PERSPECTIVES FOR AERONAUTICAL RESEARCH IN EUROPE

PARE

Chapter 20

Dissemination Articles with Key Findings and Actions

Final Report

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Chapter 20 - Dissemination Articles with Key Findings and Actions

The 58 Recommendations for Aeronautics Research in Horizon Europe in the chapter 1 as an Introduction to the PARE Report are written in a concise technical language best suited to aviation professionals, summarizing: (i) the assessment of progress towards the 23 ACARE Goals in the chapters 2 to 6 of Part I; (ii) the five major topics in chapters 7 to 11 of Part II relating to the 34 PARE Objectives. The part III consists of five specific studies in chapters 12 to 16, each containing its own sectorial assessments, recommendations and conclusions and likewise the challenges for the future of aviation, thus these are not summarized neither in the initial chapter 1 nor in the final chapter 20.

The final Chapter 20 has a purpose similar or symmetrical to the initial in chapter 1, with a different presentation of the same themes of chapters 2 to 11 for a different audience. Whereas the 58 PARE Recommendations for aeronautics research in Horizon Europe are written as concisely and precisely as possible for aviation professionals, the set of articles in the chapter 20 as conclusion aim to highlight the main points in a form accessible to the motivated non-specialist. Each article consists reports on the "key findings" and the "key actions" they imply.

3.1 Meeting Societal and Market Needs

By 2050, passengers and freight experience must be improved, in order to meet the increasing demand for travel and to handle more easily unforeseeable events. Travel services should be affordable, quick, reliable, efficient, seamless and sustainable, based on a resilient air transport system and capable of automatically reconfigure the journey, including transfer to other transport modes, if necessary.

To guarantee this improvement, the Advisory Council for Aeronautics Research in Europe (ACARE) established the Flightpath 2050 goals. The second chapter of PARE's report, entitled "Meeting Social and Market Needs" addresses Flightpath 2050's goals 1 to 5, which concern air traffic capacity, ground infrastructure, mobility, speed and punctuality, respectively.

Air Traffic Capacity

Currently, the European airline traffic is around 10 million flights per year of all types of vehicles, and is expected to rise to 25 million by 2050, including unmanned and autonomous vehicles. This forecasted growth of air transport puts increasing demand on air traffic capacity with undiminished safety, being this capacity concerned with runway, airways terminal area and en route capacity, and its evolution closely related to air traffic management (ATM). The accommodation of such a growth in flights will be determined by the most restrictive of these three capacity limits, being it the runway capacity.

Key findings:

- In 2007, in Europe, there were about 45 main airports (large and medium hubs) and about 450 country and regional airports (commercial service airports). Three years later, the five major European airports hubs were at saturation – operating at full capacity;
- In 2016, the total numbers of passengers travelling by air in the EU could be established at 973 million, an increase of 5,9% compared to 2015;
- Over a European network of more than 2100 airports, 528 airports account for just 25% of airports, but 98% of the departures. Also, the 25 largest airports in Europe generate 44% of all flights and 90% of all traffic comes from the largest 250 airports;

- There is a geographical concentration of airports in the region London – Amsterdam – Munich – Milan, which creates dense air traffic, with large numbers of climbing and descending aircraft: a significant challenge for terminal area and en route capacity;
- The cities closest to Europe's busiest airports have between 4 and 46 airfields within 100 kilometers (km) from the city centre. For 8 of the 10 cities close to Europe's biggest airports, a single airport handles 80% or more of all the departures within 100 km;
- By 2030, it is expected that no fewer than 19 airports will be operating at full capacity eight hours a day, every day of the year, which means they will be highly congested and 50% of all flights will be affected by delays upon departure or arrival, or both.

During the past years, it has been identified a growing gap between capacity and demand at a number of busy European Union (EU) hubs, being predictable that Europe will not be in position to meet a large part of the expected demand due to a shortage of airport capacity. In concrete terms, in 2050, it is estimated that 36% of flight demand will not be accommodated at European airports.

Key actions: it is recommended that a broad and deep research effort is maintained concerning all aspects of ATM that can contribute to increase airspace capacity, which is the purpose of the 1st Flightpath 2050 goal, with equal or greater safety. Additionally, there are proposed projects and measures that could improve air traffic capacity:

1. Eurocontrol measures to mitigate the capacity challenges;

2. The SESAR project PJ02 (EARTH) - Increased Runway and Airport Throughput;

3. The Airport Collaborative Decision Making (ACDM) concept.

Ground Infrastructure and Multimodal Transport

Nowadays, new airports to serve major cities tend to be built farther requiring transport to reduce access time to the airport, which affect passenger convenience. Vertiports and heliports can be sited much closer to city centres, providing an alternative with faster access than airports, if noise and community issues can be resolved. By 2050, the air transport ground infrastructure should comprise major hubs, secondary airports, vertiports and heliports, all seamlessly connected within a multimodal transport system, and should include interfaces with other modes of transport.

Key findings:

- In the U.S., from the existent 5,664 heliports in 2016, both for private and public use, most of them were essentially unused and have been declared, throughout the years, inactive and for emergency use only. In Europe, unconfirmed reports indicate less than 100 civilian type heliports;
- The most frequent distance between European airport pairs is related to approximately 1000 km, while there are only a few potential links above 3000 km. At smaller airports, departures most often travel less than 300 km, and at large and very large airports, the 400 km distance bracket Is the most common, even though they have the largest share of 3500 km flights;
- Very high – speed train point to point connections (travelling at 250 km / hour) can be more time efficient than air transport over a distance up to about 600 km, although load factors are lower than in aviation (85% on average);
- Over 50 city-pairs will be connected by new or improved links between 2019 and 2035, such as high – speed trains that can offer comparable transport times for distances up to 800km. Passengers opting for rail will reduce the demand for flights by a little over 0,5% (estimated 0,7%) in 2035.

A network of small, traditional or electric aircraft that take off and land vertically, called Vertical Take – off and Landing (VTOL), would enable rapid, reliable transportation between suburbs and cities and, ultimately, within cities. On a different perspective, shifting short – haul flights to high speed - train would reduce, even slowly, the unaccommodated demand for flights, by reducing the demand for flights.

Key actions: it is recommended that urban and land planning methodologies are developed to optimize, on a regional basis, the location of airports, vertiports and heliports to simultaneously provide convenient links to other transportation nodes and minimize environmental impacts and disturbance of populations. Some of the proposed measures mentioned before could also improve the connectivity of (or the mobility between) airports, which is the aim of the 2nd Flightpath 2050 goal, as well as the new initiative, named ONE Order, proposed by the International Air Transport Association (IATA).

Choice of Most Efficient Mobility Solutions

The progress in mobile communications and availability of information should ensure that, in 2050, European citizens can make informed mobility choices among several available travel options and have affordable access to one another, taking into account economy, speed and level of service (that can be tailored to the individual customer). Additionally, continuous, secure and robust bandwidth communications should be provided for added value applications.

Key findings:

- In 2009, according to a survey conducted within ModAir project, no airport website provided enough information for the customer to be able to plan the entire trip. Customers needed to visit several websites to do that and still, websites didn't provide information about transit times between different travel modes nor real time information about delays in ground transportation;
- According to ModAir project, a clearly important requirement for passengers is to easily access reliable, impartial and real time information, both for pre – trip planning and to be kept informed of relevant developments during the journey;
- Passengers are mainly willing for better information related to intermodality, comprehensibility of the reservation systems (including better prices when booked air and rail are together), flexibility on their bookings and a secure framework with clear operators 'liability conditions;
- Automation will enable passengers to be informed about the current status of their journey and alternative options, periodically or on demand, using smart phones or interactive panels/screens situated along the intermodal transport network.

In conclusion, nowadays there are many sources of travel information and services with different objectives and priorities making the choice confusing and often non-comparable. Moreover, there is the necessity to develop and/or implement solutions to provide passengers with real time information during their entire journey.

Key actions: to achieve the 3rd Flightpath 2050 goal, it is recommended that a one-shop centralized travel information site is promoted where the EU citizen can readily find the alternative options for connecting any two locations, including costs and timetables, with links to reliable booking.

Overall Ground plus Air Travel Time

By 2050, the interfaces of the airport with other modes of transport must allow 90% of passengers within Europe to be able to complete their journey, door-to-door (D2D) within 4 hours. This D2D time comprises the origin airport access time, the time inside the origin airport to go through airport services, the air travel time, the time inside the destination airport and the time from the destination airport to the final destination place.

Key findings:

- In 2016, the average departure delay per flight ranged from 8 to 16 minutes, with an annual average all – cause departure delay per flight of 11.3 minutes. The aircraft turnaround related processes have been the main factor that have induced delays in the air transport operation over the years;
- For almost 80% of the European cities, the nearest airport is situated at 20 km. Such a short distance reflects that the general accessibility of the European airports is high;
- Passengers spend on average, using Madrid as example, more than thirty minutes to get to the airport. Therefore, researching new ways to get to the airports (for example, the use of VLOTs) from the city centers would be the first key to actually reduce the travel duration;
- The second key to actually reduce travel duration would be the improvement of the current processes carrying at the airports or even the design of a new system regarding both passengers and luggage processes;
- Air travel times can vary significantly in Europe, from one hour in central Europe to four hours between extremities of the continent. Besides depending on flight distance, which can go up to 3000 km within the EU, travel times also depend on the aircraft engine type, being that an aircraft jet powered is faster than one propeller driven.

To sum up, key enablers to reduce overall travel times are a reduction in airport access times, a higher predictability of times accessing the airport and process times inside the terminal. However, as the aviation factor cannot be responsible for what happens outside the aircraft and airports and cannot influence travel time to or from the airport, the 4th Flightpath 2050 goal should only consider travel times and process times inside the terminal.

Key actions: it is recommended that the 4th Flightpath 2050 goal is revised to take into account the distance and duration of flight and cover the time period from arrival at the departure airport to exit from the destination airport. The project DATASET2050 can support this revision process since it addresses the EU passenger mobility in the context of the D2D objectives defined in the Flightpath 2050 vision.

ATM and Weather

In 2050, flights should arrive within 1 minute of the planned arrival time, regardless of weather conditions, thanks to a resilient transport system, capable of automatically and dynamically reconfiguring the journey within the network to meet the needs of the traveler if disruption occurs. Likewise, special mission flights should be able to be completed in the majority of weather, atmospheric conditions and operational environments.

This punctuality of air transport in adverse conditions depends on availability of meteorological data sufficiently in advance for efficient re-routing. Disruptive events and special flights that require reconfiguration of multiple flight paths can be made efficiently if supported by fast and reliable simulation tools.

Key findings:

- A flight is considered to be delayed when it is 15 minutes later than its scheduled time. In 2016, yearly airline arrival punctuality decreased, with 81% of flights arriving within this time, compared to 82% in 2015. Weather delays slightly increased, compared with 2015, to 0.57 minutes per flight;
- The basic issue is overall ATM capacity, not only at airports and in terminal areas, but also en route, with spare capacity to cope with special missions, disruptions and weather hazards (weather conditions such as icing, strong wind, low visibility, snow, etc.);
- A high average weather-related airport arrival delay is usually the result of a notable capacity reduction in bad weather combined with a high level of demand;

- At U.S. airports, the higher frequency of instrument meteorological conditions (IMC) combined with scheduling closer to visual meteorological conditions (VMC) are key elements to reduce winter delays. Weather – dependent delays are more relevant during summer months;
- Both in U.S. and Europe, weather is the predominant element affecting the airport throughput and as consequence of ATM – related departure restrictions. In Europe weather – related constraints represent a smaller share of delays than in U.S., even though weather in Europe is less favorable;
- Runway throughput rates depend on visibility conditions and are reduced significantly when Low Visibility Procedures (LVPs) have to be adopted, since they require an increased spacing between aircraft.

In conclusion, ATM performance depends on a number of factors and is affected by meteorological conditions, such as visibility, wind and convective weather, and can vary significantly in different airports, according to the airport equipment, runway configurations (wind conditions) and approved rules and procedures. Therefore, additional efforts are required to relate weather conditions on airport and ATM performance and to develop a more comprehensive assessment of weather impact.

Key actions: it is recommended that a more comprehensive weather data is made available to ATM and airlines to assist achieving punctuality targets and that a rapid near real time simulation capability is developed for ATM to accommodate special emerging flights and adjust to major disruptive events.

For more information about these topics, you can access the full chapter here.

3.2 Maintaining and Extending Industrial Leadership

By 2050, the innovative, sustainable and highly competitive European aviation industry must cement its place as the world leader and be recognized globally for its vehicles, engines, services and a large range of very cost effective and energy efficient products. This leading position should be secured though a seamless European research and innovation system that assures continuity through blue sky research, applied research, development, demonstration and innovation in products and services.

To assure that this overall goal is met, the Advisory Council for Aeronautics Research in Europe (ACARE) established the specific Flightpath 2050 goals 6 to 8, which concern the maintenance and extension of Europe's leading position in the aeronautical sector, the mastering of a wide range of technologies and the integration of these in an aircraft design and development program, respectively. The 3rd chapter of PARE report, entitled "Maintaining and Extending Industrial Leadership", addresses these goals.

Retaining and Strengthening Market Share

Nowadays, the European aeronautical industry sustains a near peer position with its worldwide competitors in almost all aerospace applications: large civil jet aircraft, regional aircraft, helicopters, military aircraft, missiles, satellites and launchers, engines and equipment. In 2050, it must be equally competitive, deliver the best products and services worldwide and have a share of more than 40% of the world market.

Key Findings:

- Airbus has a share of 50% of world market for jet airliners with more than 100 seats and the Airbus – Boeing 'duopoly' dominates the market for jet airlines of more than 120 seats, with a full range of narrow and wide body aircraft;
- ATR is the leading supplier in the regional aircraft market;
- Airbus Helicopters (formerly Eurocopter) and Augusta – Westland are market leaders in helicopters;
- Dual use and specific technologies ensure an equally strong position in the world market for military aircraft, missiles, space launchers and satellites;

- Safran and Rolls – Royce rival Pratt & Whitney and General Electric in aero – engines and in the equipment sector, Liebherr, Safran, GKN and others are major suppliers of European and non- European aircraft.

These impressive achievements across a full range of aeronautical products depend on: leading – edge technologies in all the sectors contributing to the design of aeronautical vehicles and the integration of all these cutting – edge technologies in efficient aircraft production, certification and service support programmes.

Key Actions: it is recommended that a broad – based application – oriented research and development activity is maintained covering all sectors relevant to the global competitiveness of the European aircraft industry, which is part of the 6th Flightpath 2050 goal.

