (beyond 2010) 50% of the take offs and landings in Europe will be made by regional aircrafts (Franzoni, 2008). On the other hand, Airbus (2007) expects that traffic growth will mainly come from hub-to-hub traffic and hub-to-secondary cities traffic. Growth from hub-to-hub traffic will mainly benefit from organic growth, generated by existing routes, while growth from hub-to-secondary cities will mainly benefit from new routes. These developments imply that there will be a need for both small and large airplanes. The combination of both hub-to-hub traffic and more small scale, distributed air travel in the future will also require a new air traffic management system.

Although growth in air traffic is expected in the long term, insufficient capacity of airports and air traffic management systems can put limits on the air traffic growth in the short term. Also a worsened economic situation and more stringent environmental regulations and environmental charges can hinder the growth in air traffic.

**Emerging economies stimulating traffic growth**

A main driver for the growth in air travel is coming from emerging economies and especially from the Asia-Pacific region, already representing a share of 26% of the world traffic in 2005, but expected to increase this share to 32% in 2025 (Airbus, 2006). The Asia-Pacific region demand will take over the North-America demand, which is currently the largest market for air travel. The growth in the Asia-

Pacific region will mainly come from continued economic development of China and India, deregulation in India, continuing high traffic growth rates for domestic China and China's international outbound traffics, as well as the growing importance of Low-Cost-Carriers in Asia (Airbus, 2007b; Boeing, 2008a). Despite the high growth figures for Asia-Pacific air traffic, by 2026, the volume of traffic will still be larger in the US and Europe.

Asia-Pacific airlines operate the world's largest long-range aircraft fleet and this will remain the most important type of aircraft in the future as well (Airbus, 2006). According to PWC (2006), manufacturers see the Asia-Pacific market as a major market for new aircrafts. The major airframe and engine suppliers are not only interested in the Asia-Pacific market, but also in the local suppliers, because of low cost advantages. In turn, the governments in this region are interested in the OEMS, as it offers opportunities to procure work for and to develop their own local aerospace industries. These governments support the procurement of the new aircrafts, becoming risk sharing partners in the development of new aircrafts, but in return they will require from the OEMs that they outsource development and manufacturing to their own local aerospace industries. This will help improving the position of the local aerospace industries (PwC, 2006).

**Box 3.1 Demand for air traffic in China**

The Chinese market for air traffic is the fastest growing market worldwide. While in 2000 the number of passengers amounted to about 83 million, in 2007 this number reached already 202 million. In 2006, the China's fleet size was 600 airplanes; in 2009 this number has doubled. Also in the coming 15 years, China will remain the most important growth market for Chinese airlines, but also for European and American prime contractors. The number of airports is expected to increase from 97 to 197 and the number of passengers will likely increase with 14% annually. It is estimated that the number of large airplanes will rise to 3,088 and the number of regional jet will increase to 939 in 2020. An important factor that can hinder the development is the lack of lack of captains and pilots. Liberalisation of aviation offers opportunities for new, private airlines. The first private airline (Spring Airlines) was established in 2004 and is now the biggest private airline of China. These private airlines compete heavily with the large public airlines, mainly by cutting overhead costs, higher load factors, choosing efficient routes saving fuel, and using internet as booking system. The private airlines are developing into low cost carriers. Western manufacturers like Airbus and Boeing consider China as a growth market and establish joint-ventures and build new factories in China. Smaller manufactures see opportunities as well, mainly because of the creation of extra airports and extension of the regional aviation routes. The Western manufacturers have initiated training centres for training new captains and pilots. Nevertheless, serious competition could also be expected to come from China. China is developing its own aircrafts (AJR21), which is first of all a technological prestige project, but which could lead to serious competition for the Western manufacturers by the mid-2020s. The Civil Aviation Authorities of China (CAAC) is established by the Chinese government to ensure that the Aeronautics Sector in China remains a Chinese industry (Airbus, 2007; Boeing, 2008a; NRC, 2009; MacPherson, 2009).

The Middle East is also a fast growing market for aircraft manufacturers. Major investments are being made in transportation and visitor facilities and due to its central world location, the Middle East serves as a connection point for on-stop airline services. Moreover, the region serves as an important cargo traffic hub, with Europe as the largest air cargo partner. As a result, air traffic growth in the Middle East has been much stronger than the average growth rate (Boeing, 2008a; Rolls-Royce, 2007; Airbus, 2007b).

### Rationalisation and the growth for Low-Cost-Carriers around the world

The major national airlines were the traditional major customers of aircrafts, but Low-Cost-Carriers are becoming major customers (PwC, 2006). The global market for air traffic is for 20% served by more than 100 Low-Cost-Carriers (LCC). In North America, LCCs have share of 23% and are still growing.

In Western Europe the LCCs are beginning to mature with a market share of 30%, but there are growth opportunities on eastern and southern routes in Europe. In Latin America, LCCs have a market share of 20% and in Asia their market share increased drastically from less than 5% in 2004 to 12% in 2007. It is expected that Asian LCCs will especially grow on intra-Asian markets, depending on the pace of deregulation (‘open skies’) (Airbus, 2007). It is expected that the LCCs will grow 2% per annum faster than the global network airlines. Nevertheless, network airlines (global, major, small) will remain dominant with 75% of the total worldwide traffic. In addition to the LCCs, another growing customer group includes the aircraft leasing companies. Leasing is increasingly getting important for airlines, as traditional funding sources (cash flow and secured debt) are getting scarce (PwC, 2006).

**Environmentally friendly consumption and legislation – climate change**

With air travel contributing 2% of global man-made emissions (UN IPCC), aviation is under constant pressure from governments and society to improve the eco-efficiency of flying. Moreover, the increasing fuel costs force manufacturers to design aircrafts using less fuel. Fuel can account for 36% of the airline’s operating expenses. Since 1987, the fuel consumption of the world fleet decreased with 37% (Airbus, 2007b). Also noise levels and emission of CO2 are important environmental impacts and the aircraft manufacturers have been able to reduce the levels of noise and emission drastically in the past 40 years (Boeing, 2008a; Airbus, 2007). The aircraft manufacturers are involved in several initiatives and programme to improve the eco-efficiency of aviation. Airbus, for example, participates in the Advisory Council for Aeronautics Research in Europe (ACARE), which has ambitious goals for improving the eco-efficiency of aircrafts by 2020. Another initiative is Clean Sky, which is a Joint Technology Initiative, for developing cleaner aircraft technologies. Boeing spends 75% of the R&D expenditures on developing cleaner aircraft technologies (Boeing, 2008b). Efforts are not only put into developing cleaner aircraft technologies, but also in developing sustainable fuels and in improving air traffic infrastructure and air traffic management systems. Despite these efforts, pressure on industry to improve the environmental performance is growing. Society has often objections against new airports and runways. The European Commission wants to include aviation in the Emissions Trading Scheme, which allocates CO2 allowances for companies. It is estimated that the ETS would increase the operating costs of the airlines substantially. This could force airlines to replace their older aircrafts faster by newer, more energy-efficient aircrafts, but also to purchase larger planes to increase load factors, to change flight paths and to reduce flight speed.

**Safety and security standards and legislation**

Although fatality rates in air travel are very low, when accidents do happen this often involves many fatalities. This means that safety of air travel is a major concern and strongly influences legislation and innovation, with the industry having a strong preference for proven technologies. At the same time security is of high importance with air travel being highly vulnerable to terrorist attacks as events like September 11th show. This high level of attention for safety and security shapes innovation for new technologies making flying safer (aircraft control, traffic management) but also for security checks at airports (detectors, sensors, ICT systems, etc. – not explored in this report).

### 3.1.2.2 Space - civil

The OECD publication (2005) 'Space 2030' discusses the main trends in space. According to this study the future demand for space applications will be substantial. Especially the downstream segment (space applications) has much better prospects with increasing commercialisation and the increasing demand for satellite services in the areas of earth observation, navigation and telecommunications. Information intensive activities are generally perceived as bright, but prospects of transport and manufacturing activities are uncertain as they depend on the costs of access to space, which is unlikely to fall (OECD, 2005, p.14). The upstream segment suffers from chronic over-supply with higher launch capacity than annual launches and with launch costs not expected to fall in the future, this problem is likely to persist. The same conclusion was drawn by the European Commission in 2004 (EC, 2004). But also not all downstream sectors have equally bright prospects. Information intensive activities are generally perceived as bright, but prospects of transport and manufacturing activities are uncertain as they depend on the costs of access to space, which is unlikely to fall (OECD, 2005, p.14).

Factors driving demand especially in downstream segments are related to societal challenges where space applications can help measure effects, monitor and increase effectiveness (OECD, 2005; OECD, 2007b). Societal challenges refer to environmental degradation including natural resources such as water, forestry, but also climate change, related challenges such as the mobility challenge posing high environmental costs, and a perceived need to improve security (terrorism, rouge states). Applications in this context refer to Earth Observation (EO) and Global Navigation Satellite Systems (GNSS). The OECD highlights the role of space applications for monitoring the environment, managing energy use, water management, precision agriculture, the mobility challenge, security and the information economy. Earth observation can for example be used to select locations for renewable energy, assess and monitor water resources, increase the effectiveness of forestry and prevent deforestation, help farmers to monitor crops, monitor hazardous goods, and help in disaster relief and prevention. In combination with GNSS, applications are thought to tackle the mobility challenge, by increasing productivity, reducing congestion, noise and unnecessary pollution in transport (OECD, 2005).

Commercial space travel is a very small scale market for space travel, starting with a number of civilians participating in Russian space missions. More affordable suborbital space tourism is perceived commercially viable by several companies, including Space Adventures, Virgin Galactic, Starchaser, Blue Origin, Armadillo Aerospace, XCOR Aerospace, Rocketplane Limited, the European "Project Enterprise", and others (Law-Green, 2007). This suggests that we are seeing the birth of a nascent commercial space tourism industry, although the way ahead appears very uncertain, with a wide range of economic, technological, political, legal, environmental, financial and commercial issues eventually shaping the rate and direction the industry takes (Crouch et al., 2009).

With the space sector remaining dominated by institutional actors (civil and military) public procurement is an important demand driver. In Europe institutional programmes are funded for several years with the last financing cycle closed just before the effects of the financial crisis hit. This will keep public investments in space high for the coming years, but with public finances expected to suffer severely from the current crisis for many years, the question is whether ambitious programmes can be financed in the long-term.

#### 3.1.2.3 Aerospace - military

With the end of the Cold War the nature of warfare changed from large arsenals of traditional weapons to new innovative weapon systems promoting rapid deployment and extreme precision. While budget cuts in most countries also meant reduced military R&D investments, the USA maintained its levels of R&D. Generally, within this overall negative trend, this meant a relative advantage for Aerospace activities compared to land and naval defence activities, because air capabilities are considered crucial under the changed security environment. Since September 11th the security situation has changed around the globe with growing military expenditure. With emerging powers building up considerable military capabilities (China), and Russia rebuilding its defence sector, a trend towards a multi-polar world is likely to drive future military spending.

Distributed warfare means that Aerospace is likely to benefit from this trend proportionally more than other segments. Rapid reaction requires long-distance air capabilities of high performance aircraft and management systems that integrate navigation, information and communication systems. In addition, observation and control technologies limiting the use of personnel, such as Unmanned Air Vehicles are in increasing demand.

In the military segment, the US can be seen as the technological leader with US agencies as lead customer. One of which being the ‘Defense Advanced Research Projects Agency’ (DARPA) exploring leading edge technological possibilities for military use. However, the US military segment is often restricted to US firms for security reasons, in addition to strict export rules. At the European level, a single military market is lacking, mainly because of the maintenance of separate national procurement practices. At the European level, joint public procurement is developed as a tool to stimulate the development of the military segment in Europe in order to counteract this disadvantage compared with the US market.

**Leveraging military and civil demand – dual use**

In light of scarce resources it is of increasing importance to leverage public investments to achieve technology goals. The idea is to explore the potential use across different applications of the same technologies. However, much of the debate in the past focused on commercialising existing military technologies (spin-out). Ex-post technology transfer is, however, often very difficult as the two segments have different market conditions and engineering cultures. Very few military technologies proceed effortlessly to commercial application due to secrecy, military specifications and long lead times and only occasionally have major impacts such as GPS and Internet (Wessner at Six Countries Programme, 2004). The question therefore remains, whether the concept of dual use is a very promising route to increase efficiency of research, as the structural characteristics of military and commercial applications differ substantially. Instead, the main concern has shifted to the exploitation of technological developments for military purposes occurring elsewhere in the economy (spin-in) (Molas-Gallart, 2002).

## 3.2 Scenarios: Aerospace 2040

The various drivers for innovation – demand-side and science and technology drivers – were used in a foresight workshop with sector experts to develop a set of scenarios to assess possible developments of future markets. Due to the long development times in the sector the scenarios look 30 years ahead. In a second step the scenarios were further elaborated by the research team in a way that they are relevant for aeronautics as well as space activities. Well established scenarios from both sectors were used as background material. In the case of space: the scenarios developed in the OECD study 'Space 2030' (OECD, 2005), and in the case of aeronautics: the ACARE scenarios (ACARE, 2009).

The workshop experts highlighted that key uncertainties particularly relate to demand factors, including the influence of macro trends, and specific regulations related to environmental aspects, safety and security. Essential for the development of meaningful scenarios is the identification of highest uncertainties. The two key drivers with high uncertainty shaping the future of the Aerospace sector, are:

- The **availability and prices of energy** - with fuel representing a major share of operating costs for airlines, the price for hydrocarbons and fuels is critical to the future of the sector. Fuel prices in the last years have fluctuated considerably posing high uncertainty for air travel demand in the future.

- The **level of economic growth** – growth prospects are key for investments in new technologies and infrastructures. With few prospects investors have difficulties refinancing investments.

- In addition to these two key drivers, the OECD scenarios 'Space 2030', use geopolitical uncertainties as key differentiators. The OECD describes a multilateral and peaceful world, a bi-polar world and a pessimistic future where multilateralism breaks down. This dimension is of high relevance for security applications and can be combined very well with the previous dimension of economic growth, as high growth is associated with a peaceful, further integrating world economy that is built on multilateral institutions.

For comparison the scenario descriptions follow a standardised structure. First the scenario will be presented in a nutshell. Then the underlying drivers, opportunities and risks associated with the scenario are presented. Opportunities and risks cover possible market developments, implications for firm competitiveness, and societal issues.

### 3.2.1 Scenario 1: Global Green Aerospace

This scenario describes a peaceful, highly globalised world in 2040 that has successfully taken steps for an energy transition assuring a secure energy supply at modestly increasing prices. Business people but also private individuals enjoy the freedom of being able to travel frequently and far away. Terrorism is not a major threat obstructing air travel. This leads to a flourishing of both the aeronautics and space sector. New technologies and smart regulation lead to radical improvements in aircraft efficiency and emissions, while the space sector allows monitoring and tackling many societal issues such as climate change, environmental resources and mobility issues. Furthermore, free access to space and a global judicial system for space also allow the sector to flourish commercially.

