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Aeronautics and Air Transport

Beyond Vision 2020 (Towards 2050)

A Background Document from ACARE (The Advisory Council for Aeronautics Research in Europe)

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AERONAUTICS AND AIR TRANSPORT: BEYOND VISION 2020

(TOWARDS 2050)

Background Document

Advisory Council for Aeronautics Research in Europe

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This report

AERONAUTICS AND AIR TRANSPORT:
BEYOND VISION 2020 (TOWARDS 2050)

has been prepared on the instructions of ACARE by the ACARE Strategy Review Group, which presently comprises the following members:

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* representatives of airports and airlines, and experts and research academics in aeronautics and air transport, sociology, economics, the environment, aviation sustainability, meteorology, and energy resources.

FOREWORD

At the start of the new millennium, the Group of Personalities expressed a vision for European aviation evolution for the 2020 horizon. This vision led to the formation of ACARE to define and review the content of the Strategic Research Agenda (SRA).

The SRA themes and goals have had a leading influence on aeronautical research and are paving the way for the significant improvements in sustainable, reliable, affordable and passenger-friendly aviation that will reduce the environmental impact of air travel across the world.

However, since 2000, the perception and requirements of air transport have changed significantly. In recognition of these important changes, ACARE has for the last year reflected on their implications and emergent challenges for aeronautics and air transport on a revised horizon.

A great deal is at stake: aeronautics and air transport should be considered as a strategic economic and social domain to ensure the future of European integration, independence, prosperity, and competitiveness in the global economy. Far-sighted research and development programmes are essential for the development of new ideas and to drive investment and innovation in support of an environmentally sound Air Transport System in the longer term.

An ambitious high-level vision, beyond 2020, is now needed to focus available resources on European aeronautics and air transport research for the delivery of solutions to meet the challenges for the future.

This document is intended to act as a catalyst for high-level decision-makers to stimulate further analysis with the aim of building a challenging vision for European leadership in global aviation towards 2050, responding to the needs of Society and the citizens of Europe.

François QUENTIN and Joachim SZODRUCH
ACARE co-Chairmen

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EXECUTIVE SUMMARY

Aviation has dramatically transformed society over the past 100 years. The economic and social benefits throughout the world have been immense in "shrinking the planet" with the efficient and fast transportation of people and goods. The growth of air traffic over the past 50 years has been spectacular, and will continue in the future, particularly in the growing markets of the Far East.

The European Air Transport sector made up of civil Aeronautics and Air Transport generates a turnover in excess of Euro 94 billion and represents a pinnacle of manufacturing which employs almost half a million highly skilled people directly and spinning-out technology to other sectors. About 2.6 million indirect jobs can be attributed to air transport related activities and a contribution of around Euro 240 billion to gross domestic product. The Aeronautics and the Air Transport sector is a key strategic economic domain for Europe.

A European Vision for Aeronautics and Air Transport in 2020 was launched by Commissioner Busquin in 2000. This established a vision to meet the needs of society, while maintaining European global leadership in aeronautics. This vision led to the formation of ACARE (the Advisory Council for Aeronautics Research in Europe) to define a Strategic Research Agenda (SRA) and make the vision a reality. The SRA provides strategic goals and Research & Technology (R&T) roadmaps for proposed solutions to achieve the objectives outlined in Vision 2020.

The SRA goals have had a clear influence on current aeronautical research. There is strong evidence of a vigorous programme of Aeronautics and Air Transport research, which is already delivering important initiatives and benefits for the aviation industry, including: EU collaborative research in Aeronautics and Air Transport (EC's Framework Programme research), the Clean Sky Joint Technology Initiative, the SESAR Joint Undertaking, national programmes in many Member States and research establishment as well as private company programmes.

ACARE has shown the combined strength of working together across the whole community of industry, research establishments, universities, governments, regulatory authorities, and the European Commission. This collaborative framework needs to be maintained to help develop an even more successful future Aeronautics and Air Transport System in Europe.

Towards 2050 - New Challenges

Since 2000, society's perception of Air Transport has changed following the dramatic events of 11th September 2001, growing environmental awareness, the rise of oil prices in 2008, and the recent financial crisis. In the future, aviation is likely to face even more radical challenges - with some arising from its own success.

Environment

Climate change is a major societal and political issue and is becoming more so with future emissions-related regulation expected to become more prevalent than today.

Tough challenges lie ahead. Globally civil aviation emitted 666m tonnes of CO_2 into the atmosphere in 2008 representing some 2% of man made CO_2 emissions. Non-CO_2 emissions including oxides of nitrogen and condensation trails which may lead to the formation of cirrus clouds, also have impacts but require better scientific understanding. In response to the likely volume of activity in the future, aviation must bring about step changes in technology and operational procedures on top of the currently available solutions, to improve its environmental performance by keeping total climate effects at sustainable levels. However, any reduction in absolute emissions from Air Transport will be difficult to accomplish and represents a major challenge.

Reducing disturbance around airports is also a challenge with the need to ensure that noise levels and air quality around airports remain acceptable.

Aviation is directly impacted by energy trends. As with other sectors, aviation is dependent on, and will have to deal with, energy availability in the coming decades to continue as an important

development factor in future societies. Aviation will have to develop long-term strategies for energy supply - including alternative fuels - that will be technically suitable and commercially scaleable as well as environmentally sustainable.

Environmental trade-offs, including those between emissions and noise, will have to be balanced to find optimised solutions for the whole Air Transport System and its sub-systems of the future. A European interdependency modelling capability is needed for this task.

An effective way to respond to the environmental pressure would be to improve the environmental performance of aviation in the market place by redirecting resources generated through the aviation emissions trading scheme towards the development of Research & Technology and deployment of the most efficient technological innovation. In this regard, any aviation emissions trading schemes should be applied at a global level and prove their long-term economic and environmental viability.

With the aim of a global solution, International Civil Aviation Organisation (ICAO) is promoting effort in four key areas: improved technology, efficient operations, effective infrastructure and positive economic measures. Similarly, the International Air Transport Association (IATA) has declared a target to stabilise net CO_2 emissions (carbon neutral growth) by 2020 with a long-term aspirational goal to reduce aviation net carbon emissions by 50% in 2050 compared to 2005 level.

The Copenhagen Accord “noted” by the United Nations in December 2009, highlights that “… deep cuts in global emissions are required … to hold the increase in global temperature below 2 degrees Celsius.” ICAO is seeking the mandate to implement the necessary actions for aviation.

Europe must play a major and leading role in the definition of global aviation’s approach to sustainability.

A changing world

The role of Air Transport has never been more important to society, and it is vital that aviation is prepared to meet the challenges of a changing world.

With changing demographics and increased urbanisation, society towards 2050 will need more long-range transport to connect markets and people. Passenger travel will increase with growth in business and social-related mobility (dependent on the population being able to afford air travel). This continuing growth in demand will bring increased challenges for dealing with mass transportation and congestion of infrastructure.

Transport will increasingly become a place for work, commerce, leisure, and meeting others. Some travel needs may disappear because of teleconferencing and virtual access to knowledge, but Information and Communication Technology development will add to the opportunities for interaction and ultimately contribute to transport demand.

Global forecasts show a potential demand for some 25,000 new passenger and freight aircraft between 2008 and 2028 representing an orderbook value of Euro 3 trillion. This will be driven by the need for more fuel efficient and eco-efficient vehicles to handle additional capacity as well as for the replacement of older generation aircraft. Important changes in infrastructure and operations will also be needed.

Air Transport will have to find innovative ways to meet the future needs of society for mobility. This “new version” of aviation must be competitive and complementary with other transport modes. **Europe, with its unique infrastructure, is able to develop advanced multimodal transport solutions including an appropriate role for aviation in order to provide safe, affordable and sustainable transportation.**

Financial pressure

The world economy has been in a deep downturn. GDP growth rates in 2009 have been the lowest since the Second World War. However, there are good reasons to expect a recovery to normal growth rates of world GDP and air travel demand.

Aerospace is one of the most research-intensive sectors in Europe, and despite tough times, more than 12% of its turnover is dedicated to Research & Development. However, the scale of the challenge is such that securing financing for vital new programmes and technologies will be a major issue for the future, especially as capital markets will in all likelihood remain tight in the medium term.

The oil price peak of 2008 is not an isolated event. Increasing and volatile oil prices will shape the economy of the future and exert tremendous pressures on the industry, which will challenge existing airline business models.

Europe needs a suitable solution to overcome the economic crisis and ensure appropriate support for an efficient and sustainable Air Transport System.

European aviation competitiveness

The European Air Transport sector must continuously innovate to remain globally competitive against strong competition from North America as well as emerging economies. The shift of economic power to the East implies new markets for the European industry, but at the same time new competitors will emerge from Brazil, Russia, India, and China. Some of these states view aviation as a strategic sector, which implies strong governmental support for the respective companies. For Europe, a strong aviation sector is vital to compete effectively on a global scale.

Managing the evolution of the supply chain of the future will be a key element in Europe's success. For the industry as a whole, a concentration on core competencies and high value-added activities will be key success factors.

There is an additional urgent need for a new commitment to global cooperation (*e.g.* with the USA and with emerging new competitors) to help European industry address the technological challenges. Developing a strategy for clear "win-win situations" will help aviation better serve the needs of society.

The existing ACARE Vision 2020 and associated Strategic Research Agendas (SRAs) have successfully steered European aeronautics research in recent years. The ability of the European Air Transport industry to meet future challenges will only be possible with a strong commitment to the vigorous evolution of current technologies and achieving new breakthrough technologies. There is now a need to set new priorities for an extended timescale towards 2050.

R&T is an area where public and private authorities can combine their efforts most effectively at the European as well as national levels. This is especially relevant in the search for urgently needed technology breakthroughs. One way of dealing with this obstacle is to optimise the support processes for research. An appropriate share of funding should be allocated to R&T support, proving technological capability by demonstration, and then entering the (market financed) development process. This would shorten development times, reduce costs and risks, and implement more efficient solutions in the marketplace.

Europe needs an efficient, flexible and user-friendly support system for Research & Development with appropriate funding necessary to generate the required levels of innovation.

Recommendation

ACARE recommends that for Europe to remain at the heart of the global aviation sector, policymakers must build on the substantial results the sector has achieved since setting the 2020 Vision. In view of the changing landscape of challenges facing Air Transport since 2000 and with the prospect of new and greater challenges emerging in future, the formulation of a timely new vision beyond 2020 for the horizon towards 2050 is essential.

The need for new knowledge and solutions has never been greater. Hence, a new European vision is vital if Europe is to play its part in helping to meet the needs of society and in order for Europe's Air Transport sector to maintain its lead in Aeronautics.

A new vision 'Towards 2050' is essential and must be established at the highest level within Europe to set a strategic direction for European Aeronautics and Air Transport on the revised horizon.

CHAPTER 0: WHERE ARE WE IN THE AIR TRANSPORT SYSTEM?

0.1 THE CURRENT AIR TRANSPORT SYSTEM PERSPECTIVE

Aeronautics technology has led to an aviation system that has transformed the human condition. Over the last century, air transport has evolved to "shrink the planet", modify the perception of time and distance - and airspace - and vastly expand human mobility. The resulting economic and social benefits have been immense. Conquest of the skies has liberated humankind from the bonds imposed by geography, terrain and water - and gravity. **Air routes are the highways of the global economy**, transporting people and goods over vast distances at great speed. Aviation has massively multiplied and facilitated business and leisure opportunities, cultural exchanges and the development of international institutions and political relationships. Very few other developments have made such an outstanding contribution to the spread of civilization in the past 100 years.

The Air Transport System will continue to offer significant benefits to society, both for business travel and for leisure and personal travel. The future is likely to be rather different to what we imagine, with significant scope for future innovation. The growth of air traffic over the past 50 years or more has been dramatic. **Forecasts indicate that growth will continue**, even in the more mature markets of the USA and Europe, and at even higher levels in the growing markets of the Far East. People are seeking to fly in increasing numbers. The customers' reference frame for prices has changed. Short-distance transport is increasingly considered as a "commodity", which should only be "low-fare". This is a stable trend. With the Internet and e-technology, passengers want to do everything for themselves (book tickets, choose their seats, etc.). Intermediaries could disappear. This would imply not only extra costs for the air transport industry (training, conversion of employees, etc.), but also a cultural adjustment involving a change of mindset as well as tools and instruments. The battle of tomorrow is innovation for the customer [Ref.1].

The aeronautics industry is also an asset for Europe economically. Aeronautics represents a pinnacle of manufacturing, **employing large numbers of highly skilled people, spinning out technology to other sectors and yielding consistently large balance-of-payments benefits**. This is a profitable and growing manufacturing sector, unlike many other parts of European manufacturing. The net benefit (value added) for the aeronautics and air transport sectors is high. Figures show that the turnover in the aeronautics industry[1] has more than doubled since 1980 and now stands at €94.5 billion. This represents 36.4% of global aerospace industry turnover and indicates that Europe is second only to the USA (51.1% of global turnover). These figures cover both civil and military aerospace activity and are for the year 2007. This covers large civil aircraft, military aircraft, business jets, regional aircraft, helicopters, aero-engines and equipment. The corresponding figures on employment show that 442,100 were employed in 2007, representing 35.4% of global aerospace employment, and in the USA this represents 48.5%. There was a high turnover per employee at €212,000. R&D expenditure was € 11.7 billion, representing 12.4% of turnover. This shows that **the sector invests heavily in R&D compared with other industrial sectors**. Aerospace is second only to pharmaceuticals in this respect. ACARE believes that government support for R&D is higher in the USA than in Europe because of sizeable American civil aeronautics support budgets and the greater industrial use made of defence aeronautics funding in the USA: 56% of turnover is exported, giving a sizeable positive contribution to the balance of payments.

The opportunity for the manufacturers is illustrated in the Airbus 2009-2028 Global Market Forecast which anticipates a global demand for some 25,000 new passenger and freighter aircraft between 2009 and 2028, creating an average delivery rate of some 1,248 airliners annually during this 20-year period. This need over the next 20 years represents a combined order-book value of $3.1 trillion, and will be driven by the need for more fuel and eco-efficient aircraft to cope with traffic growth, as well as for the replacement of older-generation equipment. Competition for the

[1] *Facts and Figures*: Aerospace and Defence Industries Association of Europe (2007)

European aeronautics industry will develop with the emergence of new engine and airframe manufacturers from China, Canada, Russia and Brazil. This will bring many new dynamics, as well as technological variety and complexity to the air transport sector and to the aerospace industry. [Ref. 1].

Hence, those in aeronautics have the ambition to continue to deliver these benefits, but there are some accompanying challenges. **Future growth represents a challenge for the Air Traffic Management system and for airports, but represents a significant opportunity for the manufacturers and airlines. At the same time, this presents a challenge to the need for environmental improvement**.

Over the 2009-2028 period, world passenger traffic is expected to increase by 4.7% per annum, and the numbers of frequencies offered on passenger routes will more than double (according to the Airbus 2009-2028 Global Market Forecast). Hence, **traffic demand will nearly triple, and airlines will more than double their fleets of passenger aircraft** (with over 100 seats) from 14,016 at the beginning of 2009 to 28,111 in 2028. However, this growth will not be evenly distributed across the world; for example, GDP for China and India is now expected to grow by 10.4% and 8.4%, respectively. As a consequence, airlines based in the Middle East and Asia, which will grow by an average of 6.9% and 6.0%, respectively, are expected to develop their traffic more rapidly than those operators based in other regions. This is fuelled by the aspirations of airlines, and in some cases the countries themselves, as well as by access to burgeoning markets driven by liberalisation and a growing propensity to travel. Airlines are adaptive to passenger demand and needs. At the same time, air transport is highly exposed to socio-economic fluctuations. In future, airlines will seek to further develop business models with reactivity and flexibility (evolution of LCCs and major carriers, alliances, market segmentation, and so on) in response to volatile market conditions. Airlines will look to manufacturers and other actors in support of this in-built reactivity.

The challenge for Air Traffic Management and airports is illustrated by the EUROCONTROL Long-Term Forecast: IFR Flight Movements 2008-2030. This forecasts between 16.5 and 22.1 million IFR flight movements in the EUROCONTROL Statistical Reference Area in 2030 - this is between 1.7 and 2.2 times the traffic in 2007 and represents an annual average growth of 2.3%-3.5%. The growth will be distributed unevenly in time and across regions.

The EUROCONTROL forecast also indicates that required capacity at 138 reviewed European airports will increase by 41% in total by 2030, but the **demand will exceed the capacity of the airport system** by as many as 7.0 million flights. The situation is likely to be similar in other parts of the world. Airport congestion will be a challenge for the quality of service provided by the Air Transport System. Almost no new airports will be built in Europe, the only expansion possible being with the development of secondary airports. If large airports become saturated, traffic will spread to non-saturated regional airports, unless economic and environmental regulations limit such development. In future, long-haul demand is likely to grow at the expense of short-haul. With the shortage of EU runway capacity, this means more slot substitution than growth. Passenger numbers will rise but the number of aircraft movements will not increase as fast (higher load factors, less frequency, and bigger aircraft).

The full development of precise, satellite-based autonomous navigation systems, together with the maturity achieved by rotorcraft technology (helicopters, tilt-rotors and other configurations currently being studied) may make available a new and additional component of the Air Transport System that will use existing airports, causing less community disturbance; but this will also require a network of widespread, cheaper, new heliports/vertiports.

The restructuring of air transport supply is likely to lead to the specialisation of airports in a hierarchy between hubs and regional airports, and airports being connected by rail instead of competing with each other. Compared with Europe, emerging economies are less constrained, for example, with regard to airport expansion. Many of the Middle East nations are launching huge airport infrastructure developments, coupled with very large orders for new aircraft, clearly competing with EU aviation and its commercial hubs. In addition, the Middle East owns a large

proportion of the world's fossil fuel reserves. This is a serious problem for Europe's economic competitiveness in the world.
However, in a world seeking to reduce man-made emissions to the environment, the very success of the Aeronautics and Air Transport sector represents a challenge. **Increased traffic and increased numbers of flights make it difficult to reduce the absolute emissions from air transport.** The continuing reduction of specific fuel consumption at over 1.5% per year [Ref. 2] significantly mitigates the absolute emissions, but nevertheless most future scenarios predict an increase in aircraft emissions in absolute terms. This should be seen in the proper context, where aviation presently accounts for 2% of global carbon dioxide emissions and, at worst, this would grow to about 5% in the next 30 years. Even in the context of transport emissions, aeronautics accounts for only a minor share (6%), such that politically driven efforts to reduce aviation emissions do not contribute strongly to overall environmental goals.

Aeronautics manufacturing is also moving along the path towards environmental sustainability over the whole life-cycle of aircraft production, from early design to the phasing-out of aircraft, with more environmentally friendly processes and factories. Efforts are being made to ensure the better use of raw materials and energy, as well as reducing effluents and waste. In addition, attention is being paid to end-of-life disposal and recycling issues for older aircraft.

There are also **a number of opportunities for new air transport vehicles**. The development of personal air transport (in Europe alone, the potential is for a further 40 million flights annually), the emergence of Very Light Jets (VLJ), and the integration of new aircraft carrying between 30 and 40 passengers into the system, risk overloading the market. VLJs may be used for air-taxi purposes (flexibility) or to link big cities to the remote countryside (connectivity). **Unmanned Aircraft Systems (UAS) may take a potentially high market share**, with a wide range of applications, such as delivery, search and rescue, etc. Sub-orbital transport could allow for new forms of travel and tourism.

Hence, there are a number of challenges for the future of Air Transport. Many of these are global in nature and can be tackled through global coordination of efforts. There are challenges for the industry in terms of manufacturing, building the skill base, best practice, etc; there are those challenges faced by Air Traffic Management authorities and suppliers in handling increased traffic; there are the environmental challenges; and the challenge for the industry to remain globally competitive against strong competition from the USA. **Technology can play a significant part in all of these challenges** and technology is the area where public and private authorities can combine their efforts most effectively at European level.

0.2 AERONAUTICS AND AIR TRANSPORT VISION 2020

A Vision for Aeronautics and Air Transport in 2020 was launched by Commissioner Busquin in 2000. The **vision established goals for meeting the needs of society and maintaining global leadership in aeronautics**. The position of the European aeronautics industry was recognised as world-class, leading in global markets for aircraft, engines and equipment; along with European aircraft and an Air Transport System that is responding to the needs of society. The **vision covers the airport and airline sectors, regulators and air traffic managers as well as airframe, engine and equipment manufacturers**. The 2020 timescale was not a distant deadline but a sensible reflection of the lead times in the research, development and manufacturing for many of the industry's products and services. The inclusive vision aimed to meet Europe's needs and arrive at a safe, efficient and environmentally-friendly Air Transport System that will strengthen the competitiveness of the continent's increasingly integrated economy.

0.3 ACARE

Vision 2020 led to the formation of ACARE (the Advisory Council for Aeronautics Research in Europe) as a research network to **define the content of the Strategic Research Agenda (SRA)** and help make the vision a reality. The Council is tripartite in composition, bringing together authoritative senior figures from aeronautics stakeholders, Member States and the Commission to build consensus in favour of strategic actions. The Advisory Council involves a commitment to influence all stakeholders to plan research programmes in the light of SRA priorities.

Consensus at Council level also helps in the sharing of tasks and shaping relations between national and EU programmes as well as influencing the deployment of funds in a non-bureaucratic way, while recognising the particular roles of each programme.

0.4 THE STRATEGIC RESEARCH AGENDA

ACARE has produced two versions of its SRA - as well as a 2008 Addendum. The SRA provides strategic directions for solutions and R&T roadmaps to achieve the Top-Level Objectives as outlined in Vision 2020. The clear and ambitious goals in the first SRA (particularly those on emissions and noise) have become well established globally and served as a guide and inspiration for research across Europe and beyond.

One of the main challenges remains the predicted growth in air traffic - more than doubling between 2000 and 2020. This puts pressure on the capacity of the Air Transport System, both in the air (through air traffic management) and at airports in handling the passenger and freight throughput; it also puts pressure on efforts to reduce the environmental footprint of aviation.

0.4.1. SRA1 GOALS

The technical content of the SRA is driven by five major challenges that interact when addressing the Top-Level Objectives. The ambition to **provide more affordable, cleaner, safer and more secure air travel** determines the major challenge areas. These challenges, each of which has clearly identified goals, contributors and solutions, are:

- **Quality and affordability.** The challenge of delivering products and services to airlines, passengers, freight and other customers while increasing quality, economy and performance for sustained international competitive success;
- **The environment**. The challenge of meeting continually rising demand while demonstrating sensitivity to society's needs by reducing the environmental impact of operating, maintaining, manufacturing (and disposing of) aircraft and associated systems;
- **Safety.** The challenge of sustaining the confidence of both the passenger and society that commercial aviation will not only remain extremely safe (even with greatly increased traffic) but will reduce the occurrence of accidents;
- **Efficiency of the Air Transport System**. The economic needs of Europe's citizens, international competitiveness and the convenience of passenger and freight customers - these all demand that increasing traffic will not exacerbate congestion, delay and lost opportunities. The challenge is therefore that the efficiency of the whole system must be substantially increased. This will require the introduction of radical new concepts;
- **Security.** Dramatic events have underlined the reality that protected and uninterrupted air services are a foundation to secure all the economic and social benefits of the Air Transport System. The challenge is to devise measures that will improve security, on a global basis, within a highly diverse and complex system and against a strong backdrop of increasing traffic.

The objectives are not achievable without important breakthroughs, both in technology and in concepts of operation - the evolution of current concepts will not be sufficient. The Strategic Research Agenda included the vision on mechanisms for achieving the goals. These were:

- **Research infrastructure:** capable of delivering the means by which the planned research can be completed to a world-leading standard
- **Competitive supply chain** from strong primes to the smallest suppliers, capable of exploiting all of the expertise in Europe, contributing to the necessary research and turning new technologies into competitive products
- **Certification and qualification processes** that facilitate the rapid introduction of new and innovative technologies into production models
- **Educational system** capable of delivering the required diverse and multi-cultural skilled research workforce
- **Trans-European synergy** to make best use of the research effort being applied

ACARE has set goals on the environment but new standards for aircraft on noise and emissions are set by the International Civil Aviation Organisation (ICAO) and discussed in ICAO's Committee for Aviation Environmental Protection (CAEP).

0.4.2. SRA2 AND HIGH-LEVEL TARGET CONCEPTS

The second version of the SRA (SRA2) builds on, updates, and widens the work done in the first edition. The SRA2 sets out likely directions of technological change that will need to be converted into specific research programmes over the coming years if the objectives of the work are to be realised. SRA2 proposes an approach for meeting the goals through themed High-Level Target Concepts.

Five HLTCs were selected:

- The highly customer-oriented Air Transport System
- The highly time-efficient Air Transport System
- The highly cost-efficient Air Transport System
- The ultra-green Air Transport System
- The ultra-secure Air Transport System

These concepts represent extensions of scenario work to create emphasis on particular characteristics of the Aeronautics and Air Transport System in 2020. These scenarios/HLTCs represent avenues for pursuing the goals. An important perspective to highlight is that an individual HLTC should not be pursued to its limit at the expense of the other HLTCs. Similarly, a comprehensive study of all the technologies that need to be developed for a complete Air Transport System against a set of conditions for the future would necessarily draw on all, or at least on most, of the HLTCs. The purpose of the HLTCs is therefore to identify technologies that need to be developed. (They are not models of the future from which we can choose one or more that happen to suit us.) The technologies embraced by the HLTCs will all need to be developed - but at speeds and intensities relevant to the developing world.

All of the goals can be achieved through balanced progress of the HLTCs: this will stimulate the system-wide, cross-disciplinary research so strongly needed to develop optimised solutions for a high-performance Air Transport System.

0.4.3. SRA ADDENDUM: 2008

The **2008 Addendum** highlighted the changed circumstances since the publication of the earlier SRA and gave **recommendations to ensure that the technology and institutional roadmaps for 2020 remain on track**: the conditions may change but the twin objectives of serving European citizens and enhancing European competitiveness remain the same.

The dominant issue for aviation in the immediate future is reconciling the pressure for reduced climate change-impact with the growth in aviation that brings enormous economic benefits. Further downstream, we expect the aviation community to respond to new challenges as the world changes with the effects of climate change and the pressures on energy resources, water, food supplies, and land.

The principal conclusions were:

- The present Agenda is endorsed in its essential direction and content
- Adjustments and accelerations are recommended in the areas of environmental technology development, action on alternative fuels, and on security systems - all of which should have increased priority
- Revitalised action is indicated to encourage faster and effective progress on the supporting mechanisms that will make increased technological progress and effectiveness possible, economic and useful
- A new effort is recommended for international collaboration that emphasises the European contribution to globally relevant solutions for aviation
- ACARE should develop engagement with policymakers and industrial leaders as an essential part of its understanding of the contributions from the technologies it supervises
- The importance of the long-term is re-emphasised

0.5 IMPLEMENTATION OF THE SRA

We are now half-way to 2020. Progress towards the goals is being assessed in a number of initiatives (primarily, the Commission-supported AGAPE project). Although results are not yet available, it is clear that **there has been a vigorous programme of aeronautics and air transport research**, involving industry, public authorities, the European Commission, the nations, and research establishments and universities.

The SRA has been taken forward at European level through the research in the **European Framework research programmes**, consisting of:

- Collaborative research in aeronautics and Air Transport
- The Clean Sky Joint Technology Initiative
- The SESAR Joint Undertaking

In addition, the **national research programmes** of the European countries have contributed strongly.

The SRA goals have had a clear influence on current aeronautical research. The aeronautics and air transport vision and the follow-up activity have also been supporting the advancement of EU policies in transport, research and the environment. In transport, the EU policy objectives of creating a Single European Sky with a unified traffic management system across the whole of Europe is aligned with the air transport vision and has been advanced through SESAR. Similarly, the SRA has been supporting the development of technologies for airport infrastructure and for a unified safety agency across Europe. ACARE also contributes to ensuring a strong European voice in setting the global noise and emissions standards through the International Civil Aviation Organisation (ICAO). The activity on emissions reduction supports both transport and environment policy objectives and has contributed to cleaner, more efficient air transport, with a further significant contribution to combating the effect of aviation on climate change. The aeronautics and air transport research has also been fully supporting the development of the European Research Agenda with a cohesive approach across the European countries now much more evident than in the past. The aeronautics vision of achieving global leadership in aeronautics has pursued the Lisbon agenda of developing a competitive and dynamic economy.