Cutting-edge at the Full Range of Technologies

Modern Europe is facing several challenges, among which is the introduction of innovative technological solutions to the European aviation market. To be concrete, the competitiveness of the aerospace industry depends on mastering cutting - edge technologies over a wide range of 11 technological areas. Therefore, for Europe to remain competitive, it must retain leading edge design, manufacturing and system integration capabilities and jobs supported by high profile, strategic, flagship projects and programmes which cover the whole innovation process from basic research to flight demonstrators by 2050.

Key Findings:

- The necessity to introduce new technological solutions results from the needs of society, new technologies that have appeared and new types of transport means and air transport systems;
- There are many challenges for aviation industry especially from the environmental side, being that the amount of greenhouse gases generated by the aviation industry accounts for about 13% of the total generated amount in the world;
- There are currently two aviation programs being implemented in Europe that give answer to Europe's challenges, which are Clean Sky 2 and SESAR 2020. Other smaller programs that contribute to the development of innovative cutting edge solutions are: EPATS (continued in the frame of SAT-Rdmp), FUSETRA, GABRIEL and ERA;
- Patents in the mentioned technological areas are an indicator of innovation in aviation. Since 1969, the peak in the number of patents in aviation per year was reached in 2016, with approximately 3500 patents in aviation.

Although the European aerospace industry is currently quite competitive, there are a number of emerging technologies that could be used by current and new competitors to change the balance, which need to be monitored and supported to ensure Europe remains a leader in the aeronautical sector.

Key Actions: to achieve the 7th Flightpath Goal, it is recommended that a stable independent observatory of citizen needs, global trends in aviation and technological advances that could meet them, is supported to ensure that major breakthroughs occur first in Europe or are matched without delay in reaching the market.

Efficient Development and Life-Cycle Management

The growing capability (related with certification) and complexity (frequently supported by new technologies) of the modern aircraft increases the relevance of life – cycle analysis that needs to be considered also at component level, such as batteries. Taking this into account, by 2050, streamlined systems engineering, design, manufacturing, certification and upgrade processes should have addressed complexity and significantly decreased development costs (including a 50% reduction in the cost of certification). Also, a leading new generation of standards should have been created.

Key Findings:

- Rise in the cost of development (including certification) is correlated with the increased complexity of the machine;
- Two measures of aeronautical development efficacy are: specific development cost (SDC) and specific development period (SDP), both per number of model's passenger seats;
- Significant reductions on the measures mentioned before can be achieved by:
    - Intensive use of modelling and simulation instead of physical test and experiment;
    - More specific, flexible and adaptive regulatory requirements (standards) for certification, including the involvement of airworthiness authority in virtual design; and
    - A fully integrated multi – physics and multi – scale model of the complete aircraft should be coupled with aerodynamic and thermal models, eliminating ground test rigs completely;

To reduce CO2 emissions considerably, which is a challenge for the aviation industry, the interest in hybrid and/or electric aircrafts is increasing worldwide. This would require an efficient power source for the electric engine and, in view of its high energy density, long life, and rate capability, the lithium-ion battery is an ideal candidate for this purpose. However, batteries also introduce new safety concerns to aircraft that would have to be managed.

Key Actions: it is recommended that the architecture of industrial aviation programmes in analysed in order to identify best practices in matching design, development, certification, production, operations and maintenance in the most cost – effective and time – efficient manner. Also, the introduction of new technologies and stricter safety requirements should be accompanied by more efficient testing and validation to minimize time and cost.

For more information about these topics, you can access the full chapter here.

3.3 Protecting the Environment and the Energy Supply

In 2050, the effect of aviation on the atmosphere must be fully understood by the general public and must convince it that the aviation sector has made the utmost progress in mitigating environmental impacts and therefore air travel is environmentally sustainable. For this, a combination of measures, including technology development, operational procedures and market - based incentives should be taken into account to mitigate environmental impacts at a rate outweighing the effects of increasing traffic levels.

To ensure that this overall goal is met, ACARE established the specific Flightpath 2050 goals 9 to 13, concerning the reduction of noise and emissions, emissions – free taxying, recycling enabled by design, alternative fuels and atmospheric research, respectively. The 4th chapter of PARE report, entitled "Protecting the Environment and the Energy Supply", addresses this set of 5 goals.

Reductions of Noise and Emissions

The growth of air transport at a rate of 3 to 7% per year leads to flights increased to the double by 2030, and triple by 2050. In order to avoid increased noise exposure near airports and emissions in cruise, the corresponding reductions must be made per flight. To be concrete, in 2050, technologies and procedures available must allow a 75% reduction in Carbon Dioxide (CO2) emissions per passenger kilometre (km), a 90% reduction in Nitrogen Oxides (NOx) emissions and a 65% reduction in the perceived noise of flying aircraft. These reductions are relative to the capabilities of typical new aircraft in 2000.

Key Findings:

- Overall noise reduction at airports requires consideration of two classes of noise sources: engine noise sources and aerodynamic noise sources. Noise is dominated by the engine at high thrust at take - off and by aerodynamics at approach with the engine at idle;
- The major contributor to the reduction of engine noise has been the increase in the by - pass ratio of turbofan engines, which also decreases fuel consumption, leading both to lower emissions and more favourable economics;
- The overall noise exposure of near airport residents can be reduced by land planning and by operational measures, such as noise abatement procedures (NAP), which can be broken down into three broad categories: noise abatement flight procedures, spatial management and ground management;
- Aviation emissions of CO2 and NOx are produced by aircraft, support vehicles and ground transportation dominantly. The emissions from these sources fall into two categories: emissions that cause deterioration in local air quality (LAQ) and emissions that cause climate change;
- In 2012, aviation represented 13% of all European Union (EU) transport CO2 emissions and 3% of the total EU CO2 emissions. European aviation specifically represented 22% of global aviation's CO2 emissions. Similarly, aviation now comprises 14% of all EU transport NOx emissions, and 7% of the total EU NOx emissions;
- As a result of technological improvements, the noise footprint (85 decibels dB (A) maximum sound pressure level contour) of new aircraft is at least 15% (up to 50%) smaller than that of the aircraft they replace. Further design improvements offer the potential to reduce perceived noise from aircraft by 65% by 2050;
- ACARE runs the research projects Aviation Noise Research Network and Coordination (X - Noise EV) and Forum on Aviation and Emissions (Forum AE), related to aviation noise research and emissions research, respectively.

Key Actions: it is recommended that:

1. A broad research effort is supported to reduce aircraft noise at the source through operating procedures and taking into account psychoacoustic effects;
2. A modest effort is made towards a long-term definitive solution: aircraft inaudible outside airport boundaries and hydrogen propulsion that emits only water vapour, besides struggling with short-term solutions to an increasingly pressing noise problem;
3. A set of trade-offs is formulated between different types of emissions (CO2, NOx, particles and water vapor) in local airports and global cruise flights.

Emissions - free Taxying at Airports

The taxying of aircraft on engine power and the use of auxiliary power units (APU) on the ground can be significant contributors to emissions at airports and also generate noise. By 2050, aircraft movements must be emissions – free when taxying, which can be achieved with electric towing vehicles and power supplies, especially batteries. Therefore, the feasibility and economic of emissions - free taxying critically depends on the available battery technology.

Key Findings:

- The current preferred battery technologies for ground movements at the airport or on the airfield and in the aircraft itself are the lead – acid and the nickel – cadmium (Ni - Cd) batteries. However, since these batteries are technically exhausted, no significant improvement in terms of energy density, cycle life, calendar life, etc. is expected;
- There is a shift to lithium – ion (li - ion) technology in the aviation industry, being that li - ion chemistry offers a large variety of materials and cell architectures, which enables the possibility to design high - power as well as high - energy systems;

- In general, regarding li – ion batteries, an increase in the energy density, with state-of-the-art chemistry, could be mainly achieved by optimizing the form factor and the cell production process. Nevertheless, even if the current chemistry has proven itself, efforts are still to be made to increase the energy density as well as other key performance parameters to meet future requirements;
- There are several deficiencies of actual day li – ion batteries that, if remedied with suitable ease and cost parameters, would enable superior li – ion batteries that could open new applications and expand the market for present ones;
- Although electric towing and power supplies are feasible, the investment in vehicles and support infrastructure must be assessed as well as how costs are covered.

Key Actions: it is recommended that a methodology to comprehensively assess the implications of electric taxying and electrical energy supply is developed in terms of requirements, costs, land and environmental impact for a variety of airport configurations.

Design and Manufacture bearing in mind recycling

Competition in the aircraft industry market and global warming has driven the industry to think along economic and environmental lines. For instance, in 2050, air vehicles must be designed and manufactured to be recyclable, preventing depletion of limited resources and making better and repeated use of materials already available. This goal has resulted in the emergence of a more electric aircraft (MEA) concept, providing the utilization of electric power for all non – propulsive systems.

Key Findings:

- Recycling of aircraft parts depends mostly on the materials used and also on the fabrication process. The choice of materials for an aircraft is subject to a considerable set of constraints related to performance, weight, availability, cost, ease of manufacture and maintenance, durability and resistance to hostile environments. Adding the recycling ability is an additional constraint which can bring benefits in several of other areas;
- Recent technological advances in the field of power electronics, fault-tolerant architecture, electro-hydrostatic actuators, flight control systems, high density electric motors, power generation and conversion systems have ushered the era of the MEA;
- A small size, high energy density (more than 100 watt-hour per kilogram (Wh/kg)) battery is the need of the aircraft industry as a 10kg decrease in the weight of aircraft will result in the savings of 17,000 tons of fuel and 54,000 tons of carbon dioxide emission per year for all air traffic worldwide. The reduction in battery weight is also profitable in terms of cost;

- The life duration of an aircraft battery depends on various factors such as number of operating hours, ambient temperature, start frequency and on-board charge. It is therefore difficult to determine in advance how long the expected life of a battery will be in the real situation;
- Though most of the civil aircraft have used Ni - Cd batteries, the trend is shifting towards li - ion batteries with its tremendous opportunities to be employed in MEA. However, li - ion cells comprise a sensitive electrochemistry which needs a detailed knowledge of its characteristics to allow its benefits to be exploited fully while ensuring maximum safety;
- In general, the same processes used to recycle automotive batteries are used to recycle aircraft batteries. Examples of battery recycling plants operating in Europe are: *Batrec* in Switzerland, *Umicore* in Belgium, and *SNAM* and *Recupyl* in France.

Key Actions: it is recommended that a comprehensive assessment of materials used in aircraft production is made and that recyclable alternatives and related issues of availability, ease of use, certification, maintenance and cost are assessed.

Sustainable Alternative Fuels Sources

Nowadays, there is a strong need to reduce the dependence on fossil fuels which affects all modes of transport. Even though aviation is not the largest user, it should try to improve its position and contribution to the whole by finding sustainable alternative less polluting fuels and possibly also safer handling with undiminished energy density per unit weight and volume. European aviation specifically must guarantee that, in 2050, Europe is established as a centre of excellence for sustainable alternative fuels, including those for aviation, based on a strong European energy policy.

Key Findings:

- The European Commission (EC), Airbus, and high-level representatives of the Aviation and Biofuel producer's industries launched in 2011 the European Advanced Biofuels Flightpath. This action is scheduled to achieve 2 million tons of sustainable biofuels used in the EU civil aviation sector by the year 2020;
- By now, several alternative biofuels are under scrutiny or are already approved: synthetic Fischer – Tropsch (FT); hydrogenated esters and fatty acids (HEFA); pyrolysis oils (HPO); and alcohol to jet (ATJ). Although there are already potential alternatives, it is not easy to match the energy density, usability and cost of kerosene/paraffin in large quantities;
- The use of alternative biofuels has been explored by the Initiative Towards sustAinable Kerosene for Aviation (ITAKA) project. ACARE also runs the research project entitled Coordinating research and innovation of Jet and other sustainable aviation Fuel (Core – JetFuel);
- Although airlines have been willing to test new fuels, a coordinated effort must be done far upstream to: consider a variety of sources of fuel, that do not interfere with food production and whose environmental impact is neutral or positive (waste disposal); establish the technical feasibility to meet all applicable quality and safety standards and certification requirements; and assess the economic and environmental feasibility of large-scale sustained production, distribution and use.

Key Actions: it is recommended that a comparative study of potential alternative fuels, their availability in the required large quantities and the feasibility and cost of large - scale production, distribution and use is performed.

Atmospheric Research, Weather and the Environment

Aviation is one of the most climate/weather sensitive industries: it is affected by changes to visibility, storminess, temperature, icing events, etc. Therefore, one of the most important activities is to assess the atmosphere and the environment state in order to predict the future climate issues and develop mitigation strategies, which would help to reduce possible disturbances in the airspace and allow an increase in airports capacity. Taking this into account, in 2050, Europe should be at the forefront of atmospheric research and take the lead in the formulation of a prioritized environmental action plan and establishment of global environmental standards.

Key Findings:

- The monitoring of the atmosphere is performed by a vast array of earth and satellite sensors, plus specialized weather aircraft used to fly through tropical storms and collect *in-situ* (non-space) atmospheric data. It is possible to obtain much more comprehensive weather data both in time and locations aboard aircraft in regular flights;

- There are several methods to monitor the atmosphere, such as: routine ground – based measurements (made by ground – based sensors – land based and buoys); systematic aircraft measurements (made by aircraft and balloons); and satellite measurements (made by space – borne sensors);
- Changes to temperature, precipitation, and storm patterns are all expected in the near-term, certainly by 2030. The impacts of sea level rise are more gradual and not expected until later in the century. However, more frequent and intense storm surges will have an earlier impact on European aviation, reducing capacity and increasing delay;
- Currently, there are several European initiatives and projects that have as main objective monitoring the atmosphere through satellite and airborne instrumentation, which are:
    - Copernicus project, previously known as the Global Monitoring for Environment and Security (GMES);
    - Constellation Observing System for Meteorology, Ionosphere and Climate (COSMIC) project;
    - Advanced Satellite Aviation Weather Products (ASAP) initiative;
    - European Organisation for the Exploitation of Meteorological Satellites (EUMESAT);
    - In – service Aircraft for a Global Observing System (IAGOS) project.

Key Actions: it is recommended that regular airliner flights are used to collect *in-situ* atmospheric data, which should further be processed to have near real - time knowledge of conditions along flight routes. This data could be supplemented by drones – unmanned aircraft systems (UAS) - specifically designed to fly in more remote regions of the atmosphere.

For more information about these topics, you can access the full chapter here.

3.4 Ensuring Safety and Security

In 2050, European aviation must have achieved unprecedented levels of safety and security and continue to improve. The accident rate in commercial flight must be less than one per million flights and all types of aircraft and rotorcraft must safely operate in the same airspace and in most weather conditions. On the other hand, security processes for passengers and cargo must allow seamless and non-intrusive security, air vehicles must be resilient to internal and external threats, and air transport data networks must be hardened against and resilient to cyberattacks.

