Increasing the sustainability of air transport

COMMUNICATING TRANSPORT RESEARCH AND INNOVATION

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Preface

Improving the sustainability of air transport in the European Union is a key focus of transport policy with targets as set out in the strategic documents – the Transport White Paper (EC, 2011b) and the Europe’s Vision for Aviation (EC, 2011a). In the face of increasing air transport volumes, strict targets are set for emission reduction and raising air safety and security.

As a significant area of EU transport policy, sustainable air transport has been selected for the TRIP series of policy brochures to highlight the contribution of EU-funded research to policy and the implications for future policy and research.

This series of policy brochures is an essential component of the comprehensive Transport Research and Innovation Portal (TRIP) that provides open access to the results and best practices of research programmes and projects in the European Research Area (ERA). A central theme of research policy under the Treaty of Lisbon, the European Research Area has been identified to foster the free circulation of researchers, scientific knowledge, and technology.

TRIP serves policy makers and research managers involved in all aspects of the transport sector. The Portal is developed and maintained by the TRIP Project Consortium and funded by the European Commission Directorate-General for Mobility and Transport (DG MOVE) under the Seventh Framework Programme for Research and Innovation.

This policy brochure presents an overview of current and future policy on sustainable air transport and EU-funded research to support development and implement of this policy.
Introduction

Challenges in increasing the sustainability of air transport

Air transport contributes significantly to economic growth and development, and to integration and cohesion in the European Union. With continuing increases in passenger movements and freight volumes, the challenge is to facilitate sustainable growth in air transport while limiting environmental impacts and ensuring the highest safety and security for passengers and freight.

Air transport provides 5.1 million jobs in Europe and contributes €365 billion or 2.4% of the GDP in the European Union (EC, 2011a). Furthermore, air transport is a vital factor in the integration and cohesion of the EU, connecting most cities in Europe within only few hours flying time. In 2011, over 820 million passengers were carried on 150 scheduled airlines and passed through 450 airports. Air transport has fostered economic development, international trade, and opened new markets especially in the peripheral regions of the EU (Eurostat, 2013; EC, 2011a).

Since deregulation at the end of the 1980s, air transport has increased in strategic and economic importance. Passengers have benefited from deregulation in many ways. Air fares have decreased, low-cost carriers have entered the European market, competition between airlines has increased, and secondary airports have become effective alternatives to the main airports that are becoming increasingly congested. Between 2003 and 2008, air traffic has increased steadily to reach an annual increase of 5.6% in 2008 (EASA, 2011). However, air transport, and especially air freight, has been hit by the current economic crisis that has led to reduction in production worldwide and in international trade. Despite the crisis, global air transport is expected to grow at a rate of 4 to 5% annually up until 2030 (Airbus, 2012), while freight volumes are expected to treble in the next 20 years (Boeing, 2010).

The key challenge is to enable the air transport to grow sustainably. A sustainable development path is to stimulate and enable growth and expansion while reducing environmental impacts, increasing the safety of air and airport operations, and reducing vulnerability to external security threats.

Climate Change

Air transport contributes to climate change through CO₂ emissions, which accounts for 2 to 3% of total CO₂ emissions worldwide. The expected growth in air transport in Europe will further increase CO₂ emissions to an estimated 4% annually in 2050.
While the proportion of aviation CO₂ emissions may be comparably low, the contribution to radiative forcing effect (global warming) is not negligible. The report of the Intergovernmental Panel on Climate Change estimated that this effect could be two to four times greater than that from aviation CO₂ emissions alone (IPCC, 1999). Analyses have shown that greater reductions in CO₂ emissions can be achieved more efficiently in other sectors. However, the transport sector should contribute to achieving EU targets under the Kyoto protocol. The EU has set a target of 60% reduction in the transport sector by 2050 with respect to 1990 levels (EC, 2011c). However, the expected increase in air traffic poses significant challenges in reducing CO₂ emissions to meet this target. Emission reduction will have to be achieved by improving the efficiency of aircraft engines and aero-structures, developing new and innovative technologies, use of alternative sustainable fuels for aviation, and by implementing future-oriented operational procedures such as the Single European Sky.

Local air quality

Air transport has an impact on local air quality and is a major concern in residential areas nearby airport facilities. Emissions of nitrogen oxides (NOₓ), volatile organic compounds and particulates are potential health hazards and with adverse impacts on the environment. In addition, NOₓ emissions from aviation contribute to ozone formation and thus to global warming. While over the last 40 years, reductions of up to 70% in fuel consumption per passenger seat have been achieved, expected growth in air traffic implies further increases in emissions. Advances in technology are needed to improve current air quality levels despite increases in air traffic volumes.