0.5.1. EU COLLABORATIVE RESEARCH

The central objective of Transport research under the EC's Seventh Framework Programme (FP7) is to develop safer, "greener" and "smarter" **pan-European transport systems that will benefit all citizens, respect the environment, and increase the competitiveness of European** industry. The EU Member States have earmarked a total of €4.1 billion for funding the transport theme over the duration of Framework 7. In view of the different structure and focus of the various sectors, the theme is divided into three sub-themes:

- Aeronautics and Air Transport
- Sustainable surface transport
- Support for Galileo

The work-programme for the "calls" in Aeronautics and Air Transport takes the structure of its activities directly from the High-Level Target Concepts in the ACARE SRA2.

The work programme recognises three main levels of research, detailed below, to reflect the level of readiness of the developed technologies with respect to the final application. These levels cover the full range of research and technology development - from basic research to large-scale technologies integration, and validation activities in support of research as well as policy-related activities (in particular, in the area of airport capacity):

Level 1
This comprises the research and technology development activities that span basic research to the validation of concepts at component or sub-system level in the appropriate environment through analytical and/or experimental means. The objective of these upstream research activities is to improve the technology base with proven concepts and technologies which could eventually be integrated and validated at a higher system level.

Level 2
This comprises the research and technology development activities up to higher technological readiness, centred on the multidisciplinary integration and validation of technologies and operations at system level in the appropriate environment (large-scale flight and/or ground test beds and/or simulators). The objective of these focused downstream research activities is to produce proven multidisciplinary solutions that work reliably in integration at the scale of a system.

Level 3
This comprises the research and technology development activities up to the highest technological readiness, focusing on the combination of systems and the final proof in the appropriate operational environment of the comprised technologies in fully integrated system of systems.

Levels 1 & 2 are taken forward in the calls, Level 3 activities of full-system technology demonstration will be undertaken in large-scale public-private partnerships, especially established for this purpose in specific areas: the 'Clean Sky' Joint Technology Initiative and Single European Sky Air Traffic Management Research (SESAR).

0.5.2. CLEAN SKY

Clean Sky is a Joint Technology Initiative (JTI) that will **demonstrate breakthrough technologies to significantly reduce the impact of air transport on the environment**, including the validation of technologies at a high level of readiness. This public-private partnership will speed up technological breakthrough developments and shorten the time to market for new solutions tested on Full Scale Demonstrators. The Clean Sky JTI will be one of the largest European research projects ever, with a budget estimated at €1.6 billion, equally shared between the European Commission and industry, over the period 2008-2013.

Clean Sky is expected to lead the earlier introduction of new, radically greener Air Transport products that will:

- accelerate the delivery of technologies to radically improve the environmental impact of air transport;
- increase the competitiveness of European industry, thus contributing to the Lisbon Strategy objectives;
- encourage the aviation world to make greener products.

0.5.3. SESAR

The Single European Sky ATM Research Programme (SESAR) is the European air traffic control infrastructure modernisation programme. SESAR aims to **develop a new-generation air traffic management system** capable of ensuring the safety and fluidity of international air transport over the next 30 years, while taking forward the Single European Sky. This is set against a background of the liberalisation of international aviation markets under Open Skies agreements. SESAR involves the aviation actors (civil and military, legislators, industry, operators, and users - ground and airborne) in order to define, commit to, and implement a pan-European programme, and to support the Single European Sky legislation. SESAR is a Joint Undertaking involving €2.1 billion funding from the industry, the European Commission and EUROCONTROL.

The objectives of SESAR are to eliminate the fragmented approach to ATM, transform the European ATM system, synchronise the plans and actions of the various partners, and federate resources. SESAR has three major phases:

- **Definition Phase (2004-2008):** the first phase of SESAR has delivered an ATM Master Plan defining the content, the development and deployment plans of the next generation of ATM systems
- **Development Phase (2008-2013):** will produce the required new generation of technological systems and components as defined in the Definition Phase
- **Deployment Phase (2014-2020):** seeks to build the new infrastructure on an international scale, both in Europe and in partner countries

0.5.4. NATIONAL PROGRAMMES

Many of the actions expressed in the SRA are encouraged among the nations as well as the other EU stakeholders. Nations with aeronautics and air transport industries have funding programmes to support research and technology. There are two elements of these programmes: to maintain national competitiveness and to work towards the achievement of the ACARE goals. **All programmes take the ACARE goals as their planning base** and fund work to give their companies the competitive edge to gain work shares on future platforms. The national and European programmes are fully complementary with national projects feeding into programmes at European level and *vice-versa*. This complementarity is mainly ensured through the industry's strategy and plans for coordinated technology acquisition. As the stakeholder body, ACARE - with national and European players - will continue to act as the disseminator, proposer and general promoter of the SRA as the standard point of reference for all aeronautically related research work across the aeronautics community. These actions for ACARE are almost self-evident by the nature of its role. This has resulted in a vigorous programme of technical work and research across Europe as funding has allowed.

The European Commission is funding an ERA-NET in the form of Air Transport Net (AirTN) to coordinate programmes and align "calls" across national boundaries. The vision is that the national programmes should be able to achieve more by working together than by working independently.

AirTN has been working towards stepping up cooperation and coordination of research activities carried out at national level through the networking of the relevant national government officials in aeronautics research and the mutual opening of funding programmes. The second phase of AirTN, beginning in 2009, will enable national systems to take on tasks collectively that they would not have been able to tackle independently.

0.6 CONCLUSION

Overall, aeronautics and air transport have offered revolutionary benefits to society and will continue to do so in the future. In addition, the manufacturing industry is an economic asset to Europe and is a close second to the USA in competitiveness. There is a clear, long-term vision. **ACARE has produced goals and objectives to achieve the vision through the Strategic Research Agenda**. ACARE is running, updating and promoting how this is taken forward. ACARE is also aligned with and advancing EU policies in transport, the environment and research. The implementation across Europe shows the strong influence of the ACARE Strategic Research Agenda, particularly in the EU Framework aeronautics work programme, but also in many national programmes and in Joint Undertakings in Europe, such as SESAR and Clean Sky. A full range of activity across fundamental research, applied research and technology demonstration is in place. ACARE has shown the strength of working together across the whole community of industry, research establishments, universities, regulatory authorities, governments and the European Commission. This effort needs to be maintained to ensure an even more successful future for aeronautics and air transport in Europe.

Overall funding is being made available at both national and European levels for research and technology in Aeronautics and Air Transport. Aeronautics is pursuing the EU Lisbon strategy for growth and jobs by securing a prosperous, fair and environmentally sustainable future for Europe. The industry can ensure that European economies are well positioned to take advantage of the opportunities offered by globalisation. Some work can be carried out in collaboration with global organisations outside of Europe.

The evolution of the Air Traffic System towards the Single European Sky is being carried forward almost entirely at European level with funding from the European Commission, EUROCONTROL and the industry. The European funding for research and technology in this sector is recognition of the need for more advanced technology demonstration in the Clean Sky Joint Undertaking (Level 3), but this has resulted in less annual funding being available for Level 1 and Level 2 research in Framework 7 than previously in Framework 6.

In general, the national programmes in aeronautics have been larger on an accumulated basis than the funding from the European Commission. This is a consequence of national funding increases in recent years in the major aeronautics countries, where there is acknowledgement of the sizeable future market opportunities. The aeronautics and air transport effort in the USA remains more heavily subsidised through NASA, FAA and other programmes than the corresponding activity in Europe.

CHAPTER 1: SOCIETY

Society by 2050 will be rather different from today. The needs, purpose and characteristics of aeronautics in the future will depend on the evolution of world societies that demand the air travel service, as well as the technical achievements supplied by the aeronautics and air transport industries.

Based on recent research on socio-economy and demand in future air transport, this chapter highlights a number of social factors determining mobility and air transport by 2050 with a deductive approach rather than a sociological analysis of the link between society and air transport.

1.1. SOCIETY IN 2030+

The world society of the future may be unrecognisable, but the globe's dominant themes and characteristics are to some extent predictable - or can be imagined based on educated guesses. In respect of the development of world society in the 21st century, demographic data is available from reliable sources (OECD, UN statistics); and world views or projections for the horizon 2050 and beyond have been published by writers and thinkers such as Jacques Attali, Joël de Rosnay, Friedman, *et al*.

In Europe, the EC has initiated a reflection on the Future of Transport 2050 - leading to the EC Communication dated 17 June 2009: "A sustainable future for transport: Towards an integrated, technology-led and user-friendly system". The associated study report summarises how the European economy and society is likely to look by 2050.

- **Living in a global world**: Europe will be part of a more global world, where economic differences with Asia have somewhat decreased. The whole world economy will be more integrated. Europe could have a competitive edge in complex services and research-based industries.
- **Ageing society:** society will be much older than today, especially in Europe. This might well imply many more funds (public and private) being reserved for pensions and health care. Retaining this group as a customer base for aviation is a challenge to be addressed in its own right.
- **Changing climate:** Europe will witness a change in its climate by mid-century at the latest, even if environment policies are put in place. This will influence industries like tourism, large-scale energy production, agriculture and fisheries. Public opinion towards more emissions-related regulation will also surely be affected.
- **Concentration of human activities in dense areas:** this implies substantial congestion problems and capacity shortages and is one of the major challenges for the whole transport system. It means new transport solutions for urban transportation and also for short- and long-haul transportation.
- **Energy supply and production:** the costs for energy will surely increase with the price of resources and emissions charges. This shift in relative prices will probably be one of the main design drivers for future transport vehicles.
- **Technological breakthroughs:** last year's high oil price is not an anomaly. Together with emissions charges, this will trigger tremendous research and development efforts in the field of alternative forms of energy and vehicle technologies. The most important changes will probably not be seen in aviation, but in the automotive sector (e.g., large-scale shift to electrical energy), which would nevertheless have large repercussions for the aviation industry (e.g. through energy/oil supply).

1.1.1. DEMOGRAPHY

- **Continuing growth**

The world population will experience continuing growth. **By 2050, the world population is expected to reach 9 to 10 billion people.** This growth will mostly take place in developing and emerging countries.

The **European population** is expected to remain fairly stable at around 500 million over the coming 50 years, **but will become much older**. The median age will rise from 40.4 years in 2008 to 47.9 years in 2060 [Ref.3].

- **Ageing population**

Across the face of the planet, people will grow older. From below 30 years in 1950, the median age will exceed 40 years by 2100 in nearly all countries. The biggest population group will be the over-50 year olds. With a life expectancy close to 100 in some countries, there will be an increase in (public) heath care funding and pensions. **Even though a substantial part of the older population will be able to cater for their own needs, there will probably be a strain on the economy to subsidise the health system to care for the elderly (80+) among the population.**

In developed economies, people of 80+ could be more autonomous. Greater integration of social security schemes, specialisation in health services and greater knowledge of foreign languages could induce retired people to migrate or spend a large part of their lives outside their home country. Some old people might look for higher purchasing power for their pensions by living in less well-off countries or travelling there for medical assistance.

- **Growing wealth in developing economies**

According to worldwide statistics, a “middle class” will emerge in the developing countries, although this will differ from the middle class in developed countries. In Brazil, Russia, India, and China - all ancient and powerful continent-wide countries with a huge internal market and a history of success - people will want progress in terms of access to technology and mobility. If they can afford travelling, they will do so.

The number and purchasing power of these new potential consumers will depend on the repartition of wealth in the different countries. Ultra-liberal economies are known to create a population with more of the rich and more of the poor, reducing the number and wealth of the “middle class”; other models favour more evenly shared wealth. Therefore, the proportion of the population that will be able to afford air travel may differ from one country to another, but with growing economies and populations there will still be a **growing demand from developing economies in the longer term**.

- **Urbanisation**

By 2025, two-thirds of the population will live in cities. In 2007, living in a city meant living intramuros, but by 2025 this will mean living 40 km away from “downtown”. Towns will become mega cities (with over 10 million inhabitants).

By 2030, China alone is expected to have over 400 million people living in cities of more than one million inhabitants, and 80% of the city distances will be below 1000 nm (approx.1800 km). **On the intercity links, this is a favourable distance for air transport.** On a global scale, the number of mega cities will increase from three in 1975 (Tokyo, Mexico City and New York) to 26 by 2025.

A driver for travelling needs in the years to come will be people looking to **escape the mega cities**, seeking silence and isolation from “city hype” in favour of countryside vacations.

1.1.2. RESOURCES

- **Energy**

According to various forecasts the average estimate of the production peak for crude oil will occur around 2030 and the **cost of oil will continue to increase** [Ref. 4]. Increases in fossil fuel prices could further stimulate research into renewable energy technologies and enable the wider spread of alternative fuels.

Whether or not renewable energy sources will be available by 2030 is, at this stage, difficult to predict. “Drop-in” fuels (made from coal, coal tar, or biomass) that have similar technical characteristics to current aviation fuels (ignition, energy density, freeze point) are easier to adopt as these would not necessitate the whole re-engineering of current aircraft. Alternative fuels (liquid hydrogen, liquid methane, nuclear power, etc.) would call for “revolutionary” aircraft power systems [Ref. 3] (see Chapter 3).

D**ependency on fuel availability** will continue to be a risk for air transport, especially if energy sources are held in a few hands.

- **Technology**

Advances in information and communication technologies could lead to a more dematerialised economy, where the need for physical movement of people and goods is reduced by the expansion of e-commerce and tele-working. [Ref. 5]

An important factor is the **appeal of technology in the developing and emerging economies** which will be driving the demand for transport.

Technology has become part of our everyday lives and this trend will continue with the introduction of nanotechnology. **Nanotechnology has the potential to create many new materials and devices with wide-ranging applications in the fields of transport**, medicine, electronics and energy production. The present reluctance to develop nanotechnology will be overcome in the years to come as developed applications become part of our environment. There are currently over 800 references in the on-line inventory of nanotechnology-based consumer products [Ref.6]. Acceptability is bound to follow once regulation is applied (as was the case, for example, with the in-vitro fertilisation process 30 years ago). Innovators and early adopters endorse new technology and thus encourage the majority to join them.

- **Environment**

The public is clearly becoming less tolerant of pollution (noise, emissions, and visual ”pollution” such as contrails). There is also currently a shared awareness on climate change. Global climate change has caught the attention of policymakers and the general public (see Chapter 3). By **2050 the earth’s climate will have changed and the consequences will be perceivable**. Environmental concerns will be part of “business as usual”. Global agreements for environmental regulation will be necessary to avoid unfair competition between regional economies.

Another environmental concern at the 2050 horizon is the **limited availability of fresh water resources in certain parts of the world** that could lead, some commentators speculate, to “water wars”. In 2025, water reserves will be three times lower per individual than in 1950 and water demand will increase by 62% [Ref.7]

1.1.3. GLOBAL DEVELOPMENT

- **Geopolitics**

On the geo-political scene, various governance and regulation models will emerge depending on the availability of resources and the impact of regulation in the years to come. **The rise of Brazil, Russia, India, and China is largely expected, and will lead to a multipolar world where the influence of the USA will decrease**.

An ageing society could be more peaceful, and this could reduce the probability of national and international conflicts.

According to Jacques Attali, the world could experience a period of "hyperempire" following the fall of the USA "empire". The entire planet would work according to an ultra-liberal economy. A period of "hyperconflict" would follow with the resurgence of national entities and the crystallisation of conflicts around traditional borders of ethnicity, religion, resource availability, etc. Should the world survive, then "hyperdemocracy" - based on solidarity networks, participative democracy, NGOs, micro-credits and collective intelligence - could emerge.

- **Global economy and trade**

The current financial crisis could continue to impact on the global economy in a fundamental way, undermining and delaying economic growth by a number of years (see Chapter 2). In the long term, however, the **global economic trend is still growth-leading-to-growth in transport demand.**

The areas **with outstanding growth are Asia (especially China), Russia and Latin America**. These are emerging economies that will want access to the same travelling behaviour as developed countries. This may lead to a significant growth in demand unless environmental considerations constrain this growth.

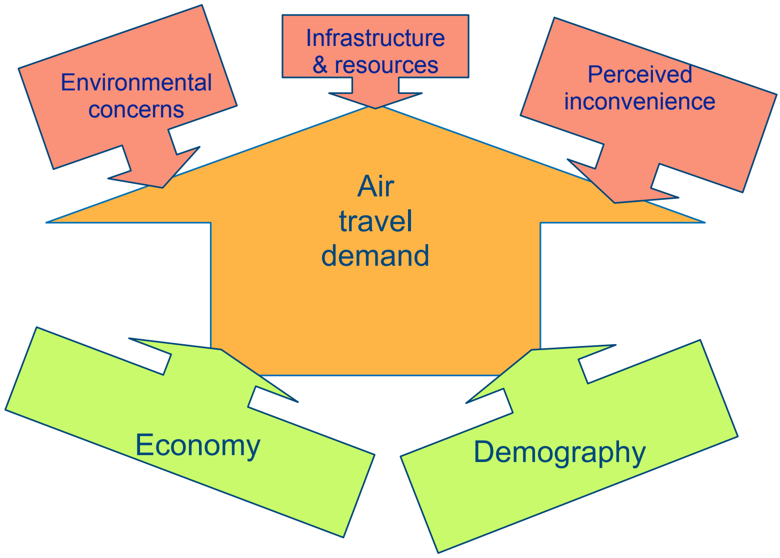
European regional integration is likely to increase and produce stronger links with both Mediterranean and Eastern European countries. **Russia and Turkey could emerge as the two main "poles" of trade flows in relation to the EU** [Ref.5].

North Africa has the potential to develop as an important trade partner with the EU. The current population of North Africa is around 141 million and is expected to grow to 236 million by 2050 [Ref.5].

Investment by Chinese and Indian companies in Africa is not only modernising industries but also increasing the purchasing power of middle-class Africans, and this may over time lead to Africa catching up and becoming a more significant trading partner with Europe [Ref.5].

1.2. AIR TRAVEL TOWARDS 2050

The growth of demand for transport in the world will be sustained by demographic growth. **The main drivers of mobility are demography and the economy**. All other factors (environmental awareness, fear of travel, etc.) seem marginal.



Passenger travel by any transport mode, and in particular by air, will increase as a consequence of globalisation - tourism, regional integration and migration - which will increase labour and business-related mobility, and associated social mobility (visiting relatives and friends). Moreover, rising incomes, ageing populations and lower transport costs would increase leisure travel [Ref.5].

Although air travel will grow worldwide, the following discussion will focus on air travel in developed economies and, specifically, in Europe (unless otherwise specified) as future demand in other regions is less well understood.

- **Connecting cities, markets and people**

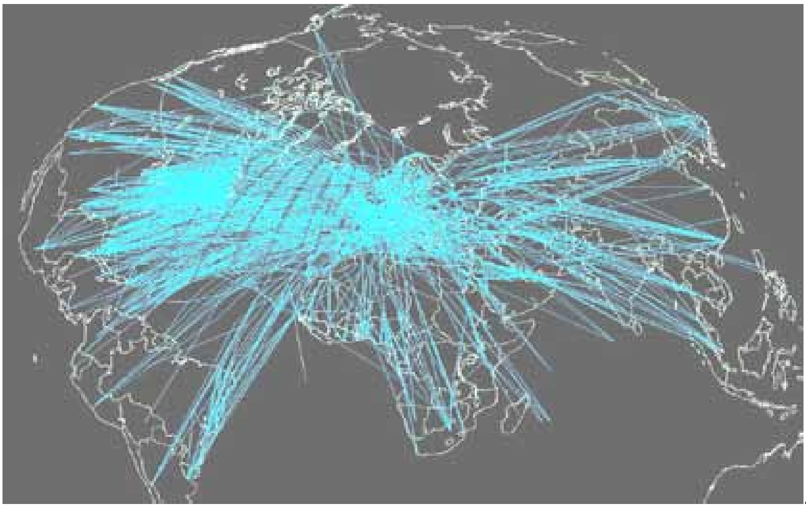
In a highly urbanised world of large megapoles, transport will be essential to connect large cities together.

In the future, there will be a very strong growth in the Asia-Pacific region, with air traffic likely to exceed the doubling observed every 20 years in the West.

Market integration on a continental scale increases demand for long-distance transport. [Ref.5]. For example, enlargement of the EU has contributed to expanding transport infrastructures and activities.

Air transport is the most efficient mode of transport when comparing speed and fuel consumption [Ref.8].

Over long distances, maritime and air transport are the main transport means, and **air transport has no real competitor** for speed (see illustration showing the long-distance worldwide connection network provided by air transport).



Source: EUROCONTROL

For short- and medium-haul distances, air transport can be in competition with other transport modes, and in particular with rail on certain city pairs; for example, in the core of Europe, where distances between capitals are short and high speed trains allow competitive travel times. However, European integration requires efficient accessibility for remote regions (the three maps at the end of this chapter compare accessibility provided by rail, road and air transport to remote European regions). In the future, **policy orientation in Europe fosters co-modality to move from modal competition towards partnership between air and rail for best usage of the common resources for the citizen.**

The situation is quite different in regions where distances between megapoles exceed 1000 km. In China or India, for example, **big cities about 1800 km (approx.1000 nm) apart will evolve into megapoles that will need intercity connectivity**. In certain parts of the world, the cost of railway construction and less competitive travel times will favour the development of air transport.

Air transport growth is a strong model, despite important short-term fluctuations.

- **Economic wealth and jobs**

Air transport is an important contributor to economic growth everywhere in the world. In Europe, the economic impact of air transport - direct, indirect and induced - contributed 2.6% of European GDP in 2000, with a **potential contribution of up to 4.1% by 2020** according to the ACARE Economic Impact report [Ref.9]. Studying the catalytic economic effect, which measures the dynamic impact of air transport on business investment and the underlying productivity of the European economy, growth in air transport is forecast to lead to **further long-term GDP growth of 1.8% by 2025** [Ref.10].

According to the same studies, aeronautics and air transport represented 1.9% of the jobs in Europe in 2000, which is expected to grow by up to **3.8 million jobs in 2020**.

- **Prestige of the aeronautics industry and skills**

Aeronautics has always been inspirational and has attracted engineers and technicians with the creativity and innovation needed for technological progress. How, though, will aeronautics continue to **attract a young and creative workforce for the aviation of tomorrow**?

In developed economies, society has a **generally positive view of the prestige of the aeronautics** industry and products as representing a demonstrable achievement of humankind's progress. Certain well-known aircraft are seen by most of the general public as pinnacles of engineering achievement serving the needs of society (mobility), even if this same achievement is sometimes seen as reflecting “all that is wrong” with engineering now, with respect to the environment.

People recognise **aerospace as one of the major drivers of the high-skill levels** in society and the significant spill-over/spin-off benefits that this gives to other products and services outside aeronautics. Aerospace provides a rich source of academic problem areas and challenges as well as a good exploitation route for scientific ideas and advances in universities.

The world-class standing of a few aerospace companies (Airbus, Rolls-Royce, Thales, Safran, etc.) is something in which people take pride, giving positive economic benefits in their countries, a healthy balance of payments surplus, and skilled employment.

1.2.1. TRAVELLING EXPECTATIONS BY 2050

The **willingness to travel is an outcome of people’s curiosity**, which some refer to as “the hunter instinct of man”, and others as “*L’homme nomade*” [Ref.11]. The average time spent travelling has not changed over the ages. Humans simply travel farther as a result of technological developments.

The appeal of travel is usually linked to the **level of education** of the individual, which is structural, and to **wealth**. Education turns people’s interest towards the outside world. If the world's middle class can afford to travel, they will do so.

Travellers’ expectations in emerging economies need to be better understood, but most likely these are similar to those in developed countries.

In Europe and developed economies, travelling expectations will be affected by the development of Information and Communication Technologies (ICT).

The **world by 2050 will be fully interconnected** through virtual technologies with the development of ICT. Through evolution in Information Technology and the extension of the web and TV connections worldwide, the knowledge of the earth will have increased. The extent of uniformisation in the world may mean that discovery **travel will have decreasing appeal and that virtual discovery will be more attractive in the future. The virtual world will come to seem like a new continent to explore**, both for leisure and professional business.

More likely, this increased world connectivity will create more opportunities for discovery, meeting and cooperation, in both the virtual and real worlds. Virtual and physical experiences do not seem to be competing today. Rather, people will expect to stay connected while travelling, with travel more integrated into normal life, in particular for professional travel.

In Europe, expectations of future travellers [Ref.7] include:

- personalised travel, with individual tailoring of the travelling experience;
- escape from the fast pace of society;
- a more friendly and entertaining experience.

1.2.2. PROFESSIONAL AIR MOBILITY

The **need to travel for work or market-conquest purposes is structural - therefore generally stable**.

In Europe, second to tourism and leading to migration flows, professional mobility by air brings wealth, growth and business opportunities. Professional mobility is supported by the EU as a channel for developing the future European economic model.

Emerging economies attract business activities, a catalyst for more transport - until levels of wealth begin to reach those in developed nations. In the future, very strong growth, perhaps exceeding the doubling of air traffic every 20 years as observed in the West, is likely to occur in Asia (especially China), Russia, and Latin America (especially Brazil).

- **Impact of ICT development**

The development and accessibility of communications technology in advanced economies by 2030+ creates less need for physical meetings at working level, and air travel will be more exclusively used by senior management and high-level sales executives.

However, a contrary trend is in play: ICT development will create more business opportunities and allow more cooperative work. ICT will facilitate increasing markets, outsourcing, and even competition for jobs in remote locations [Ref.13], boosting the need for mobility.

Professional travel time will increasingly be part of working time, and the **transport infrastructures will need to allow for professional nomadism** [Ref.11].

- Travelling ability will become essential for a job.
- Teleconferencing and teleworking (living far from workplaces) will be easier.
- Travel will occupy more time and will become a “space” for living as well as meeting, working, buying and even leisure.
- People may opt for remote work locations to achieve an enhanced living environment while travelling several times per week to different work locations [Ref.1].

1.2.3. LEISURE AIR TRAVEL

Leisure travel is sensitive to the global socio-political and economic context, since there is a choice and cost for passengers.

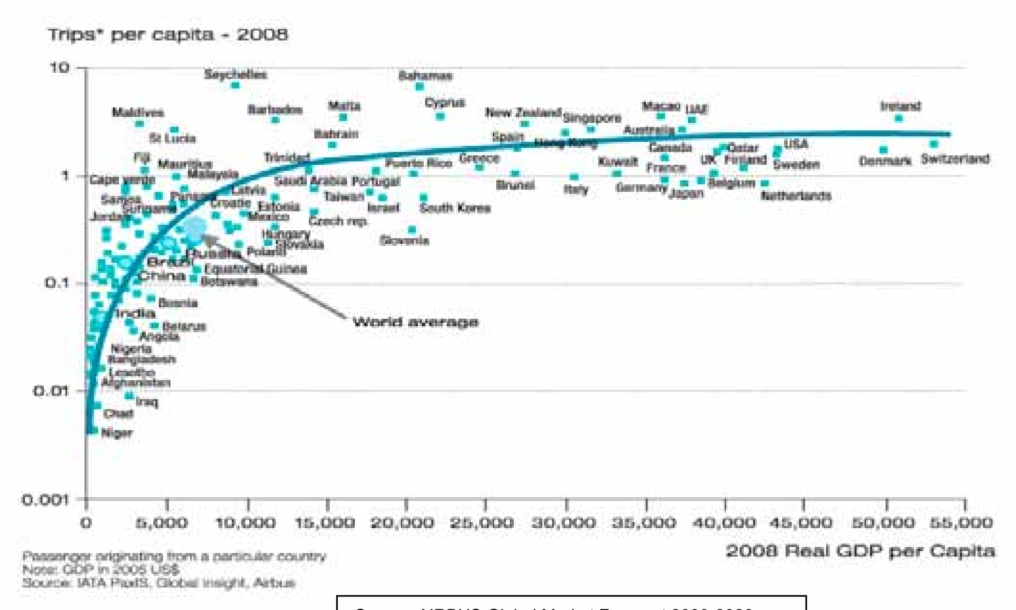
The development of leisure air travel worldwide is linked to economic growth.