To ensure that all of these goals are met, the Advisory Council for Aeronautics Research in Europe (ACARE) established the specific Flightpath 2050 goals 14 to 19, which are addressed in the 5th chapter of PARE report, entitled "Ensuring Safety and Security".

Ultra – Low Accident Rate in Commercial Flight

The aviation accident rate has been declining throughout the years, nevertheless, the rate of decline has slowed markedly since 2004 and, at the same time, we are seeing a continued growth in the number of flights, which are set almost to the triple by 2050. In 2015, the accident rate of the European Union Aviation Safety Agency (EASA) Member States (MS) operators of Commercial Air Transport (CAT) aeroplanes was approximately 3 accidents per million flights. By 2050, the European air transport system must have reduced this rate to less than one accident per million commercial aircraft flights.

Key Findings:

- From 2010 to 2015, on EU's territory and with EU–registered aircraft, there were 188 fatalities (155 fatalities in 2015 from the 3 accidents) in CAT aeroplanes and, in 2016, there was only one fatal accident involving any EASA MS operator of CAT aeroplanes;
- The Key Risk Areas identified by EASA MS operators for accidents and serious incidents are: (a) system/technical failure, (b) airborne collision/conflict – collision of two aircraft in the air, (c) movement area

collision or ground collision/handling, (d) fire, (e) runway excursion or abnormal runway contact, (f) runway collision, (g) aircraft upset – full range of loss of control situations, (h) terrain collision/conflict – aircraft collision with terrain, and (i) obstacle collision;

- Comparing the average number of CAT EASA MS accidents and serious incidents by Key Risk Area for the period 2007 – 2015 with that of 2016, the Key Risk Areas (a), (b) and (e) show a negative change in 2016 (from stable trend to increasing or from decreasing to increasing) in contribution to fatal accidents in these 10 years, accounting for 18% of those accidents. Aircraft upset represents only 3% of the accidents and serious incidents involving an EASA MS operator in 2016, but continues to be the most fatal Risk Key Area for EASA MS operators;
- With 45% of fatal accidents involving technical failures in some way during the 2007 to 2016 period, this is both a major accident outcome and a precursor to other types of accident. Over these 10 years, 27% of fatal accidents involved ground collision and other associated ground events;
- The origins of the causal and contributory factors behind the accidents and serious incidents involving EASA MS operators between 2007 and 2016 are: flight operators (56.64%), technical (21.30%), human factors (8.53%), Air Traffic Management (ATM) (5.87%), aerodrome operations (4.49%), organisational (2.40%) and maintenance (0.77%).

Key Actions: the safest mode of transport can only benefit from being made even safer, which requires investigating accident classes, finding preventive and corrective actions and proving that they can be implemented. It is recommended that accident causes are considered by order of statistical occurrence and that appropriate safeguards for each class are identified and implemented.

Weather-Hazards and Risk Mitigation

The aviation system is highly sensitive against disturbing weather effects that can become hazardous for the aircraft operation by producing setbacks such as delays and accidents/incidents. Moreover, due to the expected growth in aviation, an increasing number of airports will operate near their capacity limit and hence will be more sensitive to disturbances by weather phenomena. To ensure safety, by 2050, weather and other hazards from the environment must have been precisely evaluated and risks properly mitigated.

Key Findings:

- Weather is responsible for: 13% of all aircraft losses between 1995 and 2004, 33% of all accidents/incidents from 2004 to 2007 and 40-50% of delays at European airports;
- The severe weather-related accidents and incidents can be attributed to the following weather–hazards: wind, wind shear and turbulence; in-flight icing; low visibility due to lithometers, fog or precipitation; lee waves; hail damage; thunderstorms; and volcanic ash;
- During the flight in en-route area, aviation is only disrupted marginally by weather phenomena. However, during start and landing, it is very sensitive to those effects, especially fog, snow and wind, which can disrupt the operations with even a low intensity;
- The severe weather impact can be associated with two different, yet interdependent, risks, notably Flight Safety Risk and Flight Efficiency Risk (likelihood and potential extent of incurred flight delays or even cancellations made due to severe weather risk management). The Flight Safety Risk can have different sources and manifestations: In-flight Safety Risk (impact on flight crew), which is divided into Hazard Encounter Risk and Knock-on Flight Safety Risk, and ATCO Excessive Overload Risk. In particular, the Hazard Encounter Risk is described using two generic risk management functions: risk prevention and risk mitigation.

Key Actions: besides collecting higher-quality and more comprehensive weather data with higher spatial and temporal resolution (see ACARE goals 5 – Article Chapter 2 - and 13 – Article Chapter 4), its effects on aircraft dynamics must be modelled to identify effective prevention and corrective actions that must be simulated and further validated. Therefore, it is recommended that a low–cost basic research on flights in adverse weather conditions (*e.g.* wind, rain, ash clouds, lightning, icing, storms and weather fronts) is promoted and promising advances are selected for demonstration.

Integrating Drones in Manned Airspace

The record of aviation as the safest mode of transportation is based on the highest engineering standards and professional qualifications as regards aircraft and cannot be compromised for Unmanned Aerial Vehicles (UAVs) operating in the same airspace. These UAVs constitute a new threat to the European airspace as demonstrated by the occurrence of several incidents involving conventional aircraft and UAVs. However, in 2050, the European air transport system must operate seamlessly through interoperable and networked systems allowing manned and UAVs to safely operate simultaneously in the same airspace.

Key Findings:

- Unmanned aerial system (UAS), of which the UAV is the airborne component, comprises two fundamental types: Remotely-Piloted Aircraft Systems (RPAS), a class of UAS that has a "pilot" operating the Remotely-Piloted Aircraft (RPA) from a Ground-Control Station (GCS); and UAS with no remote pilot, or autonomous air vehicles (AAVs). The term "drone" although possibly inaccurate or inappropriate, refers to all types of UAS;
- There are two types of UAS operations: 1) the professional use of drones for various security, safety, survey and other tasks; and 2) the recreational use where the general public are using drones for fun and private activities. The Key Risk Areas identified in UAS operations are: (a) airborne conflict/collision – the collision of UAs with aircraft in the air, (b) aircraft upset, (c) system failure and (d) third party conflict – the collision of UAS with people or property;
- There is an increasing trend in the number of reported UAS occurrences (both incidents and accidents) per year from 2010 to May 2016 inclusive (which may be due to the increasing number of drones within the EU), from which 63% are related to Airborne Conflict, which is the main Key Risk Area. This means that airspace infringements and proximity of drones to other aircraft if causing a significant number of occurrences;
- Within the previous time period, the highest number of occurrences took place in D and G airspace classes and during approach and en-route phases of the flight. Regarding the altitude, when the drones are spotted the manned aircraft is most often in the area from 0-6000 feet (≈ 0-1829 meters) above the ground and the distance from the aircraft to the drone is from 0-1000 feet (≈ 0–305 meters);
- Conventional ATM cannot be applied to unmanned aircraft and therefore the EU needs to develop a UAS Traffic Management (UTM) system that allows UAVs to fly jointly manned aircraft and implement the regulatory framework regarding the integration of UAS into busy airspace as it is European airspace. Also, the use of partially unused airspace could provide testing area and additional capacity for UAVs to prove to be at least equal to manned aircraft in terms of safety.

Key Actions: it is recommended that:

1. The evolution of air traffic capacity in Europe compared with the growth of air transport is assessed to identify the spare capacity available to other users like UAVs;
2. The qualifications required of operators of UAVs and other aircraft compared with airline pilots and air traffic controllers are established to ensure that aviation remains the safest means of transport;
3. The design, production, certification and maintenance procedures for UAVs and other aircraft are defined to preserve or improve on the safety levels of current airliners that operate in the same airspace;
4. The increased use of partially underused airspace is explored to enable the expansion of operations by new types of aircraft.

Comprehensive and Unobtrusive Security Measures

The recent societal threat of terrorist acts at airports or during flight implies the reinforcement of security measures to prevent those acts to happen, resulting in delays and queues, which are the most frequent sources of traveller dissatisfaction. While the patience and understanding of passengers are essential, there should be a minimum of delay, intrusion and disruption in the implementation of safety measures, through the use of the most appropriate equipment and airport architectures. In 2050, efficient boarding and security measures must allow seamless and non-intrusive security for global travel, with minimum passenger and cargo impact.

Key Findings:

- The main types of scanning and detection devices currently deployed by European airports are based on the following existing technologies: Advanced Imaging Technology (AIT), Advanced Technology (AT) X-Ray, Boarding Pass Scanners, Bottled Liquids Scanners (BLS), Chemical Analysis Devices (CAD), Enhanced Metal Detector (EMD) and Explosives Detection Dogs (EDD) and Explosives Trace Detector (ETD);
- Passengers spend on average 20 minutes waiting in line to get to the security screening checkpoint. New technologies and procedures could significantly reduce these waiting times, allowing to process about 360 passengers per hour instead of the approximately 150 passengers per hour that are processed nowadays;
- Examples of emerging trends in technology for threat detection that could improve airport security and efficiency while reducing the burden for passengers are biometrics screening, computed tomography (CT) scanning, facial scanning and behavioural analytics. Nevertheless, all of these new technologies are in the first level of maturity, *i.e.*, in the concept phase;
- Until now, most risk-based decisions regarding the checkpoint have focused on assessing the risk of a particular item but considering all passengers as equals. A new risk-based differentiation concept is introduced, which focuses its attention on "the person" in the assessment of threats, instead of focusing on the risk of the item. As a result, based on a reasoned process of selection, different people would be screened in different ways;
- The project Smart Security, a joint initiative of the International Air Transport Association (IATA) and Airports Council International (ACI), defines a future where passengers proceed through security checkpoints with minimal inconvenience, where security resources are allocated based on risk and where airport facilities are optimized, through the implementation of new technologies and processes.

Key Actions: it is recommended that non-intrusive passenger screening methods and foolproof luggage checking that allow fast flow through registration, border and boarding procedures are developed.

Resilience to External and Internal Threats

The EU is facing one of the greatest security challenges in its history. Threats are increasingly taking non-conventional forms, some physical such as new forms of terrorism, some using the digital space with complex cyberattacks. Nevertheless, by 2050, air vehicles must be resilient by design to current and predicted on-board and on the ground security threat evolution, internally and externally to the aircraft.

Key Findings:

- Current and emerging threats to aviation security have been clustered into the following eight threat categories: 1) Improvised Explosive Devices (IED), firearms and close range destructive threats; 2) Chemical, Biological, Radioactive, Nuclear and Explosive (CBRNE) threats; 3) Ground-to-air threats; 4) Ground-to-ground threats; 5) Cyber threats; 6) Electromagnetic threats; 7) Sabotage, seizure and hijacking; and 8) Bluff threats and threats from social media;
- Currently, aviation security is primarily based on the preventive phase and is inflexible to new threats. This is also mirrored in the research landscape for aviation security once most projects concentrate on preventive measures such as the detection of CBRNE-substances. However, the aviation security system should be

resilient to the evolving threat situation, thus be based on the complete resilience cycle which has the following phases: prepare (take into account), prevent (repel or thwart), protect against (absorb or mitigate), respond to (cope with) and recover from (and adapt to).

Key Actions: it is recommended that:

1. Aircraft are designed and procedures are established to (a) prevent unauthorised entry into the cockpit, (b) allow remote take-over up to safe landing in the case of an identified flight anomaly while (c) designing the system to be immune to the most sophisticated hacking;
2. An independent observatory of external risks to aircraft overflights is set up to advise airlines, or failing that, warn passengers;
3. A worldwide airliner flight monitoring system and accident data recorders are designed to ensure that accident/incident data is available regardless of time and location of occurrence.

High–Handwidth Data Resilient to Cyber Attacks

The use of digital data and the level of interconnection of IT systems are strongly increasing in civil aviation. Consequently, stakeholders of the air transport system like airlines, airport and air traffic control (ATC) are more and more interlinked and, thus, depend on secure means of data exchange. In the future, it is expected an increase in this inter-connectivity, which means the air transport system will be even more vulnerable and exposed to multiple points of attacks. Taking this into account, in 2050, the air transport system must have a fully secured global high-bandwidth data network, hardened and resilient by design to cyberattacks.

Key Findings:

- More than a dozen wireless technologies are currently used by air traffic communication systems during different flight phases. From a conceptual perspective, all of them are insecure as security was never part of their design. On the other hand, the L-band Digital Aeronautical Communications System (L-DACS) and Aeronautical Mobile Airport Communications System (Aero-MACS) that are supposed to replace the current Very High Frequency (VHS) system, have begun to at least consider the issue of wireless security and some corresponding designs are already included by the specifications or will be in the future;
- The assessment of cyber risk involves: 1) identification and inventory of key assets – data, systems and infrastructure – that are essential to operations; 2) revision of internal controls and digital profile to identify internal vulnerabilities and external threats; 3) valuation of the cyber assets at risk using modelling and other data and technology tools;
- The vulnerabilities that need to be taken into account are: (a) in a large, complex interconnected system there are many entry points for cyber intrusion and many links to spread the cyber-attack; (b) the weakest node may be the preferred entry point, for example small suppliers of equipment or codes well protected by large industries or government bodies;
- In order to face the future cyberattacks, firstly, it would be necessary to identify the multiple threats that could compromise aviation security (*e.g.* phishing threats, jamming threats, remote hijacking, distributed-denial-of-service (DDoS) attacks and Wi-Fi-based attacks) as well as to identify the systems which could be vulnerable to attacks. Then, it would be required to develop strategies in order to mitigate the threats identified;
- Blockchain is one of the favourites current technologies focused on cyber-security. However, Blockchain has also some technical challenges and limitations (throughput, latency, size and bandwidth, security – the current blockchain has a possibility of a 51% attack, wasted resources, usability, etc.) that made its application in aviation, air transport and ATM uncertain, and that will require further research in the future.

Key Actions: it is recommended that:

1. The evolution of bandwidth requirements required to cope with increasing telecommunication needs associated with improved navigation, on-board systems monitoring, passenger connection and other services, is assessed;
2. Evolving standards for protection against cyberattacks are established, with different levels, the highest for flight systems and the lowest but non-trivial for ticketing, bearing on mind the risk of intrusion from lower levels.

For more information about these topics, you can access the full chapter here.

3.5 Prioritizing Research, Testing Capabilities and Education

In 2050, Europe's aviation industry must be underpinned by world-class capabilities and facilities in research, test and validation and in education. Europe must have the world's leading research infrastructures covering the entire aviation system from wind tunnels through simulation facilities to test aircraft. At the same time, Europe's students in aviation-related university courses, which should be academically challenging and support the evolving needs of industry and research, must perform highly.