Aircraft noise

Aircraft noise is a hindrance to people living in areas surrounding airports and on the approach routes. Over the last 30 years, improvement
in aircraft design has led to a 75% reduction in aircraft noise. However, rapid growth in air traffic means that many people are still exposed to high noise levels (EC, 2013c). Thus, new and advanced aircraft need to be designed and constructed, and further regulatory measures developed and implemented to reduce noise hindrance in and around airports.

**Improving safety**

Air transport has a high safety record. In the decade 1993 to 2003, accidents involving passenger fatalities on scheduled operations dropped continuously as did fatal accidents (EASA, 2011). Between 2002 and 2011, Europe had one of the lowest air accident rates in the world with 1.6 fatal accidents per ten million flights. However, with passenger numbers set double and freight volumes to treble in the coming decades, air operations in Europe will become increasingly more complex. The challenge is to ensure that current safety standards, such as standards for airworthiness certification and safety assessment of foreign aircraft (SAFA), are adjusted to future needs. This implies designing and building less vulnerable aircraft and airport facilities to handle increasing passenger and freight volumes safely and efficiently, and effective air traffic management to ensure safe operation.

**Advancing security**

Security has been a concern for civil aviation authorities for several decades because aircraft are targets for terrorism. Events such as the Lockerbie bombing, the terrorist attacks in the United States on 11 September 2001, and the cargo plane bomb plot have had more far-reaching consequences than the single events. Effective security measures are in place in and around airports but can constrain the efficiency of airport operations and the air transport system by increasing travel time, reducing travel convenience, and adding to airport operating costs. The challenge is to increase air security and so further reduce vulnerability to external threat while minimising disruption and delay to passenger and freight movement.

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**Figure 1: Flights in Europe – past trends and future expectations**

![Graph showing past trends and future expectations of flights in Europe from 1960 to 2015.](image-url)
Policy and research on sustainable air transport

The Transport White Paper makes the sustainability of air transport a key priority in terms of reducing environmental impacts and increasing safety and security. In support of this policy, research priorities include greening air transport, ensuring customer satisfaction and safety, and protecting the security of aircraft and passengers.

EU policy on reducing environmental impacts of air transport

The White Paper Roadmap to a Single European Transport Area (EC, 2011a) sets out a vision for a competitive and sustainable transport system, and provides the foundation for the vision on air transport specified in Flightpath 2050 (EC, 2011a). In becoming a world leader in sustainable air transport, the EU has set stringent targets for reducing environmental impacts, and ensuring the safety and security of aircraft and ground facilities. Achieving these targets requires full understanding of the impact of air transport on the atmosphere in order to mitigate the environmental impacts of the anticipated rapid increase in air traffic (EC, 2011a). Achieving 40% low-carbon fuels in air transport by 2050 would significantly reduce the sector’s contribution to CO₂ emissions and thus to climate change, and would also improve air quality in and around airports.

ACARE Flightpath 2050

The vision of Flightpath 2050 focuses on safe, efficient and environmentally friendly air transport, and on maintaining global leadership for Europe. The vision identifies goals and challenges in:
1. meeting societal and market needs (mobility)
2. maintaining and extending industry leadership (competitiveness)
3. protecting the environment and energy supply
4. ensuring safety and security
5. prioritising research, testing capabilities and education (resources).

This vision has led to a Strategic Research and Innovation Agenda (SRIA) to guide future actions in public and private funding programmes to ensure that research is adequately supported and funded.
Climate Change

The main instrument of EU policy to combat climate change, the EU Emission Trading Scheme (ETS) (EC, 2005), was extended to air transport in 2012 and covers all flights by EU and non-EU airlines in the EU air space. It embraces 31 States including the 28 EU Member States and Norway, Iceland and Liechtenstein. However, the Commission proposed to “stop the clock” on implementing international aspects of ETS aviation by deferring for a year the obligation to surrender emissions allowances from air traffic to and from Europe, awaiting international agreement on a global solution for CO₂ reduction under the International Civil Aviation Organization (ICAO).

EU POSITION ON EMISSION TRADING

The EU supports technological and operational measures to reduce the climate impacts of aviation, such as state action plans, CO₂ aircraft standards, and use of sustainable biofuels. However, these measures alone are not sufficient to deliver the emission reductions required in air transport. Market-based incentives and the ability to offset emission increases in other sectors are needed.