**Underlying drivers:**

- Globalisation continues both economically and politically
- Rising incomes: mean that people travel more; demand for space tourism
- Regulation - global agreement on climate change fostering energy transition
- Stable energy supply with modest increases in energy prices
- Higher energy prices pull technology development in aeronautics
- Free markets and access to space governed by multilateral institutions
- Cooperation in science globally increases effectiveness of innovation
- Judicial framework to assure legal certainty in space has been agreed leading to the further commercialisation of space

The underlying drivers of the Global Green Aerospace scenario pose the following opportunities and risks:

**Opportunities:**

- Due to increasing energy prices the market will demand more efficient and environmental aircraft.
- Rising incomes and further global integration is expected to lead to further growth of the personal air transport market. This is an opportunity for both manufacturers as well as new service providers offering personal air transport services.
- Global cooperation and an improved judicial framework for space leads to a flourishing of commercial activities in space. Segments that particularly benefit are (small) launchers; (micro-)satellites; space based services, and user-driven innovation.

**Risks:**

- Large emerging economies such as China, India and Brazil pose competitive threats to both aeronautics and space manufacturers.
- If energy price increases outpace income growth, real energy prices will rise. This potentially leads to shrinking demand for air travel.

- There is a potential risk to free access to space created by space waste and uncontrolled activities of actors.

- Currently, the aerospace sector is dominated by US and European manufacturing firms. With structural disadvantages from ageing and population growth, European industries are at risk of being marginalised in the global economy of the 21st century.

### 3.2.2 Scenario 2: Regional Aerospace

This scenario describes a world in 2040 with strong regions and limited ties between them. No global agreement on climate change has been reached, blocking a smooth transition to renewable alternatives. Access to fossil resources remain important and shape international relations. This combination of realpolitik and protectionist tendencies leads to slow economic growth and rising energy prices, which differ regionally. Europe tries to lead the way but struggles with strong international competitors. While still able to travel globally, people chose to do holiday trips within Europe for largely economic reasons. With increasing rivalry between regional powers, access to space becomes more difficult.

**Underlying drivers:**

- Strong regions pursue their own interests
- No global agreement on climate change can be reached
- Access to fossil energy sources becomes increasingly difficult; competition between regions for natural resources result in high price increases
- Economic growth slows as a result of trade barriers with consequences for air travel demand
- Cooperation in science continues despite economic competition
- Commercialisation of space is hindered by regional powers protecting their (military) interests

The underlying drivers of the Regional Aerospace scenario pose the following opportunities and risks:

**Opportunities:**

- Due to increasing energy prices the market will demand more efficient and environmental aircraft.
- The regionalisation of markets limits global competition and allows development of regional lead markets. However, at the same time this is also a risk for the highly export oriented Aerospace sector.

**Risks**

- Slow economic growth acts as barrier for new investments. Particularly space investments are likely to suffer from this as they carry relatively higher risks.

- The regionalisation of markets has negative effects for aerospace exports as it will become difficult for firms to access markets outside the EU
- Cooperation in space and access to space becomes fragile for security reasons as international relations between regions are driven by competitive interests.
- With relations between regions driven by competitive interests, scenario 2 carries the possibility of a downward spiral leading to scenario 3

### 3.2.3 Scenario 3: Zero sum games

In this scenario a rapid energy scarcity leads to highly fluctuating energy prices and interruptions in supply. Globalization, thriving on cheap energy and transport, comes to a halt with severe economic adjustment processes. International holiday trips are reduced sharply with people adjusting their consumption patterns to a changed economic environment. Countries seek their interests in protectionist policies leading to a downward spiral and break-down of multilateral institutions. Trade conflicts become a norm with resulting conflicts for access to natural resources. Security expenditure rises steeply at the expense of other policies such as the environment. European integration is at stake. Overall, this is an unfavourable scenario with regions competing on a zero sum basis leading to a deteriorating economic and social environment.

**Underlying drivers:**

- Quick energy scarcity with little time to adapt economic structures
- States take unilateral actions to protect access to natural resources – multilateralism breaks down and protectionism takes over.
- National security becomes primary concern – resources are channelled from civil to military technologies
- Access to space is controlled by the military
- Economic growth declines sharply leading to a global depression
- A scarcity of capital for new investments is likely

The underlying drivers of the Zero sum game scenario pose the following opportunities and risks

**Opportunities:**

- Due to deteriorating security relations under scenario 3, markets for military aircraft are likely to flourish.
- For the same reason markets for space based systems for monitoring and control technologies are likely to flourish.

Overall the risks of this scenario by far outweigh the opportunities.

**Risks:**

- Current markets for civil aircraft are driven by globalisation – in the case of the Zero sum game scenario, globalisation will reverse and this market is likely to break down.

- Similarly, with capital shortages and increasing economic risks the commercial segments of the space sector, which just started to develop are expected to perish.
- Due to capital shortages and economic risks new technologies are unlikely to be developed.
- Generally, new market segments suffer from a lack of capital for investments and a lack of demand for products/services. This scenario hence has strong negative consequences for the sector overall.

## 3.3 Future innovation themes and corresponding linkages with other sectors

This section presents key emerging innovation themes and their requirements. Innovation themes describe the commercialization of new ideas and technologies in emerging markets. This essentially is the interaction between supply and demand drivers. Innovation themes will be described in three steps: a detailed description, opportunities and risks, and barriers.

Opportunities here refer to market opportunities of firms, but also to competitive advantages of Europe and social and environmental opportunities. Risks on the other hand refer to commercial and competitive risks as well as technological and environmental risks. As there are many more innovation themes reported for aeronautics than for space, opportunities and risks for Aeronautics are reported in bullet points. Lastly, potential barriers that might obstruct these innovation themes in their future development are identified. As many of the barriers in the Aerospace sector are applicable to many innovation themes it was decided to report these in the following chapter for the sector overall. However, in case of barriers relevant to specific innovation themes only, these will be also outlined in this chapter.

### 3.3.1 Aeronautics: innovation themes and emerging markets

The environmental impact of Aerospace products is the most important topic discussed in future studies (ACARE, 2008, NASA, 2006, PwC, 2006, UK DfT, 2002; DTI, 2001). This is for two reasons: air travel is expected to double every 15 years at current growth rates, putting strain on infrastructure, natural resources and people living close to infrastructure. Secondly, the climate change debate highlights the need for lowering carbon emissions with air travel perceived as a major contributor to climate change. Hence, reducing fuel consumption and noise levels is important to achieve environmentally friendly air travel in the future. The first four innovation themes all contribute to achieve this goal:

- Air Traffic Management (ATM): to increase efficiency, and to accommodate more (small) aircraft, and in the future also personal and autonomous (unmanned) aircraft.
- Improving aircraft performance: to optimise the overall performance of an aircraft
- New airframe configuration: to increase lift and reduce drag. Radically new airframe designs might be necessary to achieve goals of a zero emission aircraft.

- New propulsion systems and fuels: e.g. direct drive turbofan, geared turbofan, hydrogen, electric engines etc. New propulsion fuels in existing systems (e.g. using renewables) and in new systems (e.g. hydrogen fuel cell, batteries, electric powered aircraft) are explored.

The other three innovation themes are related to increasingly distributed air travel and point-to-point connections possibly superseding the currently dominant hub-and-spoke system:

- Small aircraft and personal air transport services: promise a new market for air transport services similar to taxi services on the ground.
- Personal aerial vehicles: allow for air travel of individuals owning their own aircraft vehicle.
- Unmanned aerial vehicles: rapidly evolving market of ground controlled aerial vehicles.

For all innovation themes it is important to keep in mind the long development times and product cycles. These will favour a constant process of more incremental innovations, more than radical design changes. For example, the large aircraft segment is likely occupied for the next 20-30 years with the new A380 and this implies that innovation will take place within the current innovation cycle with a constant process of incremental innovations. This means that there will be few radical design changes until 2020, with a window of opportunity open for bigger changes around that time period. For any ambitious goals to be achieved, this window of opportunity should be exploited in collaboration between industry, research and policy. Lastly, the availability of talent, particularly engineers, is a key concern for the future of the sector. This issue is dealt with in detail in section 3.4.1.

#### 3.3.1.1 (New) air traffic management

The current air traffic management (ATM) system is based on technology from the 1960s (NASA, 2006). To accommodate growth in air travel and make air traffic more efficient it is necessary to improve the current system. NASA outlined the following areas to improve the Air Transportation System (NASA, 2006 pp.16-17):

- boosting the security and reliability of voice, data, and ultimately video connections to in-flight aircraft. To achieve this, the Austrian aeronautics research programme specifically calls for 'shared backbones' for air traffic control systems that are so far largely soloed solutions networked through private IT networks, compromising security (bmvit, 2007).
- increased use of satellites in handling traffic flow
- use of synthetic vision, cockpit display of traffic information, and controller displays to improve awareness of aircraft separation
- prediction and direct sensing of the magnitude, duration, and location of wake vortices. Wake vortices are turbulences of air created by the trailing edges of the wing of an aircraft affecting take-off and landing of following aircraft.
- safety buffers to account for monitoring failures and late detection of potential conflicts
- accommodating an increased variety of vehicles (e.g., unpiloted, tilt-rotor, lighter-than-air)

Europe is already busy with implementing a new system reflecting the above technology challenges – Single European Sky ATM Research (SESAR). It is implemented following a roadmap, with expected deployment by 2020. In addition to technology, for Europe the challenge is to integrate the different regional and national air traffic control agencies into a unified system (bmvit, 2007). This new air traffic management system is now more a question of political action and less of technology development. The new system opens the opportunity for Europe to set the global standard with US institutions not having agreed on a similar system yet.

**Opportunities and Risks**

- Technology standard of future ATM as lead market for European firms and potential export markets overseas.
- Satellite navigation in ATM can act as demand pull factor for Galileo (safety critical signals) and improve flight safety through continuous tracking and monitoring.
- Expected efficiency gains help reduce emissions of aircraft
- Risk of competing technology standards

#### 3.3.1.2 Aircraft Performance

Aircraft performance can be improved in three major ways: 1) improving the airframe structure through new materials and better design, 2) by improving the efficiency of engines, and 3) through avionics. These can help raise efficiency and performance. But the integration of these three technology domains requires optimisation as there are potential trade-offs between the three. This is the reason why the three domains need to be seen in context of the overall aircraft performance and why optimisation of the overall aircraft has to be seen as a separate innovation theme where in the future software modelling becomes increasingly important. The table below gives an idea how underlying technology systems can improve aircraft performance. Beware that individual improvement potentials cannot be simply added up.

**Table 3.1 Potential fuel savings by technology system**

| | | |
|---|---|---|
| Some typical estimates for fuel savings associated with 'advanced' technologies are given below. Note that these are sometimes optimistic, and cannot be simply added up. | Active Control | 10% |
| | Composites | 20% |
| | Laminar Flow | 10% |
| | Improved Wing | 10% |
| | Propulsion | 20% |

Source: Stanford, 2008

### 3.3.1.3 New airframe configuration concepts

To achieve drastic improvements in environmental performance new airframe concepts for subsonic transports, supersonic aircraft, runway-independent air vehicles, personal air vehicles, and uninhabited air vehicles should be developed incorporating composite airframe structures ,combining reduced weight, high damage tolerance, high stiffness, low density, and resistance to lightning strikes (NASA, 2006).

Over the last century, one dominant design has emerged – the metal tube with wings. New structures carry considerable technology and commercial risks due to technological uncertainties, long development times and uncertain demand. Some more radical designs have been adopted by the military but only on a small scale, such as the F-117 and unmanned aircraft.

Revolutionary changes in aircraft are possible when the ‘rules’ are changed. This is possible when the configuration concept itself is changed and when new roles or requirements are introduced.

The flying wing design, or blended wing body, is intended to improve airplane efficiency through a major change in the airframe configuration. The thick centerbody accommodates passengers and cargo without the extra wetted area and weight of a fuselage. Currently, this is the most promising alternative airframe configuration, with on-going research activities at many universities. Originally designed as a very large aircraft with as many as 800 passengers, versions of the flying wing have been designed with as few as 250 passengers and more conventional twin podded engines (Stanford, 2008). Boeing started test flights on a scaled down version called X-48B in July 2007 and complete the first phase of test flying in 2010 and new flight tests are planned, as well as a second hybrid wing body aircraft (http://www.nasa.gov/centers/dryden/research/X-48B/index.html).

However, in terms of optimization, a blended wing design is most suited for 200-800 passengers. The question is how much demand for this large scale air traffic exists in future, with the A380 filling this segment for the next 20-30 years and a trend towards smaller aircraft. Furthermore, such large aircraft require adaptations in airport infrastructure. In addition, it is reported that passengers might feel uncomfortable in the theatre-like configuration of the mock-up (The Economist, 8 June 2006).

The joined wing design was developed in the 1980's as an efficient structural arrangement in which the horizontal tail was used as a structural support for the main wing as well as a stabilizing surface. It is currently being considered for application to high altitude long endurance UAVs (Unmanned Aerial Vehicle) (Stanford, 2008).

One of the most unusual concepts for passenger flight is the oblique wing, studied by Robert T. Jones at NASA from 1945 through the 1990s. Theoretical considerations suggest that the concept is well suited to low drag supersonic flight, while providing a structurally efficient means of achieving variable geometry (Stanford, 2008).

**Opportunities**

- Potential first mover advantage in market for new aircraft
- Theoretically much higher efficiency gains than through incremental improvements of tube-fuselage design.

**Risks**

- Risk of limited/no adoption with conservative customers, particularly end consumer
- High development costs and uncertain technology (first mover - potential loser)
- Adaptation of infrastructure necessary for large ‘flying wing’

**Barriers** - the requirements for approvals of new aircraft are hard to meet - One reason why the sector evolves very incrementally. 'Robust designs' remain crucial with well-established designs (such as the Boeing 747) and substantial innovation in system-components likely. But, there should be room for new concepts to be explored by academic and industry researchers that can possibly work their way into industry to achieve the ambitious environmental goals set. In addition rather than supporting specific designs, for policy it is important to support basic research and long-term innovation as specific solutions cannot be predicted.

### 3.3.1.4 New propulsion systems and fuels

The propulsion system (engines) of aircraft is a key to reduce environmental impact, which is why breakthroughs in engine design and technologies are needed (ASD, 2007a). Over the last 50 years, only 6 different types are currently used (bmvit, 2007), highlighting the difficulty of new designs to be accepted.

**Improving current designs** - One way to simultaneously reduce noise and CO2 emissions is by increasing the engine by-pass ratio. For a fixed thrust engine this means increasing the engine diameter, while at the same time minimizing drawbacks such as increased weight and drag – 3 main engine architectures are discussed in context of new airplane development (Airbus):

- Direct drive turbofan (DDTF)
- Geared turbofan (GTF)
- Contra-Rotating Turbofan (CRTF)

Airbus has provided two airplane specifications to cover short range (A320 type, 30000lbs) and long-range (A330 type, 70000lbs) applications. Six engines have been derived from these two specifications covering a wide range of architectures: DDTF, CRTF and GTF. Concerning the fan, the DDTF focuses on lightweight material to reduce fan weight by 30%; The CRTF, a highly ambitious and promising alternative solution, allows rotational speed to be decreased by about 30% under the same aerodynamic loads, which should bring a significant reduction in noise (ASD, 2007a).

Another key element to engine efficiency improvement is to increase the air temperature and pressure at which the fuel is burnt. With current materials (nickel-based super alloys) reaching their melting point in current designs, it is difficult to further optimise combustion temperature or turbine efficiency. Refractory metal allows (RM) represent a revolutionary alternative but challenges of oxidisation under high temperatures need to be overcome (bmvit, 2007).