To ensure that all of these goals are met, the Advisory Council for Aeronautics Research and innovation in Europe (ACARE) established the specific Flightpath 2050 goals 20 to 23, which are addressed in the 6th chapter of PARE report, entitled "Prioritizing Research, Testing Capabilities and Education".

European Research and Innovation Agenda

There is a large gap between the high-quality scientific research sponsored by the European Research Council (ERC) and the market-oriented near term developments of the Joint Undertaking (JUs), *e.g.* "Clean Sky" and "SESAR", that needs to be filled by fundamental applied research with an aeronautical focus, to ensure that Europe remains a source of new ideas that are the basis of innovation and long-term competitiveness. Taking this into account, by 2050, European research and innovation strategies should be jointly defined by all stakeholders, public and private, and implemented in a coordinated way covering the entire innovation chain.

Key Findings:

- European research is defined and funded in a coherent and agile way, to avoid duplication and inefficiencies, prioritising initiatives resulting from strategic roadmaps defined and agreed by European stakeholders, satisfying actual needs (industry pull) and potential future demands (technology push);
- The European Union (EU) aeronautics programme has started with a budget of 36 M€ in the 2nd Framework Programme (FP) for Research and Technological Development (FP2) and had a steady growth to 3.6 B€ in the 7th Framework Programme (FP7), which testifies its success and the growing importance of this initiative;
- The growth of the aeronautics programme has seen a shift from (i) basic research (less than 1 M€), to (ii) industrial cooperation (4-10 M€), to (iii) large-scale demonstration (20-120 M€) to (iv) integration activities or JUs (more than 1 B€). This growth should be considered as an efficient element of integral European transport system growth that "provides completely safe, secure and sustainable mobility for people and goods;
- Technological innovation can achieve a faster and cheaper transition to a more efficient and sustainable European transport system by acting on three main factors: vehicles' efficiency through new engines, materials and design; cleaner energy use through new fuels and propulsion systems; better use of network and safer and more secure operations through information and communication systems;
- The ERC has sponsored high-quality research in basic science, including mathematics and physics, with some underrepresentation of engineering;

- Research facilities, used for different disciplines and specialities, differ greatly in size and range of application but are often linked to one another through a complex immaterial network that transforms basic scientific knowledge into competitive products while integrating environmental, safety and security requirements.

Key Actions: it is recommended that the long-term competitiveness of European aviation is safeguarded by supporting a Basic Research Programme (BRP) with a wide variety of low-cost applied basic research up to the 3rd Technology Readiness Level (TRL3), entitled "Experimental proof of concept", to bridge the gap between the fundamental research of ERC and near-market driven focus of Jus. This broad programme will ensure that Europe does not miss out the promising new ideas that could be exploited first by others to their advantage.

Industry-Research-Academia Clusters

As seen before, the EU FP have shifted from one end to the other and should be rebalanced. For this, by 2050, a network of multi-disciplinary technology clusters should be created based on collaboration between Aerospace Industry (AI), Universities and Academia (UA), and Research Centres (RC).

Key Findings:

- The creation of these technology clusters could be the result of 3 initiatives, two ongoing and one to be restored from the past: (iii) demonstration and (iv) integration activities existing in the JUs Clean Sky and SESAR; the fundamental research in mathematics, physics and engineering existing in the ERC; and restoring the (i) basic and (ii) industrial research that existed in the aeronautics programme since the beginning and lapsed with increasing scale;
- The following existing networks should be considered: Association of European Research Establishments in Aeronautics (EREA); Aerospace Engineering Universities (PEGASUS); Aviation Noise Research Network and Coordination (X-NOISE EV); and FORUM on Aviation and Emissions (FORUM-AE) project;
- From FP2 to FP7, the involvement of EU countries in FP projects suffered an evolution from a more uniform distribution towards a more concentrated one. Such change may be reasonably associated to the evolution of the relative importance of the different thematic categories (used to classify EU funded projects related to the aeronautic sector) and to the identification of a less fragmented and more specialized cooperation network;
- Considering all FPs, on average, an industrial actor participated in a mean number of 3.2 EU funded projects, with a standard deviation of 14.6, a research organization in 3.0 (11.1) projects, and a university in 2.6 (6.1) projects.

Key Actions: it is recommend to create multidisciplinary technology clusters, which require a balanced and proportionate support of 4 levels of projects:

1. basic research (3-5%): having 50-100 UA up to 1M€ each exploring up to TRL3 all sorts of novel promising ideas;
2. collaborative industrial (15-17%): 20-40 industrial research projects (4-10M€) joining AI, RC and UA develop further the more prospects;
3. large-scale demonstrators (20-30%): 5-10 large scale demonstrators (20-100M€) to reach a practical scale on the best results at a lower level;
4. JUs (50-60%): 1-2 JUs lead by industrial shorter-term applications (1-2B€).

Test, Simulation and Development Facilities

The large simulation and test facilities are essential institutional support to the aeronautical industry, representing large investments of the Member States that have been coordinated in some occasions (e.g. the joint Dutch-German aero-acoustic wind tunnel - DNW and the joint British-French-German cryogenic pressurized wind tunnel or European Transonic Wind tunnel - ETW). By 2050, strategic European aerospace test, simulation and development facilities should be identified, maintained and continuously developed, and the ground and airborne validation and certification processes should be integrated where appropriate.

Key Findings:

- Strategic aviation infrastructure is of the highest quality and efficiency, providing the basis for world-class research and competitive product development while supporting education. It ranges from wind tunnels via iron and copper birds up to experimental aircraft and simulation capabilities for in-flight and airport operations;
- The data quality and operational efficiency of European aviation infrastructure helps the industry to minimise risks and development costs and helps society to determine the impact of aviation in benefits such as fast transport as well as in penalties such as the impact on the atmosphere;
- The main topics of these facilities are:
    - Improved and validated fluid dynamics, aerodynamic control, combustion, noise and thermal modelling based on high-performance computation, covering all needs for the aircraft and its engines, external and internal;
    - Methods and tools facilitating the evaluation of aircraft and engine configurations;
    - Results from the demonstration, allowing to assess not only improvements in vehicle development but also to verify and validate new modelling techniques.

Key Actions: it is recommended that (a) a list of simulation, testing and certification needs and (b) an inventory of existing facilities in Europe are compared in order to identify the needs (i) already met, (ii) those requiring upgrades to be met or (iii) those requiring new facilities.

Young Talent and Women in Aviation

Aeronautics requires mostly but not only hard skills in STEM (Science, Technology, Engineering and Mathematics), that are becoming less abundant and eagerly sought by other sectors. Moreover, the aviation sector is already and will face a shortage of skilled aviation professionals in the future. Thus, the aviation industry must engage promising young talent of both genders as early as possible and sustain their interest. In 2050, students should be attracted to careers in aviation and courses offered by European Universities must closely match the needs of the AI, its research establishments and administrations and evolve continuously as those needs develop. Additionally, lifelong and continuous education in aviation should be the norm.

Key Findings:

- The major demographic trend in Europe is characterised by an ageing population and declining younger age cohorts. In 2010, the industry employment was already assisting to a concentration of age structures in the middle age range (35-50 years) and experiencing lower recruitment rates of youngsters – in part due to longer education and training periods – but also due to broad use of early retirement schemes. This demographic tendency, in addiction with lower proportions of qualified young people who were (and are) choosing for STEM-related careers was (is) a concern for the aerospace industry;
- Initiatives to mitigate the threat of skills shortages were already put in place in Europe:
    - national clusters units and the new European Aerospace Cluster Partnership (EACP) established opportunities to develop and expand transnational education and training programmes;
    - the Hamburg Qualification Initiative (HQI) established an exchange in the field of training between the aviation clusters of Hamburg and the French aerospace valley of the regions Midi-Pyrénées (Toulouse) and Aquitaine (Bordeaux);
    - PEGASUS alliance was created with the purpose to optimise the higher education services offered in the best interest of Europe both in terms of continuing to attract the best students and also to offer highly relevant educational and research programmes;

- To attract more young talent and women to aviation, the following measures are highlighted: (i) promotion of diversity in types of education and training; (ii) implementation of awareness programmes regarding careers in aviation; (iii) organisation and promotion of scholarships, grants and prizes; (iv) improving knowledge transfer from experienced to young employees by e.g. mentoring programmes (v) improvement of recruiting processes as well as of the working environment.

Key Actions: it is recommended that a comprehensive programme of attraction of talent to aeronautics to all education levels is fostered, complemented by job satisfaction measures at professional level, with special measures to promote gender equality and increase the participation of women.

For more information about these topics, you can access the full chapter here.

3.6 Aircraft Markets

Objectives 24 to 28 are addressed in the 7th chapter of PARE's report, entitled "Aircraft Markets", which focuses on the following markets: large or long-range aircraft, regional jet, business jet, convertibles and civil and military unmanned aerial vehicles (UAVs).

The Growing Airbus Challenge to Boeing

The long-range airliner market is dominated by the Airbus-Boeing duopoly (since the 1990s) that arose at the end of a long competitive period in which Airbus steadily gained ground starting from a newcomer status. The airlines that want a competitive choice of aircraft are least interested in the Airbus-Boeing duopoly becoming a monopoly. However, this has not deterred the long-running dispute at the World Trade Organisation (WTO), which may become a permanent nuisance if not properly contained. Considering this, by 2050, a level playing field in the large aircraft market should be promoted.

Key Findings:

- The middle of the market (MoM) segment is defined as a mid-size market, located between the narrow-body and the wide-body market, and which encompasses aircraft carrying 200 to 270 passengers and a range that can vary from 3 meters (m) to 5 m, respectively;
- The market shares in the single-aisle narrow-body and twin-aisle wide-body market are different, showing an appropriate balance: Airbus is leading the former and Boeing the latter. The third and fourth largest airliner manufacturers in the world, Embraer (Brazilian) and Bombardier (Canadian), are about one-tenth of the size of the two world leaders;
- The reasons for the duopoly are multiple:
    1. Airbus and Boeing both absorb a greater share of the industry, being that in 2018 Airbus acquired Bombardier's C-Series (renamed A220) and Boeing is currently creating a joint venture with Embraer on the E-Series;
    2. Extremely high entry barriers: to ensure the entrance in the aerospace industry, there are three required ingredients: i) strong financials; ii) powerful science and engineering resources; and iii) an efficient industrial organisation;
    3. Extreme concentration at the top of the market in terms of major revenue-producers;
- Currently, both Airbus and Boeing are in the healthy situation of having the largest order books in history and face challenges in achieving higher production rates. Nevertheless, this market duopoly means that Boeing and Airbus are constantly fighting to gain an advantage over the other in terms of aircraft sales. And the fight extends in non-technical fields like legal actions;
- In 1992, a bilateral European Union (EU) - United States (US) agreement was made regarding the trade-in large civil aircraft (TLCA), which banned support from governments in production financing and allowed up to

33% of the development programme costs to be met through government loans which are to be fully repaid within 17 years with interest and royalties. In 2005, each party (Airbus and Boeing) filed complaints against the other at WTO, claiming that each other's airline manufacturer was unfairly subsidized (*e.g.* was receiving unfair state aid from their respective governments). By doing this, the EU and US withdrew from the TLCA agreement;
- It is possible that other competitors emerge in the long-range air transport market, such as the new CRAIC CR929, formerly known as Comac C929, a wide-body twin-aisle airliner family to be developed by CRAIC, a joint-venture between Chinese Comac and Russian United Aircraft Corporation.

Key Actions: to achieve PARE Objective 24, it is recommended that a strong legal, commercial and technical basis is developed to (a) in any case, if necessary, deal with litigation at the WTO, and (b) preferably, if possible, renew the large aircraft agreement between the EU and the US.

The Regional Jet and Turboprop Market

The regional jet and turboprop market, which seating capacity ranges from 20 to 130, cannot be separated from the long-distance air travel since it acts as its feeder at major hubs and as a direct link between smaller communities in shorter routes. It is also an important market for Europe, much more accessible to other entrants than the Airbus-Boeing duopoly of giants and thus attracts increased competition. Taking this into account, by 2050, the position of the EU in the regional aircraft market must be strengthened.

Key Findings:

- The main market for regional aircraft is represented by regional carriers, which are carriers with an average stage range around 500 kilometres (km) or fleet without narrow-body and wide-body aircraft (turboprops and/or regional only);
- The link Airbus-Bombardier on C-Series (renamed A220) and the possible counter Boeing-Embraer on the E-Series imply a tie-up between regional and long-range jet airliners since the majority stake of Airbus in the Bombardier C-Series has extended the market reach to all jet airliners above 100 seats, with Boeing-Embraer as the only major competitor. This reduction of the number of competing suppliers, from 4 to 2, could extend the Airbus-Boeing duopoly from long-range to regional jets;
- In the regional market below 100 seats, the leading position of ATR (Franco-Italian aircraft manufacturer) faces fierce competition from traditional rivals from Canada and Brazil, as well as from newcomers from Japan, Russia and China;
- In the small turbofan aircraft with 50-120 seats, Embraer is the market leader with its E170 / E190 family, its position being at this moment threatened seriously only by A220 (ex-Bombardier C-Series) family. However, other potential competitors, like Comac ARJ21 (Chinese), Sukhoi Superjet 100 (Russian) and, probably, Mitsubishi MRJ 90 (Japanese) will certainly create a regional turbofan market distortion for Embraer and Airbus.

Key Actions: to accomplish PARE Objective 25, it is recommended that the development of European regional aircraft in a world with an increasing number of competitors is supported and that synergistic tie-ups between large and regional aircraft suppliers are also considered.

The Business Jet Market and Supersonic Prospects

Europe is strongly competitive not only on long-range and regional airliners but also in other categories like business aircraft, which market extends from the largest airliners customized for heads of state to private aircraft flown by their owners. Dassault Aviation (French), together with Gulfstream Aerospace (American) and Bombardier (Canadian), is a world leader in large business jets, and European share of the rest of the market could increase. Moreover, the next civil supersonic transport following Concorde (the first and only effective supersonic commercial airliner co-developed by the British Aircraft Corporation (BAC) and Aerospatiale (French), now a part of Airbus) could be a supersonic business jet. Taking this into account, by 2050, the position of the EU in the business jet market must be strengthened.