The EU supports the need for global measures. Based on the encouraging results of the ICAO Council meeting in November 2012, the Commission proposed to “stop the clock” on implementing international aspects of ETS aviation by deferring for a year the obligation to surrender emission allowances from air traffic to and from Europe. This effectively means that the EU would not require allowances to be surrendered in April 2013 for emissions from international flights during 2012. Monitoring and reporting obligations will also be deferred for such flights. The obligations relating to all operations in EU will remain and compliance with EU legislation will be enforced. The derogation relates only to 2012 emissions. The Council and the European Parliament agreed to facilitate an agreement at the 38th ICAO Assembly for a realistic timetable for the development of global market-based measures and for a framework to facilitate application of national and regional market-based measures in international aviation, pending the application of the global measures.
Air quality

Since the early 1970s, EU policy on reducing emissions of harmful substances, improving fuel quality, and integrating environmental protection has included the transport sector (EC, 2013a). The target is a 90% reduction in nitrogen oxides (NO\textsubscript{x}) emissions by 2050 from aircraft relative to new aircraft in 2000. In the meantime, the standards of the International Civil Aviation Organization (ICAO) on NO\textsubscript{x} emissions from new aircraft apply to all EU Member States. Since 1981, ICAO standards have progressively limited the permissible NO\textsubscript{x} emissions from aircraft engines to the current standard of 50% reduction on 1981 levels (CAEP/8 standard). Together with Directive 2008/50/EC on ambient air quality and cleaner air, these measures have reduced NO\textsubscript{x} concentrations in and around airports. The Directive has also spurred on airports in the EU to impose landing fees related to aircraft emissions. Long-term policy is directed to developing a coherent approach to NO\textsubscript{x} emission reduction covering a wide range of high leverage disciplines including materials, aerodynamics, vehicle and engine design.

Aircraft noise

Reducing aircraft noise is a major component of environmental policy on air transport. Over the last 30 years, aircraft noise has been cut by as much as 75% as a result of a combination of technological innovations and international policies on aircraft noise (EC, 2013c). Europe’s vision for aviation is a further 65% reduction by 2050 in perceived noise emission from flying aircraft relative to new aircraft in 2000 (EC, 2011a). This target is to be achieved through a combination of measures including more stringent noise standards for new aircraft, sustainable management of areas around airports, operational procedures to reduce noise impact on the ground, and allowing operating restrictions (EC, 2013c).

EU policy on air transport safety

EU Regulation No 1194/2009 defines standards for the airworthiness and environmental certification of aircraft, for certification of design and production organisations, for crew licensing and for aircraft operations. These regulations apply across the EU and all aircraft at EU airports are subject to safety inspection. Airlines that do not meet EU safety standards can be banned from operating in Europe.

With the goal of reducing the air accident rate to less than one in ten million commercial flights and to be the safest region in the world, the EU Aviation Safety Strategy sets an unprecedented level of air safety by 2050 (EC, 2011b). Building on the work of the European Aviation Safety Agency (EASA), this strategy includes:

- EU safety management system that incorporates safety performance targets and measurements to identify risks and to achieve continued improvement in safety;
- Data collection, quality, exchange and analysis from review of legislation on occurrence reporting in civil aviation;
• Regulatory safety framework for research and development on innovative technologies;
• Transparency and exchange of safety information with ICAO and other international aviation partners.

EU policy on air transport security

High on the EU agenda, air security issues have been brought together in EU legislation, and a common framework established to harmonise air security (EC, 2013d). These security standards apply to all airports, transport operators and entities providing services at airports in the EU Member States. The regulations cover airport and aircraft security, passengers and cabin baggage, cargo and mail, in-flight and airport supplies, staff recruitment and training, and security equipment.

The security target for 2050 is to reduce inconvenience to passengers by making security measures less intrusive, and to respect the privacy and personal dignity of passengers without disruption and delay. A risk-based approach to the security of cargo originating outside the EU is to be developed, and an EU-wide one-stop security system for air cargo implemented.

Research and innovation frameworks

EU policy on more sustainable air transport is supported by research and innovation frameworks including FP7, SESAR, Clean Sky and Fuel Cells and Hydrogen Joint Undertaking (JU).

Seventh Framework Programme (FP7)

Under the EU Seventh Framework Programme (FP7), one of the two programme lines on transport focuses on Aeronautics and Air Transport. Priority is given to research on emission reduction, engines and alternative fuels, air traffic management, safety of air transport, and environmentally efficient aviation (EC, 2013f). Specifically, the research priorities are:
• Greening air transport
• Ensuring customer satisfaction and safety
• Protection of aircraft and passengers.

Greening air transport is directed to developing technologies to contribute to the 2020 targets to reduce CO₂ emissions by 50%, specific NOₓ emissions by 80%, and perceived noise hindrance by 50%. The research focus is on developing green engine technologies including alternative fuels technology, improved aircraft efficiency, intelligent low-weight structures, and improved aerodynamics. Research extends to improving aircraft operations at airports and air traffic management, and manufacturing, maintenance and recycling processes (EC, 2011a).