**Bio-fuels** – most research on alternative fuels has so far concentrated on use in road transport. However, performance criteria of alternative fuels in Aerospace differ with extreme temperature changes and strict safety regulations. Next to the unresolved technical issues of bio-fuels, concerns of the environmental impact of bio-fuel production and competition with food use need to be addressed. Other alternative fuels that could be burnt in conventional engines are hydrogen and liquefied natural gas (LNG). The Russian manufacturer Tupolev already built a prototype hydrogen-powered version in

1989 (Tu-155) (Tupolev, no date). According to the firm the cost of liquefied hydrogen currently prohibits the development of this technology commercially. Instead, Russian industry pursues LNG as a ‘bridge technology’. The EU currently funds several projects dedicated to the development of alternative aircraft fuels. Examples of which are ALPHA BIRD and SWAFEA. The latter is carrying out a comparative assessment of the most promising short and medium-term options.

**Alternative propulsion systems** – hydrogen fuel cells is probably the most researched alternative to hydrocarbon-type fuels, also playing an important role for other transport modes (automotive). Currently, the technical and infrastructural challenges inherent in developing a commercially usable hydrogen-powered aircraft are huge. On the other hand, Boeing has made a 2-seat civilian aircraft running on electricity of a fuel cell combined with a battery. The Antares DLR-H2, a prototype by DLR and Lange Aviation, can be seen as a European equivalent presenting a technology platform that will advance the use of fuel cells in aviation (DLR, 2008). This shows the technical feasibility of the technology for small aircraft. Further research outputs are expected over the coming years with for example a number of on-going research projects in this field financed by DG Research (EC, 2009c). However, Boeing does not envision that fuel cells will ever provide primary power for large passenger airplanes (Boeing, 2008c). In addition to the cost of producing hydrogen from water, safety issues pose a barrier especially for hydrogen used in larger aircraft. But a market for fuel cells in aircraft “as auxiliary power systems” is currently being developed (Diaz-Lopez et al., 2011). This can act as a bridge for technology development for fuel cells to possibly develop into primary energy sources in aircraft in the future.

**Opportunities and Risks**

- Lead market for alternative propulsion systems and fuels
- Reduced environmental impact from improved designs and alternative propulsion systems
- Risk of unproven technologies and safety issues in case of alternative propulsion systems. This risk acts at the same time as the biggest barrier.

**Differences across scenarios** - Environmentally friendly air travel and its related technologies are expected to benefit from higher energy prices forcing the realization of efficiency potentials. However, the way this is going to happen matters. Most favourable is a managed transition as in ‘Global Green Aerospace’ that provides a higher level of planning security than the other scenarios and benefits from global cooperation in research but also production. Furthermore, to realize these technology improvements large capital investments in research and product development are required. These are available under positive economic development as in ‘Global Green Aerospace’ and partly in the scenario ‘Regional Aerospace’. In ‘Zero Sum Games’ capital is scarce and unlikely to be allocated to uncertain and long-term technology developments for which the framework conditions are not in place.

### 3.3.1.5 Small aircraft and personal air transport services

At the peak of the last economic cycle, the air transport system has operated at capacity with further growth predicted. At the same time the regional aircraft segment was the fastest growing segment in the last years (PwC, 2006). Small aircraft have several advantages. They can connect smaller, regional airfields, reducing congestion at bigger hubs and increase productivity of business travellers through point to point connections in comparison to hub and spoke servicing. An interesting business model for this segment are air taxi or personal transport services. So far this segment is explored in concept studies only, while a number of smaller air taxi services operate in the USA. A FP6 project on European Personal Air Transport Services (EPATS) foresees high demand in Europe requiring an additional 90,000 small aircraft until 2020. This would imply that by 2020 3% of total traffic falls under personal air transport services (PAT). However, demand is highly sensitive to costs of personal air transport. A sensitivity analysis showed that a 30% increase in costs is expected to result in 40% less traffic, 65% less flights, and 72% fewer aircraft (EPATS, 2009). Furthermore, it is clear that the current economic crisis adversely affects demand.

**Opportunities**

- New market of personal air transport services
- High demand for large number of additional small aircraft

**Risks**

- Demand is highly elastic (sensitive to higher costs) – especially CO2 pricing could pose a substantial risk
- Uncertain regulatory environment and changes in regulation needed (single piloting, on-route planning).
- Uncertain technology: single piloting cockpit equipment needed; TMA and on-route operation (mixing EPATS and traditional flights); Air Traffic Management system challenged to handle millions of additional flights.

**Barriers** – envisaged for PAT fall in three categories: 1) market demand, 2) regulation, and 3) technology. 1) To operate successfully, large scale demand is needed to operate flight taxis economically with sufficient load factors. This requires well established networks, to allow for planes to drop-off one passenger and pick up another passenger. This requires considerable risk taking of a firm to first provide this large scale service to stimulate demand. 2) Furthermore, safety rules in Europe require two pilots for commercial air services resulting in relative high costs. Also on demand air taxi services require on the spot flight planning, and a re-design of managed and unmanaged Single European Sky (SES) airspace (EPATS, 2009). 3) Lastly, for large scale small aircraft services, the current air traffic management and control system is not designed to handle a high number of decentralized air traffic movements. This barrier is expected to be solved by the next generation ATM (SESAR), although expected large numbers of extra flight movements could also challenge the future SESAR.

**Differences across scenarios** -This innovation theme would develop best under circumstances of high economic growth and cheap energy. For that reason it will be challenged across all scenarios. The ‘Global Green Aerospace’ scenario is most favourable in terms of economic growth, however, energy price increases pose a risk due to high demand elasticity. The ‘Regional Aerospace’ and ‘Zero Sum Games’ both do not really provide the needed economic framework conditions to develop this market segment.

#### 3.3.1.6 Personal aerial vehicles

The personal aerial vehicle segment provides an opportunity especially for small firms to exploit advances in micro-electronics, new lightweight materials and IT systems. Examples of this emerging market are the successful introduction of the D-Jet, a five sitter made of composite materials using state of the art avionics (bmvit, 2007), and the Eclipse, an American equivalent. In addition, over the last years a number of small firms have developed gyrocopters that increasingly fulfil the needs of a transport vehicle, rather than being mere sport vehicles (e.g. Autogyro, Celier Aviation, Rotortec, Gyrotec, American Autogyro). These developments could revolutionize air travel with individuals becoming an important actor.

**Opportunities**

- Market of personal aerial vehicles for air transport
- Potentially reducing road congestion

**Risks**

- Potential safety issues from increasing traffic in unmanaged airspace
- Small market segment that so far relies on enthusiast for technology and market development

**Barriers** – these are generally the same as for personal air transport services. In addition, personal aerial vehicles suffer from large differences in regulation between European countries that make attractive cross border travel difficult.

**Differences across scenarios**- Demand for these vehicles, similarly to personal air transport services, depend on income and income growth. With high economic growth this segment is expected to develop best under scenario ‘Global Green Aerospace’ also because alternative propulsion systems can be better implemented for small aerial vehicles. However, regulation so far hindering the free movement of these vehicles through airspace poses the largest barrier for this segment to become important for air transport. With current regulation it is otherwise likely that the recreational focus will remain dominant.

#### 3.3.1.7 Unmanned aerial vehicles

The segment of unmanned aerial vehicles (UAV) is expected to become increasingly important with advances in micro-electronics, new lightweight materials and IT systems that allow the air traffic management system to deal with large numbers of small air vehicles. Currently, an increasing range of unmanned air vehicles, mostly used by the military and civil security institutions, can be observed.

So far, these are largely operated outside managed airspace. With the US and Israeli military being one of the main users, firms from these countries have a particularly strong position in this market.

Next to the institutional segment, enthusiasts and entrepreneurs are exploring this segment with self-made models printed with 3-D printers on sale over the internet. These could be classified as model aircraft, but with advances in micro-electronics have increasingly powerful capabilities (e.g. cameras, GPS, etc.). This issue is already addressed by policy-makers, particularly the safety aspects (Frost & Sullivan, 2007). However, questions remain: when does a toy or kite become a unmanned aerial vehicle? How do the rules and systems for Air Traffic Management apply to UAVs? The US FAA for example has for that reason decreed that UAVs require a certificate of authorization to ensure a certain level of safety. Generally, from the point of innovation, developments in this field represent an interesting, largely user driven development that could lead to disruptive innovation.

## 3.3.2 Space: innovation themes and emerging markets

The potential future demand for space applications has been highlighted by OECD (2005), focusing on societal challenges. Prospects are much brighter in the downstream segment (EO & GNSS) than in the upstream segment that suffers from overcapacity (launchers). But the supply conditions are a main source of concern in realising its potential. The reason is that: 1) The space sector is still a small, and weakly developed sector with limited commercial activities that largely stem from institutional clients. 2) There is a need to overcome major technological and economic challenges, without which a commercial exploitation is not possible. This leads to the conclusion that while space holds a great deal of promise for society at large, it is far from clear whether this potential will actually be realized (OECD, 2005).

The following four innovation themes have been identified as highly relevant for space and explored at an expert workshop:

- Global Navigation Satellite Systems (GNSS), e.g. Galileo
- Earth Observation
- Micro satellites, including impact on launchers and services
- Space travel and tourism

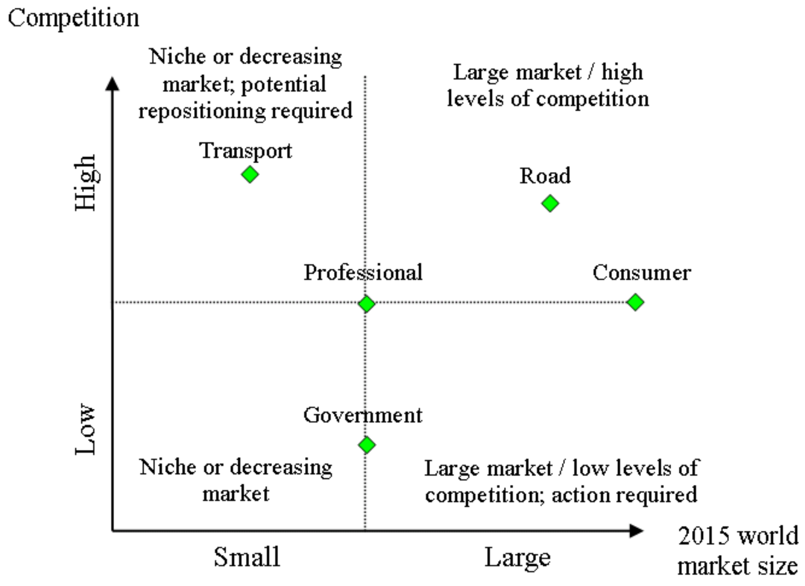
### 3.3.2.1 Global navigation satellite systems

Global navigation satellite systems (GNSS) allow small electronic receivers to determine their location (longitude, latitude, and altitude), using time signals transmitted along a line-of-sight by radio from satellites. As of 2009, the Global Positioning System (GPS) (USA) is the only fully operational GNSS. The Russian GLONASS is in the process of being restored to full operation. China has indicated it will expand its regional Beidou/Compass navigation system into the global COMPASS navigation system by 2015. The European Union's Galileo positioning system is in initial deployment phase, scheduled to be operational in 2013.

**Opportunities**

A report for the European Parliament on the market potential of space applications (Poliakov et al., 2008) presented future market prospects in global navigation satellite systems based on size and competition. Figure 3.1 shows this comparison with the different market segments clustered by expected world market size by 2015 and the expected intensity of competition. Furthermore, there is potential of Galileo for maritime applications as the US managed GPS network still does not provide full coverage. Galileo with its high level of precision could improve maritime safety, by preventing ships from colliding, from disappearing, and combating piracy. Additionally, GNSS can be used in aeronautics. It has not yet replaced radar based navigation and control but is a major component of the next generation Air Traffic Management System (SESAR).

**Figure 3.1 Market segments grouped by levels of competition and firm size**




Source: Euroconsult, Helios and Bertin, 2007

**Risks**

An important difference of the European market compared to other global market regions is the smaller size for space-based applications, the lower specialisation of the private sector, and the absence of a defence industry setting initial standards and activities (Euroconsult, Helios and Bertin, 2007). Nevertheless, the SWOT analysis of the same report shows Europe overall well-positioned to develop new GNSS based applications in several segments, especially in road telematics and fleet management, if R&D for Galileo receives more attention. The analysis is furthermore optimistic for markets of (personal) location based services, presuming high involvement of European MNEs. The study considers the new EU member states to be important drivers for economic growth (by uptake of satellite navigation applications), a strong position for road applications and growing interest in Galileo R&D. A threat is the reluctance of business angels to step in, the maturity of some market segments, the obduracy of foreign (especially US) markets and the threats posed by social concerns such as privacy, hindering novel satellite based applications. (Poliakov et al., 2008, p. 11).

In the last 10 years a large market for satellite navigation equipment has emerged. This market is driven by applications and services that make use of the free GPS signal (of the US-owned GPS system). This means that it is difficult for competing systems (Galileo) to build commercial activity based on business models around commercial signal provision. It is argued that the GPS signal is accurate enough for most applications. Investments in additional systems such as Galileo therefore have largely geopolitical reasoning, to reduce risks and dependence on a single system controlled by a third country. Instead the signal provision should be seen as a public good with positive externalities for users and European equipment and data service sectors.

Another threat in this context is the reserved frequency for Galileo that has also been reserved by the Chinese Beidou/Compass system. Current space law awards the frequency to whoever uses it first. With serious delays in the implementation of the Galileo system and the Chinese having launched their third GNSS satellite in January 2010, there is considerable threat of rivalry between the European and Chinese GNSS system in terms of frequencies.

**Differences across scenarios -** Two levels of this market are affected differently by the scenarios: the equipment segment and the downstream services segment. The equipment segment is expected to profit most under ‘Global Green Aerospace’ with more and more transport modes making use of GNSS (e.g. aeronautics). Also the downstream segment profits most under this scenario with high economic growth, high levels of global mobility and free access to space. However, under the ‘Zero Sum Games’ scenario equipment manufacturers can also benefit from increased geo-political rivalry asking for duplication of GNSS infrastructures. But the negative effects of this scenario on the downstream segment is unlikely to compensated. In short, a flourishing downstream segment based on strong commercial demand is also most favourable to equipment manufacturers in the long term.

#### 3.3.2.2 Earth observation

Earth Observation (EO) is a set of space applications that is technologically mature (OECD, 2005). It deals, broadly speaking, with the acquisition and exploitation of data acquired from remote (aircraft or satellite based) observations of the Earth. It covers a diverse range of remote sensing applications, including weather forecasting, the environmental monitoring area, surveillance, as well as numerous applications in the atmospheric, land and ocean domains. The EO service industry is an extremely diverse industry, comprising companies that work with raw or semi-processed data from remote sensing instruments and converts these data into information that brings value to end-users. The dominant profile of the companies is typically a small, specialised organisation that focuses in one or two thematic and geographical areas with small but growing profitability (Poliakov et al., 2008). Opportunities and risks are described in the following sections by market segment. Weather monitoring and forecasting as a mature segment is excluded from this report.