In Europe, currently **69% of the total number of air trips made by Europeans are leisure trips** [Ref.5]. By 2025, should this ratio remain constant, this would amount to 2.6 billion passengers. Urbanisation will increase the need to escape from large cities. Studies show that there will be an increase in the level of air traffic demand for the purpose of visiting friends and relatives, for immigrants returning home for visits, and from retired people (55-70+) [Ref. 7].

- **Household disposable income**

Households in the EU spend about 13.5% of income on transport-related goods and services. About half of this is spent on the operation of personal transport equipment (e.g. fuel); the other half, on the purchase of personal transport equipment (e.g. a car), together with the purchase of transport services (e.g. bus, rail, air tickets) [Ref.5].

How this ratio of transport-related expenditure compares with the rest of the world is an important indicator. How will this evolve in the future geo-political and economic context? This determines the source of budget for leisure travel, and in particular by air.



Source: AIRBUS Global Market Forecast 2009-2028

The middle class has been the driver of the continuous growth of air transport after its liberalisation. Emergence of low fares has not so much allowed those with low incomes to travel than helped middle-income people to fly more often. Until recently, most travellers belonged to the middle class or were senior people in developed economies. But the worldwide middle class is not homogeneous, and is - in reality - getting poorer. If this trend continues, **air transport might become too expensive for both the lower and the middle class**. At the same time, **more and more wealthy people will be able to afford personal aircraft**.

- **Ageing travellers**

Age influences travel patterns. Above a certain age, people tend to travel less frequently, but improved health conditions also mean that older people can nowadays enjoy travelling for longer periods than previous generations. In developed economies, for example, the **"baby boom" generation about to retire has participated in the development of mass tourism and is not expected to lose this habit until old age**. They are wealthy and healthy - and have the desire to travel.

Some older people looking for higher purchasing power might decide to live in less well-off countries or travel there for medical assistance, which might give rise to long distance travelling. Travel **patterns and specific needs and facilities for the comfort of older people** will depend on their lifestyle and culture. For example, in certain regions, parents would never travel alone, limiting the need for specific comfort elements.

Finally, older people's travel behaviour will ultimately be influenced by their disposable income. [Ref.5].

1.2.4. AIR FREIGHT

Maritime and air transport are both experiencing **growing markets for freight worldwide**. Both raise environmental issues that have to be addressed. Yet air transport allows just-in-time delivery. Freight is therefore growing in air transport. Lufthansa has built a huge freight hub in Central Asia, linking South East Asia, South Asia and Europe. Cargo flights have huge potential for an increase in traffic, which will add stress to the system. Freight has not yet been sufficiently studied. Freight still represents a small share of European traffic compared with passenger air transport [Ref.1].

1.2.5. SAFETY

The safety of air travel is an absolute pre-requisite for the whole aeronautics and air transport industry. Air transport has a record of impressive safety achievements over the years. **Even with constant air traffic growth, the number of accidents has not risen significantly**. EASA, the European Aviation Safety Agency, used ICAO-published accidents statistics to show that the safety of aviation has consistently improved from 1945 onwards: the global rate of passenger fatalities per 100 million miles flown has dropped by a factor of 500 in 50 years, reaching 0.010 in 2008 [Ref. 14]. Aviation is recognised as one of the safest modes of transport.

In view of the high media exposure and public attention focused on a small number of dramatic accidents, such recognition of the actual safety record of aviation must be maintained. **Society is increasingly reluctant to accept failures in the Air Transport System**, which is considered more and more as a mature industry [Ref. 23], which exerts more pressure on safety considerations.

Safety levels must be maintained despite the increase in air traffic. This will require strong and continuous efforts, resources and innovation to face safety-related challenges. For system design, development, certification and regulation, and as systems become more complex, including organisational and institutional matters, safety levels must be maintained in all economic climates.

1.2.6. SECURITY

In view of the international security consequences following the attacks on the USA in September 2001, and with the risk of groups of terrorists that can strike anywhere, alongside ongoing hostilities in Afghanistan and Iraq, there have been significant changes in the context in which aviation operates.

In a few years, security threats have increased to the point where they are becoming **an issue for passenger convenience**. Security is becoming more of a constraint, impacting on - in particular - the cost efficiency (**security costs can amount up to 25% of airport operating costs**) and time efficiency of air travel (for example, the time from home/office to destination is rising, not falling, and the lack of technology is not the only cause). **The ACARE goal of 15 minutes' transit time in the airport for short-haul flights is unachievable in today's context**, and indeed in practice the transit experience is becoming worse [Ref.4].

An understanding of how security threats and responses might evolve in the future is important in respect of:

- consequences for air transport of potential attacks and of security measures;
- security measures/projects/technologies to be developed;
- protection of the citizen, the passenger (data privacy, etc.).

New and evolving threats and measures will have to be taken into account: energy security and security of supply (with aviation as a part of the total energy system and its economy), terrorism, critical infrastructures protection, cyberspace, information flows and communication security - the **responsibility being a transversal key issue** for all of the related measures to be implemented.

The European security market exists, but is very fragmented, and the needs versus the market have to be consistent. There are some key features of the security market and equipments to be taken into account in terms of:

- policy issues related to sovereignty, international competition/competitiveness;
- norms and regulations (including intellectual property rights, classified information, standardisation, etc.);
- sensitivity of security technologies, ethical issues, data privacy, implementation measures;
- new actors in security: industry (ICT global providers), research centres, private security, and so on;
- funding (including the level of funding, potentially up to 75% in FP7), cost, affordability.

1.3. SOCIETY AND AIR TRANSPORT

Aviation brings accessibility to remote regions, speed and long-distance mobility to people, increasing both the globalisation of business and the touristic reach for everyone in terms of leisure. Aviation represents the progress of human society.

However, if low-cost transport is driving mobility, increased mobility triggers opposition to **excessive travelling trends** and the necessity to give meaning to travel.

Society is shaped by its values and their relative strength. Change in social factors results from the evolution of those values (for example, the unconscious values underlying mobility in sedentary societies).

A period of a few decades may seem rather short with regard to social evolution, but actually social values evolve by small increments year by year, which has, for example, been observable with the environmental awareness and behaviour evolution at the beginning of 21st century in developed economies.

An understanding of the **influence of growing environmental awareness, among other factors, on the evolution of air transport is important**. Sociology can provide insights into how social values, and in particular how perception, knowledge and/or beliefs can lead - but not automatically - to **changes in behaviour**. Behavioural economics shows how small changes in regulation, for example, can lead to important behavioural changes.

1.3.1. ENVIRONMENTAL AWARENESS

There is an ecological price to air mobility. Aviation uses a non-renewable energy; produces gaseous emissions at high altitude, and around airports, causes noise and air pollution, and even visual pollution [Ref.4], which affects neighbouring communities. These effects are likely to increase as traffic grows significantly in future years [Ref.15]. This could strengthen opposition to current travelling trends.

- **Noise and other emissions at airports**

Around the world, the population's environmental well-being and quality of life appears to be a central issue in debates on air traffic and airports. The **environmental capacity of airports is a major constraint on their development** [Ref. 16]. Major airports and their surrounding areas worldwide are subject to ever tighter regulations.

Considerable technical, technological and operational advances have been made. However, "Air mobility increases faster than industry today produces and introduces technological and operational advancements to reduce emissions at source" [Ref.17]. Local noise-acceptability levels seem to be falling over time [Ref.4].

There is a growing demand for **more information and greater transparency**: more studies and assessments of pollution and noise annoyance, the impact of noise and atmospheric pollution on health, property effects, social and spatial polarisation, and land-usage planning constraints. The information provided by the airport is used by the local communities, local governments and environmental services to **shape the sustainable development of airports and their surrounding areas**. Major airports will increasingly invest time and effort into more precise, broad-based regular information and data, such as:

- a profusion of information on airport websites;
- more substantial assessments and performance indicators from airport authorities, airlines and construction companies;
- estimations of impacts increasingly provided during airport expansion projects and the rerouting of flight paths;
- an increasing number of observation initiatives, measures, and evaluations by local communities.

Growing residential dissent and ever greater volumes of information on the environmental effects of airports will lead to the development of more **shared and co-built indicators** [Ref.18]. Originally, indicators were based on technical knowledge imported from the scientific field. Over time, these have slowly become products of the social and political context.

From their original status as passive markers of the heritage of centralised policies, these will in the future become **active tracers of territorial negotiations**, including the territorialised environmental effects of air traffic and airport functions. Indicators will provide both an extensive knowledge basis for complex environmental effects and an opportunity for debate between multiple stakeholders.

- **Global emissions policies**

In developed economies, increasing environmental awareness triggers debates about climate change and the contribution of aviation to greenhouse gases and in particular CO_2 emissions, and the means to limit emissions (see Chapter 3): voluntary measures, taxes, trading, and regulations.

The political objective of protecting the environment will probably lead to **regulation limiting investment in increased capacity**. The sole effect of oil price increase will not be sufficient, so other regulations will become necessary (taxes, load factor, capacity cap at airports, etc.).

In Europe (and increasingly in North America), governments struggle with the **trade-off between sustainability and economic development**. Various interests are reconciled at local level (airports) through sustainable development charters. But national debate on airport expansion projects, for example, potentially carry political risks for governments, who sometimes prefer to wait for and then follow European initiatives on the subject [Ref.19].

If European politicians decide to curb transport to reduce emissions, the public reaction might be a trade-off in favour of cars or even trains against aircraft: "*Pour mes voyages je préfère prendre le train*" ["When it comes to travel, I prefer to take the train"] (Fondation Nicolas Hulot cited in [Ref.20]).

This would be supported by the **concept of quotas** such as the "Individual Carbon Footprint". People would have to choose between several ways of using their emission entitlements. This idea of a quota per inhabitant is probably the biggest danger for air transport.

Aviation experts question **society's capacity for accepting a responsible attitude toward "flying slower"**, with some changes to cruise altitude, with shorter travelling legs, or using propellers for short-to-medium range travel, to reduce fuel-burn and the formation of contrails. Which levers will raise acceptance: money, leaders' example, **"**punishment**"** of some sort, such as consuming one's own emissions entitlements faster?

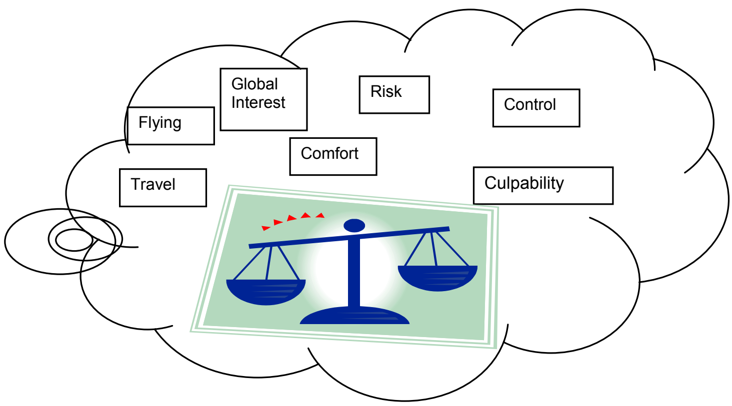
- **Aviation fuel**

Kerosene is a non-renewable energy source and aviation is in **competition with other transport modes** for the use of fuel. Fuel cost represents the most significant part of the operational costs of airlines. As a consequence, the survival of airlines depends on fuel price and fuel-burn.

Research into alternative fuels will probably affect other modes of transport long before air transport is impacted (see Chapter 3).

1.3.2. SOCIAL FACTORS

The future of air transport in Europe is partly determined by social factors such as the desire to travel and to fly, but also by notions of culpability, risk, comfort, need for control, and the importance of global interest. Some are in favour of air transport, others less so. The evolution of these social factors is likely to determine the evolution of the air transport utility for society.



Characteristics of the future world, such as technological progress and environmental science, cross over into social values to modify the future relations between European society and air transport.

- **Discovery and meeting others**

As already discussed in section 1.2.1, **human nature tends towards discovery and adventure**. Even in the face of risks, people have always travelled. As social creatures, human beings thrive on interacting with one another. This is a major motivation for discovery and for leisure, and a main driver for travel.

- **Desire to fly**

Fascination for flying has existed since antiquity; the Icarus myth is an illustration of this human dream. In the early days of aviation, flying was an adventure reserved for a few pioneers. Subsequently, flying became a symbol of high social status. The liberalisation of air transport at the end of 20th century has made flying accessible to a large proportion of the western population. Not everyone has yet flown, of course, but **most people in developed countries expect to fly at some time** in their lives; there remains an implication of status, success, discovery, and unique experience.

- **Value of time**

Travelling time corresponds to the time between leaving home and reaching the final destination. In general, past and present, there appears to be a constant amount of personal time devoted to transport of about around 1.1 hour per day. For this time allocation *versus* disposable income, **speed means power**. In the future, the value of time will continue to remain high. For air transport, real competition can only come from a faster mode of transport - which does not exist today. The high value of time also calls for a high-quality experience to make the time spent on travel worthwhile or useful in some way (for business or leisure).

- **Delegation of trust**

For passengers who access the Air Transport System in the 21st century, there is a delegation of trust to a number of entities: aircraft, airlines, pilots and controllers, safety and security systems. All of this means a **loss of control and of autonomy for passengers**, and therefore an **element of fear** is involved.

The **role of humans in the system** (e.g. pilots and controllers) may be to symbolically represent the “safety guaranty” of the delegated control. A fully automated Air Transport System may necessitate the promotion in people’s minds of a new mental picture of flying. In this regard, a study of automatic rail systems could provide insights into the conditions for success of automated systems.

- **Culpability**

Culpability is an important lever of modern societies resulting from the idealistic and sometimes contradictory character of hegemonic values; for example, between individualism and equity. Culpability may take different forms.

Today, travelling is perceived as “a right”. At the same time, some people feel guilty about flying. This may be because of the wealth associated with flying in comparison with the poverty of some far-away touristic destinations, or because of the environmental impact of flying. Some people depict air transport as an activity for the wealthy and question the need for speed, frequency, and long-distance transport. There is a **fight between the “right” to travel and the “sin” of travelling**.

There seems to be a discrepancy between what people say they will do (protect the environment, use more environmentally friendly means of transport) and the reality, where both transport by car and air is steadily increasing. People expect to do more and more travelling as their living standards rise [Ref.1]. This creates a **perception of hypocrisy** about environmental concerns, as little change in behaviour, practices and choices - all perceived as only “lip service” - can actually be noticed compared with the huge media coverage of the environment. The process by which people move from awareness to behavioural change - for example, the theory of Commitment[2] (indicating that behaviour modifies values and not the contrary) is an important social factor affecting future air transport.

[2] Commitment theory (Joule)

Political decisions must be made and measures imposed on people to reduce emissions with current technology. But **politics are likely to follow public opinion** rather than take a visionary stand. Environmental legislation may not pre-empt, but rather follow, public opinion, reflecting the equilibrium between culpability and other individualism.

- **Need for comfort**

Older people will probably travel much more by 2050 than at present. Scientific progress will help reduce health problems in most parts of the world.

This financially stable, ageing population will demand comfort and accessibility adapted to their needs. The ageing phenomenon will create enhanced comfort and security in public transport, and there will probably be a market for tailored transport services for the very old members (80+) of the population [Ref.5]. There will be demands for suitable handling of luggage and easier inter-modality for door-to-door travel (see also section 1.1.1.).

The question arises: would **easier access to air transport for passengers** curb-to-curb (ticket, security controls, and airport) **act as a driver of demand for air transport**?
Today, **air travel is at its lowest price ever**. Competition between airlines has driven ticket prices down, which, in turn, fosters air-transport growth. Many within the industry feel that air ticket prices have reached their lowest level and will never be as low again [Ref.21].

Confronted with **the choice between service comfort and profitability**, air transport will have to make full use of innovative solutions for the customer. Customers' reference frames for prices for short-distance transport, increasingly considered as a "commodity", will continue to be "low-fare",. The image of luxury is likely to remain for long-haul flights only.

Will comfort become a strong enough social value to impose high prices again?

- **Tolerance of risk**

Aversion to risk drives many societies' developments: in politics, regulation, and - particularly in developed economies - jurisprudence. The risk of terrorism could even reinforce this aversion.

Transport is a source of security concern in general and particularly for air transport. **Lengthy security procedures have tainted the appeal of air travel**. This was seen after 9/11 with the restriction on carrying liquids [Ref.1]. More capable, less intrusive systems at the level of both deterrence and detection should be implemented based on existing technology [Ref.15]. Inconsistencies of security and check-in process performance which demand that passengers arrive earlier and earlier for their flights should be avoided [Ref.4].

Safety air travel is an absolute pre-requisite for air transport. Air transport is recognised as a very safe mode of transportation**. Even with constant traffic growth, the number of accidents has not risen significantly** (see section 1.2.5). However, society's increasing sensitivity to risk is putting more pressure on safety. Society will increasingly become less tolerant of risks and could increasingly criminalise the deficiencies of professionals.

The **growth of air traffic increases the perception of risk** in the public mind: risk of flying, risk of being attacked, risk of living around airports. Such perception varies with different factors, such as wealth, lifestyle, and also maturity of the economy: air traffic growth is more welcomed in developing economies than in more mature economies, where the perception of risk seems to progressively become stronger than the benefits to society.

The ways to address and manage the risks have to be adapted to an older and more risk-adverse public. Increased **"zero risk tolerance" will lead to more resources** devoted to safety and security [Ref.21].

- **Need for control**

People are not against technology and progress; but, rather, want inclusion in the decision process and control over consequences.

The need for control is an important social value. With the emergence of industrial risk [Ref.22], citizens increasingly sensitive to risks generated by industry pay greater attention to decisions affecting industry developments, regulation and impacts [Ref.23]. The increased awareness of pollution and externalities produced by technological progress in general and air transport in particular is indicative of this trend. **As a reaction to fear, people look for control of risks**.

In this regard, social reaction to air-transport expansion follows the evolution of two main values underlying society: individualism and materialism. Personal interest prevails over the common good and the situation is likely to remain similar for the years to come. No real evolution of such societal values is to be expected in the timeframe of a few decades (unless a new theocratic wave, for example, radically modifies the values of culpability and sacrifice - which is not expected) and the **'Not in My Back Yard'** syndrome will prevail.

At the same time, the extension of ICT is creating worldwide communities with instantaneous access to the same information. This access allows **knowledge, debate and the controversies about any technological externalities to spread everywhere**, even before a new technology has been demonstrated. ICT also gives access to an understanding of global problems, leading people to gain ownership on environmental issues, and feeding an increasing value of equity.

With such developments, the social context of future air transport expansion will be more demanding than in the past.

- **Importance of global versus local interests**

Future air transport characteristics depend on decisions made today at different levels and by different people.

A recent study [Ref.19] shows that air transport is low on the political agenda in Europe. Therefore, decisions on air transport are made in a **political "hollow core"**, meaning that stakeholders have only a partial perspective on air transport and nobody has an overall picture.

In such a hollow core, when conflicts appear between local and global interests, decisions can be made by local political decision-makers who have to report to their electors on local issues, contradicting on a wider scope the general interests of society.

For example, emissions such as CO_2 are local and global. These must be reduced because they are accumulating. Noise, on the contrary, is a local issue and does not accumulate.

The political system enables broad policy decisions on CO_2 emissions to tackle climate change. However, around airports, strong noise pollution lobbyists alter airline operations to the detriment of policies aimed at reducing emissions. Noise aggravates popular opposition to an extent that could even prevent future air transport growth. Better trade-offs between noise and CO_2 emissions should be made [Ref.1].

The conflict between local and global interests is founded on contradictory social values of individualism and culpability and makes an impossible choice. A trade-off has to be made between two notions, the respective weight of which can evolve with time. Air transport will have to **find the right balance to position itself** in this debate.

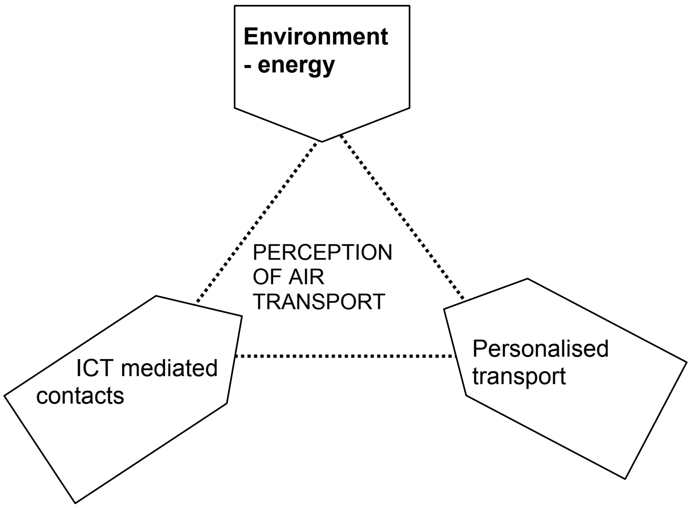
1.3.3. SOCIAL PERCEPTION OF AIR TRANSPORT

When speaking about social perception, there is a need to understand that people's perception depends on the position of the individual regarding the various socio-economic stimuli, for example, emanating from air transport and surrounding the individual.

The social aspect of air transport can therefore be seen as a **triangle of forces shaping the social perception of air transport**. The three main poles are:

- personalised transportation means;
- ICT mediated contacts;
- environment - energy.

The environment-energy pole appears to be the pole that controls the social perception of the air transport industry. This is because the aviation industry and air transport are **perceived as not embedded in "normal life"** - as a result of allocated times, spaces, and procedures.



The sector is identified as being an activity of "others", and so the consequences - including the environmental impacts - of the sector are allied (in the public mind) to an optional action, which is not an everyday activity for most people; therefore aviation is an easy target for criticism. For many people, it is more **comfortable to "finger-point" air transport** as the main cause of excessive CO_2 emissions than to look into private car emissions.

This is a **disadvantage for institutional trust**: everything is perceived as intentional, including disasters or environmental impacts, especially when vested economic interest is perceived as being at stake.

The "unfamiliarity" of aviation to the general public is the major aspect of the social perception of the industry.

1.3.4. "ANOTHER AVIATION" FOR SOCIETY TOWARDS 2050

When imagining the future of air transport, a promise of "more of the same" is not convincing enough.

Air freight is now associated with consumption. In the supermarket today, some people look at, say, tomatoes, to see if these have added to pollution by being transported from another continent. A major competitive advantage will belong to those actors within the industry who will be "ahead of the game" when it comes to applying a **breakthrough in environmental technology**: this will take a large part of the guilt out of air travel.

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People have seen that technological breakthrough is feasible in air transport.

- Low-fare air transport has brought significant change to passengers.
- Clean Sky shows that improvement for the environment is possible.

People now expect innovation, a new technological breakthrough: this needs to be cheap, **environmentally friendly, and presented as such** (as with other industries).

This would maintain the distance needed for the EU (and USA) industry to be highly operational in the internal markets that will emerge (competitive advantage).

The **only way to legitimate air transport in the long-run is through a clean approach**. Cleaning air transport is what aviation has to do for travellers not to feel guilty about flying. Also, if tourism becomes more localised, the perception of aviation and its impact on the environment will change.

- **Personalised and clean air transport**

An understanding of the perspective of the different categories of citizens is important for social projection. **Innovation, based on another understanding of society**, can define a vision of mobility based on the stratification of society in the future. Stratification follows patterns of use and consumption.

The marker of influence associated with personal/business air travel will not last forever; it will become a marker of mid- to low-status in the business world.

Business air transport is also what symbolically drives social demand. **Personalised air transport that is clean** - the key element is pollution; air before noise - could be a **driver for future aviation**. In a multipolar world, such a model could envisage the position of the air transport sector (particularly in the EU) within a world that has the means to offer itself air transportation with lower standards.

Potential policies aiming to regionalise leisure could create **specific niches for personalised air transport solutions**. The social image of future air transport could therefore be articulated around both big mass transport and light personal transport.

- **More rigorous communication on environmental knowledge**

Air transport is an easy target for the media and politicians, who look for an environmental villain. Aviation is the fastest-growing transport sector: if air traffic doubles in the next decades, emissions are perceived to be likely to double too, and this raises concerns. **Air transport suffers from a very bad image**, being seen as a luxury, and is plagued by doctrinaire attitudes.

The aeronautics industry considers that there is much excess in what is being told to the public. An informed debate - in society and within the industry - is elusive, since very diverse and often contradictory information circulates about the real impact of aviation on society and on the environment. **Statistics should be explained, with their actual meaning, adopting a holistic approach to measuring effects, both negative and positive**.

A major communication effort is required. An understanding is needed of the aspects of public perception of air transport and of the influence the media have in forming public opinion.

1.4. CONCLUSION

The social perception of air transport has been changing since 2000. The image of the industry has been tainted, triggering the need to look forward at future society needs and expectations with regard to aeronautics and air transport.

With increased **demography** and **urbanisation** in bigger cities, and more megapoles of more than 10 million people, society by 2050 will need more transport to connect cities, markets and people. The **climate** will be changing. Environmental concerns will be part of "business as usual". Global agreements for environmental regulation will be necessary to avoid unfair competition between regional economies. At the same time, society will have to satisfy the expectations of populations for a comparable level of services in remote areas.

Geopolitically, the world will become multipolar and various governance and regulation models will emerge, depending on the availability of resources and the impact of regulation. New and **evolving threats** and measures will have to be taken into account: energy security and security of supply, terrorism, critical infrastructure protection, cyberspace, information flows, and communication security. Global **wealth** will grow, even if not necessarily at an even rate, allowing more people into a world of the "middle class" with more education and more opportunities to fly.

Transport growth is driven by demography and economy. Discovery and meeting others is part of human nature and is fostered by education; **if people can afford to travel, they will**. Passenger travel will increase as a consequence of globalisation, tourism, regional integration and migration, which will increase labour and business-related mobility, and connected social mobility (to visit relatives and friends). Moreover, rising incomes, ageing, and lower transport costs will increase leisure travel.

In the future, people will look for more **personalised transport**. As virtual technologies develop, the world will become fully interconnected - with the **virtual world** as a new continent. People will become hyper-nomads. Transport will become a space for work, for buying, for leisure and meeting others. Some travel needs may disappear because of teleconferencing and virtual access to discovery and knowledge but, more likely, Information and Communication Technology (ICT) development will increase the opportunities for interaction and ultimately the growth in transport demand.

This continuing growth of demand will bring air transport increased challenges for coping with increasingly **massive transportation and congestion of infrastructure. Convenience for passengers, in particular with the security requirements, will be a challenge for the industry.**

Air transport will be **complementary to other transport modes** in regions where infrastructure exists, in particular in Europe where co-modality will allow an optimal sharing of scarce resources. **In less equipped regions and for long-distance journeys, there is no competitor for air transport when comparing speed and fuel consumption.**

In that context, the social perception of air transport is shaped by both the appeal for personalised transportation means, the possibilities brought by ICT-mediated contacts, and the environment-energy considerations. The **environment-energy axis appears to be the one which controls the social perception of the air transport industry**.

Although aeronautics and air transport, beyond providing efficient mobility and economic wealth, have always triggered fascination for technological achievements, pride in industry, and attraction into highly skilled employment, aviation also triggers opposition to excessive travel trends, crystallised around the **environmental impact of aviation and its fuel dependence**. **Such opposition, which benefits from the very diverse and contradictory information circulating about the real impact of aviation on the environment, is founded on social values,**

perceptions, knowledge and beliefs, the relative strength of which evolve, and that determine behaviours and regulations.

Future air transport will have to propose "another aviation" for society to overcome this situation: an innovative version, based on another understanding of society and mobility, taking into account the future stratification of society. Applying some of the technological breakthroughs in environmental technology will take a large part of the "guilt" out of air travel. Aviation **has to be cheap and clean, and needs to be presented as such**.