Research on aircraft safety is directed to achieving a five-fold reduction in accident rate by 2020. New technologies are being developed that will enable aircraft/engine configurations for safer operation, and increased levels of automation in all system elements. The focus is on active and passive safety measures with special emphasis on the human element.
Research on the protection of aircraft, passengers and citizens covers all aspects of the air transport system. The investigations include incorporating security measures in cabin and cockpit designs, automatic control and landing in event of unauthorised aircraft use, protection from external attack, and security in airspace management and airport operations (EC, 2012).

**Fuel Cells and Hydrogen Joint Undertaking**

This public-private partnership initiated by the European Commission is directed to accelerating market introduction of fuel cells and hydrogen technologies as instruments in a carbon-lean energy system. While the initiative is not mode-specific, new and innovative propulsion technologies will benefit air transport in the long-term.

**Clean Sky Joint Undertaking**

The European Clean Sky Joint Undertaking is demonstrating and validating technology breakthroughs in meeting EU environmental goals. The initiative expands the vision of Flightpath 2050 of a 50% reduction in fuel consumption per passenger kilometre by 2020, which directly reduces CO₂ emissions, as well as 80% reduction in NOₓ emissions and 50% in unburnt hydrocarbon emissions. The initiative is also directed to significant noise reduction in air transport sector.

Set up in 2008 as a public-private partnership between the European Commission and the air industry, the Clean Sky initiative combines research and practical experience to improve the sustainability of air transport (Clean Sky, 2013).

**SESAR**

The EU Single European Sky focuses on providing uniform and high level performances notably safety and efficiency in Europe’s skies. Its technological pillar, SESAR (Single European Sky ATM Research) is developing a new generation of air traffic management systems that will ensure safety and fluidity of air transport worldwide over the next 30 years, reducing aviation operational environment impacts and ATM cost.

Architecture for air traffic management is being upgraded under the EU Single European Sky initiative launched by the European Commission in 2004. A system approach is proposed to meet future capacity and safety requirements Europe-wide. SESAR is directed to consolidating air traffic management in Europe by developing a new generation of air traffic management with capacity to maintain safety and fluidity of air transport worldwide in the coming 30 years.

The project is being carried out in three phases. The first phase (2004-2008) has delivered a master plan for air traffic management setting out content, development and deployment plans for the Single European Sky. The second phase (2008-2013) is producing a new generation of technological systems, components and operational procedures. Because of the large number of actors in SESAR and the scope of financial resources and technical expertise required, the SESAR Joint Undertaking has been set up to oversee fund management during the second phase. Currently, the EU is establishing the basis to extend this mandate.

The third phase is the deployment phase (2014-2020) in which the harmonised and interoperable components of the Single European Sky will be implemented. In May 2013, the Commission adopted a Regulation establishing governance and incentive mechanisms to facilitate the effective and timely deployment of Air Traffic Management (ATM) functionalities that are considered essential for the performance improvement of the Union’s ATM system.

*EC, 2013h; EC, 2013i*
Reducing air transport emissions

Emission reduction is being tackled on all fronts – in aircraft design, manufacture, and operation and maintenance. Significant gains are also being made in fuel efficiency and emission reductions through improvements in air traffic management and in airport operations as well as through the use of alternative sustainable fuels. Research is developing new and innovative solutions for aircraft, their production and maintenance as well as for air transport operations.

Aircraft

The environmental impacts of aircraft can be reduced with improvements in flight physics, aero-structures, propulsion technology and avionics. Research has increased aerodynamic efficiency and reduced external noise by airframe/engine integration. Further research is being carried out on advanced concepts and technologies for flow control; drag reduction for high lift over drag ratios; innovative high lift devices to enable steeper take-off and landing flight profiles; and on adaptive wing technologies (EC, 2012).

In order to reduce greenhouse gas emissions, EU-funded research focuses on innovative aircraft structures including lightweight metallic, composite materials, multifunctional materials, and micro- and nanotechnologies (EC, 2012). Furthermore, research stimulates solutions for a long-term horizon, such as innovative propulsion concepts that run on alternative fuels or enable an all-electric aircraft.

In 2020, aircraft are cleaner and quieter and the aeronautics sector’s contribution to a sustainable environment is widely understood and appreciated. Many of its products are made of recyclable materials and have minimal environmental impact.

EC, 2001
The Clean Sky initiative combines research and practical experience to improve (Clean Sky, 2013):

- **Smart Fixed Wing Aircraft**: active wing technologies and new aircraft configurations;
- **Green Regional Aircraft**: low-weight aircraft using smart structures, and low external noise configurations;
- **Green Rotorcraft**: innovative rotor blades and engine installation for noise reduction, lower airframe drag, integration of diesel engine technology and advanced electrical systems to eliminate noxious hydraulic fluids, and reduce fuel consumption;
- **Sustainable and Green Engines**: engine demonstrators integrating technologies for low noise and lightweight low pressure systems, high efficiency, low NOx and low weight cores and novel configurations, such as open rotors and intercoolers.