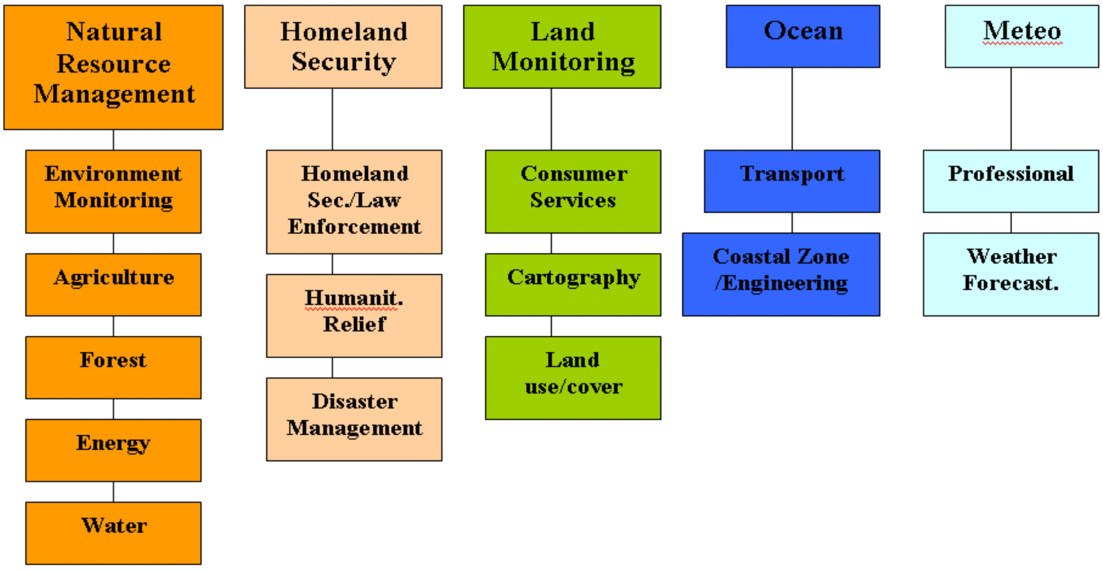
**Opportunities**

A number of emerging, civil markets for EO services have been identified by (Euroconsult, Helios and Bertin, 2007). Figure 3.2 provides an overview of the individual markets and underlying segments.

**Energy** – The renewable energy sector relies on local data on solar irradiance, biomass stock and wind profiles at a global scale. Due to their global coverage and frequent overpass, satellites are invaluable in delivering these data. Meteosat Second Generation provides solar irradiance data every 15 minutes thus enabling large energy companies to maximize grid efficiency. Synthetic Aperture Radar (SAR) instruments on board ESA's ERS-2 and Envisat satellites can provide high resolution 100-metre data on the wind field. Decade-long data archives can be exploited to assess characteristics of local wind regimes and solar irradiance for site selection of wind farms and solar energy production. (Euroconsult, Helios and Bertin, 2007). With the management of renewable energy sources becoming increasingly important, there is a market opportunity for forecasting services for local wind and solar irradiance to manage electricity supply.

**Agriculture and food security** - Remote sensing is actively used to monitor crop production worldwide. The Food and Agriculture Organisation of the United Nations (FAO) uses remote sensing to assess food security in order to be prepared for relief actions. Another application relates to precision farming which makes use of high resolution satellite imagery to derive health indicators of plant stock. Farmers can use these data to decide at what locations there is shortage of nutrients or soil moisture (Euroconsult, Helios and Bertin, 2007). However, tests of precision farming in Europe have so far been disappointing for commercial reasons as the technology is expensive and provides little benefit.

**Figure 3.2 The 5 market segments in downstream value added Earth Observation applications**




Source: Euroconsult, Helios and Bertin, 2007

**Natural Hazards** – Synthetic Aperture Radar (SAR) on board ESA's satellites ERS1/2 and Envisat have been used to develop a technique for mapping and monitoring ground motion over large areas. Currently, Italy is embarking on a program to process images covering the entire country in order to map and monitor subsidence and landslide prone areas (Euroconsult, Helios and Bertin, 2007). Natural hazards are a broad field with many potential applications. Commercial activities in this segment focus on insurance companies using EO data to assess insurance claims. With micro-satellites developing in the future insurance firms could also operate own satellites building a competitive edge over competitors.

**Ocean and maritime** – Maritime transport relies heavily on oceanographic and meteorological conditions. Local data on wind and wave regime worldwide are derived from operational satellites and stored in databases for planning maritime transport and off-shore activities (Euroconsult, Helios and Bertin, 2007). Next to that national meteorology institutes provide commercial forecasting services to large logistics and oil and gas firms to manage operations of shipping fleets and drilling platforms. Potentially, forecasting services are of commercial value to anyone operating at sea with many future applications thinkable. Apart from weather, wind, current and wave forecasts, also maritime tracking and tracing services combining EO and GNSS technology are of commercial value.

**Air Quality** - For instance, a subscription SMS-service providing local current and near-future air quality conditions is of value for respiratory disease sufferers. This service makes use of the regionally measured amounts of NO2 and Ozone by Envisat's sensors. It is already available in the London area. (Euroconsult, Helios and Bertin, 2007) Other services in this domain are thinkable also in combination with traffic monitoring and management.

An additional category to the above diagram is the potential application for climate change monitoring. Especially if binding international treaties are signed for global CO2 reduction targets, an independent monitoring of environmental indicators measuring climate change is needed. However, while this represents a clear demand, it is not a commercial market as such but rather a task for an existing institution. ESA and Eumetsat are actively cooperating on this issue already.

The above examples highlight potential markets for EO applications, which are still largely niche markets. The biggest market weather monitoring and forecasting has been excluded. The above applications might take considerable incremental innovation over the coming decades for these to develop into large commercial markets, such as two-way navigation, more intelligence, integration with non-satcom systems such as sensor networks, higher precision, etc.

**Risks**

One of the most uncontrollable risks in this context are changing market opportunities. Google Earth on the one hand is a great success for consumers, but a disaster for firms building a business model on selling this information. Similarly, what we perceive as viable business models in the above segments today could possibly be undermined by tomorrow. In that sense the above applications can evolve very differently depending on business model dynamics and be used in combination with a range of other products and services. While giving ideas how these technologies can be applied it is not possible to foresee how these will be exactly exploited commercially.

**Differences across scenarios -** The differences across the scenarios for EO are comparable to those of GNSS. EO is still largely an institutional market. The civil segments highlighted above are expected to develop best under the scenario 'Global Green Aerospace' with high levels of economic growth. Next to that free access to space and an efficient space law help develop these segments commercially. This provides the opportunity for this segment to develop from a largely institutional sector to one where more and more firms become active. On the other hand the 'Zero Sum Games' scenario makes the further commercial expansion of this segment difficult with limited access to space and scarce capital.

### 3.3.2.3 Micro-satellites

Micro-satellites are small satellites that currently are mostly launched piggy-back with larger satellites. They are sometimes also referred to as mini- (100–500 kg), micro- (10-100kg) and nano-satellites (1-10kg). With a number of smaller launchers coming on stream in the coming years (Poliakov et al., 2008), this satellite segment becomes potentially independent of larger satellite launches.

**Opportunities**

In the future, micro-satellites operating as part of a cluster or constellation forming for example a larger virtual satellite are expected to drive commercialisation of space. First satellites of this category have already been deployed but mostly in experimental context rather than commercial application (e.g. Dubourg *et al.*, 2006; AF, 2006; Boeing, 2009). They are placed in Low Earth Orbit (LEO) for new telecommunications and networking systems and should be able to provide a global, space-based, high-speed network for communication, data storage and earth observations (NASA, 2008). They are cheaper to make and place in orbit and can be mass produced compared to current satellites. In addition, they also have shorter development times. This makes them very attractive. The real commercial breakthrough for micro-satellites is expected when sensor sizes decrease allowing for high resolution and integrated sensors.

**Risks**

As cost reductions mean that many actors can enter this field, there is a positive innovation dynamic evolving around the users of micro-satellites. Instead of innovation limited to the large established players, newcomers adapt and develop their own solutions. This poses risks in the form of a disruptive innovation dynamic to established players as the segment is commercially too small for them to currently enter. Next to that there are risks stemming from safety and security. Up to now micro-satellites are mostly launched by university research groups and small start-ups. Examples are 'Surrey satellite technology' and 'RapidEye'. Research development for this seems to be on good track, but for commercialisation the regulatory framework is decisive. Currently, firms and universities launch micro-satellites, sometimes without clear and sustainable strategies for tracking and controlling the satellites, and mostly with uncertain liability. This creates a potential safety issue for other space objects as well as the built environment. This asks for clear international rules on licenses and liability to create sufficient legal certainty for commercial activities to flourish (for details on regulatory issues see section 6.3.6). Also the capacity in space for satellites is limited with space debris being a serious limiting factor.

In addition, there is a potential security threat stemming from micro-satellites. While operating in a cluster, single micro-satellites could refuel a larger satellite, upgrade its software or move around with small on-board cameras to provide live video feeds from space (Boeing, 2009). No nation currently has this capability. If one country acquires these capabilities, this will pose a potential security threat, as it allows spying on and manipulating other satellites. This development might limit the access to space and the commercial attractiveness of operating in space, highlighting the long term need for a well-grounded legal framework of operating and doing business in space.

**Differences across scenarios -** With micro-satellites difficult to detect and not possible to control these pose a potential safety and security issue. If commercial activity in this segment increases this issue will become more pronounced highlighting the need for a global space law providing legal certainty and solving liability questions. Such system is assumed to be in place in the 'Global Green Aerospace' scenario. Under the other two scenarios this theme has more difficulty to develop. Similarly, the investment climate is most favourable under scenario 1. On the other hand the military can be a lead user in the 'Regional Aerospace' and 'Zero Sum Games' scenarios.

#### 3.3.2.4 Space travel and space tourism

Over the last years a small scale market for space travel has emerged with a number of civilians participating in Russian space missions. More affordable suborbital space tourism is perceived to be commercially viable by several companies, including Space Adventures, Virgin Galactic, Starchaser, Blue Origin, Armadillo Aerospace, XCOR Aerospace, Rocketplane Limited, the European "Project Enterprise", and others (Law-Green, 2007). Most are proposing vehicles that make suborbital flights that peak at an altitude of 100-160 km. Passengers would experience three to six minutes of weightlessness, a view of a twinkle-free star field, and a vista of the curved Earth below. As of November 2007 Virgin Galactic had pre-sold nearly 200 seats for their suborbital space tourism flights.

**Opportunities and Risks**

These developments suggest that we are seeing the birth of a nascent commercial space tourism industry although the way ahead appears very uncertain, with a wide range of economic, technological, political, legal, environmental, financial and commercial issues eventually shaping the rate and direction the industry takes (Crouch et al., 2009). Economically most interesting, however, is not the relatively short flight to space itself, but the expected economic activities surrounding it. When regular tourist flights start from 2012, a new rapidly growing industry is expected to emerge with not only vehicle operations, but also resorts, ground infrastructure, maintenance companies, training installations etc. This industry currently concentrates in the US, with large inhabited areas available for take-off and landing and exemptions to FAA certification being granted for space vehicles operating in restricted areas. If Europe decides to join this development these two aspects are a pre-condition for firms to operate.

In addition to tourism, a related market that could emerge in the far future is passengers travelling via suborbital point-to-point travel (SPTP). For example, passengers flying from Brussels to Tokyo with most of the distance travelled sub-orbital. The time savings would be substantial. But the fuel consumption, a key factor for commercial viability, is highly uncertain. Furthermore, there is high legal uncertainty as such travel would be at the intersection of aeronautics and space law. Formal rules in a clear legal framework would allow economic actors to take manageable risks (von der Dunk, 2008). These risks could then also be shared by financial actors offering insurances (for more details see section 3.4).

**Differences across scenarios -** Similarly to the personal air transport services theme, space travel and tourism is at first a market segment for high income groups and sensitive to changes in income levels and growth. This means that 'Global Green Aerospace' is the most favourable scenario for development. However, in this scenario energy also becomes more expensive having a direct impact with highly elastic demand. Furthermore, with potential energy scarcity, it is a big question whether society wants to spend energy resources on space tourism instead of for example agriculture and food production. This essentially means that this theme will be challenged across scenarios with high uncertainty of long-term success and is likely to be a luxury niche. Furthermore, under the 'Regional Aerospace' and 'Zero Sum Games' scenarios tensions between regions result in these services largely been offered by countries having access to large territories.

## 3.4 New requirements for sectoral innovation: new forms of knowledge, organisational and institutional change, regulatory frameworks

This section will discuss potential barriers and required developments for innovation themes to develop into successful markets. In the previous section, specific barriers to innovation themes have already been highlighted. However, many barriers are similar for the various innovation themes. Often newly emerging markets require changes in the physical infrastructure, the institutional setting (e.g. regulations), and knowledge structures to become successful. The barriers and required developments are structured along the following topics:

- Knowledge and skill requirements
- Platforms and linkages with other sectors
- Institutional change and regulatory issues

The last aspect will deal with aeronautics and space separately.

## 3.4.1 Knowledge and skill requirements

The aerospace sector is highly clustered and knowledge accumulation is a key factor for innovation. European knowledge base particularly in aeronautics, is excellent but with new technologies becoming increasingly important (avionics, composite materials) Europe needs to refocus and strengthen its existing clusters and foster new clusters where this is more appropriate.

One specific issue is the high number of foreign PhD students in Europe. While this is largely perceived a British phenomenon (English speaking), there is generally a disinterest of Europeans doing a PhD in engineering and aerospace more specifically. While this does not represent a problem per se, some public institutions cannot hire non-European nationals (e.g. ESA) and hence have difficulties filling vacancies. European labour markets differ structurally, some more open to internationals than others. Firms work their way round regulation to hire the required engineers. However, rather than educating foreign nationals, European member states should see this as a source of talent for firms to exploit. European countries should make themselves more attractive to international talent reducing cultural and regulatory barriers.

Secondly, engineering education varies widely across Europe with traditional professional bodies guarding a closed community. This means that the above phenomenon of international PhDs is largely a phenomenon of Western and Northern Europe, and much less of Southern Europe. However, this also represents a barrier for job mobility of Europeans in the sector. Less so within larger firms, but certainly for research institutes and universities that have an important function in the innovation system.

Thirdly, one special characteristic of the aeronautics sector is the cyclical nature caused by large scale projects (Hollanders et al, 2008). This cyclicality of demand can lead to a temporary shortage or surplus of engineering capacity. Often engineers that have been laid off during times of surplus, seek employment in other sectors or world regions. This normally means that they are lost to the sector in times of recovery and boom. Firms should develop a long-term vision to avoid losing talent they need during the following boom cycle.

## 3.4.2 Platforms and linkages

Both the aeronautics and space sector are well networked horizontally. While the aeronautics sector is also well networked vertically, with the increasing commercialisation in space applications (services) new downstream actors emerge. These are not formally part of the space sector, but might be electronic firms (e.g. TomTom), media firms (e.g. Google), or other service providers. They combine and exploit close links between space, IT (software) and telecommunications technologies for satellite navigation and earth observation based services. Currently, these develop services based on existing infrastructure and standards. However, to stimulate these markets, platforms between infrastructure operators, service providers, venture capitalist and users should be supported to network the various actors. This is especially important before new hardware and large infrastructure (satellite formation) are launched to ensure that firms are also capable and willing to make use of it and exploit data. For the success of these platforms it is crucial that these are bottom-up driven, rather than top-down by policy makers.