Air transport is a means for humans to meet with others, to exchange and to cooperate. A lot of ICT products have been a failure when there is no human contact in the exchange. Meeting other people is a strong driver for leisure.

Playing on that "connection" role would legitimate a cleaner air transport.

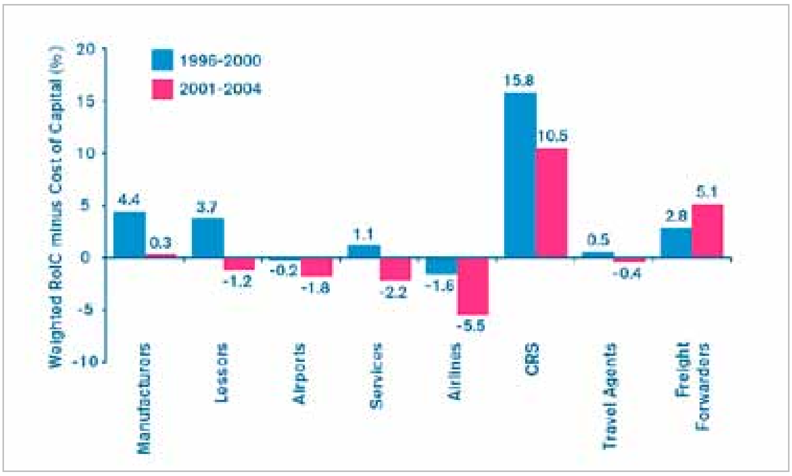
For as long as **human nature has an appetite for discovery and meeting others**, then travelling will continue. **Demography and economy drive air-transport growth**. Aeronautics and air transport research have to bring new possibilities (network-centric air transport, sub-orbital transport, cheap and clean personal air transport, etc.) to satisfy the travel expectations of society, while finding solutions for the environmental impact of aviation.

CHAPTER 2: ECONOMY

2.1. THE AIR TRANSPORT INDUSTRY - PLAYERS AND THEIR MARKETS

2.1.1. PLAYERS IN AIR TRANSPORT

When considering the future challenges for the air transport industry, there is a need to distinguish between the different players, their particularities, and their different and divergent interests. There are various companies involved in supplying the product that is "air travel": manufacturers, maintenance companies, lessors, airlines, airports, R&D institutions, travel agencies and reservation systems, air traffic management, caterers, and so on. Some of these players are under governmental control, while others operate on a more or less open market with different degrees of regulation. Within this supply chain, each player has a varying ability to generate profits. Airlines, especially, are confronted by the ongoing challenge to maintain profitability as operational conditions fluctuate; this is an issue for the whole industry, not just for the airlines, since financially sound airlines are clearly the customers for long-term aircraft development programmes.



Source: IATA (2006).

2.1.2. PARTICULARITIES OF THE DIFFERENT MARKETS AND STRATEGIC HORIZON

- **Airline industry**

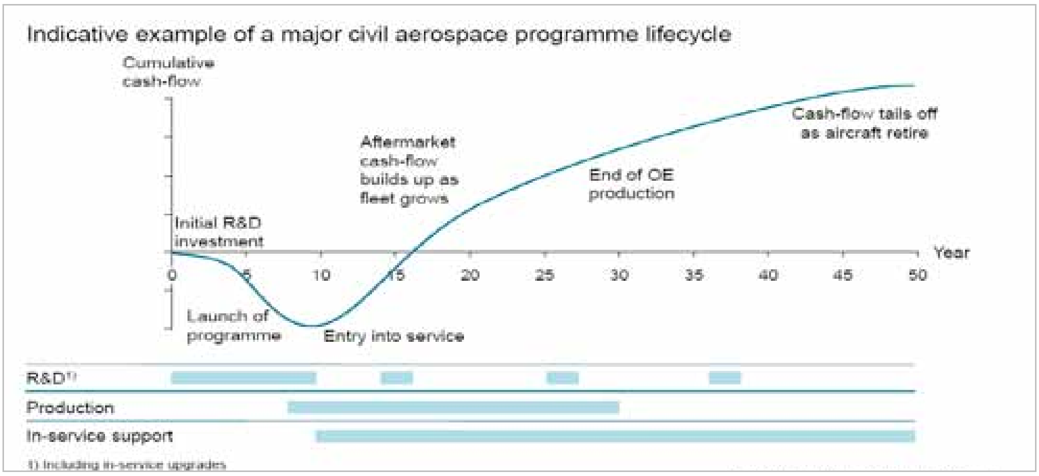
For a realistic understanding of the evolution and likely future development of the airline industry, an appreciation of its particularities is needed:

- **Very low barriers to entry.** There are two major factors that allow fairly easy entry into the airline market, which results in strong competition and high pressure on profit margins. First, there are little or no economies of scale, that is, there is no benefit-of-size for a company, with the result that even small companies with only a few aircraft can enter the market. Second, there is an ease-of-access to capital because of the exciting or glamorous reputation of the industry; and the mobile nature of *aircraft* as a capital investment (asset) - in contrast to an industrial plant or factory - means that aircraft can be relocated immediately to an application offering more profit.[3]

- **Very high barriers to exit by government restrictions and/or interventions,** implying that weak airlines do not necessarily exit the market. This leads to a sub-optimal allocation of capital and a tendency toward excess capacity (and low yields) in some markets.
- **Very fast-changing industry.** Airlines are able to change business models in a very short period of time; this is clearly not the case for aircraft manufacturers and airports, with their much longer strategic horizon.

- **Aerospace industry**

The aerospace industry is characterised by heavy up-front investments and an exceptionally long programme lifecycle, with its associated highly problematic cash-flow profile (as indicated below). As development costs are increasing because of the high maturity level of the underlying technology, this problem will become exacerbated in the future. At the same time, new competitors are entering the market as many countries support this strategic industry, which will place additional pressure on the profit margins of incumbents. The question of how to finance future programmes is therefore of critical importance for the aeronautics industry.



Source:This slide is a courtesy of Roland Berger Strategy Consultants.

- **Airports**

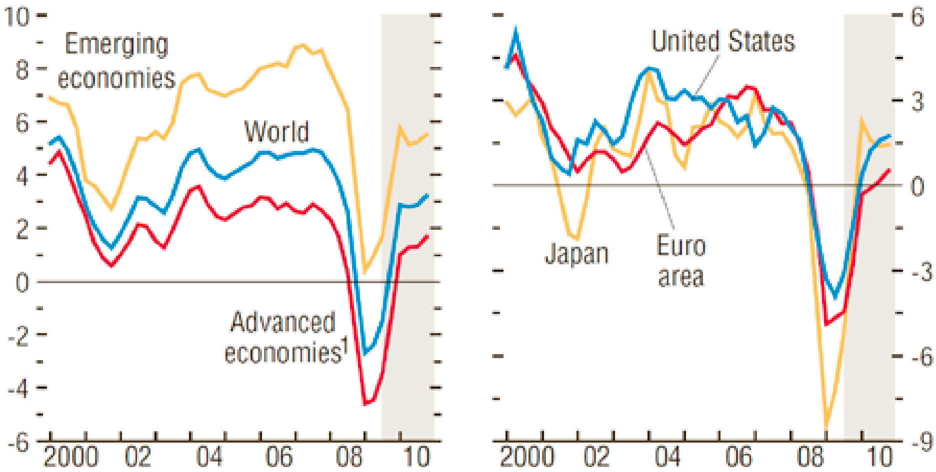
Airports represent part of the national and regional infrastructure and operate under entirely different conditions than other players in the industry. Airports have to confront large fixed costs; they share the characteristics of a natural (local) monopoly and are therefore (in the majority of countries) highly regulated. At the same time, an increase in capacity is a very long-lasting and highly political process. The set-up of a demand-oriented infrastructure within the nations and across Europe is therefore hotly debated; but at the same time this is a vital prerequisite for the evolution of the whole industry. In this report, these various actors are considered separately where appropriate.

[3] For a more in-depth discussion of this, see also Pilarski (2007) [Ref.29].

2.2. THE CURRENT CRISIS, ITS IMPACT AND THE WAY OUT

2.2.1. SHORT-TERM DEVELOPMENT

After the overheating of the financial system, with decades of building up great imbalances (like the USA trade deficit), the world economy has recently experienced a downturn unprecedented since the Great Depression of the late 1920s and early 1930s. World real GDP growth declined from a peak of 5.1% in 2006 and 5.0% in 2007 to 3.4% in 2008, and is predicted by the IMF to decline even further to only -1.1% in 2009 (the lowest rate since WWII and positive growth rates mostly only in Asia). [4] An upswing is projected in 2010 - again to 3.0% - which is, however, uncertain.



Source: IMF staff estimates; World Economic Outlook, October 2009

The crisis may end up as a chance to develop a new global financial architecture, more suitable for dealing with a multipolar political and economic landscape. However, given the sheer magnitude of the downturn and still unforeseeable dynamics, the crisis has the power to change the world economy. As with past crises such as World War I (WWI) and the Great Depression, the present crisis might also be a turning point in the history of globalisation. The consequences are not yet predictable, however.

In the short-term, the impact of the crisis (2009-2011) on air traffic flows and the aeronautics industry has been estimated (for example, by Goldman Sachs and IATA), partly based on a scenario model. The news is both positive and negative, which will influence the way the air transport industry navigates its way through the crisis.

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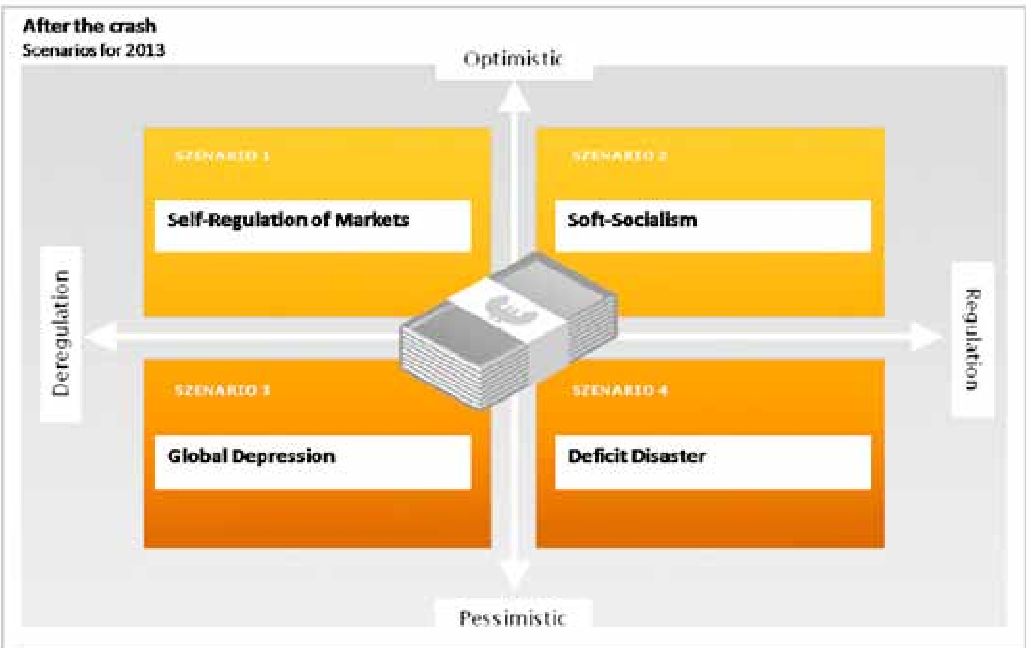
[4] GDP growth rates are adjusted for purchasing power (Purchasing Power Parity, PPP). IMF growth rates are different to the metrics of other institutes like the World Bank, which uses market-weighted exchange rates. PPP growth rates are higher than market-based growth rates.

Positive		Negative
Backlog equal to seven years of deliveries	vs.	Sharp slowdown in global air traffic
Backlog is well diversified with 50% emerging market exposure	vs.	Very weak financial situation of world airline industry
High requirement to replace old, inefficient aircraft	vs.	Difficulties obtaining finance for new aircraft
Significant overbooking of orders in 2009/10	vs.	Significant order deferrals/cancellation now likely
Manufacturers will use vendor financing to underpin deliveries	vs.	Strains on manufacturers' balance sheets
Airbus and Boeing have behaved with moderation, raising production only 65% from 2004-2008, a much slower ramp-up than in the last three cycles	vs.	Airline load factors falling, which means supply is still exceeding demand

Source: Goldmann Sachs Research.

2.2.2. THE WORLD AFTER - THE WAY OUT OF THE CRISIS

As stated above, the crisis has the power to change the world economy. What are the potential scenarios for the world economy after the crisis? An easy way is to describe the world economy is along the lines of two well-known dimensions: first, whether to adopt an optimistic or a pessimistic view; and, second (since many people assume a lack of regulation caused the crisis), whether the world will be more or less regulated globally afterwards.[5]



Source: Zukunftsinsitut GmbH, Kelkheim.

Scenario 1 *Self-Regulation of Markets* (optimistic/no further regulation):
The crisis will hit the world economy hard, but self-regulation of the markets will lead soon to stable growth rates again.

[5] This description does not come out of a full scenario process. Rather, it structures possible outcomes. Especially with regard to the pessimistic scenarios, they draw on historical experience (e.g., after the "Great Depression" in the 30s or the experience in Japan following the banking crisis in the 1990s.

Scenario 2 ***Soft Socialism*** (optimistic/more regulation):
The real economy will be hit, but new and more adequate forms of regulation will make the world economically more stable. The world will see stable growth rates again.

Scenario 3 ***Global Depression*** (pessimistic/no further regulation):
The real economy will be hit hard followed by a long-lasting global depression. Nations are not able to agree on new forms of regulations and financial architecture.

Scenario 4 ***Deficit Disaster*** (pessimistic/further regulation):
Market failure will be followed by state failure due to huge deficits. Economic crisis will be followed by a political crisis. This will also bring about currency crises even within OECD countries and Europe and years of economic stagnation will follow (as seen in Japan in the 1990s).

Both pessimistic scenarios might represent a turning point for a much more pessimistic world scenario in 2030 - 2050 (e.g. like the ACARE Bloc Building Scenario or a scenario with a general renationalisation of economic and political issues).

When thinking about the future of aviation, an important consideration is that usually business cycle phenomena should not be given too much weight, even if these are able to shape our view of the future. Our view of the future is often biased by the current state of the economy.

It is too early to evaluate, however, whether the current situation is a severe - but normal - business cycle phenomenon, or whether the financial crisis will change structural economic and political parameters.

2.2.3. SHORT-TERM CHALLENGES

- **For the aerospace industry**

The air transport industry is in a better situation compared with the automotive or other industries; for aviation, the backlog of orders from previous years is still remarkable. However, Airbus and Boeing in particular are seeing their backlogs start to fall as customers seek to reschedule delivery slots into the future - or reduce the overall level of their commitments.[6]

The delays in the B787 programme, for instance, have created a much-needed boost for the A350 programme, which has gained traction passing several key milestones. At the same time, neither manufacturer appears to be in any hurry to launch a replacement single-aisle aircraft. Both are now indicating likely into-service dates closer to 2020 than 2015, such that these important new programmes are (until now) not affected by the current crisis.

However, the financial crisis has hit the industry as a whole and SME suppliers, in particular, as there is only very limited access to long-term credits (which are highly relevant for a general ability to participate in large programmes). The credit limits for day-to-day operations are shortening on a large scale, which is a threat to financially thin enterprises, especially those also operating in the automotive industry. This situation might soon have an impact on running programmes and projects such as the A350 and the A400M.

Exposure to the exchange-rate risk will remain an issue for the industry in the short- to medium-term as currency hedging is presently almost impossible (a result of limited credit availability). Although many companies in Europe have benefited from the weaker Euro since the end of 2008, the Euro has again appreciated against the United States Dollar through 2009. This reinforces the pressure on the European industry (Airbus in particular) to successfully rebalance revenue and

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[6] Reuters, for example, reported on February 6th 2009 that Boeing and Airbus experienced more aircraft cancellations than orders in January 2009 (Airbus 12 cancellations, Boeing 31).

cost currencies. The result of this worsening currency situation is an amplification of the liquidity problems as a result of tight capital markets [Ref.30].[7]

- **For the airline industry**

The aviation sector and the airlines had to, and still have to, face the double threat of tighter capital markets and, in the long-term, the even greater threat of higher fuel prices.[8] However, the high order backlog shows that there is still long-term optimism, especially because of the need to replace significant numbers of older, less fuel-efficient aircraft. For financing these aircraft, the industry will become increasingly reliant on asset-focused financiers and lending institutions willing to invest and lend for the longer term. Overall, investors appear to be waiting to see a convincing response from airline managements to the threat of high fuel prices [Ref. 31]. If the industry successfully restructures as a result of the current crisis and the threat of high oil prices, and if new entrant business models have a harder time attracting capital (and the positive trend of increased globalisation and liberalisation remain), the industry could return to a period of relative stability. This would attract wider sources of capital in the medium- to long-term.

2.2.4. UNDERLYING FUNDAMENTALS AND TRENDS

For an understanding of the evolution of the world economy towards 2050 one needs to look at the fundamental structural parameters for the growth *trend*. (Any business cycle is *by definition* only the deviation of the current state of the economy from its long-term trend.) The following factors strongly favour further growth of the world economy in the longer term.

- **Reallocation of capital**

One of the strongest reasons for further growth of the world economy is the ongoing reallocation of capital due to existing differences in capital stocks and the associated catching-up process of the emerging countries. After the fall of the iron curtain, capital has been shifted from high income countries (the *"West"*) to the formerly closed economies of the communist bloc, and others which opened their borders. This reallocation of capital to countries with an accordingly high productivity potential automatically results in higher growth rates (as seen in Germany and Japan after WWII). This is a strong case for further growth, especially in the emerging countries, as long as the borders remain open.

The channels of this reallocation of capital are the channels of globalisation: trade in goods and services, movement of persons, financial flows, and technological diffusion.

At the same time, this reallocation of capital and the increasing trade flows imply a further division of labour, specialisation of activities, and the use of economies of scale in production, which are also strong reasons for further growth.

- **Technical progress and falling real costs for communication and transportation**

Technical progress and associated falling (real, which is inflation-adjusted) costs for communication and transportation (despite the latter being uncertain) are additional factors for a continuation of strong growth rates in the future. More than ever before, most countries have access to a large share of the world's most advanced technology through improvements in communications technology and access to the World Wide Web. This enables these countries to quickly advance up the technology ladder [Ref. 32].

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[7] For example, see the medium-long exchange rate in the area of $/€1.30 - 1.40 with a potential for further depreciation to $/€1.10 as the Euro is currently over-valuated against major currencies. This would be good news for the European aeronautics industry.

[8] The IAE predicts a surge of oil prices due to postponed investments in capacity, when the world economy recovers from the recession with potential oil prices of $200 by 2013 (interview with IEA Executive Director Nobuo Tanaka in *Sueddeutsche Zeitung*, 28th February 2009).

In view of the market size of the emerging economies, even an end to the trend of falling transport costs is unlikely to stop globalisation (especially as the need for further market access remains a dominant reason for outsourcing and off-shoring). However, an end to the trend might change the shape of international trade flows, which could lead to a higher degree of regionalisation [Ref.5].

There are additional important drivers for growth: demographic change, education, savings, changes in institutions, and so on, but there is no general trend in these factors. The most dominant factor is demographic change, which in all likelihood will also boost economic growth (but not in *per capita* terms). However, the crucial transmission from demographic change to labour force participation rates is unclear. In general, any clear trend from these factors cannot be extrapolated.

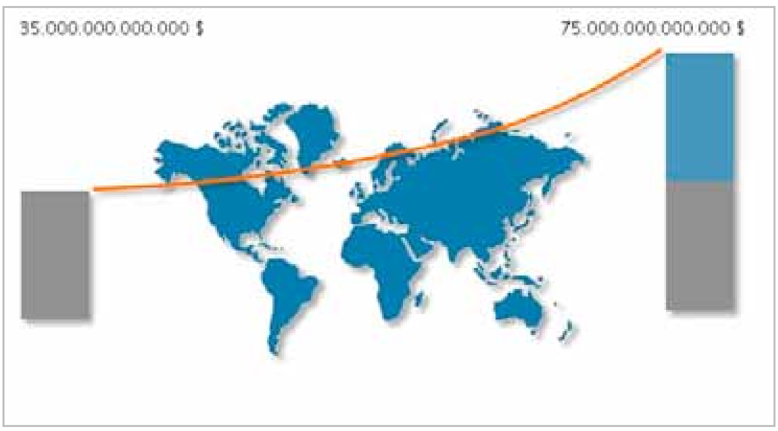
2.3. GENERAL ECONOMY SCENARIOS

Note: The current problem is that all major global scenarios were made more of less before the crisis hit the economy. As stated above, the current crisis has the power to change the world as we know it. However, as long as the crisis is a business cycle phenomenon (and not a major change of structural parameters) these scenarios can in general still be used - assuming that the current crisis leads only to a postponement of the relevant figures by 1 to 3 year(s). The current slight recovery in many countries such as France, Germany and China supports this view (with positive growth rates in the second quarter of 2009).

2.3.1. THE GLOBAL ECONOMY TOWARDS 2050

- **Growth and the evolution of a global middle class**

Using the World Bank (2007) scenario as a benchmark, the world will grow at an average rate of about 3% for the time period from 2006 - 2030.[9] This is the same growth rate that we have seen between 1980 and 2000 but less than 1960-80 (4.7%). World GDP would then nearly double between 2005 and 2030.



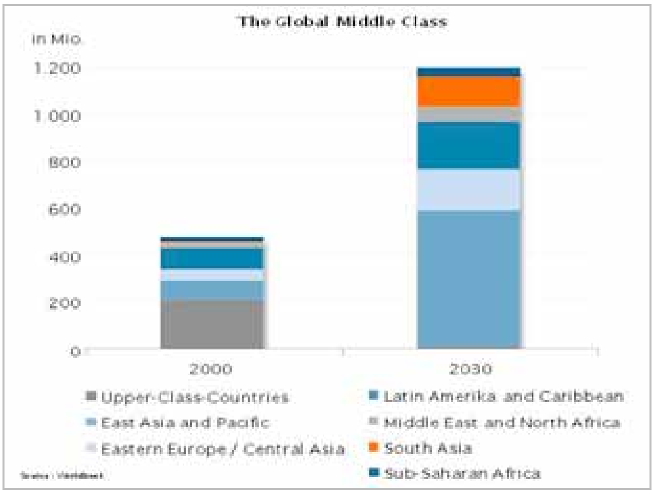
Source: Bauhaus Luftfahrt based on World Bank (2007) data.

This high growth rate would mainly be driven by the growth in East Asia and the Pacific (8.1%; China alone 8.7%) and South Asia (7.0%; India alone 7.2%). OECD countries are projected to grow only at about 2%. This implies that China will be the second largest economy in the world,

[9] These numbers are GDP growth rates in 2000 constant dollars at 2000 prices and market exchange rates. Using the same metric, the growth rate in 2006 was 3.9%. This is different to the numbers used by IMF, for example: GDP in 2000 PPP weights. Using this, the 2006 growth rate was 5.1%.

ready to overtake the USA some time between 2030 and 2040. India will be third. Using GDP *per capita* as an indicator, we will also see a convergence, but even China and India will still be far away from reaching western *per capita* values.[10]

The world will therefore witness the evolution of a new global middle class, which will be the main driver for transport demand growth in the emerging countries.[11] By 2030, more than a billion people in low- and middle-income countries will buy cars, engage in international tourism, demand world-class products, and require international standards for higher education.



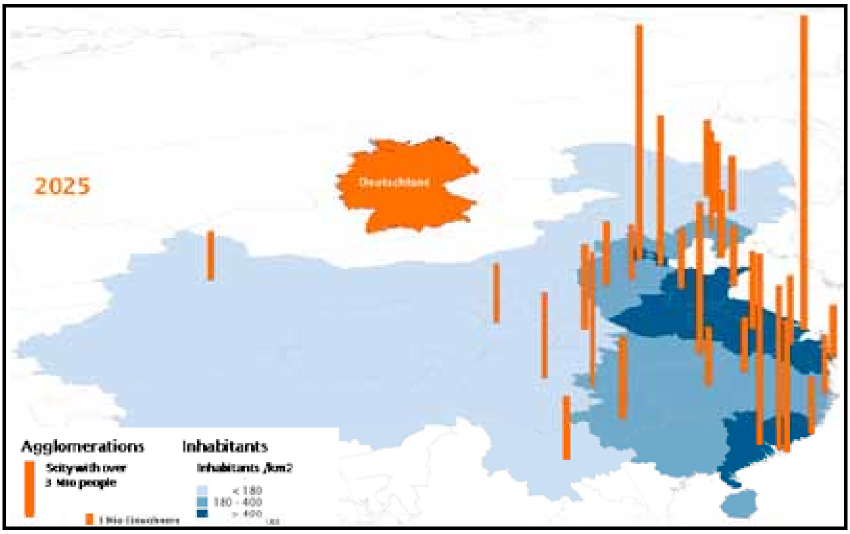
Source: Bauhaus Luftfahrt based on World Bank (2007) data.

- **The new players - spatial distribution of economic activities**

The described shift of economic power from the west to the east, from OECD to low- and middle-income countries is accompanied by the dominant trend of urbanisation. Economic power is now much more concentrated in these areas, which have a much higher population density than in Europe. To put this into a perspective: as a rule-of-thumb, 50% of the Chinese population lives on 10% of the available land. This would be like 260 million people living in Germany and 300 million in France.

10 Using PPP exchange rates, China would, under this scenario, be able to lift its income from 19% of the average high income level to 42% [Ref. 32].

11 Note that this is based on an *absolute* definition: people belonging to the middle class are those whose income is between the *per capita* income of Brazil and the *per capita* income of Italy ($4,000 – $17,000 in 2000 international dollars). This is why the vast majority of OECD inhabitants will be found in the upper class [Ref. 32].



Source: Bauhaus Luftfahrt based on UN Population Division (2007) data.

This has a strong influence on how we think about transportation needs (e.g. in terms of aircraft size, range, etc.).

2.3.2. THE WORLD AND EUROPEAN EVOLUTION OF TRANSPORT

- **Future air transport demand**

Based on ongoing GDP growth, transport demand and air transport demand in particular is projected to grow in all basic trend scenarios (e.g. ACARE SRA2; EUROCONTROL 2008; Consave, 2006; manufacturer's forecasts, etc.). Following the latest EUROCONTROL *Challenges of Growth* Report (2008), by 2030 there will be between 1.7 and 2.2 times the number of flights in Europe than in 2007, with 1.8 being the most likely forecast. For global traffic, the latest forecasts of Airbus and Boeing assume a RPK growth of around 5% and a RTK growth of 5.8%. (The numbers by the manufacturers can be seen as a realistic upper boundary.)

The ACARE scenarios themselves assume a global RPK growth of 6% - 7% in Scenario 1 (*Segmented Business Models*), 3% in scenario 2 (*Constrained Air Traffic Growth*) and 1% - 1.5% in Scenario 3 (*Bloc Building*). The Consave (2005) scenarios assume a global RPK growth of between 0.5% and 3.8% for the time period 2000 - 2050 and between 0.9% and 3.4% for 2000 - 2020.

In this basic demand for more mobility lies the chance for the success of the industry, but at the same time the related environmental consequences are one of its main threats. Following a projected increase in CO_2 emissions by the IEA (2008), the transport sector will be the major contributor to emissions *growth*. And within the transport sector, air transport has the fewest options for the shift to greener technologies.