## Production and maintenance

Ecological production and maintenance will ensure more environmentally friendly air transport, focusing on clean processes in the manufacture and maintenance of aeronautical products. Research focuses on innovative processes to reduce toxic emissions and to improve re-usability and disposal (EC, 2012). Clean Sky research includes an Eco-Design objective to optimise raw materials and energy in aircraft design and production, withdrawal and recycling.

## Operations

In green air transport operations, research addresses improving air traffic management and airport operations in order to increase fuel efficiency and to optimise energy consumption and thus reduce emissions (EC, 2012). Improvements in air traffic management under the Single European Sky Air Traffic Management Research initiative (SESAR) are directed to reducing environmental impacts by optimised flight routes, for instance by shorter flight distances between airports.

Research on airport operations under FP7 is oriented to developing concepts and technologies to replace ground vehicle services with more environmentally friendly technologies, such as hydrogen-driven vehicles. Furthermore, advanced concepts and technologies are being investigated for greener apron operations and new concepts in aircraft de-icing.

SESAR is developing operational improvements to support the Master Plan for Air Traffic Management. Clean Sky research includes developing systems for Green Operations that take account of all-electric aircraft equipment and systems architecture, thermal management, capabilities for green trajectories and mission, and improved ground operations.
SUCCESS STORY

Environmentally Friendly Aero-Engine

VITAL

Project reference: VITAL AIP4-CT-2004-012271
Status: Completed
Total cost: EUR 90 486 049
EU contribution: EUR 50 490 000
Coordinator: SNECMA (Société nationale d’études et de constructions de moteurs d’aviation, Paris, France)
Website: www.transport-research.info/web/projects/project_details.cfm?id=11001

Improvements to individual engine components have contributed to an eight-decibel reduction in noise per aircraft operation and an 18% reduction in CO₂ emissions. New technologies were developed for aircraft fans, boosters, engine structure, torque capability and turbines. Future efficiency gains are to be achieved through assembling and optimising the engine components developed under VITAL in fuel- and noise-efficient engines.

BACKGROUND

Growth in air traffic volumes is greatly impeded by noise and harmful air emissions from aircraft engines, which are the primary source of CO₂ and NOₓ emissions and noise in and around airports. The VITAL consortium, an association of 14 institutions from aeronautics research and industry, developed the next generation of commercial aircraft engine by redesigning and improving each engine component.

RESULTS

The VITAL project provided important milestones to prepare for the future of the European aeronautical industry. New technologies were developed for aircraft fans, boosters, engine structure, torque capabilities and turbines. A very high By-Pass Ratio engine was developed that reduces noise emissions and fuel consumption, and minimises drawbacks of engine drag and weight associated with low specific thrust.
The VITAL technologies were tested and validated using major aerodynamic, acoustic and mechanical rig tests throughout the project.

The innovations were assessed in a techno-economic and environmental risk assessment for quantifying innovative development. Together with results of related research on weight reduction (EEFAE project) and noise reduction (SILENCE(R), research project), the new engine technologies achieved an eight-decibel reduction in noise per aircraft operation, which is effectively more than 80% noise reduction. Furthermore, aircraft engine components developed reduced CO₂ emissions by 18%.

VITAL provided a validated set of engine technologies and integrated research infrastructure supported by a validated exploitation plan for the use of these technologies in next generation of low-noise, cost-efficient engines. Future research will build on these results to assemble and optimise components in completely new aircraft engines.
Increasing safety in air transport

As air traffic volumes continue to rise, research is focusing on gaining a better understanding of the human factor in order to ensure high standards of air safety. Innovative decision-support tools are being developed to assist air crews in reducing aircraft vulnerability in crowded airspace and under high workloads.

“...In 2050, European aviation has achieved unprecedented levels of safety and continues to improve. Manned, unmanned, legacy and next generation, autonomous aircraft and all types of rotorcraft operate simultaneously in the same airspace and in most weather conditions.”

EC, 2011a

High safety levels in one world region can only be achieved and maintained if all partners apply comparable safety standards worldwide. Thus, safety in the EU also depends on international agreements. Research has intensified international cooperation and information dissemination, for instance with the United States, Canada, and Japan. The EU supports international cooperation, which is vital in ensuring the safety of air networks.

Aviation accidents rarely result from a single failure but rather from a combination of events.
Thus, a system-wide approach is needed to reduce the vulnerability of the entire system. Research addresses innovative solutions and technologies in aircraft design, the human factor, operation of system infrastructure such as airports and air traffic management, and integrated safety solutions. New technologies and measures need to be developed that increase safety and that are cost-efficient for the entire sector without hampering the movement of products, services and people.