## 3.4.3 Institutional change and regulatory issues

One special characteristic of the Aerospace sector is the institutionally dominated supply chain, which compared to other industry sectors is not determined by the market mechanism but influenced by politics. This is certainly the modus operandi for the military segments but also in parts for the civilian segments. Production locations of Airbus are largely located in countries of EADS shareholders. Contracts for space technology often have geo-return mechanisms protecting interests of funding countries. And even international customers of Airbus such as Air China or Air India might ask for compensation mechanisms as part of their contracts. These factors mean that public authorities have considerable power and responsibility over future technological developments and markets. Below, four institutional and regulatory issues for aeronautics, and three issues for space will be highlighted.

### 3.4.3.1 Risk taking and long-term investments

A substantial challenge is to continue investing in long term research to sustain the competitiveness of Europe’s aeronautics and space sector. Innovation implies risks, for business and for policy. A concern is that European R&D programmes become more risk averse, with detailed procedures and very high transaction costs, and research programmes possibly moving towards short term, pre-defined and incremental innovation. This can be at the expense of long term, ‘blue sky’ and radical innovation. Relevant debates include the progress report of FP7 and the steps towards FP8, and the broader debate towards a common understanding of the concept of tolerable risk of error (EC, 2008b).

### 3.4.3.2 Fragmented markets and research activities

The previous Europe INNOVA report (SIW-I, Hollanders et al., 2008) stated that innovation barriers in aeronautics are low. Nevertheless, one third of companies face problems due to high innovation costs. About 26 per cent of companies perceive economic risks as excessive while 20 per cent of firms see a lack of appropriate sources of financing (Hollanders, et al., 2008). Internal financing of innovation is weak with firms failing to significantly yield more than 5% operating surplus (Cleff, et al., 2008 p.28). The fragmented small European markets, is one explanation, particularly for the space and military segment. The US market in contrast has a structural advantage being 4 times the size compared to the EU (Hollanders et al., 2008). Furthermore, in the US especially the military segment is much more open and experimental with new technologies but often restricted to US firms. Secondly, also research activities are still fragmented between European member states although in the case of space, ESA plays a very important role of concentrating European efforts (Hollanders et al., 2008). This means that research effectiveness can still be improved.

### 3.4.3.3 Financing innovation

Experts see public money in the form of subsidies and grants and public procurement as necessary to stimulate innovation in the sector (Cleff, et al., 2008 p.28), as fiscal incentives, tax credits and R&D allowances are of minor importance (Cleff et al., 2008, p.65). This is also reflected in the way innovation is financed in the commercial and military segments. The military often pays firms up front to develop a new product compared to the commercial sector where R&D investments have to be earned back on the product. This passing of risk to the customer in the military segment allows much more risky and innovative projects. But while institutions can take this risk, commercial actors are unlikely to do so, posing a barrier to innovation in the commercial segment. One way of overcoming that barrier could be to better support R&D in the commercial segment through public institutions. However, while in the past governments have supported their national Aerospace industry quite openly; this becomes more difficult with EU single market rules and WTO rules.

Another successful example to stimulate more radical innovation without large subsidies are prize rewards such as the X-Prize and other prizes used by DARPA and NASA. DARPA has achieved large progress in the field of driverless vehicles, whereas the X-Prize was the key driver for the developments around the commercial space tourism vehicle. The model of a prize reward is that instead of supporting a specific technology, a challenge is set. How this challenge is solved is left to the imagination of prize contestants. This passes the technological risk to the inventor and hence is a relatively low cost mechanism to stimulate innovation. Furthermore, the prize contest itself often creates media attention that is used by contestants to commercialize results. However, prize rewards only work under specific conditions and hence can only be a complementary option to stimulate innovation. Currently, the X-prize foundation plans to set out total prizes of $100m in the coming 5 years for solving challenges in the field of space exploration, life sciences, energy and environment, and education and global development (X-Prize, 2010).

### 3.4.3.4 Tension between safety and innovation

While standards and regulation are very important in guiding the sector towards new technologies based on road mapping, (safety) regulation at the same time also acts as a inhibitor for technology adoption, as proven technologies are preferred by customers and authorities whose prime goal is passenger safety. This priority for safety is justly chosen, as the engine failure of a Quantas A380 in November 2010 has shown. Innovation, promising desired efficiency gains through for example use of new materials in engines but also structures, is in tension with safety goals. How this tension can be relaxed is a difficult topic requiring creative thinking. One part of the solution - that was stressed during the workshops - is to speed up the procedures to get approval for introducing new technologies. While this might not be realistic overall, as safety goals require detailed testing, desirable technologies such as environmental technologies that help increase fuel efficiency, could be prioritised. Furthermore, environmental standards are currently mostly set at international level, e.g. aircraft noise, engine emissions (ASD, 2007a, p.11). While this is positive as it leads to industry wide standards, it also means that it is challenging to introduce ambitious standards as many actors have to agree.

### 3.4.3.5 Cost of access to space as commercial barrier

Access to space is currently largely taking place from government controlled launch sites using large launchers. These services are comparatively expensive being the only space segment where costs have so far not fallen over time (Poliakov *et al.,* 2008). Furthermore, the market suffers from overcapacity. Where possible firms make use of low cost, smaller launchers, using converted Russian intercontinental ballistic missiles. Especially, for micro-satellites access to space is an issue as they so far rely on piggy back delivery of larger satellite launches. Access to space for this satellite type is hence restricted by the launch capacity of larger satellite types. However, several smaller launchers (e.g. Vega) are expected to come to market over the coming years. For Europe the question remains whether Vega will reduce launch costs for firms sufficiently to be commercially attractive.

### 3.4.3.6 Unresolved liability issues and commercial risks in space

If commercialisation of space is to be seriously pursued the current space law needs to be developed into an independent globally judicial system, with formal rules (von der Dunk, 2008). Especially rules on ownership and liability need to be established to be able to resolve cases such as the satellite crash between a Russian Cosmo and American Iridium in February 2009 in an independent court system. This would drastically reduce commercial risk of actors and increase legal certainty. It would hence facilitate commercial space deals, and allow economic actors to share risks through insurances. Such a global system would also prevent countries to attract space research and space firms by means of poor rules on liability and poor enforcement. It is important to note that there is a trade-off between strict rules and commercial dynamics and innovation. On the one hand firms need legal certainty. On the other hand if for example potential liabilities for firms are too high this will reduce investments and commercial activity.

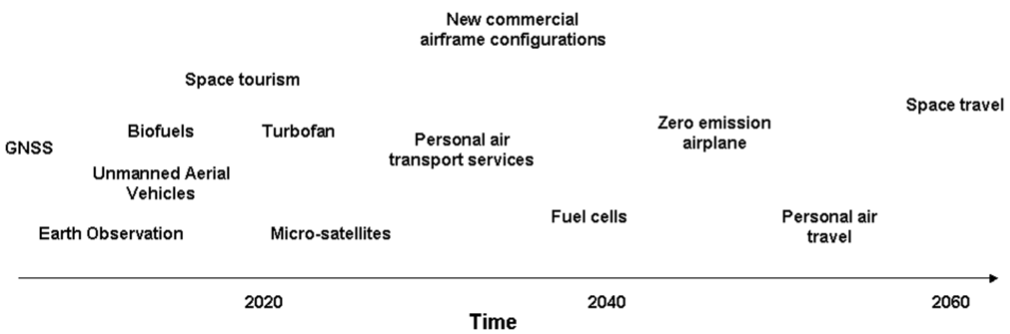
### 3.4.3.7 Space infrastructure and data policies

Space infrastructure is costly and hence duplication of infrastructures, such as in the case of GNSS, should be prevented, if possible. In case of EO in addition to space infrastructure often costly ground infrastructure is necessary. Such infrastructure is not feasible for a single firm to finance. For that reason access to space data of institutional actors is very important if commercial services to be developed. While most institutions operate data access policies, these vary widely. In the US for example data from public institutions is accessible free of charge under the Freedom of Information Act as long as national security is not comprised. In Europe, however, data access is often restricted with different data access levels. For example, Eumetsat data is made available to members and against pay. In addition, researchers and countries suffering from extreme weather conditions also get free access to data. Next to that anyone can access Eumetsat data with a time embargo. There is an ongoing debate to make data from public space infrastructure access free, to stimulate downstream services. However, as the benefits do not necessarily accrue to the actors that have provided the infrastructure investments, it remains a debated issue. One alternative could be to handle different levels of data access with real time, high resolution data available against payment, while making basic data available free of charge.

# 3.5 Sectoral innovation policy in a scenario framework

The previous sections on the innovation themes and requirements for innovation revealed several areas for policy intervention. As much as possible, the policy issues are linked to innovation themes and the barriers to innovation within these innovation themes. The policy issues will be discussed for 1) broader innovation policy, 2) aeronautics, and 3) space. Because the foresight analysis is forward looking and has as a broad scope, the policy recommendations provide directions rather than highly detailed suggestions. The discussion of policy issues is linked to the three scenarios that are developed for 2040: Global Green Aerospace, Regional Aerospace and Zero Sum Games. In each of the scenarios, specific innovation themes and policy issues may require less or more priority, or a different balance between the interests of industry and other stakeholders. The innovation themes are plotted on the timeline below. This allows for prioritisation of policy interventions, based on future developments.

**Figure 3.3 Timeline expected developments**




## 3.5.1 Conclusions with regard to broader (innovation) policy

### 3.5.1.1 Support strategic basic science

Radical designs in America are largely explored through military institutions such as DARPA or universities with military grants. With the military becoming a much less important actor in Europe, the role and financing of strategic basic research should be strengthened, if Europe wants to maintain its strong role in aerospace innovation. This is even more important for long-term, radical innovation themes such as new commercial airframe configurations.

### 3.5.1.2 Maximise use of available talent

Fewer students follow degree courses in engineering and sciences. At the same time, more and more PhD positions in the North-West European countries are filled with overseas students. These are high skilled sources of talent that cannot always be recruited by European institutions and firms due to labour market restrictions. This should be changed, allowing Europe to profit from overseas talent that is educated in Europe and often opens the doors for overseas business contacts in the future. This talent is very much needed to solve technological challenges in various fields such as new engine designs (e.g. turbo fans), airframe configurations, bio-fuels, fuel cells and new materials.

### 3.5.1.3 European Research Area

Policy should aim to improve the effectiveness of research in the sector. Research activities are fragmented between European member states. Moreover, the links between aeronautics, space and other sectors should be taken into account. For example, micro-electronics and other ICT clusters are highly relevant for avionics and micro-satellites.

The differences between scenarios are most clear for policy issues that are specific for aeronautics or space. Still, a few remarks can be made in the context of broader innovation policy. Characteristics of the Global Green Aerospace scenario are collaboration between Europe and other regions, globalisation of markets and sectors, economic growth, a steady but modest increase in energy prices, and priority for environmental sustainability. This scenario allows leading industry players in Europe to collaborate with non-European firms, research organisations and universities. The investments in global collaboration will pay-off for long-term innovation themes such as personal air travel and space travel. Talented people can easily leave and enter Europe.

European collaboration is crucial in the Regional Aerospace scenario. In this scenario, a number of strong regions emerge, with limited direct market competition, partly due to increased protectionism. This is at the detriment of economic growth. The scenario does stimulate Europe and other regions to invest in (fundamental) science, to innovate and ‘be the first’. However, financial resources are modest, due to low or negative economic growth. In this scenario, the European Research Area will be important. Modest financial resources and limited collaboration with other regions, will be among the reasons for European actors to specialise and collaborate, often with a mix of European and private funding.

The focus on Europe and the scarcity of financial resources is even more substantial in the third scenario: Zero Sum Games. Partly due to energy scarcity, globalisation comes to a halt. This leads to severe economic adjustment processes, protectionism, a break-down of multilateral institutions, and trade conflicts. Support for science and financing of innovation - by governments and industry - is at risk. The exceptions are innovation themes that are relevant for security and defence, and for reducing energy scarcity. Examples are Unmanned Aerial Vehicles, Earth Observation, GNSS and bio fuels.

## 3.5.2 Specific conclusions aeronautics

Global production of aircraft is highly clustered with two factors leading to potential geographic shifts in the current cluster structure: 1) market growth, and 2) a shift to electronic technologies and new materials. Market forecasts see fastest growth in air transport in Asia-Pacific. This means that customers for aircraft in Asia-Pacific become more important for the two main competitors Boeing and Airbus, with likely shifts in future production locations. Airbus for example already assembles aircraft in

China. New competitors mainly from China and Brazil enter the market currently dominated by Boeing/Airbus. In the future, aeronautics clusters in these two countries are hence expected to grow in importance. With electronics and new materials playing an increasingly important role, production clusters might also experience regional shifts based on technological competences. Asia for example is very strong in electronics production for other sectors, and Japan has built up competences in new materials, particularly carbon fibres. These underlying dynamics in market competition and technology competence are very important.

New innovation themes can help build a competitive edge over global competitors. The most important innovation theme in civil aeronautics is environmental air travel. ACARE (2008) has set a strong research agenda. In the short term efficiency gains can still be booked through refining existing designs and the use of new materials to make engines more efficient and aircraft lighter. In the medium term biofuels become important to reduce the environmental impact of air travel. However, in the long term, big technological challenges need to be solved such as the use of fuel cells for powering aircraft and new aircraft designs. Commercial actors cannot finance this type of research given the financial constraints outlined above.

Any financing of research should be complemented with lowering barriers for market adoption. The most effective tool for this are market mechanism and commercial interests of actors. One example of such a mechanism is the proposed emission trading system. For successful implementation, however, a level playing field should be ensured and certificates auctioned rather than allocated on past emission volumes. Another is a harmonised value added tax on kerosene that would have a similar effect as CO2 certificates. Thirdly, to reduce noise pollution from aircraft, landing fees could be based on noise emissions of aircraft.

Generally, policy should be creative in the use of mechanisms. Prize rewards such as the X-prize have been very successful with DARPA to reduce technological challenges such as the driverless car. Such challenge could also be implemented in Europe, opening up the innovation process to multiple actors and possible solutions at relatively low costs. On the other hand the certification process for aircraft technologies could be used to speed-up market introductions of environmental technologies. Environmental technologies could be prioritised compared to other technologies in the certification process.

Lastly, two emerging markets in the field of aeronautics struggle with regulatory issues. These are personal air transport services, and unmanned aerial vehicles. Personal air transport services are subject the regulation currently requiring two pilots for safety reasons. This means that personal air transport services remain relatively expensive. Other countries, such as Canada allow for single piloting transport services. Furthermore, flight routes need to be decided beforehand and cannot be changed during flight. Technologically, on-route operations are not an issue and could hence be assessed for possible changes in regulation.

Unmanned aerial vehicles are increasingly used by civil and private actors. Safety regulation and regulation regarding certification and authorization should be developed. The balance between protecting citizens and stimulating innovation (and security) is a political matter. The importance of legal certainty and efficient procedures can be stressed. How do the rules and systems for Air Traffic Management apply to UAVs? How to improve – and harmonise – European procedures for certification of new types of UAVs? Furthermore, privacy has emerged as a policy issues in the context for UAVs. It could be explored how existing European conventions and directives apply to UAV; how the data can be captured and used.