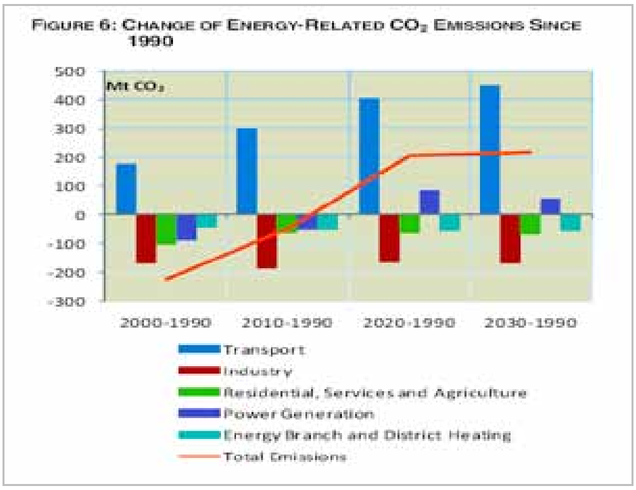


FIGURE 6: CHANGE OF ENERGY-RELATED CO_2 EMISSIONS SINCE 1990

Source: IEA (2008).

- **Modal split in Europe**

How will the modal split change over time? Europe in particular has, for a long time, been working on the establishment of a high-speed train network, connecting more and more city pairs over time. If the train connections remain below a couple of hours, there is a great chance that the train achieves the highest market share for passengers travelling on this route. However, it is doubtful that even an accelerated investment in high-speed networks will increase the modal split in favour of the rail system. People will travel further, with an increasing demand for all high-speed connections, and in particular by air.

Following the baseline scenario of DG TREN's *European Energy and Transport - Trends to 2030* (2008)*,* the modal split in the EU 27 of aviation will increase from 8.1% in 2005 to 12.1% in 2030, whereas the share of rail will only slightly increase from 7.1% to 7.5% (measured as the share of the respective mode in overall passenger-kilometres, excluding freight).
Although high-speed connections are a strong competitor for the airlines on specific routes, aviation's share in transport activities is very unlikely to grow slower than that of rail. According to EUROCONTROL (2007), even an increase from 98 high-speed train city pairs to 300 city pairs would reduce aviation demand by only 0.3 - 0.5 million flights, accounting for only about 2% of 2030 flights.

The combination of low operating costs, with high-frequency flights between hubs and small- to medium-sized communities, and point-to-point service will increase the demand for regional air transport. The provision of innovative solutions and environmentally friendly operations will become vital in meeting these needs.

- **New airlines business models, demand and product segmentation for aeronautics**

The increasing demand for air travel will very likely be accommodated by the evolution of new business models. The massive growth of the low-cost carriers (LCCs) in particular has created a new demand for a set of modified product and technology requirements. A specialised low-cost aircraft, made in China and operating in Africa, is a realistic example. The emergence of other new business models, such as personal air transport and air taxis, is also conceivable.

There is also the realistic prospect that former niche markets (e.g. with regard to range and capacity) could open up as a result of high growth rates in Asia and South America, with the chance for a specialised aircraft serving the routes between megacities between these two continents. A dedicated freighter (e.g. as a blended wing configuration) is also possible.

The possibility of other forms of customer segmentation will clearly depend on the ability of airlines to separate these customers, either through price or product discrimination. A separation between business and economy class passengers is, in this regard, much more realistic than a separation of O&D and hub-and-spoke passengers.

2.3.3. ECONOMIC CHALLENGES

- **General challenges**

The challenges raised by the general projected increase in traffic demand have been well documented by EUROCONTROL (2008):

- **Airport capacity**, which in the most likely forecast scenario, will lag behind demand by some 2.3 million IFR flights (11%) by 2030, even if all the current plans can be delivered
- **Environmental impact**, including difficult trade-offs, not just between growth and environmental impacts, but also between CO_2 emissions, noise and local air quality
- Operating a **congested air traffic network**, which will be very vulnerable to perturbation, as more parts of it operate close to the capacity limit (e.g. through bad weather) and will be less able to recover from these effects
- Achieving **institutional and social change** so that SESAR can deliver the required air traffic capacity on time
- Impact of **climate change** that will affect demand for travel, threaten parts of the infrastructure, and make operations more difficult

- **Specific challenges for the aeronautic industry**

A very particular challenge for the aeronautics industry and its supply chain might come from the dependence on long-term finance for the above-mentioned cashflow profile. How the capital markets will evolve after the crisis is unclear, but the following factors point to tighter capital markets and greater budgetary constraint for governments:

- **New regulation for banks** and other actors on the capital markets. The current implementation of Basel II [*c.* 2004-2009 international banking regulation] and the ongoing discussion of further regulation of the sector clearly point to much higher equity requirements. This would decrease the ability to leverage equity and would therefore reduce the ability to supply credits
- **Renationalisation of the banking system** due to the higher influence of regulation
- **Decrease of savings in an ageing society**. This reduces capital supply and “ceteris paribus” points to higher real cost of capital. An ageing society might also lead to more funds going to health and age related industries
- **Governments** will probably demand **a higher share of private savings** to finance the increase in public spending due to the crisis (and potentially due to the demographic trend as well)

The industry will therefore have to address the question of where the funding for future programmes will come from. Those companies which need to rely on bank finance could face especially severe problems for financing long-term programmes. **One solution might be to follow a step-by-step approach for upstream activities and prove the technical capability by demonstrators.** Another approach might be to use more sources of funding by combining the potential military and civil use of different new technologies.

- **Specific challenges for the airlines**

Increase in energy prices and emissions-related charges might well challenge some currently successful business models. In particular, low-cost carriers might find their advantage in relative prices will strongly decrease.

- **Foreign ownership of (air) transport infrastructure?**

Another issue is whether or not the EU should follow the USA in developing a policy for reviewing foreign investments in the EU (e.g. like the Exon-Florio Agreement in the USA). In the event that air transport infrastructure and parts of the industry are deemed strategically important, the EU would need a political mechanism to prevent foreign ownership and control. This might also be discussed in the general context of a European industry policy in view of strong regulation of these industries in other regions of the world.

2.3.4. MAIN UNCERTAINTIES

Although the realisation of the above trends is relatively likely, the complex interactions between the various drivers of transport are not really predictable. In addition, several relevant factors cannot really be foreseen. Some of them are listed below [Ref. 5]:

- Changes to the **geopolitical situation** in Europe and the world, e.g. a return to economic nationalism triggered by the current crisis or other changes induced by economic instabilities or decreased energy, food or water supplies
- Growing **inequality** could also easily change the geopolitical situation
- As a positive scenario: **decreasing inequality** and more stability in Africa, which could have a major impact on trade flows and the directions of foreign direct investments. This might open a new wave of globalisation including Africa
- **Climate change** might bring with it changes in the geopolitical situation or might, through non-linear changes, lead to abrupt and potentially catastrophic impacts on whole regions
- Ageing populations, increasing infrastructure costs, and the currently rising public debts, could dramatically force governments to **rationalise public spending,** which might imply less R&D funding and military expenditures

2.4. SUPPLY CHAIN EVOLUTION

2.4.1. CHARACTERISTICS OF THE INDUSTRY

The following four points have emerged, which depict the peculiarity of the aircraft industry. These strongly influence its complex production organisation and, accordingly, its evolution [Ref. 33].

- **High technological level**

The high technological level of current aircraft configurations implies that a slight improvement in the technology is obtained through great efforts and a steep increase in the final costs of the vehicle. This also explains the significant homogeneity of technological solutions: a little erroneous variation of the technology and price involve massive financial losses. There is a very high risk for an incorrect positioning in the technology matrix. Companies try to reduce these risks through various collaboration and cooperation agreements with other firms, including those that could be potential competitors.

- **Technological complexity**

The complex nature of an aircraft is a barrier to innovation as there are limited possibilities to control all technologies and interdependencies. Again, huge efforts translate into small technological improvements. Companies therefore focus their know-how on particular areas to push the technological frontier. The manufacture of an aircraft therefore implies the need to develop a system of relationships between specialised firms.

- **High and increasing development costs**

At the end of the 1980s, some authors estimated that development costs for a new generation aircraft would reach $10 billion. Today, the estimates for the A380 reach $15 billion (*c.* 2004 data). As a way of reducing high development and management costs and reducing financial risks, firms have an intensive pre-project period to single out those partners best suited for the work.

- **Small break even numbers and small markets**

There is no single country in the world able to absorb the numbers of aircraft necessary to reach the break-even threshold, which assures the profitability of a single manufacturer. Furthermore, many governments impose direct and indirect barriers on the acquisition of aircraft not manufactured with the contribution of local firms. Large manufacturers get around these market barriers by making agreements involving firms from different countries in the production process.

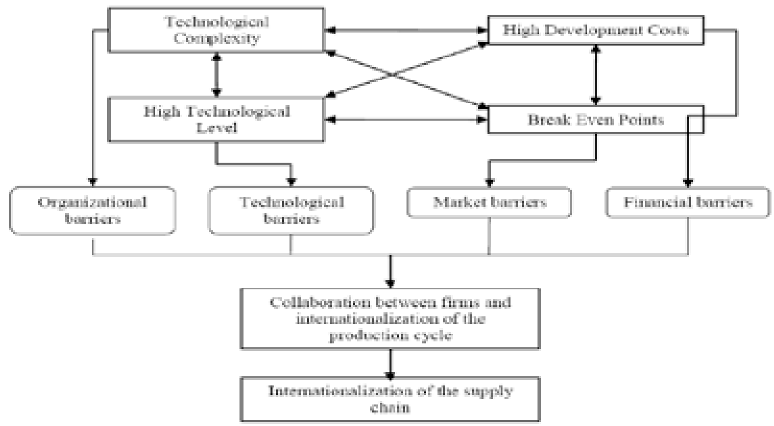


Figure 1. Structural characteristics of the production organization in the aircraft industry

Source: Esposito and Raffa (2006).

2.4.2. IMPACT ON ORGANISATION (HORIZONTAL AND VERTICAL)

In the past, the factors described above imposed various barriers for firms operating in aviation, resulting in a production organisation on an international scale with an intricate network of collaborative arrangements between firms.

These factors, and the corresponding barriers, have also lead to an ongoing (horizontal) consolidation of the industry, within Europe and in America. In recent times, we have seen the emergence of six major groups in the civil and military landscape (Boeing, Lockheed Martin, Northrop Grumman, Raytheon, EADS, and BAE Systems).

2.4.3. THE FUTURE OF THE SUPPLY CHAIN

- **Current development**

The characteristics of the industry have also re-shaped vertical relations (the production pyramid). In the civil aviation markets, Boeing and Airbus (EADS) now concentrate on product and system integration and the management of the supply chain as a core competency (as well as customer relations). They have started to shift system integration to first-tier suppliers. They are also forcing their suppliers to take more responsibility for the development and design process (and asking to share non-recurring costs) and the associated programme and currency risks. At the same time, they offer long-term relations, with stable and reliable relationships, and run electronic links with suppliers. Boeing has now gone "*the extra mile*" - e.g. outsourcing the entire wing design and manufacture for the 787 to external suppliers.

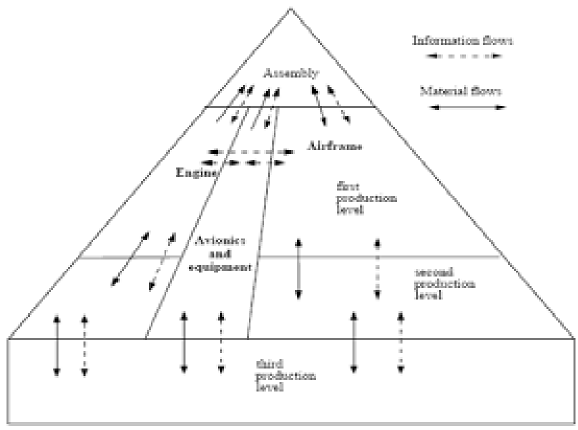


Figure 2. The production pyramid of the aircraft industry

Source: Esposito and Raffa (2006).

- **Drivers for the future**

As in the past, there will be relevant drivers for the future of the supply chain. The technological level is so high that there is no single technology that will drive future developments. In contrast, new aircraft will probably be more influenced by innovations between the various systems and by manufacturing technologies. The substantial costs associated with new developments will therefore lead to a further widening of the collaboration network already found in the sector.

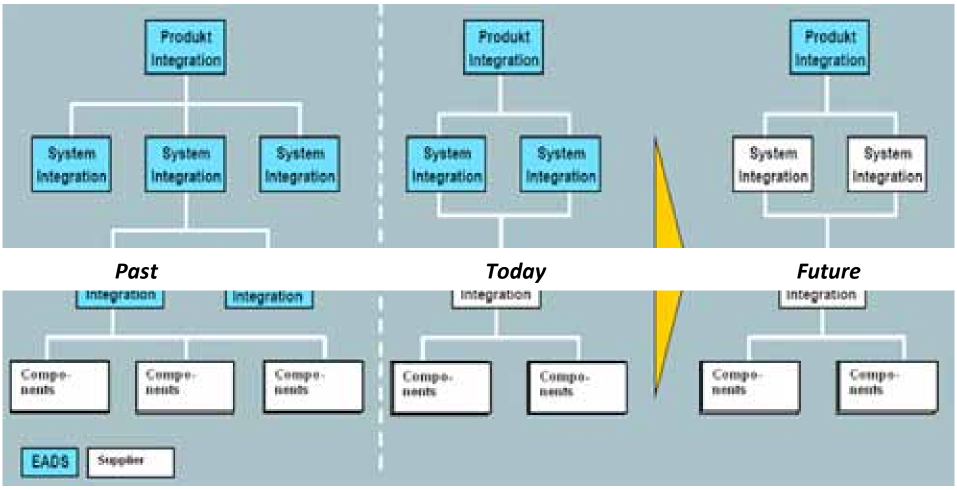
In addition, the manufacturers face more financial pressure from the airlines, who themselves have been subject to more competition following the ongoing liberalisation of the markets since the 1990s. At the same time, the industry itself has come under more and more pressure from the financial markets - especially in the current situation. New competitors from China and Russia will also force the industry to focus on core competencies to preserve technological leadership. The ability to manage the complex supply chain will become increasingly crucial for this to happen.

- **Reorganisation of the supply chain**

In the 1990s, the industry was mainly driven by cost reductions. Now the emphasis is to secure quality and "grab" the various strategic chances offered by specialised firms all over the world (along with the potential market access offered by these firms).

The new organisation will be characterised by the following aspects:

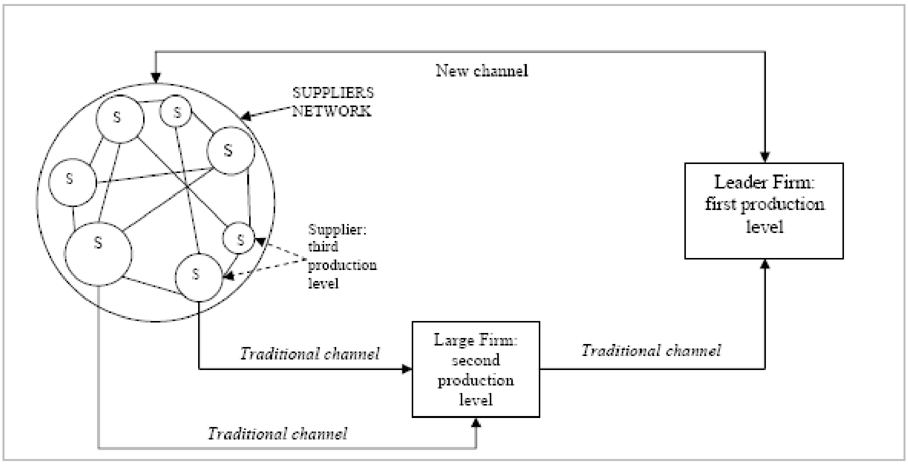
- An increasing **focus on product integration** for leaders such as Boeing and Airbus (moving closer to a "total" system integrator and lifecycle value provider role). They will move their core technology towards programme coordination, final assembly and interaction with the market (airlines, governments, etc.).



Source: Presentation by EADS / AERVICO 2007.

- A **reduction of suppliers** to cut transaction costs; consolidation of suppliers for a stronger financial backbone to enable the necessary investments.
- Further **shift of responsibilities and risks** to first-tier suppliers. Suppliers moving from short-term service providers to long-term partners. The result is that the suppliers will have an improved position in the production pyramid. They will no longer be engaged only in technical problems, but also in the management of the significant technological and production process. Their supply activities are therefore evolving from a mere production of parts and components to the offer of a service (from production to service phase).
- Suppliers must **provide detailed product information** (more so than today). Selling black boxes is impossible.
- **Establishment of supplier networks** through adoption of information technologies, enabling network-wide connectivity for coordinating complex interdependencies. Data exchange with a common tool will be mandatory at a worldwide level.
- **Further internationalisation** to take advantage of international diversity and expertise.

In this context, the suppliers need to reduce costs, improve the technological level, and guarantee a higher quality and service level to the customer. These changes are particularly challenging for small and medium western supply firms, which have been operating in the sector for some time. These factors are pushing the suppliers towards the creation of supply networks, which incorporate various skills and competencies to meet customers' requirements. Within these networks the leader firm will directly communicate with lower-tier suppliers, creating a new channel of interaction. The model will change from a linear model to a more "unstructured", network-like model.



Source: Esposito and Raffa (2006).

These new supplier networks must be efficient, robust and competitive. The management of the supply chain needs to build on simple processes, monitored by Key Process Indicators (KPIs), and should be suited to the relevant business models (civil, military). The supply chain must be robust enough to resist any failure of one of its elements, which implies careful anticipation and risk management. In addition, the networks need to be competitive, which means that there is an industrial maturity reached from the first item produced. The management must be devoted to continuous improvement of productivity and needs to react and adapt fast to changing environments.

- **Need for action?**

The internationalisation of aeronautics is a challenge and an opportunity for the European industry and policy. Market access and the reduction of exchange-rate exposure point to a relocation of activities of the leader firm (EADS in particular) to countries outside the European Union. However, European industry might well capture a larger share of production from other market leaders in the world. Policy makers would need to clarify whether and how to support industry in this regard. Relevant questions here are: what are the strategic relevant capabilities and core competencies we want to focus on? How could Europe gain a higher share of the value of the supply chain? And, last but not least: is there a way to keep a large share of value in Europe in view of the high labour cost?

2.5. COOPERATION OPPORTUNITIES

2.5.1. INTRODUCTION

The aeronautics sector is characterised by a high capital and technological intensity with strong requirements in safety and performance. The RTD costs are very significant, especially for the validation and integration phases.

The cycles are very long, and consistent with return on investments of 15 years and more. This sector is traditionally considered as strategic in the industrial countries (USA, Europe) and more and more so in (re-)emerging countries (such as Russia, China, India, Brazil). The research effort is concentrated within large companies that have the capacity to sustain heavy investments during a long period of time; and research establishments which receive public subsidies tend to have less profit pressure.

2.5.2. AERONAUTICS PANORAMA

A limited number of aerospace companies serve the global market. These are mainly located in the USA and Europe (except Mitsubishi and Embraer). But only these two “poles” have a complete supply chain covering all the segments of the market: large aircraft, regional aircraft, bizjets, general aviation, helicopters, engines, equipments and systems, and ATM.

The companies involved are, in general, also present in the defence segment/area. The supply chain includes large integrators, first-rank partners (which are participating in the co-development with financial risk-sharing), and SMEs involved as partners or subcontractors.

The RTD is also mainly implemented in North America and Europe at present, involving a large number of actors from the air transport industry, research establishments and academia. All the aeronautical countries have their own national research establishments.

A century was necessary to create this industrial fabrication infrastructure able to address the global market with a high level of competitiveness. Huge efforts, made by the industry in private investments, together with the support of national public authorities, and now by the European community, have been necessary to reach the leadership of the European aeronautics sector. The situation is similar in the USA. Europe and the USA are now leading the market.

The current industrial landscape is the result of a continuous process of consolidation initiated in the 1970s and 1980s. This process remained confined within the geographical zones (the significant transatlantic operations did not provide the expected results when defence activities where included). This process is not yet complete.

Large European integrators already have a multinational European industrial basis, and - in some cases - even transatlantic ones. This contributes to the move in the direction of more coordination in research. ACARE has accelerated and organised the coordination process at European level, involving all the private and public European stakeholders.

2.5.3. THE USA CASE

The USA aeronautics industry is the most important in the world with about 635,000 employees and annual sales of about US$185 billion.[12] This sector is strategic in terms of technological leadership and economical and financial spin-offs.

The Federal Government has confirmed the objective to ensure the global supremacy of the USA aeronautics and air transport industry, and has decided to increase the RTD effort. In parallel, the NTSC published (28 December 2007) the National Plan for Aeronautics R&D. This programme includes similar topics and approaches to those currently addressed within *Clean Sky* and *SESAR*.

NASA plays a pivotal role in research with a US$594 million budget for 2007 (US$512 million for 2008). The other key player in research is the FAA, which is implementing the National Aviation Research Plan with a US$270 million budget for 2008.

The industry is also supported by the Department of Energy, the Department of Defence (including DARPA and USAF) and the Department of Homeland Security.

2.5.4. OTHER CANDIDATE COUNTRIES FOR GLOBAL LEADERSHIP

A limited number of countries have expertise in aeronautics (defence and/or segments), but more and more have ambitions in civil aeronautics, with a vast potential to serve the worldwide market: Russia, China, Brazil and India. These nations present the “genuine triptych”: large internal

[12] Aerospace Industries Association (AIA), 2007

markets, financial resources, and a highly skilled human capital base. These countries have the capability to invest a huge amount of money in RTD to compete with the current leaders.

These nations express a strong interest in participating in the EU research programmes. The EC's Framework Programme (FP) is an opportunity that provides for full access to the European technology base. There is also an interest for European industry and research organisations to develop cooperation and partnership with these emerging countries.

It is important to consider balanced, long-term perspectives, preserving European interests. The FP needs to be adapted to take these elements into account.

Cooperation should be prepared by an institutional framework, as necessary: EU summits with third countries, European Commission agreements, and other ad hoc multinational cooperation. This institutional framework should be supported by pilot projects and programmes to create confidence and to help overcome all kinds of barriers: cultural, language, practices, operation, processes, legal matters, financial regulations, funding schemes, IPRs, and so on. These pilot cases should provide opportunities for fair market access.

2.5.5. EU/USA COOPERATION

A cross-over approach should be developed for transatlantic cooperation. The EU and the USA have both launched initiatives to develop breakthrough technologies to meet the challenges of sustainable green air transport, including propulsion and energy issues. Joint efforts in upstream research could be an opportunity to accelerate the innovation process and develop global solutions. Competition should remain at integration level. A promising field for cooperation may be the search for alternative fuels for aviation. The European Emission Trading System (ETS) could also be included in such cooperation.

The Group of Personalities could provide guidelines, objectives and roadmaps regarding the various cooperation schemes with different countries.

2.6. CONCLUSIONS

The world economy seems to be at a crossroads. For the first time since WWII, 2009 will most probably see negative growth rates. The aftermath of the crisis that began in the American subprime market is unpredictable. However, if political leaders refrain from new forms of economic nationalism, there are still enough reasons for further strong growth of the world economy. Air transport demand will therefore rise again after the crisis.

The coming decade will bring many challenges for the whole industry. The era of cheap oil is over, new countries with new markets but also new players will enter the scene, and the environmental impact of human behaviour becomes more and more evident. The future is uncertain, except that changes will be rapid and marked, especially in the price of resources, and this scenario will become a normal phenomena.

Airlines will be the first to experience these changes: traditionally, in a not-very-profitable situation; but, now and in the future, through increasing energy prices and emissions-related charges airlines will face increasing pressures. Airlines need to continuously identify risks to their business model and react - fast - if they want to stay in business. The ability to participate in the long-term financing of new aircraft developments will therefore rather diminish.

The aeronautics industry also has to face a double threat. There is the urgent need for further improvements or even a technology breakthrough (in partcular for the next generation of aircraft. This need is amplified by the increasing environmental impact of aviation and emissions-related regulation. Manufacturers face a greater level of uncertainty than before about the future evolution of air transport (a positive scenario with an increasing demand for more customized aircraft; or a more pessimistic scenario, especially with regard to climate change or resource constraints).[13]

The industry will probably face more problems when raising finance on the capital markets for these necessary developments. There is a strong likelihood that future capital markets will be tighter than today. Industry will have to compete for funds with other industries like automotive, energy, etc. At the same time, the European industry has to face more competition on the aircraft market from China, among other nations, who are strongly supported by their governments - and this places additional pressure on prices, market share, and profit margins. Another factor to consider is that the current "*cash cow",* the A320 (and B737) will enter the last stage of its production cycle (thereby reducing the internal sources of finance for new products). In general, development costs are increasing significantly as a result of the high maturity level of the key technologies. Consequently, more and more funds only translate into small increases in efficiency.

For Europe to maintain its technological leadership therefore becomes increasingly difficult. Any incorrect positioning in the product and/or technology matrix can easily lead to a financial disaster and even bankruptcy for the company involved. This is especially true within the search for an urgently needed technology breakthrough. One possible way to deal with this pressure is a stronger segmentation of the R&D process, moving more activities upstream to gain access to wider sources of funding. A larger share could be shifted to R&T support, proving technological capability by demonstration, and then entering the (market-financed) development process. This would shorten development times and bring more trust to potential investors for financing new products.

Another possibility lies with an increased focus on military developments (and sales) within a company, since the funding of these projects follows different rules. However, this might stabilise a company's turnover and profits over the business cycle, although it is not clear whether technological complementarities between military and civil use will be large enough and really serve the needs (as emissions reduction will be an important driver) of the civil markets.

[13] These factors do also explain to a large extent the reluctance of Airbus and Boeing to introduce a new single aisle aircraft.

CHAPTER 3: ENVIRONMENT

Research into climate science, aircraft noise and air quality around airports over the last decade has provided a great deal of understanding about how aviation affects the local and global environment. The environmental challenges have given rise to public and political concerns prompting legislative measures to be put in place for aviation, including environmental targets. The Air Transport sector recognises the serious nature of these environmental concerns and is committed to finding solutions to mitigate the impact resulting from them. To achieve the greatest improvement in environmental performance, it is vital that innovative solutions are available at the right point to be built into the future generation of aircraft and Air Transport System.

3.1. INTRODUCTION

The impact of human activity on global climate is becoming a more and more serious concern based on the Intergovernmental Panel on Climate Change (IPCC) in its most recent Assessment Report[14] re-evaluating this risk. Some of the main panel conclusions were:

- Global atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial levels.
- It is very likely (greater than 90% probability) that most of the global warming of the past half century is due to increases in man-made green house gases.

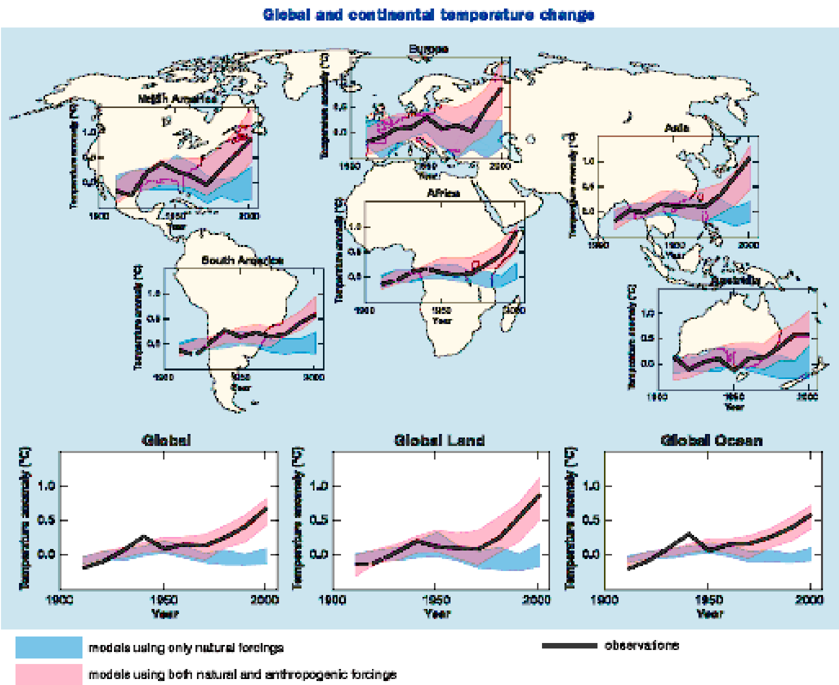


Figure SPM.4*. Comparison of observed continental and global-scale changes in surface temperature with results simulated by climate models using either natural or both natural and anthropogenic forcings.*

[14] IPCC fourth Assessment Report (2007)

- A reduction in global CO_2 equivalent emissions of 30% to 60% by 2050 (relative to the year 2000) is necessary in order to limit global mean temperature increase to 2.4 - 2.8°C above the pre-industrial level[15]. For a temperature range 2.0 - 2.4°C emissions reduction by 50% to 85% would be necessary.