Key Findings:

- According to the General Aviation Manufacturers Association (GAMA), three classes of business jets are identified by specific performances and price levels: i) light jets (*e.g.* Cirrus SF50, Cessna Citation series lower end or Pilatus PC-24); ii) midsized jets (*e.g.* Bombardier Challenger, Cessna Latitude or Embraer Legacy); and iii) large business jets (*e.g.* Gulfstream Aerospace, Bombardier and Dassault Aviation' Falcon families);
- Europe is far from leading in this market. Of the total number of business jets delivered worldwide in 2018 (703 units), only 60 were manufactured in Europe, of those 41 being Falcons shipped by Dassault Aviation;
- Concorde was designed in the 1950s, first flew in the 1960s and ceased airline operations in 2003 due to high operating costs and difficulties in maintaining an old aircraft for lack of spares;

- The prospects for a commercial supersonic aircraft look dim because i) the sonic boom would prevent flight overland, leading only overwater routes, with the transatlantic market small and the transpacific market requiring more range; and ii) the overall number of aircraft, perhaps a few hundred, could hardly cover the high development cost of a supersonic airliner and a dedicated engine;
- Of all aircraft manufacturers, Dassault Aviation would be best placed to design and produce a supersonic business jet, since it has: a) decades of experience with supersonic jet fighters; b) a complete range of high-end efficient business jets; and c) researched the critical aspects of a supersonic business jet;
- The miniaturization of electronics allows business jets to be adapted to other missions like sensor platforms, patrol and surveillance, that are high-value extensions of the baseline business jet market.

Key Actions: to achieve PARE Objective 26, it is recommended that the development of European business jets and their expanded use as sensor/surveillance/control platforms are supported.

Markets for Helicopters and Convertibles

Within the convertibles aircraft (those capable of vertical take-off and landing (VTOL)), the helicopter market is one of Europe's major successes: Airbus Helicopters is the world leader and Leonardo (Italian manufacturer that currently owns the former British aircraft manufacturer named AgustaWestland) also holds a strong position in the market. The main competitors are Boeing-Vertol, Bell and Sikorsky from the US and Mil and Kamov from Russia. The strong US investment in greater hot-and-high and high-speed capabilities must be matched if the EU wants to maintain long-term market share. Taking this into account, by 2050, the EU leadership in the world helicopter market must be maintained.

Key Findings:

- The helicopter market has some stable elements like search-and-rescue (SAR), emergency medical services (EMS) and law and order protection. Other elements are more volatile and vulnerable to large fluctuations, such as off-shore oil exploration and wars in inhospitable places lacking safe ground infrastructure or alternative means of transport (*e.g.* hot and dusty Iraq and high, hot and dusty Afghanistan), but are the main cause of helicopter's expansion;
- The decline in military operations in the countries named before and the reduction in oil exploration caused a reduction of both military and civil helicopter markets that are slowly recovering. Consequently, faced with reducing order books, the American helicopter industry is pressing the US government to end decades of stagnation in helicopter technology;
- The US has started a major programme Future Vertical Lift (FVL) to design helicopters or tiltrotors with (i) twice the range, (ii) 50% higher speed, (iii) over twice the hover payload in demanding hot and high conditions,

using engines with double power but similar fuel consumption, size and weight. Although it is a military programme, it could have civil spinoffs: (i) double-range for off-shore oil exploration; (ii) higher speed for medical emergencies and executive transport; (iii) greater payload for rescue and transport missions. All this could challenge the position of Europe with over 50% of the world helicopter market;

- Russia is also funding the development of an advanced high-speed helicopter. The Central Aerohydrodynamic Institute (TsAGI) has confirmed on 2018 that Kamov Design Bureau started working to create a flying laboratory on the basis of the Ka-52 helicopter. It is expected that new technologies will provide more speed (probably about 400 Kilometres per hour (km/hr)) and range and better fuel efficiency;
- To compete with US and Russia, Airbus Helicopters has recently unveiled the aerodynamic configuration of the high-speed demonstrator it is developing as part of the Clean Sky 2 Joint Undertaking (CSJU) European research programme. The demonstrator Codenamed Racer, for Rapid and Cost-Effective Rotorcraft, will incorporate a host of innovative features and will be optimised for a cruise speed of more than 400 km/hr. It will aim at achieving the best trade-off between speed, cost-efficiency, sustainability and mission performance.

Key Actions: to accomplish PARE Objective 27, it is recommended that Europe keeps at least abreast of developments in high-power high-speed helicopters and tiltrotor aircraft with enhanced hot-and-high lift capabilities.

Current UAVs Markets Demand

Europe has the technology to develop all classes of UAVs that are increasingly relevant to a wide range of defence and civil missions. Nevertheless, Europe is far from being competitive in the particular large Unmanned Combat Aerial Vehicles (UCAVs), commonly known as combat drones, market due to a lack of coordination in the allocation of resources at EU level. There must be an end to the European dependence on foreign UAVs, and a move to enter the international market since there is the technology to achieve both targets. To be concrete, by 2050, a European alternative to the drones used in Europe with the potential to also enter the world market must be provided.

Key Findings:

- There are currently several prototype programmes across EU countries, such as i) Taranis in the UK; ii) Talarion in Germany; iii) HammerHead in Italy; and iv) multi-national nEUROn implemented by Dassault Aviation in France. However, none of these programmes has reached production;
- In the meantime, Europe is buying the following drones from non-EU countries: Global Hawks, Reapers and Predators from the US and Herons and Hermes from Israel. Moreover, the in-development US programmes using Artificial Intelligence (AI) like Loyal Wingman and Skyborg have no EU equivalent at present;
- Other countries had progressed in this field, ahead of Europe. The reluctance of the US to export armed drones has allowed China to take a leading position as the supplier of such systems in Asia and the Middle East. While during the decade 2009 to 2018 the US exported just 15 Reapers, China exported 163 UCAVs of 5 models to 13 countries;
- Moreover, the efforts made by the Chinese to develop a wide range of almost state-of-the-art drones and the willingness to export them at unbeatable prices creates a market advantage that will be difficult to challenge. One unit of Wing Loong II Chinese UCAV is offered at a list price between $1-2 million, compared with $16 million for the Reaper, only slightly superior in performance.

Key Actions: to achieve PARE Objective 28, it is recommended that the technological capabilities demonstrated in several prototype drones are leveraged into a coherent European Programme covering all levels, to satisfy internal needs and compete in the world market.

3.7 Emerging Aviation Technologies

Objectives 29 to 36 are addressed in the 8th chapter of PARE's report, entitled “Emerging Aviation Technologies”, which concern new disrupting technologies that are reshaping the aviation sector.

Electric Propulsion and Electrified Aeroplane Components

Although the automobile sector may lead the electrification of transport vehicles, the specific needs of aeronautics and fast technological evolution, in particular advances in electric propulsion (EP) and systems, will have increasing importance from drones to aeroplanes, including convertibles (those capable of vertical take-off and landing (VTOL)) taxis. Moreover, many components/systems of conventional aircraft (*e.g.* actuation, de-icing, and air-conditioning), which use mechanical, hydraulic and pneumatic power sources have been replaced throughout the years by electrical ones due to lack of reliability and high maintenance costs. Considering this, by 2050, the EU must be kept at the forefront of progress in the electrification of aircraft, including components.

Key Findings:

- EP uses electrochemical power sources (ECPS) such as batteries or fuel (often hydrogen) cells (FC). Currently, it is more effective for small vehicles, with short or medium ranges with a low weight such as drones transporting measuring sensors. Nevertheless, strongest developments of EP also take place at VTOL taxis, normally with a range between 50 and 100 kilometres (km) and partially larger. Under development are also regional and business aircraft with targets around 500 km;
- The flight range of all-electric aircraft depends on the specific energy (Watt-hour per kilogram - Wh/kg) of the ECPS, besides engineering parameters (such as lift over drag ratio, battery mass fraction – mass battery / total aeroplane mass - and efficiency of powertrain). The today all-electric aircraft are limited to the low total weight, *i.e.* small passenger numbers and/or low payload as well as limited endurance and speed. Applications that fit reasonable these limitations are the ones stated in the first bullet point;
- Long-range transportation of a large number of passengers or heavy cargo will rely for some time to come on conventional propulsion that still has a considerable development potential on its own and as part of hybrid systems. Considering the latter, high flight ranges (≥ 1000 km) are possible with FC as ECPS, because their energy (and consequently the flight range) is determined mainly by the hydrogen, which has relatively low weight and contributes only insignificantly to the total aeroplane mass. Nevertheless, the costs of FC related to the power are higher as for batteries;
- Concerning battery-powered aircraft, solar-powered aircraft (SPA) that are solar generator/ECPS hybrids should eliminate the current disadvantage of all-electric aircraft. Furthermore, they offer the ultimate promise of environmentally clean operation for long periods up to a month or even years and the radiation increases with higher altitude. Nevertheless, a commercial introduction is only expected from 2035;
- ”Fly by Wire” (FBW) systems include electrically actuated thrust reverser, hybrid electro-hydraulic actuation systems for wing and tail flight control surfaces, electrically powered environmental control (air-conditioning) system, electrically actuated brakes etc. The higher electrification leads to reduced weight, greater reliability, lower maintenance costs and increased efficiency and of course lower emissions.

Key Actions: to achieve PARE objective 29, it is recommended that a thorough assessment is made followed by support measures on (a) emerging electric systems and propulsion technologies, (b) their potential to satisfy mission requirements and (c) the likely evolution of both.

Additive Manufacturing

Additive manufacturing allows the production of complex pieces with fewer parts and could replace spare part inventories with local production, as limitations in series production, choice of materials and quality finish are overcome. Although it is an industry-wide activity, aeronautics may be the leader in some areas and should keep up with progress in other areas. Taking this into account, by 2050, advances in additive manufacturing must be promoted and exploited.

Key Findings:

- Additive manufacturing has several attractive features: (i) since it consists of adding layers, it does not waste material unlike processes such as milling that carve a part out of a larger block; and (ii) it allows the manufacture of large complex specimens that would otherwise have to be built-up of smaller parts with junctions. Thus, additive manufacturing is one of the contributors to more efficient production;
- It also has limitations: (i) it is a slow process more suited to laboratory use or limited production of prototypes than to large scale high-rate serial industry; and (ii) the surface smoothness is dependent on the number of layers that cannot be excessive, thereby requiring subsequent operations to ensure a better finish;
- If the limitations of additive manufacturing can be overcome there are promising prospects: (i) producing parts locally and as needed instead of transporting them from large stocks in a warehouse; and (ii) coupled with digital imaging and sensing producing replicas and replacements for damaged parts already out-of-stock or unavailable. These features will become more useful as the range of materials suitable for additive manufacturing and their physical properties widen.

Key Actions: to accomplish PARE objective 30, it is recommended to consider the implications on prototyping, series production and spares supply of additive manufacturing regarding (a) usable materials, (b) quality standards and (c) life-cycle costs.

Efficient Production

The more complex world of aeronautics compared with other sectors, *e.g.* the automotive sector that has taken the lead on efficient production, provides opportunities for cross-fertilization in new technologies and their efficient utilization and management. The next stage in the evolution towards efficient production is known as "Industry 4.0" and aeronautics can benefit from 4.0 technologies, especially by integrating the full life-cycle design-production-operation-maintenance. Considering this, by 2050, the experience from other sectors should be incorporated to achieve more efficient and economical production in aeronautics.

Key Findings:

- Some of the key concepts of efficient production read across production volume, value and rate and include: (i) just-in-time delivery avoiding large and costly static inventories; (ii) work planning that maximizes human motivation and efficiency; and (iii) the right mix of automation and human intervention;
- There are counter-factors that favor aeronautics regarding efficient production: (i) higher added value justifies bigger investments in quality and efficiency; and (ii) large order backlogs if they are achieved give a measure of long-term stability;
- The term Industry 4.0 refers to the combination of several major innovations in digital technology, all coming to maturity right now, all poised to transform the energy and manufacturing sectors. The following nine technology trends form the building blocks of Industry 4.0: (1) big data and analytics; (2) advanced robotics and artificial intelligence; (3) simulations; (4) horizontal and vertical system integration; (5) the industrial Internet of Things (IoT); (6) cybersecurity; (7) cloud computing; (8) additive manufacturing; and (9) augmented reality;
- Even though 4.0 factory requires significant investment, it will change traditional production relationships among suppliers, producers, and customers - as well as between human and machine – and lead to a reduction on development time and costs of production and operation, thus leading to greater efficiency.

Key Actions: to achieve PARE objective 31, it is recommended to consider the best combination of 4.0 technologies, including automation and information, as applicable to various production rates and scales of equipment in aeronautics.

Telecommunications

Telecommunications is a major innovation and growth sector in modern societies that become readily embedded in aeronautics technologies and the services they provide, including navigation and air traffic management (ATM), on-board monitoring and preventive maintenance, flight safety and security, etc. The expected growth of air traffic and consequently the need for increased air traffic capacity and safer and more efficient aircraft operations will require increased data sharing and larger telecommunications bandwidth protected from unintended or malicious interference. Taking this into account, by 2050, the telecommunications capacity needed for connected aircraft, navigation, monitoring and other services must be provided.

Key Findings:

- The cluster of air traffic management (ATM), communication, navigation and surveillance (CNS), meteorological (MET) and aeronautical information (AIS) services are called air navigation services. Likewise, ATM services are divided into three different services: air traffic flow management (ATFM), airspace management (ASM) and air traffic services (ATS), which are composed in turn by air traffic control (ATC), flight information services (AIS) and alert services (AL);
- Telecommunications are the core of this network in such a way that they allow, for example, communications air to air, air to ground, ground to ground, as well as aircraft navigation or surveillance through the application of radio frequencies. Thereby, available communication and surveillance systems are essential for the correct functioning and effectiveness of ATC services as well as equipment based on radio waves is essential for the correct aircraft navigation;
- As a consequence of the growth of air traffic and, likewise, of the growth of the number of Navigational Aids (NAVAIDs), the need for a higher number of radio channels was identified due to the congestion of radio spectrum. This change in the frequency assignment has managed to increase the number of available channels in very high frequency (VHF) band of aeronautical communications, which has allowed the creation of new control sectors and has contributed to increasing the ATM capacity;
- The future scenario of communications relies on the use of the Aeronautical Mobile Satellite Service (AMSS) through the use of satellite communication (SATCOM) as well as the use of data link via VHF and high frequency (HF). Data link is a method for connecting one location to another in telecommunications, to transmit and receive digital information. However, in aeronautics data link is a generic term encompassing different types of data links systems and subnetworks;
- Satellite-based navigation will transform ATM because it will allow attaining the full implement of area navigation (RNAV). Besides, its precise time reference is expected to be used in surveillance and communications strategic applications. Therefore, within Global Navigation Satellite System (GNSS) network, the development and deployment of GALILEO system will be essential for the EU owing to GALILEO has been designed to fulfil all the required features for aviation users hence it can be widely used, unlike GPS which is hardly certifiable. In this manner, GALILEO will be more accurate and reliable than GPS and it will also inform users about possible system failures.