Differences between scenarios are*:* in Global Green Aerospace, high energy prices will work as an effective market driver to stimulate innovation in environmental air travel. Policy largely facilitates this development through international cooperation and a global emission trading system. With rising income, new markets around personal air transport services are likely to emerge, requiring policy attention. Also the space sector benefits from international cooperation requiring a stable international judicial framework to blossom commercially. In the Regional Aerospace scenario, international competition is less fierce, but therefore cannot act as a strong market driver for innovation. However, regional market structures allow for European regulation to stimulate environmental technologies. Generally, the military and security segment of both the aeronautics and space sector benefit from deteriorating international relations in the Regional Aerospace scenario.

### 3.5.3 Specific conclusions space

The most pressing issue for the space sector is to develop a legal framework for the commercialisation of space. The current space law was developed in the 1960s under a Cold War situation with few countries, and a few public organisations active in space. Liability is currently imposed on the country from which a spacecraft is launched. Formal rules - such as national space laws - and commercial deals will decide how liability is shared between governments and space firms. This will strongly influence investment decisions by space firms. The damage from collision can be substantial, whereas the business revenues in emerging markets are uncertain. Several countries have introduced risk-sharing, hybrid mechanisms in which firms are liable for a maximum amount, and are obliged to insure this risk, with governments covering additional damage. National space laws and solutions could be complemented by international institutions such as a space court.

In addition, European and national policy makers should continue to stimulate innovation in downstream space and satellite applications. European Commission, ESA and OECD reports have demonstrated how downstream applications can address societal challenges, to the benefit of citizens, firms and public organisations. Well known are examples in the field of monitoring of natural resources and transport. At the supply side, public support will have a positive impact on innovation and the competitiveness of the space sector and related sectors. The policy approach should, and does, include funding for research. Two more issues are platforms/networking and data access policy.

Policy makers should increase the support - budgets, expertise and involvement - for platforms that bring together industry, research organisations, universities and policy makers. For downstream applications, this includes the space sector, but also telecommunications, energy, transport, and other sectors that use space data. The variety of firms is substantial, in terms of sectors but also in terms of large space actors, SMEs and start-ups. As mentioned above, steps can be made towards the European Research Area. European platforms can contribute, but national or regional clusters may also require their own platform, to stimulate close collaboration. Platforms do not only facilitate a shared vision, standards, and finding the right partners and investors for research projects and market activities. Platforms/networks also serve to identify (future) market barriers, including barriers that are caused by the application of existing laws to new applications.

One of these barriers is data access policies. Timely or even real-time access to data from satellites is a crucial input for many downstream applications. Location-based services is only one of many examples. The willingness of firms to invest in the development and roll-out of services is influenced by guarantees on access to data. This still is a major barrier for developing services that are based on Galileo. The signal is still not available and operation of the signal is not yet guaranteed.

Two emerging markets in space are micro-satellites and space tourism. In both cases, a combination of conceptual and technological innovations has led to new products and markets (or market segments). The new products have raised safety issues. An important objective for policy-makers should be to achieve a high level of safety to people on the ground (and space tourists), while not over regulating these emerging markets. In striking this balance, one concern is to involve well established interest groups but also start-ups in emerging markets that are not yet organised. To stimulate space tourism, policy makers can designate areas in which the impact potential accidents are limited, and where new spacecrafts can operate with exempt certificates.

Differences between scenarios are*:* in Global Green Aerospace, policy makers can increase support for downstream applications that protect the environment, and decrease support for space tourism. In Regional Aerospace - the scenario with a number of regional powers and limited direct market competition - policy makers are very reluctant to explore new ways of safeguarding safety, to stimulate innovation. Furthermore, European policy makers can be more cooperative towards the US, Russia and other regions, when developing data access policies that include access to data from satellites and organisations from other regions, and to share data with organisations from other regions. In Zero Sum Games, European and national policy makers will be more focused on improving the competitive position of European firms and research organisations, for example by strongly supporting micro-satellites, listening to industry and innovation platforms/networks, and sharing the business risks that are related to liability.

# 4 Barriers to innovation[6]

An analysis of market and regulatory factors influencing sector innovation patterns provided a more fine grained analysis of the factors influencing innovation in the space and aeronautics sectors. General and sector-specific literature was studied to define what (1) market factors and (2) regulatory factors hamper or stimulate innovation in the sector. These factors were operationalized and measured by using CIS4 micro-data and a complementary survey conducted by the Sectoral Innovation Watch consortium. Almost 800 firms indicated what market and regulatory factors influenced their innovation activities and innovation outcome. For the space and aeronautics sectors 31 cases could be used in the analysis. Finally the literature on drivers and barriers is confronted with the outcomes of the CIS4 analysis and the survey to draw up conclusions for the space and aeronautics sectors.

## 4.1 Factors ranking (based on CIS4 data)

This section describes the role of different drivers upon innovation based on CIS data, the level of innovation activities reported by those managers that participated in the SIW-II survey as well as those outcomes arising from innovation.

It is important to note that CIS4 data do not allow for a distinction between space and aeronautics sectors. As the space sector is only representing about 7% of the space and aeronautics sectors in terms of employment and turnover, the CIS4 survey data will likely say more about the aeronautics sector than the space sector. Another important remark is that he anonymous CIS4 database includes data for 20 European countries. Some countries which are relevant for the space and aeronautics sectors are missing in the database, including for example the United Kingdom, Germany, the Netherlands and Belgium.

The factors affecting innovation surveyed by CIS4 are displayed in table 4.1. This ranking is based on a MANOVA analysis[7]. The results indicate that access to federal funding, lack of access to new information in Journals, no demand for innovations and the high cost of innovations have a negative effect on innovation in the space and aeronautics sectors. Collaboration, complying with regulation and standards, information from government, participation in Framework Program research projects, and expected increases of market share appear to drive innovation. The MANOVA analysis produced rather contradictory results concerning the uncertainty of demand for new products (that appears to influence positively innovation) and the lack of demand for innovations (that appears to have a negative influence on innovation). The rest of the factors included in the pool ranked beyond the 10$^{th}$ place showed no significant relationship with innovation.

Regulation and standards in the space and aeronautics sectors resulted ranked in 5th place relative to all other factors included in the analysis. It worth to note that according to CIS4 data regulation only in

[6] This chapter is based on the analysis performed in Task 3 of the SIW-II. The full analysis is available in Montalvo et al., 2011.
[7] Multivariate Analysis of Variance

two sectors of those included in the SIW-II are actually driving innovation (the other sector being electrical and optical equipment).

**Table 4.1 Ranking of factors affecting innovation**

| Rank | | Coef. |
|---|---|---|
| 1 | Collaboration | 0,814 |
| 2 | Federal funding | -0,751 |
| 3 | Uncertain demand new products/services | 0,593 |
| 4 | Info from Government | 0,576 |
| 5 | Info from Science Journals | -0,541 |
| 6 | Met regulation & standards | 0,536 |
| 7 | No demand for innovations | -0,528 |
| 8 | EU FP-RTD | 0,524 |
| 9 | Lack of information on tech opportunities | 0,519 |
| 10 | Innovation cost too high | -0,465 |
| 11 | Increase market share | 0,447 |
| 12 | reduced cost per unit | 0,372 |
| 13 | Faster response to customer | 0,363 |
| 14 | Info consultants | -0,355 |
| 15 | Info from universities | 0,351 |
| 16 | Lack of funds in the enterprise | 0,344 |
| 17 | Info own enterprise | -0,276 |
| 18 | Improved product flexibility | 0,271 |
| 19 | Better environment and health performance | -0,253 |
| 20 | Reduced materials & energy | -0,249 |
| 21 | Market dominated by incumbents | -0,245 |
| 22 | Difficult of find partners to coop | -0,233 |
| 23 | Info from Associations | 0,148 |
| 24 | Improved production cap | 0,141 |
| 25 | Info from conferences | 0,134 |
| 26 | Increased range products | -0,129 |
| 27 | Lack of outside funds | 0,123 |
| 28 | Info from clients | -0,109 |
| 29 | Improved employee satisfaction | 0,081 |
| 30 | Improved quality prod/serv | 0,061 |
| 31 | Improved quality prod/serv | -0,059 |
| 32 | No innovation due to prior innovation | 0,054 |
| 33 | Info from competitors | 0,036 |
| 34 | Lack of qualified personnel | 0,034 |
| 35 | EU funding | 0,031 |
| 36 | Reduced labour cost | -0,021 |
| 37 | Info suppliers | -0,007 |
| 38 | Lack of information on markets | -0,006 |
| 39 | Regional funding | 0,001 |

Source: CIS4, SIW-II calculations, N=968, N usable=93, $R^2$=0.65

## 4.1.1 Businesses environment

Respondents rated R&D costs, technical risks, long development cycles and the availability of human capital (lack) as affecting innovation to ‘a large extent’. Also the availability of funds for innovation inside and outside to firms is perceived as affecting innovation considerably. In addition to the literature, the variable ‘capital risk’ is rated by respondents as affecting innovation considerably, not surprising for a very capital intensive industry. The factors pioneering advantages, customers willingness to pay for innovation and the likelihood of losing know-how in collaborative projects is rated considerable. On a positive note ‘business opportunities’ was rated highest by respondents as affecting innovation to a large extent.

The correlation analysis highlights three business environment factors affecting a number of innovation types: 1) Long development cycles are correlated with product innovation, manufacturing methods, actor interaction and design. 2) Anticipation and avoidance of regulatory uncertainty is correlated with manufacturing methods, layout of production, actor interaction and sales distribution methods. 3) The ‘Likelihood of losing know-how control in collaborative projects’ is correlated with manufacturing methods, management systems, actor interaction, design and sales methods. Especially the first and the third business environment factor confirm the trend of innovation and production in complex networks of suppliers and partners and the focus on improving profitability by diminishing cost overruns and late deliveries. Most other business environment factors show at least one strong correlation coefficient including availability of outside funds for innovation, capital risk and customers willingness to pay. However, three of the most highly rated factors by respondents, R&D costs, availability of human capital and technical risks show no strong, highly significant correlation. However, in the case of availability of human capital, many correlation coefficients are found with a slightly lower significance level (0,05). The correlation analysis of CIS variables did not uncover any significant correlations.

### 4.1.2 Innovation culture

The literature does not provide any indications on effects of innovation culture on innovation in the space and aeronautics sectors, although Brandes and Poel (2011) highlight the conservatism in the airline sector as an important factor affecting innovation in the aerospace sector. However, the survey responses do not provide a clear indication that innovation culture affects innovation in the sector.

## 4.2 Market factors affecting innovation

From the literature the following positive market effects on innovation have been identified. Globalisation and growth of emerging economies stimulate demand for newer and more efficient aircraft. The liberalisation of air transport markets around the world has had a similar positive effect on demand for aircraft. Innovations in IT have allowed for business model innovation with aerospace manufactures but also the user industries (airlines). With energy prices representing a substantial share of aircraft operating costs, these stimulate environmental innovation reducing fuel consumption. Specific market drivers applicable to the space sector are the growth in demand for navigation and positioning services, earth observation services and satellite communication services. Negative market effects on innovation stem from restrictions in public procurement, including flagship carriers, preventing a truly global market and level playing field for aircraft. Furthermore, a long technology development cycle, combined with high capital investments and low profitability in the airline sector put pressure on innovation investments which are largely focused on later stages of the development cycle. This factor is further amplified by the cyclical nature of the sector. Negative market effects specific to the space sector include the scale of demand for space based services resulting in relatively high unit costs and the high cost and restrictions of access to space.

The survey results largely confirm the factors identified from the literature but with some variation in the direction of the effects. For example, oil and energy prices were not clearly identified as having a positive effect on innovation, instead respondents more broadly rated optimisation and efficiency as having the most positive market effect on innovation. In addition to the literature, the survey also identifies customer preferences, new fashions in consumption and the life-cycle of the products as market factors affecting innovation slightly positive. Geographic proximity of suppliers was rated as having a slightly positive effect on innovation, confirming the importance of clustering in the sector. The global financial crisis was rated by respondents as the only market factor affecting innovation negatively. This is not surprising for a capital intensive industry, where the financial crisis also impacts the demand for air travel and hence aircrafts.

The correlation analysis highlights three market factors affecting a number of innovation types: 1) Relocation of activities outside EU is strongly correlated with all innovation types except service innovation and sales methods. 2) Optimisation and efficiency is correlated with manufacturing methods, layout of production and actor interaction, whereas 3) 'cost of labour relative to that outside the EU' is correlated with manufacturing methods, actor interaction and design. These results are very much in line with a sector known for being under pressure to improve competitiveness by increasing efficiency and lowering development and production time and costs. Moreover, the relevance of actor interaction, relocation, manufacturing methods and layout of production confirm the on-going rationalisation process as well as the outsourcing and off-shoring R&D and production of subsystems and components to a complex network of suppliers. Other factors highlighted by the survey responses, such as increased demand or market structure show single strong correlations with innovation in design. This could be related to the fact that aerospace manufacturers are adapting their products towards the increasing and changing demand in emerging markets (e.g. large long-range aircrafts for Asia-Pacific markets, smaller places for regional destinations, focus on fuel-efficiency, lower operating costs etc.). On the other hand some factors rated by respondents as affecting innovation slightly positive, do not show strong correlations including competition within and outside Europe as well as customer preferences, new fashions in consumption and life cycle rate.

## 4.3 Regulation and innovation

The literature has revealed that regulation and competition act as drivers for innovation in the sector. Safety and environmental regulation on the other hand are found to act as drivers as well as barriers to innovation depending on the specific circumstances, while price regulation, regulatory differences across Europe and public procurement regulation act as barriers to innovation. These claims are largely supported by our survey results, highlighting the positive effect of security, health and safety, as well as competition regulation on innovation. In addition to the literature, the survey also indicates a positive effect of industrial standards, alternative materials regulation, waste regulation, land and labour regulation.

Interesting to note is that environmental regulation, including waste regulation and regulation on hazardous materials shows positive relationship with innovation in actor interaction and layout of production. A reason for this could be that the development of new, innovative eco-friendly materials and other new technologies that are less harmful for the environment is performed by suppliers of sub systems and components. These suppliers are acting in complex supplier networks to the large system integrators. Workforce safety regulation and health regulation show a positive correlation with innovation in management systems, support activities, and layout of production. These are typically the types of innovation that can contribute to safer and healthier work environment. Housing, buildings and community development regulation and land regulation both show many significant correlations across innovation types, similarly to price regulations and interoperability compatibility of equipment. The importance of regulation on housing, building and community development could reflect the activities of local and national governments to stimulate and foster clusters of aerospace firms. The impact of public procurement, industrial standardisation and interoperability compatibility confirm the importance of institutional structures and standardisation in the space and aeronautics sectors.

## 4.4 Systemic failures

### 4.4.1 Public procurement and market protectionism

Public procurement, often stated in the literature as a factor to stimulate innovation in the space and aeronautics sectors, is rated by less than 50% of respondents as having a slightly positive or higher effect on innovation. Moreover, public procurement and market protectionism call up mixed and contradicting feelings among respondents. On the one hand public procurement can stimulate innovation, while on the other hand this same public procurement can become a barrier to innovation because differences in national public procurement regulations and geo-return principles turn public procurement into an instrument for market protectionism. This would call for European policy efforts focusing on increasing harmonisation of public procurement regulations and creating a truly European market and level playing field for space and aeronautics.