All industry sectors including aviation are affected and need to contribute their share of emissions reduction in order to meet the environmental imperative.

A comprehensive assessment of the effects of aviation on the global climate was undertaken by the IPCC in 1999 and significant updates have since been done in Europe and the rest of the world.

Political Pressure has significantly grown since international talks about the post Kyoto protocol started in 2007 with the Bali roadmap, culminating in the Copenhagen Accord[16] which was "noted" by the 15th UNFCCC Conference Of Parties (COP15). The first commitment period of the Kyoto Protocol will expire at the end of 2012. It is anticipated that a legally binding agreement will be agreed by December 2010 at COP16 in Mexico.

In order for aviation to be incorporated with an international agreement, both the International Civil Aviation Organisation (ICAO) and industry have developed detailed assessments of the potential contribution that could be made by aviation to the post Kyoto commitments.

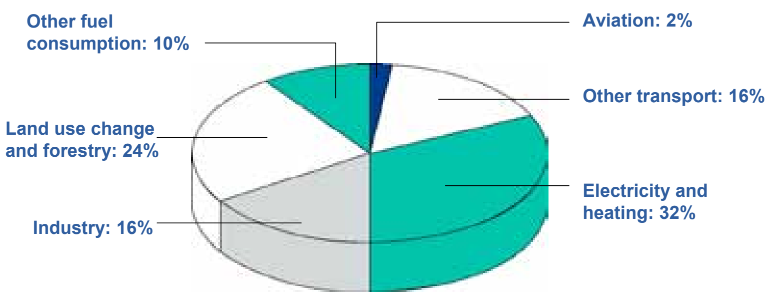
3.2. THE ENVIRONMENTAL CHALLENGE

3.2.1. GLOBAL IMPACT OF AVIATION

Carbon dioxide (CO_2) is recognised as the dominant man-made greenhouse gas due to the fact that it remains in the atmosphere for over a hundred years.

Globally, aviation currently accounts for around just 2% of man-made CO_2 emissions, compared with 16% from other forms of transport and over 30% from electricity and heat supply. Future emissions levels from each sector will depend on the relative rates of growth and the scale of technological improvements.

The prediction is that net aviation emissions will continue to increase if radical technological improvements beyond that anticipated today are not forthcoming.



Global man-made CO_2 emissions - *Source:* World Resources Institute

Although CO_2 is the only Kyoto greenhouse gas aviation emits there are other effects on the climate resulting from non- CO_2 emissions at altitude.

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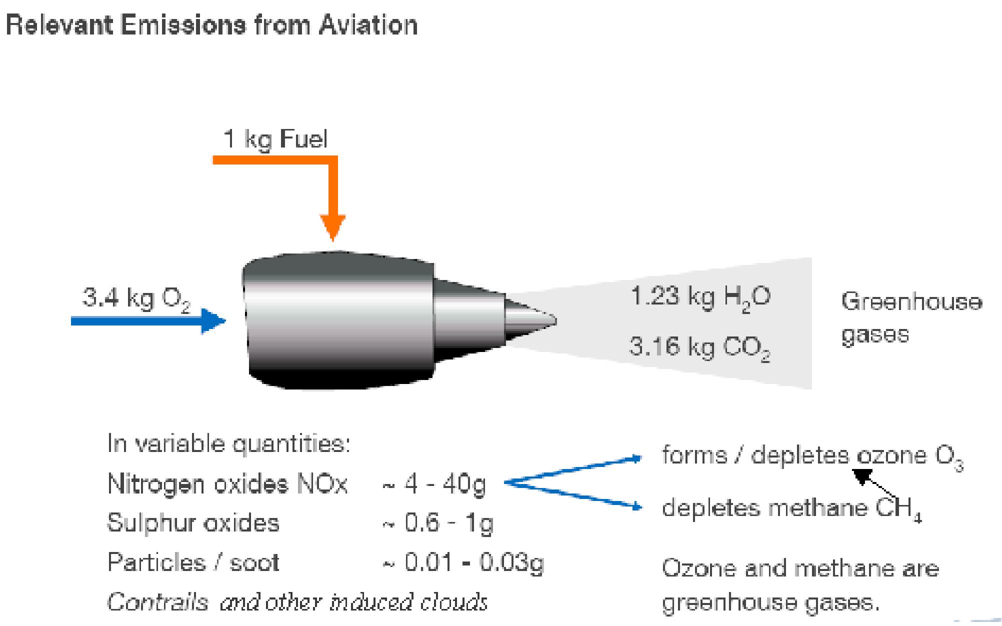
[15] IPCC Assessment Report of Working Group III (Mitigation) -Summary for Policymakers (Table SPM.5)

[16] UNFCCC – Copenhagen Accord, December 2009



Source: ASD

The following gives an overview on how aviation affects climate:

- Greenhouse gases, i.e. carbon dioxide (CO_2) and water vapour directly affect the radiative energy flow through the atmosphere.
- NOx (nitrogen oxides) through photochemistry in the atmosphere enhances the formation of ozone (O_3) and destroys methane (CH_4), both being greenhouse gases.
- Water vapour emitted by aircraft at cruise altitude can lead to the formation of contrails (condensation trails). Contrails are initially visible as line-shaped clouds (see aerial photograph below). In cold and moist air masses, contrails may spread and in some cases may form cirrus clouds. Contrails and induced cirrus clouds reflect visible radiation from the sun and absorb and emit infrared terrestrial radiation. The current state of knowledge suggests that the total result is a net warming.
- Aircraft induced aerosols (soot and particles formed from sulphur oxides) indirectly affect natural cirrus-cloud formation by acting as ice nuclei long after emission and long distances away from the flight routes.

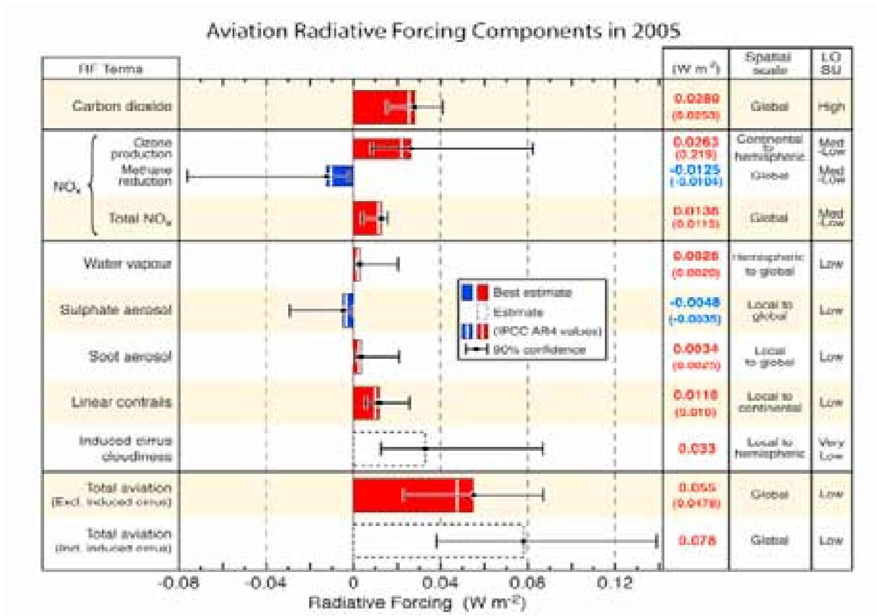
Technology, alternative fuels and operational measures can help to deliver improvements to reduce aviation's impact on climate change. This can be done in a number of ways including:

- Reduce fuel consumption. A reduction in fuel consumption will result in lower CO_2 emissions as well as less water being emitted.
- Reduce NOx emissions. This will help to address local air-quality issues as well as altitude effects that are still subject to scientific uncertainty.
- Change where and when emissions are produced e.g. avoid persistent contrails through changes in aircraft operations such that atmospheric conditions which result in contrail formation are avoided.
- Enhance operational measures to minimise the overall impacts from NOx, CO_2 as well as contrails.

- Deploy more efficient or alternative technology including biofuels which could help to reduce life-cycle emissions.

3.2.2. IMPROVEMENT REQUIRED IN SCIENTIFIC UNDERSTANDING

Over the past decade, scientific understanding has improved in several areas – the chart below shows the instantaneous radiative forcing (RF) from the integral of aviation emissions up to the year 2005.



Source: Radiative forcing components from global aviation – "Aviation and global climate change in the 21st Century", David.S.Lee et al, 2009.

Large uncertainties and knowledge gaps with respect to aviation's impact on climate change remain. Further scientific understanding, accuracy and suitable metrics are needed in a number of areas:

- <u>Contrails leading to cirrus cloud formation</u>: More knowledge on their climate impact as well as the efficiency of possible mitigation options is needed, e.g. change in flight altitudes and routing (flying at higher or lower cruising levels).

- <u>Actual impacts of NOx at altitude</u>: Both warming and cooling effects need to be better understood.

- <u>Effects of particulate matter</u>: More knowledge on soot-induced cirrus cloud changes, especially with regard to the nucleation behaviour of these particles, is required.

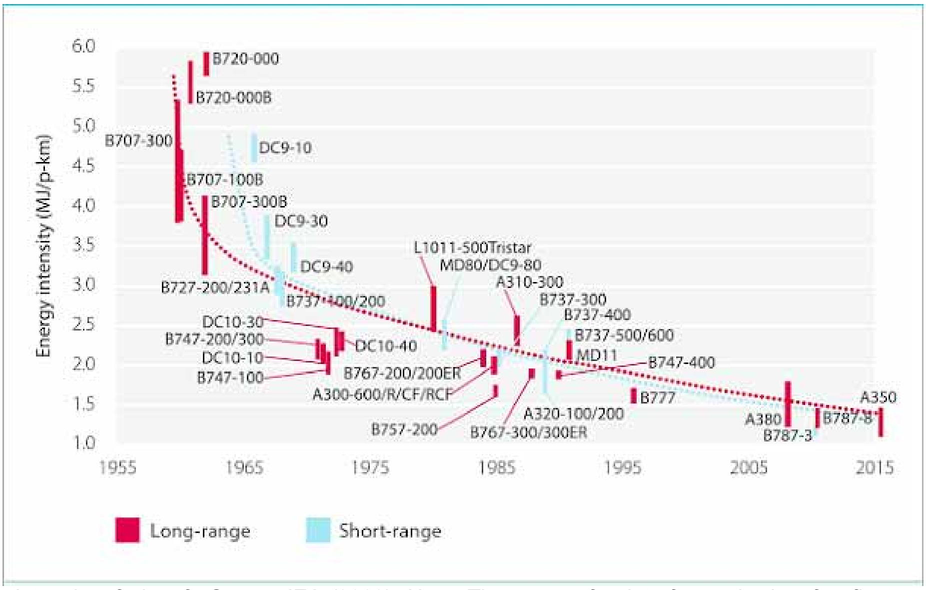
- <u>Metrics</u>: A sound metric to compare the climate effects of aviation CO_2 as well as non-CO_2 effects is not yet available. Such a metric could facilitate informed decisions on how to mitigate short-lived effects, e.g. contrails, and longer-lasting atmospheric effects of CO_2 lasting hundreds of years. It will also enable fair comparison with other industrial sectors allowing each sector to minimise its specific climate impact.

A top priority is to understand the science of climate change to guide the industry's substantial research and development programmes over the long-term so that new approaches and breakthroughs can be developed to mitigate the climate impact of aviation and provide a path to sustainable aviation.

3.3. AVIATION IN CONTEXT

3.3.1. TRACK RECORD

Historically, aviation has been extremely successful in driving down fuel burn for good economic reasons. Since the introduction of jet-powered civil aircraft, around 50 years ago, the technology both in the engine and airframe, as well as other measures, has helped to reduce the aircraft fuel burn per passenger kilometre by 70%. Similarly, aircraft have become 20dB or 75% quieter over the same period.



Energy intensity of aircraft. Source IEA (2009). Note: The range of points for each aircraft reflects varying configurations; connected dots show estimated trends for short and long-range aircraft.

3.3.2. LOCAL ENVIRONMENTAL IMPACTS

Local air quality near airports

Local air quality can be an important issue for airports and one which can lead to "capacity constraints" being applied to control emissions and meet ambient air quality standards set by the EU. The main concern centres around the impact of air quality on human health, particularly through near-surface NOx and Particulate Matter (PM) emissions resulting from commercial and private sector activity including all modes of transport, e.g. taxis, trucks and aircraft.

Ambient concentrations of NO_2 (nitrogen dioxide) and PM are regulated at national and European level for health reasons. Although regulation is in place, further improvement strategies need to be found, particularly to determine the major source of emissions at airports in situations where non-compliance warrants an assessment of whether the emissions emanate from aviation or other sources.

Mitigation responses need to be based on a full understanding of the effect of airport emissions on local air quality, i.e.:

- Refined assessment of ambient air quality at and around airports through appropriate measurement techniques
- Modelling refinement on aircraft engines, Auxiliary Power Units, brake/tyre emissions and their dispersion at the airport
- Knowledge on composition of PM emissions from aircraft exhausts at the airport
- Non-aircraft-related emissions at the airport and road transport emissions around the airport with their share and impact on local air quality
- Determination of the share and impact of aviation on local air quality to help in attribution between sources

Future airport growth and development may be critically dependent on aviation's ability to reduce emissions from aircraft around the airport. However, reduction of emissions not emanating from aircraft around the airport from other modes of transport and infrastructure sources will also be equally important.

With the anticipated growth of global air transport in the long-term, local air quality could well become an important capacity constraint with more and more stringent air-quality standards in the future on NOx and PM emissions.

Therefore, aviation must strive to develop solutions to improve local air quality with the aim of long-term sustainability.

Reducing noise pollution

Disturbance from aircraft noise continues to be perceived as the single most important issue around airports. As a result, many airports have implemented noise-related operating restrictions, e.g. night-time limitations, and these can have a serious impact on the economy, freight services and intercontinental flights. At many of the larger airports in Europe, capacity is already being constrained by noise requirements.

External noise reduction of the Air Transport System is and will remain an important challenge in the future. New technologies (airframes, power plants, operations), innovative ATM (mission and trajectory management) and new vehicle configurations (aircraft, rotorcraft, etc.) will be the challenges. They are being investigated in current large European programs (JTI clean sky) with a view to reducing noise in the medium term.

A significant issue with noise around airports is the attitudes and perceptions of affected people regarding management of operations and new technologies. So, in order to improve noise management, physiological, psychological and sociological determinants of disturbance have to be considered. New noise metrics at airports should be developed to promote improved airport-community relations linked to future aviation development.

Progress towards eliminating noise pollution outside the airport boundary by day and night can be achieved by operating quieter aircraft, better planning of airports and land use around airports, and systematic use of noise-reduction procedures such as continuous descent approach. Further research is required to define new ATM procedures, enhance operational noise abatement and improve understanding of how to mitigate aircraft and airport noise at the level of local communities.

3.3.3. ENVIRONMENTAL INTERDEPENDENCIES

It should be noted that safety is the number one priority of the aviation industry, and that no trade-off against safety will be contemplated. However, there are various other trade-offs that need to be considered, among which environmental trade-offs have become increasingly important.

The aviation industry has constantly strived to reduce emissions of CO_2, NO_x, and noise. Achievement of any one of these three parameters is challenging enough, but to achieve all three simultaneously requires considerable ingenuity, coupled with a clear understanding of the trade-offs that exist between them.

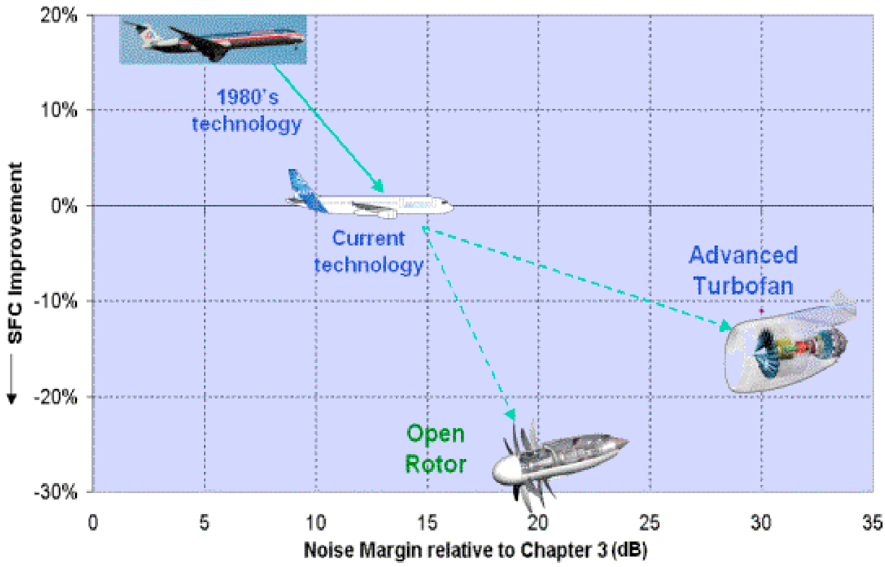
Policy decisions regarding climate change have to be made to reduce global CO_2 emissions from the many contributing sources including aviation. At the same time, political decisions have to be made regarding airport planning and capacity where a strong lobby on noise by local residents is concerned about future air transport growth. This dichotomy is at the heart of trade-offs that need to be considered between noise and CO_2.

A detailed understanding of the quantification and implications of trade-offs, as well as a more precise definition of the various impacts, may help to develop solutions that can minimise aviation's environmental impacts further. With comprehensive modelling, drawing upon such understanding, it may be possible to assess the most effective solutions to the effects of the Air Transport System on the environment including non-technical effects (economy, society, policy, etc.). The following aspects should be considered in this regard:

- Technological trade-offs at aircraft level that lead to an optimal compromise between total environmental performance at system and subsystem level
- Trade-offs at operational level, e.g. airport airside and en-route ATM, considering efficiency versus environmental performance
- Trade-offs between mission, operational and global impact levels of aviation's environmental impact associated with the structure and business practice of the total Air Transport System
- Trade-offs between economic considerations versus the environment, e.g. fleet turnover or transition scenarios for the potential introduction of alternative fuels

As an example, regulations or operational restrictions may influence technology design and development decisions with desired and positive environmental consequences. However, these could also have some less desirable adverse consequences. A comprehensive understanding of the integrated and dependent effects of different technologies or operational pathways is essential to give confidence to the sector in delivering progress.

For example, "open rotor" engines offer a credible way of achieving significant reductions in fuel burn (20-25%) relative to current in-service short-medium range aircraft. However, they will probably be limited to lower flight speeds hence their application will be limited to short-haul aircraft, where marginally increased journey times may be acceptable. Open-rotor technology is therefore affected by operational trade-offs as well as "emissions versus noise" trade-offs. Long-haul aircraft are more likely to continue to be powered by advanced turbofan engines where flight time, airport noise curfews and operational issues may preclude open-rotor solutions. In this example, interdependencies prompt two potential solutions showing that fuel burn can be decreased at the expense of noise compared with equivalent technology turbofans.



Specific fuel consumption versus noise for open-rotor engine technology[17]

Developments in aviation, towards 2050, will almost certainly mean that non-technical drivers will play an increasingly significant influencing role. Nevertheless, the environmental imperative will have to be aligned with other important drivers like economic viability and competitiveness, mobility requirements, social acceptance, policy and regulatory framework (see Chapters 1 and 2) and these considerations will influence the development of the most efficiently optimised green Air Transport System technology options.

3.3.4. IMPACT OF A CHANGING CLIMATE ON AVIATION

A changing climate resulting in changing weather patterns will also have an impact on the air transport sector across a number of aspects including the Air Transport System, operations and consumer habits.

Air Transport System
The Air Transport System may have to endure severe convective and extreme precipitation events and harsh environments more frequently. As a result of this, further emphasis on condition monitoring, improved reliability, sophisticated Communication Navigation Surveillance and related technologies may have to be prioritised.

Weather pattern change could have an impact on flight movements and disruption resulting from potential delays and cancellation. Adapting and adjusting to altered meteorological conditions will pose challenges to all sectors of the Air Transport System in the future.

Operations
Infrastructure in locations that will become more susceptible to more frequent harsh weather or to sea-level rise will require adaptation to such conditions. Patterns of travel may also change as a result of the effects of a changing climate.

[17] *Source: Rolls-Royce*

3.4. SIGNIFICANT POTENTIAL FOR FURTHER EMISSIONS REDUCTIONS

Existing ACARE environmental goals for 2020 against a baseline of the year 2000 are extremely challenging and aim to:

- reduce CO_2 emissions by 50% per passenger kilometre;
- reduce NOx emissions by 80%;
- reduce perceived aircraft noise by 50%.

Each of these goals presents significant engineering challenges. Achieving all three goals on a single aircraft requires optimisation of complex technical solutions. Conventional engineering design indicates that decreasing CO_2 for an engine at the same time as decreasing NOx, poses very significant technical challenges which are compounded further if noise is also to be reduced. Novel solutions outside of the conventional approach to design are required to address these trade-offs.

The reduction in fuel burn and CO_2 will require contributions from engines (15-20%), airframes (20-25%) and improved air traffic management and operational efficiency (5-10%). These goals represent a doubling of the historic rate of improvement and considerable investment in research and development is underway to develop and validate the new technologies necessary.

Meeting these challenging goals will require hard work and further step-change technologies in order to succeed. Much of the innovative technology and process improvement work is carried out by ACARE stakeholders in collaboration with partners, the supply chain and academic institutions utilising relevant skills and knowledge wherever it may exist worldwide.

Environmental improvement in aviation in Europe will provide major benefits to the worldwide fleet of aircraft commensurate with the levels of export that this sector commands.

European aeronautics in collaboration with their partners, invested around 12% of their turnover (which is in excess of €94 billion) in Research and Development in 2007[18]. A significant proportion of this has the objective of reducing the environmental impact of products and operations. The European aviation sector has a significant technological influence that stretches across the worldwide fleet of aircraft.

Looking forward, the challenge is to enable society to continue to benefit from the social and economic aspects of aviation whilst ensuring that aviation plays its part in meeting global environmental targets. Demonstrating growth in traffic without a corresponding growth in long-term emissions is an important step towards sustainability.

3.4.1. TECHNOLOGY IS KEY

For aircraft and engines, ongoing year-on-year improvements result from the progressive introduction of technologies such as lighter materials and structures, improvements in turbo-machinery, and replacement of hydraulics with electrical systems. More radical technologies such as open-rotor engines might be ready for deployment around 2020.

[18] Source: ASD statistics 2007

A 1% structural weight saving, can lead to approximately 0.5% to 1.5% benefit in fuel consumption. The exact benefit depends on many factors, particularly configuration and range (with more benefit being available for medium-range aircraft than long-range), and on whether the whole aircraft design can be re-optimised following the weight change.

Airframe aerodynamic improvements such as natural or hybrid laminar flow control, advanced riblets, low-drag technology and innovative aircraft configurations are together predicted to offer a fuel burn reduction of around 10%[19].

As an example of comparing the assumptions with products currently being designed, the long-range A350XWB, which will enter into service in 2013, is forecast to burn around 30% less fuel than existing aircraft (1980s /1990s technology) on a 4000 nm sector mission[20].

Technology development is expected to continue post-2020, driven essentially by competition. Fuel prices and carbon prices further drive technology implementation.

After 2020 we also anticipate that development work will progress on the next generation of radically new technologies, potentially including such items as blended-wing-body aircraft configurations. We note that, despite the more speculative nature of these assumptions, strong economic and environmental drivers will continue to provide incentives for radical new developments.

Such technologies may offer an additional 20% fuel-efficiency and if they can be fully developed by around 2030, we anticipate that they could largely be deployed into the active fleet by 2050. Such considerations underpin the need for urgent and significant activity on R&D to develop the much-needed solutions to reduce emissions and the associated impacts as early as possible.

The Clean Sky Joint Technology Initiative[21] (JTI) which was launched in Brussels on the 5th of February 2008 is a major EU-wide research programme designed to integrate results of earlier research programmes into large-scale demonstrators. The €1.6 billion, seven-year project will develop and validate technologies and operating practices to focus and drive EU research effort and provide an important impetus towards achieving the ACARE 2020 targets.

Although there is a gap in commitment from 2014 when the existing research programmes conclude and 2020, there is an even bigger concern due to the lack of a vision beyond this timeframe and what will be required to deliver further environmental improvements in aviation in the future.

3.4.2. OPERATIONS

Improved operational practices and optimised aircraft deployment across a network may have the potential to reduce fuel-burn by about 5%, through measures such as better flight planning, speed management, selection of appropriate aircraft, equipment weight reduction and taxiing with one engine shut down after landing. Improved air traffic control resulting in more direct routes and reduced delays could reduce overall fuel burn by 6-12%.

The Single European Sky ATM Research Programme (SESAR) as the European air traffic control infrastructure modernisation programme will be key in developing the new generation air traffic management system to support more efficient operational practices.

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19 Source: Airbus Holistic Road Map to the Future

20 Airbus Technical Press Briefing (May 2008) based on a load factor of 80%

21 Phillips, P. and Koenig, J. (2008). “Clean Sky: The Joint Technology Initiative for Aeronautics and Air Transport, SFWA Brief Status Presentation”, ET-EU Meeting 27 February 2008

3.4.3. SUSTAINABLE FUELS

Renewable fuels could present complementary solutions to reduce greenhouse gas emissions further. These may answer key concerns raised by the use of fossil resources.

For safety and reliability reasons aviation fuel has to match very stringent specifications including energy density, thermal stability and freezing point. It must also be compatible with the materials used in the aircraft and engine fuel systems.

In order to ensure that an overall benefit is sustainable, the net contribution to reducing carbon must be assessed over the whole fuel lifecycle. Broader environmental and social concerns over land use will also determine the viability of particular fuel sources.

Engines and fuel systems are already cleared to use a “synthetic” kerosene blend partially derived from coal rather than oil through the Fischer Tropsch process. In 2009, fuel from coal to liquid (CTL), gas (GTL) or biomass (BTL) generically referred to as XTL was approved for use in civil applications with up to 50% blend with conventional jet fuel.

There is also potential to create synthetic kerosene from other feedstocks including biomass. Although not yet industrially developed, it is the most promising alternative to kerosene, as it will benefit from the experience gained on the coal-to-liquid process above. Concerns over the availability of biomass and its transport would need to be addressed. Efficiency over the complete fuel cycle and related technical and environmental issues will need to be resolved before commercial scale application in aircraft fleets.

The aviation sector will continue to explore all potential options for renewable fuels and invest in new developments in this area working with fuel companies, research laboratories, aircraft manufacturers and authorities as necessary.

Lower carbon fuels produced from sustainable, second- and third-generation feedstocks such as jatropha, algae, biomass or hydrocarbon-containing waste could make a significant contribution to reducing CO_2 emissions from aviation.

For a candidate fuel to represent a viable alternative to kerosene:

- It must be **technically suitable** for use in existing aircraft, engines and fuel systems, meeting or exceeding current fuel specifications.
- It must be derived from **environmentally sustainable** sources without adversely impacting food-production, land-use or water-scarcity, and must show a reduction in carbon dioxide emissions over its lifecycle, relative to kerosene.
- Production must be **industrially scaleable** and economically feasible.

In order to have any significant impact by 2050, sustainable fuels will need to be compatible with existing engine, airframe and fuel supply systems and infrastructure.

Beyond this timescale hydrogen or other alternatives may offer potential.