Increasing air safety

Most fatal accidents in air transport occur during the flight including take off and landing. Key components of research on improving aircraft safety are gaining better understanding of the human factor and developing improved decision-support tools for air crews. Advanced concepts, methods and techniques for human-centred design of cockpit displays are being developed and human-machine interaction is being analysed. Furthermore, studies have been undertaken on the role of automation in decision-making and collaboration in the cockpit in managing information from various sources including cockpit, air traffic management and ground control.

An integrated approach is followed in developing new cockpit technologies to alleviate crew workload. On this technological basis, research is developing conceptual architecture that includes innovative health monitoring, prognostics, communication and decision-making strategies to enable an increased level of automation (EC, 2012). Such new concepts will enhance safety especially in situations when the crew faces peak workload.

In addition to the human factor, the propulsion system is being analysed directed to reducing vulnerability. Advanced tests and innovative models are being developed to enhance understanding of the tolerance of aircraft engines to particle ingestion, particularly volcanic ash. The eruption of Eyjafjallajökull volcano in Iceland in 2010 reinforced the need for research on the impact of particles on aircraft propulsion systems. This relatively small eruption caused enormous disruption to air travel in Europe, with some 20 countries closing their airspace and affecting more than 100,000 travellers. Research covers aspects such as effective anti-clogging measures, abrasion, and flameout with the objective of making recommendations on acceptable ingestion thresholds, particularly for volcanic ash (EC, 2012).
Another area of air safety research is the impact of icing on flight, including disruptions to sensors and engines. Directed to reducing the risk to aircraft flying in such weather conditions, research is developing measurement techniques and instrumentation for use on-board commercial aircraft. The physical characteristics of glaciated and mixed phase icing conditions are being measured and the data used to improve ground testing and modelling.

Safety in the air can be improved through innovative aero-structures. Research is being carried out on advanced modelling tools, design techniques and structural concepts to ensure safety particularly of aging airframe and engine structures (EC, 2012).

Increasing safety on ground

The highest reduction in fatal accidents and increase in aviation safety levels will be achieved through measures in the air including air traffic management and in aircraft. Ground operations are less vulnerable but increasing traffic will create new challenges with higher use of airport facilities requiring innovative measures to maintain current safety levels. High precision systems are needed including advanced techniques for the control and surveillance of mobile vehicles and equipment operating in the movement and manoeuvring area (EC, 2012).

Figure 2: Fatal accidents in commercial air transport worldwide

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<th>Year</th>
<th>Third country operators</th>
<th>EASA Member States operators</th>
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EASA Member States: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, The Netherlands and United Kingdom.

EASA, 2011
HUMAN

Model-based Analysis of Human Errors during Aircraft Cockpit System Design

Project reference: 211988 (Framework Programme 7)
Status: Completed
Total cost: EUR 3 909 789
EU contribution: EUR 2 777 378
Coordinator: OFFIS e.V. (Institute for Information Technology, Oldenburg, Germany)
Website: www.human.aero

HUMAN developed a cognitive model of air crew behaviour that can enhance the accuracy of pilot error prediction by 40% and reduce design work in active and passive safety measures by 30%. By increasing understanding of the human factor and prediction of potential pilot error, the project has contributed to human-centred cockpit design and to flight safety.

BACKGROUND

The Transport White Paper (EC, 2011a) sets a target to save thousands of lives through improved safety in all transport modes. The HUMAN project was set up to improve aviation safety through improved human pilot interaction in a complex and dynamic cockpit environment. The project is directed to enhancing air safety and to contribute to an 80% reduction in the accident rate.

RESULTS

The project has contributed to better understanding and prediction of pilot behaviour (including errors). The human tendency to erroneous actions was tested in virtual and physical flight simulations. Predicted and actual crew reaction were compared to assess the model predictions and to derive measures for increasing safety from the results.
Using comparisons between the predicted and actual errors made during flight simulation, guidelines have been derived for cockpit design based on the interrelationships between pilot, cockpit system, aircraft and environment. These data can be used to improve cockpit design to accommodate and correct pilot errors.

HUMAN enhanced the accuracy of pilot error prediction by about 40%, thus contributing to eliminating and recovering from human errors. The design work in developing active and passive safety measures has been reduced by about 30%, and flight simulator tests for the same purpose by about 30%.

The project developed techniques and prototype tools for analysis of simulator data, and a methodology to integrate all techniques and tools for use in cockpit system design. Thus, the project has opened the way to further improvement in cockpit design and further interaction between the pilot and airplane technology.
Increasing security in air transport

With increasing air traffic volumes, tight security is required that is non-intrusive, respects individual privacy and personal dignity without disruption to passenger movements and cargo operations. Developing these measures requires a system-wide approach covering both aircraft and operations in the air and on the ground.