### 4.4.2 Eco-efficiency

While increasing oil and energy prices are in the literature generally considered as a stimulant for innovation in the space and aeronautics, the respondents seem not to be convinced yet. A reason for this could be that high oil and energy prices can also lower the demand for aerospace products and increase production costs for the aerospace manufacturers. Another reason could be that there might be some tension between safety and environmental regulation, as identified by Brandes and Poel (2010). Ambitious environmental goals require radical innovation, but strict safety regulations can act as inhibitor for technology adoption as proven technologies are preferred by both authorities and customers. Nevertheless, the increasing external pressure from society, governments, and customers to limit the environmental impact and improve fuel- and eco-efficiency requires European policy efforts to lower barriers for market adoption of new environmental technologies. This could involve for example a different approach to certification processes, harmonised value added tax on kerosene, emission trading systems based on auctioned certificates, and public procurement for eco-efficient technologies.

### 4.4.3 Risks of R&D investments

The space and aeronautics sectors are very R&D-intensive with very high R&D costs and long development and production times. Together with capital risks and high technical risks these factors are confirmed as market factors having a highly negative effect on innovation, and especially radical innovation. European policy efforts could focus on several approaches to overcome these barriers. First, European policy should support investments in long term and risky R&D to stimulate radical innovation. There is some concern that European R&D programmes become more risk averse, with very high transaction costs, focusing on short-term results. This could be at the expense of long term, blue sky and radical innovation. Second, European policy could focus on introducing instruments that lower the risks on R&D and the uncertainty with capitalisation on R&D investments. Moreover, governments could stimulate the development of different models of funding, for example through prize reward models. In addition, governments could assure that SME’s are also able to join (publicly funded) long-term research projects.

### 4.4.4 Complex innovation networks require different skills

The clear trend of outsourcing and collaborating in complex innovation and production networks supports the firms in focusing on their core competency, improving efficiency and lowering risks. However, coordinating the complex value chain of many suppliers and partners is difficult and can contain many risks. This requires improved skills and capabilities in supply chain management, but also sufficient in-house know-how and the ability to integrate and use new technologies from suppliers and partners. Moreover, different capabilities are required from suppliers, as they increasingly take over R&D and innovation activities and the related risks. European policy efforts could focus on supporting and stimulating the creation of new and improved skills needed in coordinating and acting in these complex innovation networks. Especially SMEs will have difficulties to operate in complex innovation networks. More cooperation at the supplier level is needed and European policy efforts could focus on stimulating this cooperation. In addition, aerospace technologies are increasingly adopted by other sectors to develop new products and services. However, firms from these different sectors are not natural partners and European policy efforts could stimulate and support platforms between infrastructure operators, service providers, venture capitalists and users to network the various actors.

# 5 Horizontal issues relevant to the sector

## 5.1 Impact of national specialisation on economic performance[8]

### 5.1.1 Specialisation in terms of value added

Some countries are more specialised in the space and aeronautics sectors than others. An interesting indicator for national specialisation is the relative share of the sectors' value added in the national economy. As mentioned in section 1.3 the UK, France and Germany dominate the sectors in terms of value added and employment. These three countries also dominate the sectors in the sense that they are relatively specialised in these sectors, shown by the relative specialisation ratios for value added and employment. These countries contribute more than average in the EU-27 to the non-financial business economy.

### 5.1.2 Technological specialisation

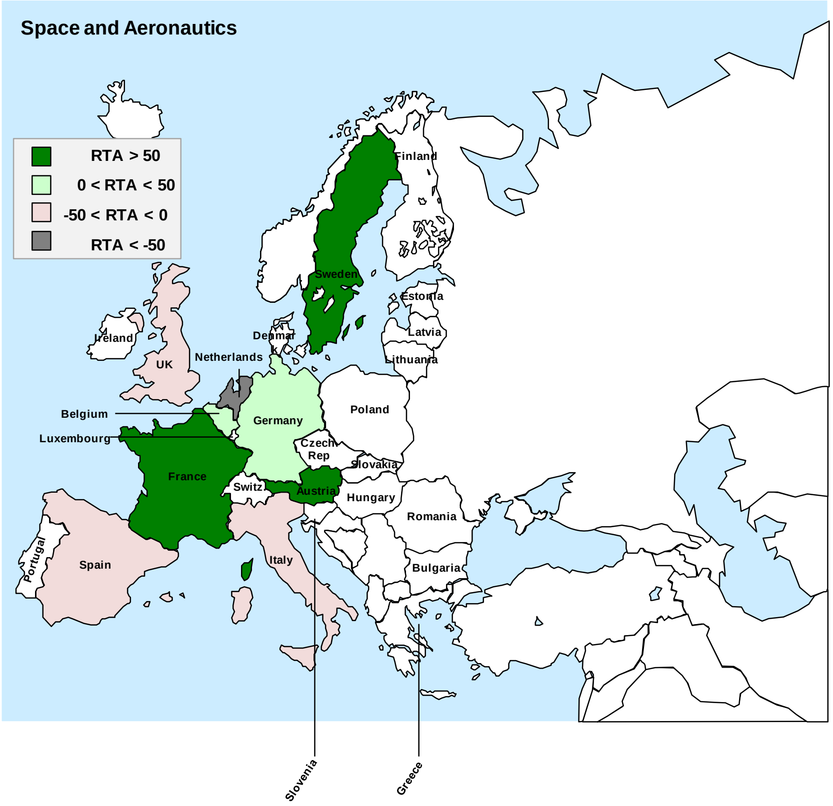
The national specialisation analysis of the SIW-II reveals that in the period 1987-2005, the patenting activities in the space and aeronautics sectors were relatively modest, accounting for 0.44% of the total patent applications in this period in Europe. Nevertheless, propensity to patent is low in Aerospace and secrecy is used more often to protect inventions. Most patents in the Space and Aeronautics Sectors have been applied by the EU-15 countries (Grupp et al., 2010):

- EU 15 countries: while Belgium and the United Kingdom have lost their comparative advantages at the beginning of the 1990s, Austria, Germany, France and Sweden show comparative advantages in this sector. However most other countries (e.g. Denmark, Ireland, Italy, Luxembourg and the Netherlands) have remained under-specialised in the Space & Aeronautics sector.
- New Member States: Most New Member States held none or only a few patents in this sector and therefore show strong technological disadvantages.
- Non EU countries (China, Japan, India and United States): Also the Non EU countries seem to have technological disadvantages in the Space & Aeronautics sector.

Based on the $RTA_h$-Index[9], Austria, Germany, France and Sweden belong to Europe's most technologically specialised countries in the Space and Aeronautics Sectors (see figure 5.1).

[8] This section is based on the analysis performed in the horizontal report on national specialisation in Task 4 of the SIW-II. The full analysis is presented in Grupp et al., 2010.
[9] RTA-Index: Relative Technological Advantage – Index; the share of a sector in a country's total patent output in relation with the share of this same sector over world total patent output.

**Figure 5.1 Most technologically specialised countries in the space and aeronautics sectors**




Source: Grupp et al. (2010)

The specialisation analysis also shows that specialisation patterns with respect to patent counts can differ from the specialisation patterns with respect to patent citations. Only France has positive values in both the specialisation index based on patent counts and on patent citations, while Hungary is de-specialised on both indexes in the periods 1994-1996 and 2000-2002. The UK is not so much specialised in terms of patent counts, but in the period 2003-2005, the UK had a very positive specialisation rate in terms of patent citations (Grupp et al., 2010).

The specialisation analysis also looked at the relationship between technological specialisation and collaboration during the creation of knowledge (based on co-inventorship / co-patenting). In the case of space and aeronautics, the USA appears to be the central player in the network. This is interesting because the USA is also de-specialising in the space and aeronautics sectors. This could imply that American players have a strategic role in the innovation network. In Europe, France plays an important role. Overall, the space and aeronautics collaboration network has fewer connections, which might be the result of the strategic importance of technology and the priority given to secrecy.

## 5.2 Impact of organisational innovation[10]

Organisational innovation is at least as important for aerospace firms to pursue as technological innovation to sustain competitiveness. For example, organizational innovation increases productivity in

[10] This section is based on the analysis performed in the horizontal report on organizational innovation in Task 4 of the SIW-II. The full analysis is presented in Rubalcaba et al., 2010.

the sector, improving the efficiency of system integrators. Furthermore, the increasingly complex R&D and production networks are further supported by organizational innovation, such as open sourcing – system integrators such as Boeing and EADS source products increasingly through open IT platforms allowing suppliers to compete openly, which can also stimulate innovation.

As part of the consolidation of the industry system integrators, such as EADS, have increasingly passed on responsibilities (and risks) to suppliers. These increasingly have to take over the role of sub-system integrators requiring new capabilities (Mundt, 2008). The role of suppliers has therefore become relatively more important (ATKearney, 2007), but makes managing innovation also more challenging as experienced by Airbus (A380) and Boeing (7E7). Consortia of competitors are increasingly formed to share high risks of new developments (e.g. engine consortium A340; Galileo operating consortium). Collaborations between competitors but also integrating partners along the supply chain can help sharing the high risks of new developments, but is not a guarantee as managing these networks is a challenging task.

One special organisational innovation for European firms is the increasing tendency to diversify currency risk through global sourcing in addition to efficiency increases and financial hedging strategies. Firms like EADS aim to lower their foreign currency exposure by increasing its sourcing from firms located in countries operating with US dollars. This raises issues of relocating production activities in the sector. EADS expects by 2020 China, India, Russia and South Korea as important production locations, with Brazil, Israel and Canada as additional possible candidates (Mundt, 2007).

Products are increasingly sold as a service rather than a single product. The most famous example being Rolls-Royce selling ‘power by the hour’ rather than simply jet engines. This combination of physical products with add-on services such as maintenance has been an important trend in the past expected to continue. But this also means that producers retain operating risks of the products they sell. However, such business models might help customers adopt more innovative and risky products, posing a potential stimulus for innovation, as risks for customers can be managed.

The above examples of organizational innovation are often complementary to technology development and help firms to improve productivity. Rather than being exhaustive, the above gives an impression of important developments in the sector. However, the use of IT will also in future re-shape the way firms are structured, how they collaborate with partners or how they sell their products and services. For firms it is important to continuously engage in organisational innovation to adapt to market needs and technological possibilities.

## 5.3 Impact of eco-innovation[11]

Climate change and sustainability are positioned high on the global agenda for both governments and industry driving new legislation and consumption patterns in the aeronautics industry. Air travel contributes with 2% of global man-made $CO_2$ emissions – 1,7% civil air transport 0,3% military air

[11] This section is based on the horizontal analysis of eco-innovation opportunities in Task 4 of SIW-II. The full analysis is available in Montalvo et al, 2011.

traffic (ACARE, 2008). While significant technological progress has been made in terms of efficiency and noise reduction of aircraft over the last 50 years, the overall increase in demand has offset these efforts (NASA, 2006). ACARE (2009) highlights that the environmental impact of air transport, aircraft manufacturing, maintenance and disposal still has knowledge gaps. Consequently, the direct (and indirect) environmental problems caused by manufacturing activities are currently not dealt with at sector level, but in line of overall environmental regulation. For the space segment contribution to climate change of manufacturing activities is up to now not a relevant issue.

The contribution to climate change of the sector is mostly discussed in context of emissions of air travel rather than the direct (and indirect) emissions of manufacturing activities. The reason being that only very few percentage points of total GHG emissions over the life-cycle of an aircraft are attributed to the manufacturing process (Chester, 2008). The US Environmental Protection Agency in its sector notebook on aeronautics and space (EPA, 1998b) list a comprehensive overview of pollutants as direct output of aeronautics and space manufacturing activities. Evidence from the UK suggests that transport sectors, particularly aviation and shipping, are among the fastest growing sectors (WRAP, 2009), the majority of which can be associated with international aviation and shipping (Agnolucci, Ekins et al. 2009)). These are the two sectors currently outside the Kyoto Protocol.

### 5.4.1 Eco-innovation opportunities in the space and aeronautics sectors

Overall, the space and aeronautics sectors plays a key role for eco-innovation lowering the carbon footprint of air transport services. So far eco-innovation opportunities are to a lesser extent identified for manufacturing processes although emissions of chemical substances are dealt with through environmental regulation. But frequently exceptions are made to wider environmental regulation due to reasons of flight safety (e.g. chromates in coatings). Environmental regulation and safety regulation are hence potentially in tension.

For aeronautics and space, the largest potential for eco-innovation does not lie with the sector itself (manufacturing activities) but within the use sectors. In the case of aeronautics, the sector can help reduce environmental impact of air travel. It is of key importance to place the sector activities in context of the product use and life-cycle. Eco-innovation opportunities have been identified for five areas: new materials for light weight aero structures, new materials for engine performance improvements, fuel cell as alternative propulsion, bio-fuels to lower the carbon footprint of air transport, and aeronautics and space coatings reducing chemical emissions in manufacturing and reducing fuel consumption of aircraft. The last category, aerospace paints and coatings, represent an important step in manufacturing and being responsible for a large share of VOC emissions. The use of bio-fuels also generates high expectations to lower carbon emissions during aircraft operations. Table 5.1 shows an overview of eco-innovation opportunities in the space and aeronautics sectors as collected in the eco-innovation analysis of SIW-II.

**Table 5.1 Eco-innovation opportunities in the space and aeronautics sectors**

| Eco-innovation | Brief description | Example |
|---|---|---|
| Lightweight & composite materials in airframe structures | New materials play a crucial role in airframe structures, engine components and in related systems and devices. This category includes both composites and metallic cellular structures enabling weight reductions for vehicle structures. | Airbus A320 Winglets (part of Next generation composite wing) using Atkins Carbon Critical Design ™ tools |
| Materials engines | This category includes high performance alloys for jet engines help improve jet engine efficiency by increasing pressure and temperature of steam cycles. Refractory metal alloys (RM) represent a revolutionary alternative for jet engine efficiency but challenges of oxidisation under high temperatures need to be overcome. | Rolls Royce's Trent XWB™ engine Scnema's LEAP-56™ engine |
| Alternative propulsion systems | Alternative propulsion systems are currently being envisioned as auxiliary power systems. Boeing developed a 2-seat civilian aircraft running on electricity of a fuel cell combined with a battery, showing the technical feasibility of the technology for small aircraft. | Antares DLR-H2, a prototype by DLR and Lange Aviation |
| Biofuels | These represent drop-in alternatives of kerosene – renewable fuels that can be added and used in the current kerosene. Since 2005 different mixes have been tested by several airlines, mainly using camelina, jatropha and algae. | Bio jet fuel from Dutch SkyNRG |
| Coatings | Coatings represent a weight factor and provide the outer shell and hence influence air drag of the aircraft. But the weight and smoothness have to be balanced against environmental factors, airframe integrity, and legislation issues in the development of new aerospace coatings to protect the aircraft structure against the extreme conditions they are exposed to daily. | Toluene, xylene and chromate free engine coatings from British Indestructible Ltd` DeSoto® chromate free exterior nano primer coating from PPG Aerospace |

Source: Montalvo et al (2011)

Space applications can help in the future monitoring and managing climate change. It is expected that the space sector can play an important role in the future to lower environmental impact of many sectors improving resource management and efficiency. Nonetheless, this area will not be covered in this review as their likely impacts on eco-innovation have indirect effects. On the other hand space applications (downstream services) have the potential to address many societal challenges (OECD, 2005) providing opportunities for eco-innovation. Societal challenges refer to environmental degradation including natural resources such as water, forestry, but also climate change posing high environmental costs. Applications in this context refer to Earth Observation (EO) and Global Navigation Satellite Systems (GNSS) that help monitoring the environment, manage energy use, water management, precision agriculture and the mobility challenge. Earth observation for example can be used to select locations for renewable energy, assess and monitor water resources, increase the effectiveness of forestry and prevent deforestation, help farmers to monitor crops and monitor treaties and hazardous goods (OECD, 2005).