Key Actions: to achieve PARE objective 32, it is recommended to assess the growth of capacity needs for navigation, systems monitoring and passenger services, and how the required bandwidth can provide free from unintended or malicious interference.

Cybersecurity

The increasing reliance on computer systems tied by telecommunications links (more interconnected systems) multiplies the entry points for disruptive and malicious intrusions, which can compromise major systems and lead to unlawful physical acts like hijack of aircraft, destruction of an aircraft in service or hostage-taking on board an aircraft or at airports. Considering this, the global aviation industry has many layers overseeing the safety of all the stakeholders involved, from aircraft manufacturers to the passenger boarding a flight. Aeronautics needs no less and perhaps more than many other sectors to implement security measures to safeguard civil aviation against these acts of unlawful interference. Thus, by 2050, threats in cybersecurity must be monitored and timely protection must be devised for all levels of aviation systems.

Key Findings:

- Cybersecurity is about the prevention of and/or reaction to deliberate malicious acts undertaken via cyberspace (*i.e.* the domain of information flow and communication between computer systems and networks and includes physical as well as purely virtual elements) to either compromise the system directly or wherever systems play a key role. Airport and ATM cybersecurity is aimed at limiting the effects of such cyber-threats and the impact on airport organization and operations and the overall ATM network;
- One of the keys to fighting successfully against cyberattacks is to identify the potential cyber attackers, normally divided in 4 groups: state cyber-forces, who have a large number of resources at their disposal, state backing and are very highly skilled); cyber-criminals (who are interested in making money through fraud or from the sale of valuable information); terrorists (who are interested in obtaining and using sensitive information to launch a conventional attack); and hacktivists (who have a cause to fight for such as political or ideological motives);

- Cybersecurity has become a real issue for aviation, driven by different factors such as:
    - i) the increasing interconnectivity of ATM which means that the impact of an attack may extend across a growing number of interconnected systems;
    - ii) the increased reliance on integrated data which means a high potential for operational disruptions if connectivity is lost;
    - iii) the migration toward common and Commercial Off The Shelf (COTS) components, underpinned by industry-standard protocols such as Internet Protocol (IP), with published vulnerabilities which means that more people will have the technical background to launch attacks and more people will have access to core infrastructures through extended supply chains; and
    - iv) new methods of attack stemming from either criminal activities and/or state-sponsored actors, of increasing levels of sophistication;
- Cyber-vulnerabilities have also been exposed at industry and government level, even in the largest aerospace programmes, like the F-35 Lightning II – Joint Strike Fighter Programme: a) industrial espionage has used small sub-contractors with modest security resources to access up the supply chain to main contractors; b) intergovernmental meetings among the representatives of participating nations have had uninvited, invisible "guests" from other nations;
- To ensure the identification of appropriate preventive security measures, the level of threat should be continually reviewed, and risk assessments carried out, taking into account international, national and regional situations and environments. In this manner, whenever a specific threat exists, selected and predetermined preventive security measures should be applied, commensurate with the associated risk assessment and the nature and severity of the threat.

Key Actions: to accomplish PARE objective 33, it is recommended to consider the levels of cyber protection needed for the various aeronautical activities, and how to monitor and counter threats.

Big Data

The new generation of aircraft generates a lot of data from multiple sources: flight tracking data, airport operations data, meteorological data, airline information, market information, passenger information, aircraft information and air safety. Some of these data can be obtained through thousands of sensors and sophisticated digitalised systems that are installed on-board an aircraft. Using big data analytics to process efficiently the great amount of data from different sources can have several applications on aviation: optimising fuel consumption, crew deployment and flight operations, reducing cost, improving maintenance, forecasting weather and air safety, and enhancing passenger experience; that will become standard to support real-time decision making. By 2050, the implications in aeronautics of advances in big data, including the use of what is already available must be assessed.

Key Findings:

- Currently, the aviation industry adopts on condition/preventive maintenance procedures due to its operational efficiency and it depends upon the failure mode calculations made after testing a part under circumstances. These conditions may fluctuate depending on the external factors/human errors which may result in the variation in the lifetime of components, in turn, reducing the operational efficiency of the aircraft;
- A study by the Federal Aviation Administration (FAA) states that during a year a jet engine generates data equivalent to 20 terabytes (TB). Most of this data is not used for any of the analytics purposes since this data is unstructured. Big data analytics can be used to predict the fault in the component by analysing data obtained from various sensors and account of the specific component attached to an aircraft or fleet in which it is present;
- A typical aircraft has millions of parts. The amount of data output is immense and is increasing rapidly with a new generation of aircraft. Legacy aircraft used to capture more than 125 flight parameters. The Airbus A320, for example, produces 20,000 data parameters but the latest A350 produces 400,000 and has a data output of approximately 250 gigabytes (GB) per flight. Boeing 787 captures more than 1000 flight parameters with some reports claiming half a terabyte of data per flight;
- Nowadays, data mining, which is a broad field of data science used to make predictions on future data based on patterns found in collected data, can be used to improve aviation safety by analysing all the data collected from the reports and searching for patterns and anomalies that indicate potential incidents and hazardous situations before they happen. However, this method presents several limitations, e.g. the requirement of some knowledge of what should be searched for and found and therefore, the necessity of a method that determines the relevant and important data. Besides, as the data included in reports is overly generalised, it is difficult to identify unknown patterns, and, in consequence, data mining usually discovers known trends.

Key Actions: to achieve PARE objective 34, it is recommended that the expected benefits versus the required investment in using big data techniques in aeronautical activities for which relevant data already exists or has to be newly sourced are considered.

Artificial Intelligence

Artificial intelligence (AI) has the advantage of systematic learning from large amounts of data ('Artificial Imitation') and therefore it can lead to the more efficient and reliable implementation of known tasks. However, it lacks any form of imagination when facing unforeseen or untrained situations, when it cannot replace human imagination, resourcefulness or true and real intelligence. Considering this, by 2050, the potential benefits and risks of the use of AI in aeronautics must be assessed.

Key Findings:

- Some existing AI use cases in aviation include:
  1. Flight management computer systems used to assist the pilot with information and for handling purposes;

2. Computer systems behind the autopilot feature to steer the aircraft along a predefined trajectory without the need for pilot intervention;
3. Computer systems supporting automated aircraft cabin pressurization to ensure the cabin environment is safe and comfortable for passengers;
4. Analysis and prediction of passenger behaviour/demand;
5. Seamless airport security processes, through facial recognition and biometrics, currently being used to perform customer identity verification and to match passengers to their luggage through kiosks;
6. Provision of support to the optimization of revenue management, route network, fleet management, and pricing strategies;
7. Self-flying planes and autonomous in-flight services e.g. meals, snacks, beverages, duty-free shopping and others made available during a flight for the convenience of the passenger;
8. Autonomous airport processes, *e.g.* ground handling, loading, fuelling, cleaning, and aircraft safety checks;
9. AI assistants that answer customer inquiries and voice commands for domestic airline flight information and ticket availability through interactions using natural language; and
10. Aeroplane simulators which process the data taken from simulated flights. One example is aircraft warfare where computers can come up with the best success scenarios in these situations as these machines can create strategies based on the placement, size, speed and strength of the forces and counter forces;

- Despite all the benefits and advantages of AI, there are still many problems to overcome before its widespread applications: (i) dependence on large datasets (that can still have limited training data and lead to the failure of the model) and lack of abstraction and generalisability; (ii) lack of interpretation of the obtained trained models and use of current AI approaches as a black box; and (iii) lack of robustness, being that most current AI systems can be easily fooled, which is a problem that affects almost all machine learning techniques.

Key Actions: to achieve PARE objective 35, it is recommended that the situations in aeronautics in which the learning processes of AI can be efficient and safe are identified and those where there is limited training material or potential dependence on imagination are distinguished.

New Materials and Structures

The development of new materials and structures employing them is driven both by the pull of aviation needs and by the progress of technologies. The contribution of materials and structures to progress in aeronautics has been steady and gradual, *e.g.* a 10-30% weight saving replacing a metal wing or fuselage by a full composite one, and the prospect of structures having a fraction of their current weight is brought by nanotube developments. Considering this, by 2050, the implications on aircraft design, certification, operation and maintenance of new developmental and breakthrough materials and structures, including nanotube structures and microelectromechanical devices, must be assessed.

Key Findings:

- Progress in materials has been a key to advances in aeronautics since its birth at least in two areas: (i) strong and light structures able to withstand flight and landing loads without demanding more than the essential lift and incurring excessive drag; (ii) high-temperature turbine blades of jet engines subject to rotational and aerodynamic loads combined with heat fluxes;
- Forty years ago aluminium dominated the aerospace industry - as much as 70% of an aircraft was made of it, from the fuselage to main engine components. Materials such as titanium, graphite, fibreglass or composites and alloys were also used, but only in very small quantities. Nowadays, a typical aeroplane is

constructed as little as 20% pure aluminium and most of the non-critical structural material consists of even lighter-weight carbon fibre reinforced polymers (CFRPs) and honeycomb materials;

- While CFRPs represent the lion's share of composite material in both cabin and functional components, and honeycomb materials provide effective and lightweight internal structural components, next-generation materials include ceramic-matrix composites (CMCs), which are emerging in practical use after decades of testing;
- For engine parts and critical components, there is a simultaneous push for lower weight, increase strength and higher temperature resistance, intending to reduce the cost of aerospace manufacture, improve fuel economy through efficiency and light-weighting. Considering that the melting point of current superalloys is around 1,850°C, to meet these temperature demands, heat-resistant super alloys (HRSAs), including titanium alloys, nickel alloys, and some non-metal composite materials such as ceramics, are now being brought into the material equation;
- The major drivers in current aerospace R&D are towards lighter construction materials and more efficient engines - the overall goal being to reduce fuel consumption and carbon emissions associated with air travel and air freight. The significant interest in nanotechnology for the aerospace industry is justified by the potential of nanomaterials and nanoengineering to help the industry achieve this environmental goal.

Key Actions: to achieve PARE objective 36, it is recommended that the progress in advanced materials like composites, ceramics and special alloys and also the prospects of less mature developments like nanotube structures and other nanotechnologies is considered.

3.8 Cooperation beyond Europe's Borders

Objectives 37 to 42 are addressed in the 9th chapter of PARE's report, entitled "Cooperation beyond Europe's Borders", which concerns areas of aeronautics that require cooperation between the worldwide communities. These include Air Traffic Management (ATM), harmonized certification rules, environmental effects, safety and security, and fair trade and open markets.

Air Traffic Management

Air traffic is expected to continue to grow at a rate of 2 to 7% per year depending on the region of the world. The main potential limitation to this continuing growth is the capacity of the air traffic system, including airports and ATM. Airports are a local issue, although with far-reaching geographical implications in the case of major hubs. On the other side, ATM is a global issue in the sense that it should function seamlessly worldwide, over continents and across oceans, and in densely, sparsely or uninhabited regions.

Therefore, ATM is the major potential bottleneck to the growth of aviation on a global scale, with a particular incidence in developed regions with dense traffic like Europe and the north-eastern US, but gradually spreading to other regions. Considering this, by 2050, the seamless compatibility of ATM systems must be promoted worldwide, across continents and oceans.

Key Findings:

- When traffic approaches the available capacity, there is a combination of entirely undesirable consequences: (i) departure and arrival delays that cause passenger dissatisfaction and can hinder business activities; (ii) aircraft in flying holding patterns awaiting permission to land and take-off queues of aeroplanes waiting to gain access to a runway; and (iii) increased fuel consumption, pollution and noise, precisely near the airport areas where these issues are more sensitive. The economic losses are not just increased fuel costs and lost revenues for airlines but also the loss of valuable time for passengers and business travel;

- Through advances in technology and procedures, ATM in Europe and the US has mostly managed to stay ahead of the growth of air traffic, but not by a wide margin all the time, so there are still occasional delays and the overall challenge remains. This challenge is recognized at a political level as testified by the large programs SESAR - Single European Sky ATM Research - in Europe and NextGen - Next Generation Air Transportation System - in the US that aim to keep air traffic capacity ahead of air transport growth and avoid the risk of massive flight delays and cancellations;
- The market for ATM equipment and services includes radars, navigation and communication systems, satellite links, equipment for Air Traffic Control (ATC) centres and control towers, including operator consoles and other hardware and operating systems incorporating sophisticated software. The market for ATM equipment and services is considerable and not to be underestimated compared with the market for aircraft and airlines services since they are all complementary and interdependent;
- The US, by being a single nation, has a unique Air Navigation Services Provider (ANSP) and certification authority, which is the Federal Aviation Administration (FAA).On the contrary, in Europe, although the Single European Sky (SES) initiative was launched at the beginning of the present century, the national border division of the airspace leads to a diversity of ATM services, dominated by national ANSPs, as well as to national certification authorities. Despite all these factors, Europe betters the US in most ATM performance indicators (e.g. timeliness of flights) and achieves the same or higher safety standards;
- To achieve SES goals, the European Parliament established an implementation framework of five interdependent pillars - technology, legislative, safety – the European Union Aviation Safety Agency (EASA) –, airport and the human factor. Within the first pillar, SESAR was set up in 2007 as a joint undertaking (JU) on research & development in ATM, entitled SESAR I. Today, the second SESAR program is ongoing (SESAR 2020), more than €2 billion have been committed to this SES pillar and it is estimated that around 3000 experts are currently engaged in this program to improve ATM efficiency;
- Even though SESAR and NextGen have the same basic aim, the implementation frameworks for each are radically different, with the European approach based on a single, multi-stakeholder consortium, and the US model requiring close internal coordination between various government-led programmes to ensure interoperability of components delivered by a variety of consortia. To ensure compatibility, the EU and US systems don't need to be identical but have aligned requirements for equipment standards and technical interoperability.

Key Actions: to achieve PARE objective 37, it is recommended that cooperation between SESAR in Europe and NextGen in the US is supported to ensure compatibility across the North Atlantic and provide the basis for progress in the world ATM market as the growth of air travel increases capacity needs elsewhere.

Harmonized Certification

Aircraft certification is the process whereby an applicant requests approval from an aviation regulatory authority, such as the FAA and EASA, for manufacturing a new aircraft model or making changes to an existing aircraft. Some decades ago, different national certification authorities required different tests for the same purpose, duplicating effort and increasing cost with no benefit to safety or efficiency. The harmonization of certification standard avoids such costly duplications.

Since FAA and EASA are the leading certification authorities, the continuation of common or compatible certification standards and the mutual acceptance of certification results should continue as new technologies emerge and possibly new aircraft configurations as well. Taking this into account, by 2050, harmonized certification standards must be promoted worldwide as already exist in other sectors to ensure the growth of aviation as the safest mode of transport.