3.5. ECONOMIC, SOCIAL AND GLOBAL CONSIDERATIONS

Globally, over 2 billion passengers flew in the course of 2007. The air transport industry generates approximately 29 million jobs worldwide and has an economic impact that is estimated to be equivalent to 8% of the global gross domestic product (GDP) making aviation an important mode of public transport for the modern world. The challenge for the industry is to preserve the benefits to society of aviation whilst minimising its environmental impacts.

A competitive and commercially viable Air Transport System can make a substantial positive contribution to the European economy and also support regional development and social exchange (business, travel, and visiting friends and family).

The aviation sector recognises the importance of strong relationships with local communities, customers, partners and employees to meet society's air transport needs.

Consumer habits
As society becomes accustomed to the notion of carbon constraints, a number of considerations could alter the future of civil aviation, including:

- flying slower in order to save fuel burn;
- accepting shorter hop journeys in place of single long-haul travel;
- more advanced systems enabling use of personal communications and data systems on-board aircraft;
- altered business models; and
- alternatives to flying to serve communication needs.

These important considerations warrant further study taking due account of likely climatic effects going forward. Some of these may have an impact on local noise and air quality and on safety.

There is no doubt that choices will need to be made by both policy makers and companies in terms of investment decisions as well as by society over where to spend its carbon budget. For these reasons it makes sense to explore the full suit of opportunities that exist to reduce aviation emissions and leave no stone unturned.

3.5.1. AVIATION AND THE EMISSIONS TRADING SCHEME (ETS)

ACARE stakeholders have worked with European policymakers to develop pragmatic approaches to the design elements for the EU Emissions Trading Scheme (EU ETS).

EU airlines and operators broadly support the inclusion of aviation in the European ETS, as an interim step towards a global scheme. In the last two years legislation to include aviation in the EU Emissions Trading Scheme has been under development between the European Parliament and Council, through the co-decision process. Some airlines and airports have actively contributed to that debate, supporting the inclusion of aviation into emissions trading on the basis that is environmentally efficient and economically credible.

A decision was reached during 2008 to include aviation in the EU ETS from 2012, an important step towards a global solution.

To be more effective, any aviation emissions trading schemes should be applied at a global level. Other market-based measures linked with or embedded in ETS, e.g. auctioning, will have to prove their long-term economic and environmental viability in redirecting resources toward the most efficient technological innovations. This would be an effective way to improve aviation's environmental performance in the market place.

3.5.2. GLOBAL AGREEMENT TO ADDRESS CLIMATE CHANGE

In December 2009, governments met in the Copenhagen UNFCCC 15th Conference of Parties (COP15) to negotiate the post-2012 Kyoto climate change targets. Although a detailed legally binding commitment has yet to be agreed, a Copenhagen Accord was "noted" by the UN, setting out broad aims including the following:

- a collective desire to limit global temperature rise to no more than 2 degrees Celsius, through "deep cuts in global emissions"
- pledges of some $30 billion of short-term funding for mitigation and adaptation in the developing world (from EU, Japan, USA), together with a commitment to find $100 billion per year by 2020
- appendices which list 1) economy-wide emissions targets for developed nations, and 2) mitigation actions to be taken by developing nations, respectively
- specific mention of "substantial finance to prevent deforestation"

The international aviation and shipping industries may in the future be incorporated into the UNFCCC through sectoral agreements in which their respective emissions are attributed not to nation states, but viewed as a global whole. Although delegates at the conference reportedly viewed proposals of this nature positively, no formal outcome concerning these sectors was declared.

The negotiating position[22] suggested by the European Union Council of Environment Ministers for COP15 describes how any post-Kyoto agreement should deal with international aviation:

Clause 19. *REITERATES that the global emission reduction targets for international aviation and maritime transport, consistent with a global reduction path towards meeting the 2 deg.C objective, should be incorporated into a Copenhagen agreement and that the Parties should commit to work through ICAO and IMO to enable an agreement that does not lead to competitive distortions or carbon leakage, that is agreed in 2010 and approved by 2011; CONSIDERS that for negotiating purposes at COP15, global reduction targets for greenhouse gas emissions from international aviation and maritime transport should be set by UNFCCC to –10 per cent for the aviation sector and to –20 per cent for the maritime sector below 2005 levels by 2020 to be implemented globally in a manner that ensures a level playing field; REAFFIRMS that, in this context, the EU supports the use of global market-based instruments to reduce emissions from these sectors and that such instruments should be developed within ICAO and IMO, respectively.*

International Civil Aviation Organisation (ICAO) proposed way forward

In 2007 ICAO created a Group on International Aviation and Climate Change (GIACC) consisting of 15 high-level representatives (including 3 European representatives) to develop a strategy with respect to the limitation and reduction of international civil aviation global climate impacts.

The following areas were covered by GIACC to define a programme of action:

- more efficient operational measures in the maintenance and operation of aircraft and airports
- market-based measures including emissions trading
- voluntary measures including carbon offsets, recognition mechanisms, measuring efficiency and verification of outcomes

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22 EU proposal for aviation at COP15, 21 October 2009, paragraph 19

- improvements in Air Traffic Management (ATM) including technological advances that take into account the Global ATM operational concept and the Global Air Navigation Plan (GANP)
- dissemination of technological advances, e.g. alternative fuel, improved engine performance, airframe advances, etc.
- identification of the most effective ways to assist States in achieving emissions reductions

In October 2009, ICAO agreed a set of recommendations[23] to put forward to COP15, and a key aspect of this includes a declaration that "*International Aviation and Climate Change, States and relevant organizations will work through ICAO to achieve a global annual average fuel efficiency improvement of 2% over the medium term until 2020 and an aspirational global fuel efficiency improvement rate of 2% per annum in the long term from 2021 to 2050, calculated on the basis of volume of fuel used per revenue tonne kilometer(RTK) performed.*"

This and other targets detailed by ICAO are dramatic and the level of effort required to achieve them needs a comprehensive assessment of all potential improvement opportunities.

Global Aviation Sector proposals

The Global Aviation Sector[24] comprising IATA, ACI, CANSO and ICCAIA has reached an agreement setting out specific targets for the global industry, including international and national emissions and a process to secure their achievement. These targets are as follows:

- to improve CO_2 efficiency by an average of 1.5% per year up to 2020
- to stabilise net CO_2 emissions from 2020 (i.e. achieve carbon-neutral growth)
- to reduce net CO_2 emissions by 50% by 2050, compared with 2005 levels

The Global Aviation Sector, in its common position, propose that *Aviation CO_2 emissions should be addressed through a global sectoral approach and accounted for in the global emissions inventory, not at a regional or national level. It is essential that emissions from aviation are accounted for only once, whether from domestic or international activities and that any market-based measures addressing aviation are not duplicative.*

The ICAO, EU and Global Aviation Sector proposals provide very strong reasons for the need for a new vision so that new challenges may be addressed with the urgency they deserve and for the long-term, towards 2050.

With a view to the European sector playing a full role in these important international debates and fulfilling its obligations, ACARE must promote solutions and pathways that enable Europe to play a strong and important leading role to define aviations position for the post-Kyoto agreement as well as the long-term.

ACARE is in a position to do this, as its mission is to lead innovative thinking towards easing the environmental impacts of a thriving aviation sector delivering the social and economic needs of society.

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23 ICAO high-level meeting on international aviation & climate change, 7-9 October, Montreal 2009

24 Global Aviation Sector comprises International Air Transport Association (IATA), Airports Council International (ACI), Civil Air Navigation Services Organisation (CANSO), and International Coordinating Council of Aerospace Industries Associations (ICCAIA)

3.6 CONCLUSION

The environment is a major societal and political issue and becoming more so with future emissions-related regulation expected to become more prevalent than today. The air transport sector recognises the substantial challenges posed by climate change and other environmental concerns such as noise and air quality and as a major contributor the sector is committed to finding solutions to mitigate this impact.

A significant proportion of the European aeronautics investment in Research and Development has the objective of reducing the environmental impact of products and operations. As a result of the European aviation sector's technological influence that stretches across the worldwide fleet of aircraft, this investment has the potential to provide significant environmental benefit at global level.

Even though the aviation industry's current share of total man-made emissions is small, the expected growth in air traffic represents a significant challenge, and therefore aviation will have to make a major effort to reduce its environmental impact. Any reduction in absolute emissions from air transport will be difficult to accomplish, unless radical improvements in technology are forthcoming. Aviation must therefore continue to improve its environmental performance by keeping emissions at sustainable levels, and reducing the global CO_2 and other emissions impacts through mitigation based on a better understanding of the environmental impacts.

More so than ever before environmental trade-offs, including those between emissions and noise, will have to be balanced to find optimised solutions for the whole Air Transport System and its sub-systems of the future. A European interdependency modelling capability is needed for this task.

Reducing disturbance around airports is also a challenge, with the need to continue noise reduction and ensure that air quality around airports remains acceptable. Choices may need to be made on trade-offs between these parameters.

Aviation is coupled with energy trends. As with other sectors, aviation is dependent on, and will have to deal with, energy availability in the coming decades to continue as an important development factor in future societies. **Aviation will have to develop long-term strategies for alternative fuels that will be technically suitable, environmentally sustainable as well as commercially scaleable.**

The sector recognises the role that market-based measures can play on schemes such as emissions trading which may be more effective when applied at a global level.

The air transport sector is in a unique position to develop technology solutions, which can play a significant part in addressing the environmental challenges. Europe must play a major and leading role in the definition of the post-Kyoto orientations for the long-term that will affect the future development of aviation.

The air transport sector is proud of its record in developing products which have brought, and continue to bring, huge social and economic benefits to Europe and to the rest of the world. We are confident that we can continue to rise to the environmental challenge going forward. **A new vision is now essential to plot the way towards assuring a sustainable future for aviation.**

CHAPTER 4: TECHNOLOGY AND OPERATIONS

4.1. INTRODUCTION

Technology has always been critical to progress in aeronautics. While the basic configuration of today's air transport vehicles and the system in which these operate may appear to have been substantially the same **since the 1960s**, that impression is superficial - **almost everything has changed**.

Compared with 30 years ago, today's airliners use 70% less fuel, create 75% less noise, and yet carry more passengers farther, with increased safety and security, and at a lower real cost every year. This significant capability improvement, allied with the unrivalled point-to-point service capability of air transport in a rapidly developing world, has brought aviation to the masses and enabled the average 5% year-on-year growth over the same period. This extraordinary improvement has been achieved through technology. Yet if the growth is to continue at the same rate over the next 30 years as forecast, then significant continued improvements have to be developed.

The information presented in Chapters 0-3 indicates that the growth demand is likely to continue against a background of evolving social, economic and environmental factors and requirements. **This chapter looks at possible ways in which the Air Transport System and its elements need to evolve and the technologies that would be required to enable this evolution**. Some improvements could be made via the development of current concepts, but these are naturally limited, hence breakthroughs will have to be sought. The mechanisms for developing new technology are considered, with a discussion of the changes that will be required to meet the challenges of the future.

4.1.1. SOME IMAGES OF THE FUTURE

Any forecast towards 2050 represents a journey into the unknown, but the operational challenges air transport is likely to encounter are already emerging. There exists some scope, then, for speculating about possible scenarios or alternative "images" of the future Air Transport System. As an illustration, here are four possible future concepts of air transport.

The ultra green: This is an aircraft and operational concept that has been considered before, but some elements have to be re-emphasised given the growing importance of the environment. For this aircraft, almost everything will be compromised in favour of "green" operations. As a consequence, the aircraft will be designed to use the minimum of fuel in every phase of flight. The aircraft will be designed and maintained to operate at the highest possible efficiency, whatever the cost. Radical operational practices such as formation flying may be considered. This will lead to operational changes such as speed reduction and altitude optimisation to minimise environmental impact. Systems will ensure the aircraft engines are only used in flight, and then for the most efficient point–to-point trajectory, even if this means longer waiting times to find that perfect mission slot availability. Every effort will be expended to meet noise concerns: 5-degree approach at all airfields; no on-ground engine running except for take-off; and significant design and operational changes to minimise take-off noise (almost at any penalty).

The flying wing cargo aircraft: A move away from the current configuration of aircraft has its challenges. Flying wings or blended-wing-body aircraft offer an opportunity for the future. Since such designs present challenges for passengers, this configuration of aircraft could first find a role for cargo transport. The design could be adapted later for passenger applications.

The people-oriented system: Today's traveller is sometimes treated not as an individual but as part of a herd. The experience of air travel often includes the invasion of privacy by security measures, discomfort during long transits, lengthy waiting times, inadequate information, and uncomfortable conditions - both on the ground and in the air. As the period towards 2050 approaches, there is likely to be substantial effort expended on improving the present situation on all fronts. Solutions for passenger-focused, end-to-end service will undoubtedly appeal strongly to the flying passenger of the future. Expect solutions that provide the same level of ease-of-access as buses and trains, significant improvements in the treatment of luggage, and all-in-all a system that responds to people's demands and expectations. Seamless flow for both passengers and freight can be seen as a logistics issue, but technology will be essential to enable the appropriate logistic systems and associated co-modality needs.

The highly intelligent, cognitive system: Imagine a whole system that is self-monitoring and controlling, with a very high degree of communication between the various system elements and many of the operational decisions managed by the system through integrated optimisation, rules and algorithms to manage the whole complex system in an optimised system-of-systems fashion. Human intervention and control is at an absolute minimum, the autonomy of the vehicle is maximised, and overall system robustness and reliability significantly enhanced.

These four images, among others, may be somewhat extreme, but they do serve to open the imagination to some possibilities as to the ways in which the Air Transport System could evolve.

Towards 2050 - getting "Out of the Box": As a result of the concern over the rate of progress of innovation in air transport, **the European Commission funded the "Out of the Box" project to identify potential new concepts and technologies for future air transport.** [25] [Ref. 43]

The project focused on a number of radical changes to the system rather than taking incremental steps. During the first part of the project, some 100 ideas were generated. (These are described in Chapter of this report.) The ideas were then assessed in a workshop event during the second part of the project and the most promising of these were then developed. The assessment resulted in six promising ideas, covering alternative propulsion, Global ATS, the cruiser/feeder type of long-range transport, ground-assisted take-off and landing, personal air travel, and advanced systems for airports.

The technological content of these concepts was then reviewed and identified. A consequence of looking far into the future for radical solutions is that some may take a long time to come to fruition. Therefore, some type of incubator mechanism should be set up within Europe to help such fundamental knowledge develop. Out of the Box developed a systematic approach to stimulate radical and novel ideas for air transport, proposing that future workshops and in-house research by European air transport stakeholders could lead to additional ideas which, once assessed, could provide additional opportunities to support and develop new ideas for the Air Transport System of the future. After reviewing and shortlisting possible ideas, some of the radical concepts proposed within this exercise were:

- examination of new primary energy sources for propulsive power
- distributed propulsive power and control functions
- glider-like aircraft with low power consumption
- formation flight for power reduction
- connecting the passenger to the aircraft as a process
- off-shore airports and flying boats
- door-to-door journey ticketing
- personal air transport systems
- global, seamless and autonomous ATS
- cruiser/feeder concept
- ground-assisted take-off and landing

[25] Out of The Box: Ideas about the future of air transport, European Commission, 2007

4.2. TECHNOLOGY IN THE AIR TRANSPORT SYSTEM

The Air Transport System of the future will need to address various, changing requirements in an efficient way with **technology adapted at three levels**.

Firstly, the role of air transport in the wider transportation system will evolve, competing with ground transport in some areas, and often as a result of the unique capability of aviation in maintaining a strong set of specific roles and support systems. This will inevitably lead to air transport aviation having to find ways to better integrate with intermodal transportation systems so that an improved point-to-point service is provided for the end user.

Secondly, the overall Air Transport System will have to develop, with improvements from evolutions and changes that **reconfigure the system or impact across a number of elements of the system in an integrated way.**

Thirdly, each individual element will have to improve and develop in its own right.

The system can be viewed as four main blocks:

- air vehicle (inc. the power plant)
- air traffic management (ATM) system
- airline and operations [inc. maintenance, repair and overhaul (MRO) & training]
- airport

Each of these blocks will have to improve in its own right, and each will need new technologies to enable these improvements.

Any individual new technology may be able to deliver a specific benefit, but it is important to consider when and how the technology is used, and how the initiative integrates into a final solution to maximise the benefits. Many technologies are enablers, but if the design solution or process that the technology enables cannot fully capitalise on the potential of technology, then obviously the benefits cannot be fully realised. Many technologies appear to offer significant advantages in isolation, but when integrated into the complete solution result in negative impacts elsewhere, so the overall gain at system-level is reduced. For these reasons, **it is** also **essential to understand the issues involved in deploying and utilising new technologies** and how to overcome the barriers that exist and inevitably resist or slow down any change. Often, the more far-reaching a new technology is the greater the potential benefits, but there are also barriers to its introduction.

Another important consideration is that new technology need not only be in the hardware/software of the product. New technical approaches can dramatically improve operational practices and services that exist in the Air Transport System. This is especially so where **new technologies in the hardware/software enable new operational processes or service offerings not previously considered possible**. It is often essential to understand and apply these changes across the whole ATS to realise maximum benefits, but making changes across the whole system is difficult because of the multi-national, multi-user involvement in air transport. New efforts will be needed in coordination and cross-sector international leadership and standardisation to truly optimise air transport efficiency.

Even with the growth forecasts and the improvements made in the past, the challenges and opportunities for the future remain enormous, and the need for new technology and operational practices to address these challenges is greater now than ever before. Environmental concerns allied to increasing fuel prices and the potential reduction in availability mean that fuel-burn efficiency and emissions are of the highest priority on most agendas at present, but other improvement targets remain important for the long term-growth, profitability and stability of air transport.

Evolving business offerings and capabilities drive new needs for technology. In the last 10 years, the massive growth of the Low-Cost Carrier (LCC) has created a new set of product and technology requirements for the LCC of tomorrow. The very high utilisation, rapid turnaround, no-frills service generates differing product requirements from the more traditional full-service operation. The growth of ancillary revenue streams to improve the profitability of the LCCs is adding demands. In the next few decades, we can imagine the emergence of further new business models (e.g. personal transport, air taxis, vertical take-off and landing services into city centre "vertiports"), and with these come new challenges for the flexibility of ATS components, which must be incorporated into operations effectively.

As a result of the safety-critical and hence highly regulated nature of the whole Air Transport System, an understanding of the regulatory implications of new technologies and associated product/service changes is vital. Defining and agreeing changes in regulations can take years and hence significantly slow technology deployment**. Some new technologies will allow new regulatory approaches for addressing existing concerns (aircraft health management is a good example) but without these associated regulatory changes the benefits offered by the new technology will not be fully realised.**

Many of the technologies and solutions we use today have evolved over many years, and while there are still improvements to be found in most areas, it is reasonable to assume that by the 2050 timeframe **the limits of improvement will be met in some areas. This will drive the need for breakthrough solutions to enable the next step**. Introducing breakthroughs is challenging when these have to compete with existing, highly optimised solutions in a safety-critical industry that has long product-development cycle times. This will lead to a need to identify new ways to research and develop these breakthrough technologies in a low-risk, high-gain approach. Design and design analysis of breakthrough technology applications do not have the benefits of experience, so there is an inevitable increased uncertainty and risk in development. This leads on to **an increased need to test and validate new technologies**, and with this increased R&D cost and timescales.

Finally, whatever the targets set for technologies within the ACARE Vision or elsewhere, **there are only two real reasons why any new technology should be applied** in the products or elements of ATS. The greatest motivation for the application of any technology is the realisation of a commercial benefit that justifies the change, i.e. **there is a business case for the application of the technology. In the absence of a business case, there is typically only one other motivator - legislation**. Yet even where a technology will only be applied because legislation requires it, any new technology application must still have an optimised business case to avoid undue commercial penalties and pressures on the providers.

4.3. TECHNOLOGICAL REQUIREMENTS

Before committing to directions for technology, and considering measures of improvement, we need to understand the demands of the future which operational changes and technology will have to address. The demands (covered in the previous chapters) made on the future ATS have the following themes:

- Current ATS and furture requirements
- Social factors
- Economic factors
- Environmental factors

If we combine these themes, we start to see a world of the future where aviation faces much greater challenges than at present. In this rapidly changing situation, the global environmental challenges and the long-term growth of the global economy, particularly the rapid development of Asia, will come to exert massive pressures on the air transport industry to adapt. These pressures will come in the from of the (already identified) ACARE 2020 areas, but with further, even more challenging goals in the 2030+ timeframe - along with a number of new considerations.

4.3.1. EXISTING ACARE GOALS

Through the previous ACARE work, the technological improvement targets have been focused on delivering benefits in the areas of:

- Quality and affordability
- Environment
- ATS efficiency
- Safety
- Security

The details of the 2020 targets behind the existing ACARE goals are addressed in Chapter 0, and the associated referenced ACARE documents: Vision 2020 and the SRAs. Beyond 2020, the same areas will clearly remain, but the future targets will be even tougher - though these are unclear. A number of organisations, including IATA, are starting to target "Carbon Neutral by 2050". This is a very high expectation, and without plans to meet this type of target, the industry may come to be seen as irresponsible, socially unacceptable, and - at the extreme - subject to sanctions and penalties. Some of the targets will need to be adjusted to changing needs and the latest thinking. Of particular interest, there is the need to move the environmental targets from simple CO_2 per revenue passenger-kilometre to the more acceptable and rigorous approach of a complete lifecycle analysis that would address all the manufacturing, disposal, and an even system infrastructure impacts

4.3.2. ADDITIONAL DEMANDS AND CHANGING OPERATIONAL SCENARIOS

All of the existing ACARE areas remain as suitable technology and operational practice improvement targets, but - over time - new, more focused areas are likely to arise and will require new technology to enable them, while existing areas find their scope or intent extended. For example, consider the following:

- Capacity enhancement/congestion management
- Reliability and robustness vs. flexibility
- Improved revenues through ancillary offerings and new business models
- Passenger Comfort/service offering
- No dependence on fossil fuels
- Improved integration within ATS and extended systems (e.g. ground transport, the Internet)
- Extended environmental challenges
- Integration with new ATS users
- Development cost and timescales
- Noise and airport and air traffic restriction from noise regulations

These *new* challenges can be detailed in the following way.

Capacity issues and reliability/robustness

- **High levels of reliability will be needed across the entire transport system** as each element will be approaching the optimum, so little or no spare capacity exists in any element, thus any failure will have a wide impact.
- **High interdependency: many elements of ATS will become collectively responsible for increasing and sustaining the capability and capacity of other elements**.

- Passengers and freight operators could become less patient and less tolerant, resulting in greater demand for regional airports to offer connections for a higher number of global destinations.
- The entire transport chain will have to become more robust and resilient to shocks in the system. The transport chain will accept high levels of automation to maintain acceptable levels of service. This will include increased levels of aircraft automation, aircraft autonomy and cooperation.
- Fewer new large airports are likely to be constructed, so the existing ones will need to increase capacity to a maximum; current minor and regional airports as well as heliports and vertiports will expand their roles and capacity.
- The Air Traffic Management system will reach natural limit capacity in Europe and other busy areas, naturally limiting growth - unless new approaches can be developed.
- If current practices do not change, then in many areas it can be predicted that by 2050, the transport chain involved in supplying airports with passengers, mechanics, crew, staff, food, fuel, etc., will regularly experience failures at numerous points along the chain. Within a highly optimised system, the knock-on impacts of such failures are likely to be considerable.

Operating cost challenges and improving revenues through new business models

- As air travel continues the move from a luxury to a commodity service in many areas, ticket prices will decrease - so the cost base will have to be continually reduced. This will lead to major cost pressures on the unavoidable operating costs and cancellation of the “free” full service offerings to end-users, or - more often - these services being sold as options. Many low-cost carriers already see this as the only way to sustain growth.
- Increasing fuel prices will lead airlines to place increased commercial focus on fuel efficiency.
- Airlines will also look for ways to reduce labour costs. De-skilling and automation will therefore be strong themes in the future - both in the air and on the ground.
- Airlines need to maintain profitability, so the role of the ancillary service offerings and associated revenue streams will increase. To maximise the opportunity here, it is necessary to employ new technologies to develop innovative business offerings alongside the primary transportation role. This affects airlines and airports directly, since both interface with the end-user; however, the air vehicle is also impacted since this has to provide enabling technologies to the airline.
- A fully integrated multi-modal system will generate new business models where the Air Transport System is an integral part of the overall public transport system, playing its role wherever this is the most efficient mechanism within the overall system.

Increased passenger comfort/service offering

- At the same time as air transport is becoming a commodity and highly price sensitive to some, the socio-economic factors in some areas are also resulting in the opposite effect, with an increase in wealthy, older travellers, who will be looking for a better service. The provision of technology to enable such a service offering across all aspects of ATS will be necessary.
- Based on existing or new Information and Communication Technologies (ICTs) adapted to aeronautics, full aircraft connectivity (i.e. inside and outside the aircraft) will offer new services and more comfort for passengers.

Eliminating dependence on fossil fuels

- Outside of the environmental concerns, the increasing cost and decreasing availability of fossils fuels will result in a need to lessen or remove this dependency.

Improved integration within ATS and the extended transport system

- Today, every element of ATS is interdependant to some extent, and there are many points of interaction and integration. To achieve any significant improvement in the system of the future, **it will be necessary to take a holistic approach and look to optimise the whole system in order to provide a seamless solution for both passengers and freight**.
- Significant new technology steps in any single element will impact most if not all of the other elements. An integrated approach to the introduction of new technologies will ensure that benefits are maximised at system level, such that major barriers to change are removed.
- End-users of the transport system will become more and more focused on complete journey measures (time, cost, etc.). This requires a whole system optimisation, and future ATS improvements will need to be developed in close association with the extended transport system.
- As large numbers of the “ACARE 2020 vision” aircraft start to operate, the system-level optimisation potential that these aircraft offer will be unlocked. As a result, ATS will evolve and individual elements will need “re-tuning” - future-proofing will be required to allow for these adaptations.

Extended environmental challenges

- While environmental targets have been on the agenda for some years, the ever-increasing focus means that every aspect will need to be addressed, however minor. This broad-ranging approach will mean that technology will have to address issues that are today not so high on the research agenda; for example, contrail avoidance, health hazards in manufacturing, airport environmental footprints, recycling, disposal, etc.

New ATS users

- Emergence of unmanned aerial systems
- Emergence of very light jets and leisure traffic
- Emergence of a number of supersonic aircraft
- Growth in scheduled VTOL air transport by rotorcraft
- Potential emergence of emissions-reduced aircraft with different operating characteristics

The operating characteristics of these aircraft are likely to make smaller airfields accessible to aviation, leading to more point-to-point connections and more dispersed traffic flows.

At the same time, spacing will be needed between established commercial aviation, which will continue to use existing airports, and these “new” traffic participants with other envelopes.

4.4. KEY TECHNOLOGY THEMES

All of the new and existing challenges should be considered when shaping and directing future research activities allied to the Air Transport System. This research will need to be applied to both whole-systems issues and to the individual elements, and should be used to develop existing technologies to the limit, provide new integrated solutions, and search for breakthroughs.

In many cases, existing technologies have been developed over a number of years, and, while these still have some developmental capability, they may well approach a natural asymptote towards the 2050 timeframe - so some breakthrough(s) will need to be identified. Breakthrough technologies by definition are hard to identify and have a long development lead time. As such, these technologies have an uncertain value and are at risk until a late technology-readiness level is attained. However, breakthrough technologies also typically have a wide impact on other aspects of ATS.

The Air Transport System has a number of constituent sectors, namely: the air vehicle, including the power-plant; the Air Traffic Management system; the airports; and the airline and airline operations - along with maintenance, repair and overhaul (MRO). Each sector has a role to play in the overall transport system, with its individual contribution to a vision for the future. Each sector can contribute in isolation, but many are also interdependant, and many of the changes envisaged for the future are likely to be multi-sectoral. It is envisaged that tomorrow's needs will only be met by taking a holistic view of improving ATS, and even - to some extent - considering how ATS may have to become a more integrated part of a total transport system.