“In 2050, [...] aviation security is part of an integrated security strategy for all modes of transport and is based on the three principles of: resilience and effectiveness; passenger experience; and fast, integrated and seamless processes.

EC, 2011a

A very high level of security has been maintained in air transport over the last few decades. Travellers and citizens are well protected from injury, loss, damage and disruption due to aircraft misuse (EC, 2013g). It is essential to maintain and strengthen security as air traffic rapidly increases and national transport networks become more interconnected in an enlarged Europe. EU policy is supported by research directed to preventing hostile action and aircraft misuse that leads to injury, loss, damage and disruption to travellers and citizens. Research in support of strengthening security in air transport focuses on both aircraft and air operations.

EU policy is directed to increasing the already high security standards for air transport within, and to and from the EU Member States. To meet these policy goals, EU-funded research is directed to defining standards for aviation security and to reducing aircraft vulnerability to security risks.

Aircraft security

An essential aspect of aircraft security involves improving aircraft security features. Research is being carried out to improve security measures in cabin and cockpit design, automatic control and landing in the event of unauthorised aircraft use and to protect against external attack.

A current research focus is the development of advanced concepts and technologies for blast-resistant cabin structures and bomb-proof cargo
containers. Numerical tools are being developed for vulnerability mapping of aircraft sub-structures. Vulnerable locations in an aircraft are being identified, new design approaches introduced, and tailored novel composite and hybrid materials are being used. Implicit and explicit measures are being considered based on reinforcing design strategies and novel materials to increase blast and fire resistance with minimum weight penalty (TRIP, 2013a).

In addition to preventing explosives being placed on board, research is being carried out on mitigating the effects of on-board explosion. New prototypes for baggage and cargo containers are being designed to withstand a small to medium explosion by controlled expansion and containment of the shock waves while preventing hard projectiles of baggage fragments striking the main aircraft structure at high speed. The challenge is to develop baggage containers that are less vulnerable without increasing weight and cost compared to standard containers.

**Operational security**

Operational security focuses on improving the intrinsic security in air transport infrastructure. Key issues are how to mitigate potential future threats. A wide range of threats is being investigated including security in air traffic management, at airports, and of the entire system.

Security must be embedded in the design of air traffic management, and become part of the culture of air traffic management in the same way as safety. The concept of a closely integrated partnership of service users and providers depends on a level of trust between parties involved in the face of an evolving threat; the trust to share information, to link networks, to protect airspace, to share staff and to implement joint security policies to protect the system.

Research includes developing advanced security control methods based on biometric data and other novel non-intrusive detection techniques, advanced techniques for detection of hazardous materials, tracing mechanisms for communicable diseases, and advanced secured communication systems. Another research priority is better understanding the human factor and modelling human behaviour as an essential component in crisis management and personnel training.

A system-wide approach is used in air cargo security. A potential security risk is the air shipment of dangerous materials such as explosive devices. Detection technologies and implementation strategies at airports are currently being reviewed for effectiveness in detecting dangerous goods and for cost effectiveness in terms of time and convenience. The results will be used in developing innovative strategies for a secure air cargo chain including security processes and operational tools and concepts.
BEMOSA

Behavioural modelling for security in airports

**Project reference:** 234049  
**Status:** Completed  
**Total cost:** EUR 4,235,967  
**EU contribution:** EUR 3,399,934  
**Coordinator:** TECHNION – Israel Institute of Technology, Haifa, Israel  
**Website:** http://bemosa.technion.ac.il

BEMOSA has developed an innovative training approach to alert airport staff to security threats. Software has been developed to capture and predict behaviour of airport staff in stress situations and to enable the development of realistic emergency scenarios. The project improved the way airport staff can learn from experience in updating their skills in safety and security.

**BACKGROUND**

Eliminating and mitigating threats to air transport is a key global objective. Most investments in new systems to increase security at airports have led to increases in costs and time at checkpoints, which put strain on overall efficiency of the air transport system. However, little attention has been paid to the human factor – the people operating the technology and interfacing with passengers and the system. Better training for security personnel will enable more effective and efficient use of technology and equipment.
RESULTS

By examining airports throughout Europe and focusing on key decision-making stakeholders such as control tower operators, security employees, service vendors and passengers, BEMOSA has delivered the basis for a comprehensive and practical training programme. The programme is directed to enhancing the capability of airport authority personnel to detect potential security hazards through improved training and by learning from experience. A training programme was tailored for airport staff based on a behaviour model that reflects the complex situation in airports.