Key Findings:

- The certification of an airliner is the final stage of the development process and can also be the most complex, time-consuming and expensive, involving: approved standards, guidance, tests, methods, procedures as well as data submittals and plan documentation. It takes about 3 000 flying hours for 3-5 years involving 3 to 6 prototype of pre-production aircraft, and it is difficult to compress without significantly increasing risks that could become delays and further costs;
- Grandfather rights refer to the right of a manufacturer to continue certificating successive derivatives of a mature aircraft type under the certification rules applicable when the original design was cleared, despite subsequent advances in safety regulation. They were established in the EU in 2003 with the creation of EASA, under the safety pillar of the SES framework;
- The overall framework for harmonized and coordinated certification between EASA and the FAA is currently established by the agreement between the US and the EU on cooperation in the regulation of Civil Aviation Safety, which entered into force on 2011. The main purposes of the agreement are to automatically accept certain approvals issued within the other certification system and enable the reciprocal acceptance of findings of compliance during validation processes;
- Despite the advantages of harmonized certification, an inevitable consequence is that certification can become a hurdle to newcomers to the market that do not have either the technology demonstration or the program discipline capabilities to go through a complete certification process.

Key Actions: to accomplish PARE objective 38, it is recommended to strengthen the cooperation of EASA/FAA on common certification standards and their adoption worldwide to avoid duplication or degradation in specific regions.

Aviation Effects on the Environment

The effects of aviation on the environment can be considered at two levels: (i) locally as the emission and noise near airports; (ii) globally as in-flight emissions worldwide. Aviation contributes a small percentage (about 3.5%) to global pollution of the environment caused by human activity, but its influence is extremely unfavourable locally, in the areas of airports. Nevertheless, contrary to airport noise (generated by taking-off and landing aircraft) that can be solved at a local level, emissions are a global issue and require considerable international negotiation. Considering this, by 2050, the effects of aviation on the environment on a global scale must be minimized.

Key Findings:

- Emission of aviation pollution is a result of the combustion of fuel used to power the aircraft, and its level depends on the fuel quality and the process of combustion. Basic fuel used in modern civil aircraft is aviation kerosene. During the different phases of aircraft operation, several greenhouse gases (GHG) are emitted to the atmosphere, including i) carbon dioxide (CO2) – which is composed by carbon monoxide (CO) and oxygen (O2); and ii) nitrogen oxides (NOx) – which includes nitrogen oxide (NO) and nitrogen dioxide (NO2), and cause the occurrence of ozone (O3) and photochemical smog;
- In 2012, it was estimated that European aviation represented 22% of global aviation's CO2 emissions. Similarly, aviation now comprises 14% of all EU transport NOX emissions and 7% of the total EU NOX emissions. From 2005 to 2014, CO2 emissions increased by 5%. The increase in emissions is, however, less than the increase in passenger-kilometres flown over the same period, due to an improvement in fuel efficiency driven by the introduction of new aircraft, the removal of older aircraft, and improvements in operational practice;
- Projections indicate that future technology improvements are unlikely to balance the effect of future traffic growth (and consequently emissions growth). Although alternative clean propulsion technologies are under development - such as electric-powered aircraft or cryogenic hydrogen fuel - these options are unlikely to be commercially ready before 2030. Alternatives include sustainable aviation fuels (SAFs), which are produced from bio-based feedstocks that have lower GHG emissions. Nevertheless, the price of bio-based aviation fuel relative to fossil-based kerosene is one of the major barriers to its greater market penetration;

- Emission regulations can also play an important role in mitigating the environmental impact of aviation, but they need to be implemented on a global scale. The International Civil Aviation Organization (ICAO), created in 1944 as a specialized agency of the United Nations (UN), is committed to implementing a global market-based measure to address GHG emissions from international aviation, entitled CORSIA - Carbon Offsetting and Reduction Scheme for International Aviation;
- Modern solutions directed to reduce aircraft impact for the environment was the subject of two biggest programmes concerning aviation implemented by the EU: 1) SESAR I which aimed at decreasing of air transport impact on the natural environment by 10%; 2) Clean Sky 2, a continuation of the Clean Sky programme, in the frames of which there would be developed new technological solutions which would be more environmentally friendly (new aircraft, new power units, airborne systems and so on).

Key Actions: to achieve PARE objective 39, it is recommended that the reduction of environmental effects of aviation on a global scale is a key point in the EU cooperation with other countries.

Safety

Aviation authorities in Europe have banned foreign airlines from flying into Europe deemed not to meet adequate safety standards. This is necessary to protect the safety of those flying into and out of Europe, for business or leisure travel, and also of the residents that could become the victims of eventual accidents. On one side, the list of banned airlines could be of use to warn passengers that might be attracted to fly with those airlines in other regions of the world. On the other side, an effort to cooperate with aviation regulatory authorities worldwide, in particular in less developed regions, helping them to implement safety standards by providing technical assistance, would be a preventive measure leaving bans as the necessary last resort in fewer cases. Taking this into account, by 2050, aviation safety must be promoted worldwide, including for European and other passengers flying with non-European airlines.

Key Findings:

- In principle, all airliners should be equally safe because they meet the same applicable EASA/FAA certification standards, Airbus/Boeing/Bombardier/Embraer and other manufacturers have comparable engineering skills and thoroughly develop operating and maintenance procedures. As a consequence, aviation remains the safest mode of transport, although with relatively large differences across the globe;
- The reasons for reduced relative safety in other regions of the world can be several: (i) persistence of extreme weather conditions in some regions, like arctic, tropical or deserts; (ii) operation of older aircraft requiring more careful maintenance; (iii) less adherence to maintenance and operating procedures that conditions (i) and (ii) require; (iv) weaker oversight by authorities. It must also be acknowledged that in all regions of the world the safety standards also vary considerably depending on the type of operation: (i) airliners and business jets are much safer than private aircraft; (ii) transport is safer than crop spraying or firefighting that involve low altitude flying near obstacles and obscurants;
- In Europe, the blacklist program began in 2005. First, an EU Member State (MS) identifies airliners subject to operating bans within their territory (after inspecting its aircraft that landed at the MS airport) and afterwards, the FAA and EASA, in coordination with the EC, evaluate on common criteria the airliners. The resulting EU Air Safety List or "blacklist", which includes a list of all airlines banned from operating in Europe and another of airlines that are restricted from operating under certain conditions in Europe, is published at least every three months in the Official Journal of the European Union. These banned airliners are encouraged to improve their levels of safety and can request a compliance review from the EC to be removed from the list;
- ICAO is the primary forum for cooperation in all fields of civil aviation among its 193 MS. The UN agency promulgates Standards and Recommended Practices (SARPs) to facilitate harmonised regulations in aviation safety, security, efficiency and environmental protection on a global basis. As part of this effort, ICAO

established in 2015 the Aviation Safety Implementation Assistance Partnership (ASIAP), to coordinate efforts for the provision of assistance to its MS, and created the initiative "No Country Left Behind" (NCLB), which focuses on assisting all MS on priority basis to provide support for the implementation of ICAO's SARPs;

- Despite the excellent safety performance of aviation in Europe, recent events remind the need to always remain vigilant and constantly search for weaknesses in the system before they manifest in an accident. EASA, MS and industry have been working closely together in safety risk management (SRM), namely hazards identification, risks assessment and decision-making on the best course of action to mitigate those risks at European level. EASA's 9th edition of the European Plan for Aviation Safety (EPAS), which covers the five years between 2020 and 2024, puts increased emphasises on the importance of the SRM process.

Key Actions: to achieve PARE objective 40, it is recommended to support activities raising the aviation safety standards to more uniform high levels across the globe, in particular helping the improvement of airlines banned from flying into Europe that may still carry European passengers elsewhere.

Security

European citizens often travel to countries with popular tourist destinations and important business hubs, outside the jurisdiction of the authorities that apply stricter security standards (such as Europe, the US or Japan), and are at greater risk of security threats like extremist groups that target aviation and foreigners. To boost security in these less developed regions and continue to attracting business and tourism, which may be of interest to these regions, it is fundamental to support and cooperate with the local authorities. Thus, by 2050, aviation security must be promoted worldwide, including at airports and destinations frequently used for European business and holiday travel.

Key Findings:

- Integrating security systems and operations into the planning and design of airport construction and refurbishment projects can be a very complex task since (i) security systems involves equipment, technologies, procedures and operational approaches that need clear and concise guidelines; (ii) there is an environment of evolving threats, often accompanied by the implementation of new legal or regulatory requirements and operational updates to counter the changing threat conditions; (iii) security systems are inherently difficult to plan, design, and implement when applied to airports, which are designed to facilitate the fast and efficient movement of customers and goods;

- Moreover, airports tend to be in a constant state of change in terms of their physical layouts, operations, and tenants, and while the number of new airports being built is relatively small, many airports and terminals are being remodelled, expanded, and upgraded. The majority of changing security requirements will be accomplished in existing facilities that are often decades old, designed at a time when the threat profile and the security environment were dramatically less stringent than they are today.
- The airport operator has a responsibility to provide a safe and secure operating environment and infrastructure. The extent of necessary facility protection should be examined by the local Airport Security Committee, based on the results of a comprehensive security assessment of the existing facility. High priority should be placed on the protection of the aircraft from the unlawful introduction of weapons, explosives, or dangerous substances;
- Secure air transport service enhances connectivity in trade, tourism, political and cultural links between States. ICAO has a Global Aviation Security Plan (GASeP) that seeks to unite the international aviation security community and help MS and stakeholders enhance the effectiveness of global aviation security. Based on the main challenges that ICAO MS face, GASeP identifies key priority outcomes where ICAO, States and stakeholders should focus their urgent attention, resources and efforts: (1) enhance risk awareness and response; (2) develop security culture and human capability; (3) improve technological resources and foster innovation; (4) improve oversight and quality assurance; and (5) increase cooperation and support.

Key Actions: to accomplish PARE objective 41, it is recommended to support high-security levels at airports outside Europe by cooperating with authorities eager to keep European business/tourism travel, and otherwise warn travellers of risk.

Fair Trade & Open Markets

Aircraft manufacturing is arguably the most contested industry in international trade governance, mainly because the traditional tools of trade governance are particularly ill-suited to aircraft manufacturing. Considering this, promoting a level playing field is not easy and desirability and quality may function more effectively and subtly than harsh political pressures. Regarding open markets, major exceptions in civil (all non-military) aviation do exist, generally uncontested, being the most visible and long-standing the Japanese airliners' tendency to buy Boeing aircraft more often than from Airbus, though the difference has reduced over time. To help undermine protectionist and biased local choices, safe and efficient aircraft should be made available. Taking into account this, by 2050, an open and fair market for aircraft must be promoted as far as possible at least in the civil sector.

Key Findings:

- Trade disputes are not unknown in aviation at the highest level of the World Trade Organization (WTO). Since Airbus emerge some 40 years ago to challenge Boeing's position as the world's dominant aircraft manufacturer, the US and EU governments on behalf of Boeing and Airbus, respectively, have been accusing one another of illegitimately propping up their respective national champions, while simultaneously professing their own innocence in providing support. The Canadian government on behalf of Bombardier has also accused the Brazilian government of subsidizing Embraer;
- The basic logic behind trade enforcement mechanisms, whether pursued unilaterally or multilaterally through the WTO, is an attempt to "level the playing field" or to correct the market for the distortions of government interventions. However, when it comes to aircraft manufacturing, there has never been anything close to a perfectly competitive, distortion-free market: not only are subsidies on the production side, but governments are also the most important consumers of aircraft, buying both military planes and consumer planes for publicly-owned national airlines;
- Since 1953, Boeing has been the top provider of commercial jetliners (Japanese carriers have ordered more than 970 Boeing jetliners) to Japanese airlines and a major supplier of military equipment and aircraft to the Japanese Ministry of Defence, retaining still today deep supplier (around 150 Japanese companies are suppliers to Boeing), customer and partner relationships across Japanese government, industry and civil society. In the past decade, nearly 80% of the commercial aircraft ordered by Japanese customers have been Boeing products;
- In recent years, Airbus has significantly strengthened its position in the Japanese commercial aircraft market. In 2013, Japan Airlines (JAL) signed a major order for the A350 XWB, which was soon followed by orders from All Nippon Airways Holdings (ANA) for the A320 family and, early in 2016, for the A380. Besides, over 20 major Japanese companies work with Airbus on various commercial aircraft programmes.

Key Actions: to achieve PARE objective 42, it is recommended a competition based on quality rather than other interests, which is supported by the advances in efficiency and compliance with the highest environmental, safety and security standards.

3.9 Attracting Young Talent to Aeronautics

PARE objectives 43 to 48 are addressed in the 10th chapter of PARE's report, entitled "Attracting Young Talent to Aeronautics", which analyses the reasons and factors that influence the career inclinations of young people and the measures to consider to attract them to aeronautics.

According to the Social Cognitive Career Theory (SCCT), the academic and career choices of young people are influenced by personal, cognitive and contextual factors (namely prior experience, social support, self-efficacy and outcome expectation) and form gradually more consciously from childhood and primary school, through teenage and secondary school to adulthood and university. The career choices also depend on the image and reputation of the employer and its ability to provide good living and working conditions and to foster the commitment and fidelity of the workforce as a second family.

To attract young people to aeronautics, it is also important to understand that aeronautics involves diverse job types (e.g. engineers, senior technicians and operators), all that require the so-called STEM - Science, Technology, Engineering and Mathematics – skills.

Childhood and Primary School

In the history of aviation, many of the pioneers and major contributors started their interest at an early age. It is therefore essential to stimulate the interest of children in aeronautics (objective 43), which can be done in a more informal context by parents or more formally in primary schools, through specific programmes or educational materials developed for children.