The availability of recent studies signposting a number of opportunity areas that are expected to drive eco-innovation in this sector is limited. Further research outputs are expected over the coming years with for example a number of on-going research projects in this field financed by DG Research (EC 2009d). EU-funded projects VITAL and NEWAC promise to deliver solutions.

### 5.4.2 Eco-innovation and regulation in the space and aeronautics sectors

The eco-innovation analysis in the SIW-II has also looked at the effects of regulation on eco-innovation in the space and aeronautics sectors.

The space and aeronautics sectors are strongly shaped by international standards and agreements and health and safety regulation. This makes changes to current standards a complex process, acting as a potential barrier for innovation. A clear driver for eco-efficiency in aeronautics is planned global emission policies. The Emission Trading System for example use economic incentives to further improve energy use during aircraft operations. However, this cost driver has been very strong in the sector for some time caused by levels of hyper competition between airlines that struggle to earn their cost of capital. Other regulations are often also locally administered. Noise reduction is another important driver for eco-innovation with stricter regulation especially for night flights.

While public policies can act as driver, often different policies work against each other. EASA, the European Aviation Safety Agency, is the centrepiece of the EU's strategy for aviation safety in Europe. Aircraft and components must be certified to meet standards of airworthiness. The aerospace industry is also affected by other policy initiatives and EU regulations (e.g., REACH; environmental and transport initiatives), which impact time-to-market and development costs (EC 2009a). This complexity in public policy means that ACARE calls for certification and qualification processes that facilitate the rapid introduction of new and innovative technologies into production models (ACARE, 2009 p.84).

Furthermore, goals for GHG emission reductions during product operations might be counterproductive to the environmental impact of aerospace manufacturing overall. The reason being that so called ‘new materials’ for, for example, high performing jet engines require much purer raw materials and special alloys that use a lot of energy and have high environmental impact. This makes assessing policy tools for overall impact on the life-cycle important to prevent counterproductive outcomes for other environmental characteristics.

The survey conducted on the role of markets and regulation (see chapter 4) revealed that the space and aeronautics sectors are most sensitive to regulation. All types of environmentally regulations are associated with most types of innovations, thus is very likely that many innovations are at least partially environmentally driven. Surprisingly, energy efficiency regulations resulted moderately associated only with innovation in manufacturing methods and relations with others but not in end products. This finding contrasts with the great effort that for example, airliners are putting in the improvement of their efficiency of their products (the survey includes only 2nd and 3rd tier companies). Although environmental regulations might be playing a role in motivating eco-innovations in this sector, other types of regulation (on safety, health, pricing, housing and community development, IPRs and interoperability between new machinery and equipment) might be motivating more innovations of other character rather than eco-innovations. Box 5.1 below illustrates a case of eco-innovation driven by regulation that has a combination of regulations on advanced materials and waste minimisation for aeronautic products.

**Box 5.1 New waterborne coatings for planes**

As such eco-innovation in aerospace coatings can help reducing environmental impact, resource use, and weight of aircraft and air drag of aircraft during flight operations. But the weight and smoothness have to be balanced against environmental factors, airframe integrity, and legislation issues in the development of new aerospace coatings to protect the aircraft structure against the extreme conditions they are exposed to daily. The US Environmental Aviation Agency in 1998 stated that alternative coatings – solvent free – have been developed but may be prohibited by FAA (Federal Aviation Agency, USA) guidelines (EPA 1998b).
Recently, a European chemical firm has introduced a new coatings series to the aerospace market that is waterborne reducing VOC emissions, contains 75% less chromates, lowers paint consumption and requires up to 20% less coating weight. This product line was developed for a large European aircraft manufacturer that needed to reduce its emissions to comply with European regulation; yet the technology has not been adopted yet. Aircraft manufacturers prefer trusted products and are reluctant to take-on innovative solutions. While it takes time to develop new market uptake it takes even longer to get old products out the market. An aircraft has a lifetime of 30 years. Coatings used for maintenance and repair must be made to original (old) product specifications which means that new products take very long to penetrate the whole market. Now that customers are convinced that the new product (water borne alternative) works, the next step is to convince them to adapt their production (processes). Water borne coatings differ substantially in their physical properties to old coatings requiring physical investments and adaptations in production structures of aircraft manufacturers.

Source: Eco-innovation futures database, TNO

# 5.4 Impact of innovation on new lead markets[12]

Growing air travel is seen as a key demand-side factor shaping innovation and future development in the aeronautics industry. Higher prices for fuel as well as stricter environmental regulations may also have substantial impact on individual and business air travel, making at the same time new materials for energy and resource efficient aircrafts necessary. Furthermore, safety of air travel is expected to continue receiving high attention. On the contrary, development of the space sector is expected to be driven by public demand and regulation. Societal challenges in the field of managing and monitoring transport and security are key demand-side drivers in the space sector.

Further technological improvements are expected in the fields of IT and aviation electronics for increasing autonomy of aircrafts, artificial satellites and spacecrafts. New materials and technologies for alternative fuels and propulsion systems will at the same time enable increased environmental sustainability and performance.

Environmental impact in terms of noise and emission is a key topic for both demand as well as science and technological development ("green technologies"). Thus, emerging innovation themes and new market potentials for the European aeronautics industry are particularly oriented on more environmentally friendly air travel (Brandes and Poel 2010). They concern:

- Improved aircraft performance through better engines as well as optimisation of several integrated sub-systems; *new aircraft configuration*, new propulsion systems and alternative fuels will additionally be explored in order to approximate to zero emission aircrafts. High demand is expected for environmental friendly but high performance aircrafts and thus, first-mover advantages in new markets ("green technologies") as well as Lead Market potential are expected to arise for the European aeronautics industry.

[12] This section is based on the analysis performed in the horizontal study on Lead Markets in Task 5 of SIW-II. The full analysis is available in Dachs et al., 2011.

- Innovation designs regarding small and personalised air transport products (personal or unmanned aerial vehicles) and services (similar to taxis) also promise new market opportunities and high demand in the near future. At this, large-scale demand is highly dependent on costs but at the same time a prerequisite for suppliers to operate successfully.
- Opportunities for Europe to achieve a Lead Market position and to set international standards concern new systems of *air traffic management* (ATM) by integrating different levels into a unified system of air traffic control. An increasing demand for air travel and a high number of decentralized air traffic movement challenges ATM and requires new management systems to handle this.

Expected future demand for the space segment is often related to wider goals such as the ‘grand’ challenges and is usually mediated by institutional clients such as governmental agencies. Emerging innovation themes and markets concern:

- Global Navigation Satellite Systems: Although Europe has a smaller market size for space-based applications compared to other global regions, potential may arise from the European positioning system Galileo. New market opportunities may concern global navigation as well as maritime applications.
- New applications in the field of earth observation include inter alia meteorology (e.g. weather forecasting), natural resource management at a global scale (environmental, air quality, agriculture or alternative energy monitoring), ocean and maritime as well as homeland surveillance. These possible applications still refer to niche markets, but have considerable potential for developing into large commercial markets in the near future. Decreasing costs for micro-satellites make applications increasingly interesting for a broader range of customers. Additionally, new launchers for space objects are expected to emerge in the respective field.
- Further development and increasing demand is expected in the segment of space travel. Although it is expected to remain a luxury niche market, the services provided by several companies will be more affordable and a growing space tourism industry with several interlinked applications and services is expected to emerge (infrastructure, maintenance, training, etc.). Regarding this there are still a range of uncertainties of economic, technological, political, legal as well as environmental nature.

Due to the large concentration in both sectors, it is most likely that large EU member countries such as Germany, UK and France, which host the main firms of the European aerospace industry as well as the main players on the demand side, offer the best framework conditions for the emergence of lead markets in these sectors. In addition, the patent analysis in the national specialisation analysis (Grupp et al. 2010) suggests that also Austria and Sweden have comparative advantages in this sector.

# 6 Policy analysis and conclusions

The space and aeronautics sectors are high-technology sectors and belong to the most innovative sectors in Europe and are world leader in specific segments. The European sectors are dominated by a small number of large firms concentrated in the UK, France and Germany. Large system integrators orchestrate the supply chain with complex sourcing and technology management processes and also shifting R&D activities and with fierce competition among 2$^{nd}$ and 3$^{rd}$ tier suppliers. High performance and safety are crucial. Technology and product development cycles take a long time and are very expensive with returns only available in the long run. Hence, the sectors are more oriented towards incremental innovation and mainly refer to process innovation. The need for eco-efficiency and cost-efficiency is an important driver for innovation.

The foresight (chapter 3), barriers to innovation analysis (chapter 4) and horizontal analysis (chapter 5) point out several policy implications for stimulating competitiveness in the Space and Aeronautics Sectors.

**Provide long-term and stable support to risky science and R&D**

Breakthroughs and radical innovations are needed to address the pressing innovation challenges, such as eco-innovation in the space and aeronautics Sectors. The space and aeronautics sectors are very R&D-intensive with very high R&D costs and long development and production times. Together with capital risks and high technical risks these factors are confirmed as market factors having a highly negative effect on innovation, and especially radical innovation. European policy efforts could focus on several approaches to overcome these barriers. First, European policy should provide stable and long-term support to risky R&D. There is some concern that European R&D programmes become more risk averse, with very high transaction costs, focusing on short-term results. This could be at the expense of long term, blue sky and radical innovation. Second, European policy could focus on introducing instruments that lower the risks on R&D and the uncertainty with capitalisation on R&D investments. Government could for example use public procurement mechanisms to take the risk of radical innovative projects in the civil market segment like they do in the military market segment. Moreover, governments could stimulate the development of different models of funding, for example through prize reward models. In addition, governments could assure that SME’s are also able to join (publicly funded) long-term research projects.

**Support the creation of platforms and linkages with other sectors**

The European research system for space and aeronautics is rather fragmented and links with other sectors are hardly available. Aerospace technologies are increasingly adopted by other sectors to develop new products and services. For example, micro-electronics and other ICT clusters are highly relevant for avionics and micro-satellites, but also for downstream space-based services, sectors such as telecommunications, energy and transport are very relevant. However, firms from these different sectors are not natural partners. European policy efforts could stimulate and support platforms bringing together different actors, both large firms and small firms, infrastructure operators, service providers, venture capitalists and users. These platforms can stimulate collaboration; facilitate shared visions and standards, as well as identifying market barriers. Moreover, these platforms can support service innovation in the downstream sectors, as firms developing these downstream services and applications will get involved in the development and planning of new space infrastructures and hardware.

**Strengthen market mechanisms to support innovation**

Because of the high costs and high risks of innovation in space and aeronautics, commercial actors have many difficulties financing this type of research and establishing attractive return on investment. Hence, market adoption should be stimulated and the most effective tool is the introduction or stimulation of market mechanisms.

One example of such a mechanism is the proposed emission trading system. For successful implementation, however, a level playing field should be ensured. Another is a harmonised value added tax on kerosene that would have a similar effect as CO2 certificates. Thirdly, to reduce noise pollution from aircraft, landing fees could be based on noise emissions of aircraft. The certification process for aircraft technologies could be used to speed-up market introductions of , especially, environmental technologies. Environmental technologies could be prioritised compared to other technologies in the certification process. Another issue is the access to space data. Space data are a crucial input for many downstream services and the willingness of commercial actors to invest in service innovation is influenced by the guarantees on access to data. Data access policies should focus on this guarantee on access to data.

**Remove regulatory barriers and support smart regulation**

The space and aeronautics sectors are highly regulated sectors, especially in relation to safety regulation. Safety is understandably the first priority in these sectors, however strict safety regulations can also limit innovation and adoption of new technologies, as proven technologies are preferred because of established certification and certainty. Nevertheless, new technologies and innovation is needed to establish efficiency gains, reach eco-efficiency and address societal challenges. Hence, innovation and safety are in tension. Creative thinking and smart regulation is needed to solve this tension. For example, procedures for certification and authorisation of environmental technologies could be speeded up. Moreover, in emerging markets stakeholders could be involved in developing smart regulation and policy makers could designate areas in which the impact of potential safety issues is limited and where exempt certificates can be used. In space, unresolved liability issues need to be resolved and regulatory frameworks in relation to safety, environmental protection, and public procurement need to be harmonised to reduce commercial risks of actors and increase legal certainty. This is needed to facilitate the commercial development of space applications and to share risks.

**Support talent and the development of new skills**

Fewer European students follow degree courses in engineering and sciences. At the same time, more and more PhD positions in the North-West European countries are filled with overseas students. These are high skilled sources of talent that cannot always be recruited by European institutions and firms due to labour market restrictions. Next to stimulating European students to follow degree courses in engineering and sciences, policy efforts should concentrate on resolving labour market barriers. This would allow Europe to profit from overseas talent that is educated in Europe and opens the doors for overseas business contacts in the future. This talent is very much needed to solve technological challenges in various fields such as new engine designs (e.g. turbo fans), airframe configurations, bio-fuels, fuel cells and new materials. Moreover, firms should be stimulated to establish a long-term view on recruitment and employability in the sectors. The cyclical nature of large scale projects also impacts the supply and demand of engineering capacity leading to a loss of talent to other sectors in downturn periods.

Also in terms of skills and capabilities, there are pressing requirements. The increasingly complex value chains and networks of many suppliers and partners are difficult to coordinate and contain many risks. This requires improved skills and capabilities in supply chain management, but also sufficient in-house know-how and the ability to integrate and use new technologies from suppliers and partners. Moreover, different capabilities are required from suppliers, as they increasingly take over R&D and innovation activities and the related risks. European policy efforts should focus on supporting and stimulating the creation of new and improved skills needed in coordinating and acting in these complex innovation networks.

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# Annex Foresight workshops participants

| | |
|---|---|
| Boele John | TNO |
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| Gérardine Meishan Goh | DLR |
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# Annex Overview SIW deliverables

Overview of the deliverables from the Europe INNOVA Sectoral Innovation Watch

Deliverables can be downloaded from www.europe-innova.eu

**Task 1 Innovation Performance Sectoral Reports**

Ploder, M., C. Hartmann, E. Veres, B. Bertram (2010) Sectoral Innovation Performance in the Automotive Sector, Final Report Task 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, June 2010, revised December 2010

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**Task 5 Input and Output Papers**

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**Final Synthesis Report**

Montalvo C. and A. van der Giessen (2011) Sectoral Innovation Watch – Synthesis Report, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011