BEMOSA developed advanced software simulations that capture and predict social behaviour in stressful emergencies, and provides a platform for developing training modules and packages. The training is based on how people make security decisions in routine and in crisis situations at airports. By facilitating coordination of all stakeholders in security threats and emergency decision-making, BEMOSA supports diagnosis, interpretation and training on security threats and increases airport efficiency.
Policy and research outlook

The Seventh Framework Programme for Research and Innovation started the development of new technologies for air transport and their readiness for integration by validating and demonstrating their operability. A strong focus was placed on greening air transport to increase the sector’s sustainability. Research was also conducted on safe and seamless mobility including safety and security.

EU-funded research in combination with EU policy has reduced the environmental impacts of air transport significantly. Technological improvements and the optimisation of processes have reduced emissions from engines and aircraft, increased fuel efficiency, demonstrated practical use of alternative fuels and optimised air transport operations, aircraft maintenance and production.

The new Framework Programme, Horizon 2020, will bring together research and innovation on a multidisciplinary and international basis and will focus on reducing time to market. Horizon 2020 starts from the achievements under FP7 and complements research on technology, maintenance, operations and organisation that has resulted in products, processes and innovations for market entry.

Air transport research will continue to play a vital role in achieving the ambitious targets. Research will develop solutions to reduce the sector’s oil dependency by improving engine technologies and developing innovative aero-structures (fuel efficiency) as well as by pioneering breakthrough technologies in aircraft design, propulsion systems, air transport management and new cost efficient alternative sustainable fuels.

Future policy and research is targeting the development of an aviation safety strategy and non-intrusive security processes and techniques for passengers, and an EU-wide one-stop security system for cargo services. Innovative developments in decision-support tools will assist cockpit crews to reduce their workload and to prevent human error, and automatic routines to cope with unforeseeable circumstances, such as icing conditions and particle ingestion by engines.

The Advisory Council for Aeronautics Research (ACARE) proclaims that Europe leads the world in sustainable air transport products and services (EC, 2011a). Remaining competitive is a prerequisite for air transport in the EU and can only be achieved by operating in comparable environments worldwide. Future challenges for EU policy are to create international standards and instruments for sustainable air transport, such as international agreements on climate change mitigation, minimum safety and security for airports, aircraft and crews worldwide, and efficient and immediate implementation of the Single European Sky.

Being aware of the political challenges ahead, the close interaction of policy and research will have a long-term impact on the development of sustainable air transport in Europe, on European integration and cohesion, and will act as a catalyst for growth.
Bibliography

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- Eurostat (2013): Database: Overview of the air passenger transport by country and airports (avia_paoc), Luxembourg.
## Glossary

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<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ACARE</td>
<td>Advisory Council for Aviation Research and Innovation in Europe</td>
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<td>ATM</td>
<td>Air Traffic Management</td>
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<td>BEMOSA</td>
<td>Behavioural modeling for security in airports</td>
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<tr>
<td>CO₂</td>
<td>Carbon Dioxide</td>
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<td>DG MOVE</td>
<td>Directorate General for Mobility and Transport</td>
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<td>EASA</td>
<td>European Aviation Safety Agency</td>
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<td>EC</td>
<td>European Commission</td>
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<td>ERA</td>
<td>European Research Area</td>
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<td>EU</td>
<td>European Union</td>
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<td>EU ETS</td>
<td>European Union Emission Trading Scheme</td>
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<td>FP7</td>
<td>Seventh Framework Programme</td>
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<tr>
<td>HUMAN</td>
<td>Model-based Analysis of Human Errors During Aircraft Cockpit System Design</td>
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<tr>
<td>ICAO</td>
<td>International Civil Aviation Organization</td>
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<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
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<td>JU</td>
<td>Joint Undertaking</td>
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<td>NOₓ</td>
<td>Nitrogen Oxides</td>
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<td>SESAR</td>
<td>Single European Sky Air Traffic Management Research</td>
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<td>SRIA</td>
<td>Strategic Research and Innovation Agenda</td>
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<tr>
<td>TRIP</td>
<td>Transport Research and Innovation Portal</td>
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<tr>
<td>VITAL</td>
<td>Environmentally Friendly Aero-Engine</td>
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Contributing to economic growth and development, and to integration and cohesion in Europe, sustainable air transport is a central part of EU transport policy and research. With ever increasing passenger movements and freight volumes, the challenge is to facilitate sustainable growth while reducing environmental impacts and maintaining high levels of safety and security in the air and on the ground.

Policy and research on increasing the sustainability of air transport in the European Union are presented in this Policy Brochure which is a component of the Transport Research and Innovation Portal (TRIP). The Portal provides access to the results and best practices of transport research in the European Research Area.