4.4.1. ATS TECHNOLOGIES IN THE WIDER TRANSPORT SYSTEM

Opportunities for improving the complete transport offering, by providing an optimised end-to-end service, are considerable. Future solutions will need to provide seamless services, whatever the transport modes involved. The challenge will be to find ways to build a service that allows customisable, linked systems that represent a single-booking and check-in, with little or no waiting time, no inter-modal baggage handling or repackaging of freight, no intermediate security checks, no travelling away from the eventual destination, and so on.

The provision of this seamless service will require a significant step forward from where we are today, on many fronts. The detailed research needs are not as yet defined as such, but a range of "topics" or "research areas" will need to be developed. Studies should be undertaken to fully understand how this model could be optimised and to determine which technologies would be required. As air transport will be the mode that covers most of the overall distances on such inter-modal journeys, then air transport will have to be effectively integrated with other modes in remote destinations around the world. The leadership for meeting this challenge will therefore most likely need to come from within ATS.

Challenges and opportunities for improved inter-modality in the future:

- Existing and new major airports will have to become substantially more integrated with ground transportation systems.
- Increasing use of smaller airports is likely, but this will bring new integration challenges.
- Networks of new heliports/"vertiports" will be integrated with the whole Air Transportation System and located as close as possible to urban and business centres.
- There will be a focus on integrated travelling opportunities rather than on aviation.
- Improved inter-modal handling processes will be developed, alongside technologies for passengers, luggage and freight, including ticketing, security, and physical transit.
- Shared information systems will be put in place to provide all modes with access to and use of common data.
- New technologies will be developed for customers to plan and book travel, using mobile communications networks and systems to adjust these, and see the progress of any element while travelling.
- New travel concepts will need to be identified based on door-to-door service provision.

4.4.2. INTRA-ATS TECHNOLOGY

Since the elements of ATS are interlinked on many levels, it is important to recognise the opportunities and risks that this presents as we move forward.

Where the capability of a multi-sector element requires a significant performance improvement, it will be necessary to stand back and review the total ATS approach prior to making the next step. Each sector puts constraints on the other, so truly significant change is likely to be multi-sector. A good example of this would be security: this remains a challenge for ATS, and innovative approaches must be found to deal with new and demanding technical and societal needs. Splitting down the security issue of the air transportation system into segments could make it easier to focus on the issues, but this may inhibit the optimisation of the total system. The individual elements of security in inter-modal structures involve: security in ground services, etc.; security within air transport infrastructures (people and goods); security while boarding; air space security; take-off, en-route, approach and landing subspaces. These elements can all be studied individually and within each part of ATS. However, to achieve the greatest benefit with the least impact, **technology solutions have to be developed with a more systemic view.**

Health monitoring and predictive maintenance are similar fields of technology, where an integrated, multi-sectoral approach will yield the maximum benefits for all, but may prove to be of limited benefit unless addressed in a truly integrated fashion, with an understanding of how each part enables the others and with a precise focus on the complete value chain.

If major step changes are anticipated in any one sector, then as well as studying and maturing this technology in the primarily affected sector, the impacts in other sectors must be studied, and potential benefits maximised at global level. ATM is a field which is often impacted in this way, since improvements in the ATM system cannot stand alone; the air vehicle is inevitably affected - as are the operators.

There are numerous inefficiencies between the sectors, so work on optimising the interfaces will yield system-level benefits.

With increased integration and whole-system-level optimisation, the transport chain will have to become more resilient and accept a high degree of automation to maintain acceptable levels of service.

As a worldwide industry, the progress of air transport in some areas will need to be achieved beyond Europe, with improvements made for all nations in global ATS.

4.4.3. THE AIR VEHICLE

The only worldwide element of ATS is the air vehicle, thus intra-ATS improvements may be best driven from the air vehicle as the natural hub in the system of systems.

Key air vehicle technologies improvement themes

- **Configurations and overall aircraft**
  - Continuous improvement of conventional configurations will deliver benefits up to an approaching asymptote, but there is a natural limit here that will entail significant change to in order reach the targets likely towards the 2050 timeframe. Alternative configurations **will need to be introduced for step change**, or to respond to substantial rebalancing of priorities in optimisation targets; for example, ultra-fast rotorcraft and tilt-rotors, blended-wing-body (BWB), and so on. Enormous effort will be needed to overcome the barriers to revolutionary configuration change; major, full-scale demonstration programmes will be required and many integration issues will need to be addressed.

- **Aerodynamics and flight performance**
  - Continued optimisation approaching natural limit in timescale
  - Step changes needed in flow control and drag-reduction active and passive systems

- **Systems**
  - The pace of advance for many under-pinning technologies is very rapid (electronics, data processing power, communications network). The major challenge, therefore, is to enable upgrades over the life of the product. Scalable, modular and unified platform infrastructure covering the whole aircraft will offer a global low-cost solution for all computing and network domains (safety critical, AOC applications, cabin control and in-flight entertainment).
  - **Information management systems: the backbone of on-board systems infrastructure will need to extend functionality and move to full integration with rest of ATS and other systems.**
  - Communication, Navigation, Surveillance Systems (CNS) should improve the seamless integration of the aircraft within ATS.
  - New systems will be able to grow and adapt to ever-increasing demands for the new functions required, while maintaining safety and interface capability with non-aeronautical solutions and standards (open architectures).
  - Advanced aircraft control systems should support control of unconventional configurations and unstable airframes.
  - Mission management systems will need to improve, inclusive of step change in automation (single or no pilot) and full integration with ground systems for ground and air movements, with increased aircraft autonomy enabled when appropriate.
  - Dynamic on-board energy management
  - Health monitoring and management for both systems and structures
  - **Health monitoring will be the technological frame for integration of any new enabling technologies**, affecting systems, engines, structures and cabin, with improvement in safety records, effectiveness, reliability and affordability, reducing weight, consumption and cost.

- **Structures**
  - Materials
    - Metallic lightweight, low-cost alloys are likely to improve in the evolutionary sense and cope with composite material in the case of titanium.
    - **Composites still have step change potential, enabled through nano-technologies**, etc., to deliver new capabilities; self-repairing, signal carrying, electrical conductance, etc. **A further innovation here will be the development and application of composites from renewable sources - "bio-composites".**
    - Multifunctional materials and related integrated solutions
  - Automated Assembly Technologies
  - Component solutions
    - Innovation integrated approaches
  - Other innovative technologies that can provide breakthroughs and will need long investment to deliver benefits:
    - Health monitoring
    - Adaptive structures capable of modifying properties or geometry according to demands
    - **Nano-technology: the creation of tailor-made structures with step changes in capability or properties not previously provided by structural materials**

        - Self-repairing coatings
        - Additive manufacturing
        - **Bio-organic inspired structures**

- **Cabin**
    - Fastest-moving technology area: the need for flexibility and adaptability, with opportunities for significant service improvements and integration with ground systems, etc.

- **Product development**
    - Multi-disciplinary virtual design will enable full aircraft optimisation, risk reduction, and allow development time/cost improvements.

- **Manufacturing and operations**
    - Strong emphasis on the efficient factory of the future, with more innovation, flexibility, environment neutral status, etc.
- **In-service support technologies**
    - Step changes in integrated systems between aircraft and maintenance systems leading to zero/ultra-low maintenance impact on revenue operations.

- **Power plant**
    - Conventional turbofan architectures and installations will approach limits within the 2030+ timescale; nevertheless, research should continue to realise any potential, particularly in terms of the lightweight systems for enabling higher bypass ratios and the high-temperature systems for improved thermal efficiency and reduced NOx emissions. These technologies will, in the majority of cases, also deliver benefit in novel architectures and installations.
    - Novel engine architectures are beginning to be explored, but a dramatic increase in activity is needed. This must be executed in even closer collaboration with airframe and system-technology themes because of close coupling between new engine architectures and new aircraft and system configurations. Key areas include:
    - Ultra-high bypass ratio systems, including open rotors
    - Active/adaptive engines which self-optimise performance in real time
    - Complex cycles, making more effective use of heat within the system, such as intercooled engines
    - More electric engines
    - Power plants for alternative fuels - in particular carbon-neutral bio fuels - requiring an integrated approach between fuel suppliers, airframe, systems and powerplant

4.4.4. AIR TRAFFIC MANAGEMENT SYSTEM

The challenges placed on the ATM system in the Vision 2020 and existing SRA represent the opportunities realisable by replacing fragmented legacy systems with the benefits available from the SESAR initiative, combined with a number of specific improvements. Further improvements in these areas, particularly with the full integration and development of aircraft systems, can yield further efficiency improvements.

Key ATM concepts and capabilities to be developed

- 4D planning and flight execution to fully manage and optimise aircraft mission in time and space

- Increased aircraft autonomy through topics such as airborne self-separation, to enable aircraft to effectively interact with other aircraft
- Enhanced airspace management to maximise the efficiency and availability of airspace
- **The role of the human operator will be critical for a period, but in the timeframe under review it is likely that automation will take over and enhance safety, performance and cost, subject to major issues of social acceptance and technology**
- Key enablers will need to be developed in the fields of communication, navigation and surveillance
- Global Integration - full interoperability across the USA and Europe by 2030 - with moves toward worldwide integrations and common approaches essential towards 2050
- Management and optimisation of air traffic as a complex system, including understanding macroscopic effects in the air traffic system, such as delay propagation, punctuality and safety cannot be understood by aggregating mechanistic models of subsystems
- **Addressing the certification and timescales to deploy change is a major issue. In view of the absence of a worldwide approach, progress will be inhibited by continuance of legacy systems in some countries/regions**
- In the future, ATM could evolve in the form of an Air Transport Mission Management concept

Further challenges and opportunities

<u>Advanced information management</u>

- Advances in sensor and communication technology make up a wide range of data, especially from the aircraft available on the ground and in the air
- **Aggregating relevant data and extracting information allows for a wide range of applications, both for real-time usage and analysis**
- Potential applications**: enhanced meteorological models, real-time safety monitoring, delay and capacity management, safety analysis**
- Challenges: identify relevant data; two-way communication technology for data transfer; data aggregation and information extraction; analysis capabilities

<u>Non-homogenous traffic and mixed-equipage operations</u>

- New traffic participants with different flight envelopes and operating characteristics (VLJ, UAS, etc.)
- Wider range of performance envelopes means greater difficulty to separate these aircraft (either self-separation or ATC)
- Smaller airports can be used by UAS and VLJ, leading to more point-to-point connections and hence more dispersed traffic flows
- Challenges: airspace management; safety levels of new traffic participants; separation methods; UAS in an ATC-less environment

4.4.5. AIRLINES AND MAINTENANCE OPERATIONS

For the airlines, the continual challenges of maximising asset utilisation at low operating cost and maximum revenue will always remain critical. Each airline will have to tailor its offering and position itself accordingly, whether as a low-cost, regional or full-service long-haul carrier. The various business models and offerings impact on the technology needs to some extent, but the basic business principles do not vary. Airlines will continue to develop their business, utilising technology where this can bring benefits.

Key areas for technology application and improvement

- **Automation** and **general removal of "people costs"**
- Sales and ticketing - maximising market access and revenue per mission. Creating intelligent fare structures, frequent-flyer programmes
- Efficient routing and aircraft operations - having the most direct route, utilising constant energy descents, minimising waste in ground operations, removing positioning flights
- Fleet and crew management - getting the right people and vehicles in the right place at the right time, ensuring assets have the highest practical utilisation, managing downtime to minimise impact on operations
- **Service offering - ability to provide supplementary services and generate ancillary revenues - not just a transport provider**
- Flexibility - adjust aircraft and operations to changing needs, both short- and long-term
- Maintenance practices - effective planning of maintenance schedule, utilising health-management systems to predict maintenance, identify need for on-condition repairs, minimise DMC and IMC, and improve availability and reliability
- Advanced information management - efficient management usage of operational data leading to new services and capabilities

As with other areas, airline operations will have to seek breakthroughs to meet the challenges of the **future. Ideas such as adjusting cruise speed, altitude, staged long-haul flight and formation flying may appear fanciful, but the mathematics show a significant fuel-efficiency advantage, so serious studies into these and other revolutionary changes need to be pursued**.

4.4.6. AIRPORTS

Airports of the future are facing many serious challenges from capacity, integration with ground transportation, local environmental issues, safety, and security - all associated with ever-increasing efficiency challenges in bringing together aircraft with passengers/freight. In view of these challenges, airports offer substantial technology-improvement opportunities, which can be realised through improving all operational aspects: from ground systems integration, passenger and cargo handling, through to aircraft handling.

Each aspect has many technologies and technology needs, with opportunities for step changes in a range of areas:

- Advanced airport design to enhance efficiency and capacity, including advanced pavement
- Ground transportation interfaces and integration
- Aircraft ground movements management and optimisation, including automatic taxiing and extension of flight management to mission management (i.e. from gate-to-gate)
- Airport operations and maintenance
    - Next generation passenger, luggage and cargo systems - utilising the likes of RFID and biometrics
- Ticketing/boarding pass/immigration improvements
- Aircraft integration and support services
    - Ground power
    - Fuel
    - Food and waste
- Integration with ATM/no-hold arrivals/departure scheduling
- Fleet management
- Collaborative decision-making systems to enhance integration with ground services and ATM
- Airport and wildlife hazard abatement to improve safety
- Rescue and fire-fighting improvements
- Security
- Ancillary revenue capabilities
- Advanced information systems and data management

4.5. APPROACHES TO RESEARCH AND TECHNOLOGY DEVELOPMENT

The Strategic Research Agenda (SRA) included the vision on mechanisms for achieving the goals. These were:

- **Research infrastructure** capable of delivering the means by which the planned research can be completed to a world-leading standard
- **Competitive supply chain** from strong primes to the smallest suppliers, capable of exploiting all of the expertise in Europe, and contributing to the necessary research and turning new technologies into competitive products
- **Certification and qualification processes** that facilitate the rapid introduction of new and innovative technologies into production models
- **Educational system** capable of delivering the required diverse and multi-cultural skilled research workforce
- **Trans-European synergy** to make best use of the research effort being applied

The same spectrum of mechanisms will have to be applied in the future, with some effort taken to benefit from lessons learnt about the efficiency of current mechanisms, combined with adaptations to address the new research and development challenges. Studies need to be undertaken to review the progress and effectiveness of each of the above areas**. Where current approaches have not delivered the expected or required benefits, or where these have proven inefficient because of bureaucratic overhead, multi-partner complications, and so on, then revisions should be proposed**. These revisions should take into account the changing needs of the future (as discussed below). **Further reviews of the strengths and weaknesses of the research approach in the USA and elsewhere should be undertaken to identify any best practice opportunities, particularly in the face of changing needs.**

The biggest challenge will undoubtedly be that, towards the 2050 horizon, some significant breakthroughs will be required, either already available or in the pipeline for later years. These breakthroughs will be challenging in many ways:

- **Fostering innovation**. Breakthroughs require innovation to generate the new concepts. It will be necessary to encourage and promote increased innovation and "out of the box" thinking. The strong technology "pull" generated by studying the needs of the industry is important, but it is just as essential to create the technology "push" that comes from the next generation of ideas and possibilities
- **Multi-sector issues.** Many of the opportunities are multi-sectoral, so specific mechanisms to identify and develop solutions across the sectors will be required. This will need to be done while actively minimising the natural inefficiencies of multiparty activities
- **Enhanced support for risk-taking.** Innovation and developing "out of the box" ideas implies an increased risk of technology development failures. Mechanisms will be required to support and enable early research by minimising commercial impact on the entities involved and actively encouraging early technology readiness-level work. Many innovative ideas will need to be nurtured and opportunities explored, without a clear understanding of benefits or indeed any certainty of the success of application
- **Developing breakthrough technologies**. Achieving maturity levels where these can be used for products, especially if they are multi-sectoral, takes significant time and effort, but will also require some special measures**. By definition these types of technology go outside of the existing knowledge base - so extra efforts will be required to:**
    - develop and demonstrate the performance benefits
    - identify, understand and address the challenges of the application within and across sectors
    - identify the approach to optimise the application
    - gain confidence in the technology and address certification, commercial and even social-acceptance barriers
    - develop the associated skills, knowledge, tools, etc.

All these issues will require technology demonstration on a larger scale than previously considered, including whole vehicle/sector or even ATS sector-wide test and demonstration.

4.6. CONCLUSION

The Air Transport System has significant requirements for future technology improvements for the timeframe towards 2050, both in the range of challenges and the level of improvement required. The industry has a successful track record of significant improvements enabled by technology, but the need for breakthrough technology steps and the stretching of targets make the 2030+ requirements far more challenging than ever before. The challenges of the future will affect all sectors of the Air Transport System, and improvements will have to be sought within and across sectors. The future challenges will to some extent be met by the technologies under development, or by the future potential within existing technologies. Yet, to fully meet the demands of the future, new and radical approaches will most likely be required.

In a number of areas, improvements will need to be sought in a more holistic way, at least by seeking an optimised solution across the sectors of the Air Transport System. In some cases, this will mean looking at ways to support multi-modal solutions, thereby developing air transport as an integral part of a wider transportation system.

Within Air Transport System technologies, there is significant potential for improvement, but many technologies may be approaching the limit of their potential in the available timeframe. This will then require significant innovation and technology breakthroughs to be identified and matured.

Delivering technology breakthroughs with sufficient maturity to allow application, where the impacts are far-reaching and go beyond experience and previously calibrated usage, will require new approaches to research and technology development. Innovative ideas will need to be nurtured in a low-commercial-risk environment, and subsequently developed and demonstrated to a high confidence level before committing to a commercial product. New technology development approaches will be required.

ACRONYMS

4D	Four Dimensional
ACARE	Advisory Council for Aeronautics Research in Europe
AGAPE	ACARE Goals Progress Evaluation
AGD	Aviation Global Deal group
AirTN	Air Transport Network
AOC	Advanced Operational Capability
AR4	IPCC's Fourth Assessment Report
ATM	Air Traffic Management
ATS	Air Transport System
BWB	Blended Wing Body
CAEP	Committee on Aviation Environmental Protection
CH_4	Methane
CNS	Communication, Navigation & Surveillance
CO_2	Carbon Dioxide
COP	Conference of Parties
CRS	Computer Reservation Systems
DARPA	Defense Advanced Research Projects Agency
DG	Directorate General
DG-TREN	Directorate General Transport and Energy
DMC	Direct Maintenance Cost
EC	European Commission
ERA-NET	European Research Area Network
ETS	Emission Trading System
EU	European Union
FAA	Federal Aviation Administration
FP	Framework Programme
FP7	7th Framework Programme
GANP	Global Air Navigation Plan
GDP	Gross Domestic Product
GIAC	Group on International Aviation and Climate Change
GMF	AIRBUS Global Market Forecast
GoP	Group of Personalities
H_2O	Water vapour
HLTC	High Level Target Concept
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
ICT	Information and Communication Technology
IEA	International Energy Agency
IFR	Instrument Flight Rules
IMC	Indirect Maintenance Cost
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IPR	Intellectual Property Rights
JTI	Joint Technology Initiative
LCC	Low-Cost Carrier
LTO	Landing and Take-Off
MRO	Maintenance, Repair and Overhaul
N_2O	Nitrous oxide
NASA	National Aeronautics and Space Administration
NGO	Non-Governmental Organisation
NO_X	Nitrogen oxides
O&D	Origin and Destination
O_3	Ozone

OECD	Organisation for Economic Co-operation and Development
PM	Particulate Matter
PPP	Purchasing Power Parity
R&D	Research and Development
R&T	Research and Technology
RF	Radiative Forcing
RFID	Radio Frequency Identification
RPK	Revenue Passenger Kilometres
RTD	Research, Technology and Development
RTK	Revenue Ton Kilometres
SESAR	Single European Sky ATM Research Programme
SME	Small and medium sized Enterprises
SRA	Strategic Research Agenda
UAS	Unmanned Aircraft System
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
USAF	United States Air Force
VLJ	Very Light Jets
VTOL	Vertical Take-Off and Landing
WWI	World War One
WWII	World War Two

BIBLIOGRAPHY

1. Pilon N. and Brom L., *Challenges in Air Transport 2030: Survey of Experts' Views (2007-2008)*, Report n° 09/07/15-20, EUROCONTROL CND Experimental Centre, 2009 http://www.eurocontrol.int/eec/public/standard_page/DOC_Other_2009_003.html
2. Penner J.E., Lister D.H., Griggs D.J., Dokken D.J., McFarland M. (Eds.) *Aviation and the Global Atmosphere*, IPCC, 1999. http://www.ipcc.ch/ipccreports/sres/aviation/index.htm
3. EC Demography Report 2008: Meeting Social Needs in an Ageing Society, SEC(2008)2911
4. ACARE, *The Strategic Research Agendas SRA-1, SRA-2 and the 2008 Addendum to the Strategic Research Agenda*: http://www.acare4europe.org/
5. European Commission/TREN, *The Future of Transport* « Focus Groups Report », 20 February 2009
6. http://www.nanotechproject.org
7. Cassan C., Laplace I. and Lenoir N., *Evolution Of Demand For Leisure Air Transport In 2025*, EUROCONTROL Experimental Centre, EEC Note n° 11/07 http://www.eurocontrol.int/eec/public/standard_page/DOC_Report_2007_011.html
8. Niedzballa H. A., Schmidtt D., *Comparison of the specific energy consumption between aeroplanes and other vehicle systems*, in Aircraft Design, Elsevier 2001
9. ACARE CERMAS Report, *The economic impact of air transport on the European economy,* 2003
10. Cooper A., *The Economic Catalytic Effects of Air Transport in Europe*, EUROCONTROL Experimental Centre, EEC/SEE/2005/004 http://www.eurocontrol.int/eec/public/standard_page/DOC_Report_2005_025.html
11. Attali, J., *Une breve histoire de l'avenir,* ISBN 978-2-213-63130-1, Ed. Fayard, Paris, 2007
12. Attali J., *L'Homme nomade*, éd. Fayard, 2003
13. Friedman, T., *The World is flat*, ICM Inc., London, 2006
14. EASA *Annual Safety Review 2008* http://www.easa.europa.eu/ws_prod/g/doc/COMMS/RZ_EASA_Annual_low_090811.pdf
15. ACARE Press Release 18 November 2008 http://www.acare4europe.com/docs/ACARE_Bordeaux_20081118_Press_Release_final.pdf
16. EUROCONTROL *Challenges of Growth 2008 Report (CG08),* 2008 http://www.eurocontrol.int/statfor/gallery/content/public/documents/Challenges%20of%20Growth%2008%20Summary%20Report%20v1.pdf
17. European Commission: *White Paper "European transport policy for 2010: time to decide* , COM (2001) 370, 27 November 2001
18. Faburel, G., EUROCONTROL Experimental Centre, *Environmental effects around airports*, EEC Note n° 09/07 http://www.eurocontrol.int/eec/public/standard_page/DOC_Report_2007_009.html
19. Courty G. and Mahaud P., *Growth of Air Transport as seen by the political actors in Europe (2000-2006)*, EUROCONTROL Experimental Centre, EEC Note n° 10/07 http://www.eurocontrol.int/eec/public/standard_page/DOC_Report_2007_010.html
20. Rosnay (de), J.*, 2020 : les scénarios du futur*, Des Idées & des Hommes, Paris, Avril 2007
21. Young D., Pilon N. and Brom L., *Challenges ahead for European Air Traffic* in "*Computational Models, Software Engineering, and Advanced Technologies in Air Transportation: Next Generation Applications*", IGI Global, October 2009
22. Beck U., *Risk Society: Towards a New Modernity*, London: Sage, 1992
23. Cook A. ed., *European Air Traffic Management*, Ashgate Publishing, ISBN: 978-7546-7295-1, 2007
24. EU FP6 -European Personal Air Transportation System -D2.1, *Potential transfer of passenger demand to personal aviation by 2020*, 22 Feb 2008
25. UNCCC, *Report of the Intergovernmental Panel on Climate Change Working Group III,* May 2007

26. Metrot, F., EHESS/CEMI - EUROCONTROL, *The energy dilemma: European Air Transport growth between the devil and the deep blue sea*, at the Air Transport Research Society conference, Nagoya, May 2006

27. Grimme W., DLR, *Measuring the long-term sustainability of air transport – an assessment of the global airline fleet and its CO2-emissions up to the year 2050*, at the European Transport Conference 2008 http://etcproceedings.org/paper/measuring-the-long-term-sustainability-of-air-transport-an-assessment-of-the-g-1

28. See e.g. "IATA environment stand inauguration at Rome Fiumicino Airport - Remarks of Giovanni Bisignani" IATA, 16 Jan 2009. http://www.iata.org/pressroom/pr/2009-01-16-01.htm

29. Pilarski A., *Why can't we make money in aviation*?, Ashgate, Aldershot 2007

30. Bénassy-Quéré A., Béreau A. and V. Mignon, Equilibrium Exchange Rates: A Guidebook for the Euro-Dollar Rate, CEPII Working Paper, March 2008

31. Behrend-Goernemann A. and Stone, D.W., The impact of tight capital markets and high fuel prices on aviation finance, Airfinance Annual 2008 / 2009, Euromoney Yearbooks, 2008

32. World Bank , Global Economic Prospects – Managing the Next Wave of Globalization, Washington 2007, http://www-wds.WorldBank.org/external/default/WDSContentServer/IW3P/IB/2006/12/06/000112742_20061206155022/Rendered/PDF/381400GEP2007.pdf

33. Esposito E. and Raffa, L., Evolution of the supply chain in the aircraft industry, Proceedings of Ipsera Conference, San Diego, April 2006

34. ACARE (Advisory Council for Aeronautical Research in Europe), "European Aeronautics: Vision for 2020": http://www.acare4europe.org/docs/Vision%202020.pdf

35. Air Transport and the Energy Challenge, Toulouse, 30 November 2006: http://www.inst-aero-spatial.org/news.php3?id_article=197

36. International Energy Agency (IEA), Energy Technology Perspectives 2008 – Scenarios and Strategies 2050, 2008, http://www.iea.org/Textbase/techno/etp/index.asp

37. EUROCONTROL Challenges to Growth 2004 Report (CG04) : http://www.eurocontrol.int/eatm/gallery/content/public/library/CTG04_report.pdf

38. EUROCONTROL Statistics and Forecasts STATFOR, Long Term Forecast 2006 Report (LTF06) : http://www.eurocontrol.int/statfor/public/standard_page/forecast3_reports.html

39. European Commission, Constrained Scenarios on Aviation and Emissions – CONSAVE 2050, July 2005, http://www.dlr.de/consave/CONSAVE%202050%20Executive%20Summary.pdf

40. European Commission, European Energy and Transport – Trends to 2030 / Update 2007, 2008, http://ec.europa.eu/dgs/energy_transport/figures/trends_2030_update_2007/energy_transport_trends_2030_update_2007_en.pdf

41. Esposito E., Strategic alliances and internationalisation in the aircraft manufacturing industry, Technological Forecasting & Social Change 71, 2004, p. 443- 468

42. Goldman Sachs Group, Global Investment Research – Europe Aerospace & Defence, October 2008

43. United Nations Population Division, World Urbanization Prospects, The 2007 Revision, 2008, http://www.un.org/esa/population/publications/wup2007/2007wup.htm

44. European Commission, Out of The Box: Ideas about the future of air transport, 2007 http://ec.europa.eu/research/transport/pdf/oob_bookmarked_en.pdf

45. Airbus Global Market Forecast (2009-2028) http://www.airbus.com/en/corporate/gmf2009

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The Strategic Research Agenda supporting Vision 2020 has paved the way for significant improvements in sustainable, reliable, affordable and passenger-friendly aviation to reduce the environmental impact of air travel across the world.

However, since 2000, the perception and requirements of air transport have changed significantly. An ambitious high-level vision, beyond 2020, is now needed to focus available resources on European aeronautics and air transport research for the delivery of solutions to meet the challenges for the future.

This document is intended to act as a catalyst for high-level decision-makers to stimulate further analysis with the aim of building a challenging vision for European leadership in global aviation towards 2050, responding to the needs of Society and the citizens of Europe.

François QUENTIN and Joachim SZODRUCH,ACARE co-Chairmen

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