Key Findings:

- At the beginning of childhood, children's attention span depends on their age and the interest that objects and tasks awaken in them, in particular their ability to manipulate these objects nearby. It is very difficult for kids to focus on a monotonous and less attractive activity and consequently, they tend to easily move on from one activity to another frequently;
- Fortunately, flying-related stories are usually entertaining for children. In this manner, they usually enjoy doing activities such as playing with kites, listening to tales that take place in space or watching flying-related cartoons as well as make paper gliders. These kinds of funny activities related to aviation can act as an incentive to awaken in kids the feeling of loving this thrilling sector and, in this way, they could grow up willing to work in a job related to aviation;
- Primary school programmes/material and events are also a way to stimulate this interest in children in a more formal way. Examples worldwide include:

Country	Promoting Institution	Educational programmes/materials and events
Portugal	Aeronautical Promotion Centre & Nortávia	Visits for children to have their first contact with the aeronautical environment, in which they can have direct contact with the aircraft and their pilots and mechanics in a playful and relaxed way
Switzerland	Fédération Aéronautique Internationale	Young Artists Contest which encourages young people to demonstrate the importance of aviation through their art
United Kingdom	Royal Aeronautic Society	Primary education programmes: 1) Cool Aeronautics (outreach programme); 2) Amy's Aviation (two children's animated series called 'Amy's Aviation' that charts the adventures of Amy as she discovers the wonderful world of aerospace and aviation)
United States	Science Spark	The USA Science & Engineering Festival includes events that aim to show where "STEM Can Take You" to participating kids and produce also STEM classroom materials that teachers can download

	American Institute of Aeronautics and Astronautics	STEM programs which aim to inspire, influence, and mould the next generation of aerospace scientists and engineers by providing a series of resources and programming to teachers, students, parents, and aerospace professionals
	NASA	NASA's website has a variety of educational and entertaining materials such as explanatory videos with attractive illustrations; interactive online games and "hands-on" experiences and activities that children can explore as they learn about STEM

Table 20.1. Worldwide examples of educational programmes/materials and events.

Key Actions: to stimulate children's interest in aeronautics, it is necessary to make STEM fields funny and enjoyable for kids. To achieve this objective, PARE recommends making available on-line and accessible to primary schools and parents, children stories and cartoons involving flying that are both entertaining and educational.

Teenage and Secondary School

The basic teaching of physics, natural science and mathematics, even at the secondary school level, can lead to some understanding of flying in the atmosphere. In a more practical side, 'toy' drones are now so common and inexpensive that they can be readily used to give real flying experience, train piloting skills and can teach also responsible use. Moreover, these more relaxed activities, which can occur in leisure times at school or outside the school, can be complemented by visits to university laboratories and presentations from aeronautics professionals. This combination of advanced technologies and bright prospects should be employed to motivate teenage and secondary school students to choose university degrees in aerospace engineering (objective 44).

Key Findings:

- A variety of informal and complementary learning activities can be promoted among students and STEM educators, in a way to connect them with the STEM community and workforce, such as: teach youth at science summer camps or after-school programs; getting students to join STEM-related clubs, namely Space and Aeronautics Clubs; promote and support students' participation in science fairs and competitions; create job shadow opportunities; promote visits to Aerospace Companies; give them books and magazines on STEM topics;
- To specifically promote aerospace engineering, the ALLIES partnership has focused upon the design and development of wind tunnels that are donated to secondary schools. The wind tunnels have proven to spark interest in aerospace-related phenomena among the secondary students. The most recent ALLIES effort focuses upon the design of a wind tunnel that can be fabricated using materials, parts, and components available in most regions of the world, such that disadvantaged schools can easily replicate a wind tunnel;

- The Learn&Fly project, which finished last year, implemented innovative teaching methods in Spanish, Portuguese and Polish schools (using the world of aeronautics as an inspirational theme and involving teachers, parents and professionals) and supported teachers by providing information and materials about career opportunities in the aeronautics field and different education/training paths available to embrace them.
- The student finishing secondary school has a wide and sometimes bewildering choice of university degrees to apply for. Even restricted to aerospace engineering, there are several European universities (of which some were selected in the Table below) with promising and high-quality degrees that will provide the necessary knowledge, skills and abilities that allow them to work efficiently within the aerospace field.

University (Country)	Aerospace areas covered by the university degree (besides basic operation principles of an aircraft)

	Airport processes and operations	Aircraft engines system / Propulsion	Structures and Materials	Business Management	Air Traffic Management (ATM)	Aircraft systems
Polytechnic University of Madrid (Spain)	x	x	x		x	x
ISAE-SUPAERO Institut Supérieur de l'Aéronautique et de l'Espace (France)	x		x			
Polytechnic University of Turin (Italy)		x	x	x		
The University of Bristol (United Kingdom)			x		x	x
Delft University of Technology (Netherlands)		x	x			
Zurich University of Applied Sciences (Switzerland)	x	x		x		
Polytechnic University of Bucharest (Romania)	x	x	x	x		

Table 20.2. Aerospace areas covered by university degrees across Europe.

Key Actions: to achieve this objective, PARE recommends to:

1) Make available from the early teens, on-line and to secondary schools, a set of easy to implement flight experiments and challenges such as drones now so commonplace and cheap;
2) Give secondary school students at later stages the opportunity to come to presentations and laboratories at a university, together with a parent/mentor or trusted friend.

Adulthood and University

The strong analytical and problem-solving skills of the graduates from the best aerospace engineering degrees are in much demand from other sectors in and out of engineering (e.g. civil construction, automotive domain, consultant and financial services, etc.). Although an aerospace engineer would have as first-choice aeronautics or space, some consultant companies may be quicker to offer professionally enticing and well- paid job opportunities, often advertising before the university degree is complete. Considering this and the increasing competitiveness from other countries (such as the US and Japan), the European aeronautical industry should do its best to attract the brightest graduates in aeronautical engineering to industry before they are lured away by attractive, well-paid offers elsewhere (objective 45).

Key Findings:

- Today, aeronautics and air transport are among the main drivers of European cohesion and competitiveness, representing 220 billion euros and providing 4.5 million jobs in Europe (2019 data), a figure that is expected to double in 2050. These data reveal that aeronautics plays a key role in facilitating European economic growth and social inclusion, providing income to regions that are otherwise isolated and helping people to broaden their horizons;
- Employment opportunities for which graduates in Aerospace Engineering are specifically trained lie mainly in the aerospace field: (i) major European aerospace industries; (ii) small and medium-size industries which supply the former; (iii) agencies and contractors responsible for aircraft maintenance; (iv) airline companies; (v) ATM authorities; (vi) the air force and other military aviation sectors; and (vii) public and private bodies for testing in the aerospace field;
- European-level data show that about 50% of aerospace engineers are employed in other industrial sectors, even in regions where aerospace activities are most strongly established and offer the greatest employment opportunities (France, Germany, UK, Italy, Spain). In the Netherlands, a study regarding career for graduates from TU Delft's Aerospace Engineering degree in 2017 concluded that: 88% of MSc graduates find a job within 6 months after graduating; 40% become employed in the Aerospace sector; 60% find a job within another field of engineering (wind energy, automotive) sectors, consultancy or management;
- The famous "pipeline" problem in STEM fields, which is the need to attract more students and workers too, and to retain them (especially women and minorities) can be related with self-efficacy expectations and has a special impact for aeronautics. Self-efficacy itself is linked directly to persistence and can be improved through increased self-awareness of the sector and formalized mentoring programs and initiatives that involve students in research or activities;
- To ensure the persistence of students in the aeronautical sector after graduation, industry and other employers should engage them at an early stage through professional stays and follow-up with attractive job offers without delay after graduation. For example, the Partnership of a European Group of Aeronautics and Space Universities (PEGASUS) was established with the aim of attracting the best students and also to offer highly relevant educational and research programmes. As of 2014, it included 25 members academic institutions (4 of the universities mentioned before) and most PEGASUS engineering programmes include also one or several periods of practical training, in laboratories or industrial structures.

Key Actions: to achieve this objective, PARE recommends providing industrial stays for students of aeronautical engineering with mentoring that values their skills and keeps track of the most promising for employment after graduation.

Careers in Aeronautics and Space

The aerospace sector can be divided into two major areas: aeronautics industry and air transport, both of which offer a diverse range of interesting career opportunities. However, young people may not be fully aware of all of them and/or need more insights and guidance to decide to pursue a career in aviation. Regarding the first area, to ensure promising students' choice (over other sectors, as stated before) or to make careers in aeronautical industry interesting relative to other alternatives, the aeronautical industry must focus on fascinating technology with adequate reward (objective 46) and invite them during their university course, thereby establishing early links that ensure their choice before other attractions arise.

Key Findings:

- The European aeronautics industry develops and manufactures civil and military aircraft, helicopters, drones, aero-engines and other systems and equipment, which involves designing components and system, generating CAD models and drawings and undertaking fluids and thermal analysis, etc. The industry work also involves testing the systems and equipment manufactured and supporting the products in service afterwards. For this, it is necessary a range of job categories:
    1. engineers (system engineer, mechanical design engineer and others),
    2. senior technicians (logistic technician, method preparer and others) and
    3. operators (boilermaker, fitter-fitter and others).
- Air transport includes the transportation of people, goods and mail on regular lines and non-scheduled activities (charter, taxi, plane rental with the pilot, flight training and others) and relies on aeronautical maintenance activities and airport assistance activities (rack and field operations, shipboard trades, civil aviation professions). Considering this, job categories in this area include:
    1. Airlines or handling agents: flight crew (pilots and cabin crew), ground handling;
    2. Airport operators in airport management, maintenance, security and operators: maintenance, repair and overhaul market (MRO) technicians, airport security and passenger screening operators, etc.
    3. On-site employees at retail outlets, restaurants, hotels, etc.
    4. Air navigation service providers: air traffic controllers.

Key Actions: to achieve this objective, PARE recommends bringing an aeronautical engineering student together with a mentor/relative/trusted friend, which can play a major role in advising a mature choice, to a one-day visit to industry, with briefings and access to facilities, to be remembered for life as a career choice.

Motivating and Rewarding the Workforce

Besides attracting people to the aerospace sector, it is necessary to have favourable conditions and create measures to motivate and reward the existent workforce in the sector to promote dedication, ingenuity, efficiency and loyalty (objective 47). The best motivation and reward for the workforce is the openness to new ideas and giving an opportunity for sensible innovation that benefits also the company's interests. Moreover, some companies: i) share a part of the profits with the employees; and ii) allow employees to buy a limited number of shares at favourable prices with the condition that they cannot be sold for a number of years. Measures like these motivate employees to work harder for the aims of the company they share, knowing that the success due in part to their efforts will be recognized.

Key Findings:

- According to the HiPAir project, a strategic partnership co-funded by the ERASMUS+ Programme of the European Commission, one of the new forms of work organisation, which have been developed, is the concept of High-Performance Work Practices (HPWP). Though many of the practices referred as high performance are commonly used by most organisations to motivate workers, such as financial incentives, flexible job descriptions and continuous skills development programs, the concept of HPWP is fairly unknown. HPWP can be defined as modern management practices design to stimulate the employees and organisation performance and include, for example, recruitment and integration, employee involvement, internal communication, training and reward and commitment. Some examples of practices used in companies at European level are:

Recruitment and integration	Interviews, theoretical tests Induction programs Internship programmes Search talented people in collaboration universities and other training institutions Preparation of job descriptions and selection procedures
Employees involvement	Functional flexibility program (mobility inter and intra-department) Suggestions programs Organisational climate and satisfaction Surveys Employee engagement survey Individual development plans Employee action plans Performance appraisal Annual objectives for each employee, individual and/or global Key Performance Indicators (KPIs) for teams Continuous improvement system Excellence achievement programme
Internal Communication	Communication packages for employees Intranet Webinars Communication meetings (involving all the workers, who may present their opinions and suggestions to improve the company's procedures)
Training (learning and education)	Scholastic program Post-graduate studies Language courses Training technical and non-technical (internal and external courses) Mentoring, coaching, tutoring Talent identification and development plan Talent development program to women-leadership in aeronautics industry Specific training plans based on competencies/skills matrix to answer to identified gaps and to support life-long learning processes
Reward and commitment	Compensations plans (production, administrative, management, etc.) Flexible working conditions Rooms for nursing mothers Retention policy Standardized job roles Compensation, bonuses related to objectives achievement Salary increment related to the objective review

Table 20.3. High-Performance Work Practices adopted by companies at European level.

- Companies in the aviation sector that use high-performance practices at European and global level include FerroNATS (ES), Fokker Elmo Turkey (TR), Groundforce (PT), Global Training & Aviation (ES and ID), FTB Lisi

Aerospace (TR), MTU Aero Engines Polska (PL), Pratt & Whitney Rzeszów S.A. (PL) and the Southwest Airlines (US).

Key Actions: to achieve this objective, PARE recommends to give employees opportunities for innovation, let them share important and interesting work, and recognise their contribution to the success of the company.

Retaining the Fidelity of Employees

The traditional model of a society of lifetime work in a company still exists in countries like Japan, but is presented by some as a 'lack of mobility'. As an alternative to the modern high-mobility, short-term employment, and not excluding intermediate cases, there is nothing wrong with the old model of a company-family which support a dedicated workforce with long experience and attracts the next generation. The mobility of employment has more to do with cultural traditions than with company efficiency. Therefore, aerospace companies in Europe should retain a capable and faithful workforce by providing stable employment, interesting work, reliable benefits and a friendly environment (objective 48).

Key Findings:

- Employee's satisfaction is a measure of how happy workers are with their job and working environment and can be seen as an emotional state that results from the evaluation of one's job or experience. To enrich the levels of employee satisfaction, some measures include: a) foster and reward the training of employees; b) facilitate schedule flexibility; c) give opportunities for professional improvement; d) provide laptop and/or mobile phone for work; e) value the opinions expressed by the employees; f) create a good work environment and conditions for workers;
- Employee fidelity can be defined as employees who are devoted to the success of their organization and believe that being an employee of this organization is in their best interest. Not only do they plan to remain with the organization, but they do not actively seek alternative employment opportunities. The maintenance of a faithful long-experienced workforce can also attract new ideas and support further recruitment by proving a stable and progressive environment for progress;
- A significant percentage (approximately 30%) of the current aerospace workforce in Europe is at or near retirement age. Considering this, companies have to ensure they maintain current expertise while forecasting future hiring needs, such as what skill sets will be needed and when to hire for them, and transferring the talent from older to younger employees, an issue that is becoming more acute as the older employees retire;
- This lopsided demographic mix, coupled with high attrition rates and increased labour mobility, poses serious risks to the industry. Companies can mitigate the risks with employee retention and succession planning. Besides wage, other factors determine the loyalty of the workforce in an aerospace organisation: perceived high job security (reduced risk of being made redundant), a good and reliable pension system, an effective health insurance scheme and an optional extension of the retirement age could only increase the attractivity and the excitement of the employment in aerospace and retain talent, especially people with the STEM skills.

Key Actions: to achieve this objective, PARE recommends having competent staff, able to adapt to change and to contribute to progress, sufficiently well integrated not to wish other careers and serve as example to relatives and friends.

3.10 Increasing the Participation of Women in Aerospace

PARE objectives 49 to 58 are addressed in chapter 11 of PARE's report, entitled "Increasing the Participation of Women in Aerospace", which analyses the factors that influence the participation of women in this sector and proposes measures to attract and retain more women.

Some of these factors are: women's interest in the aerospace sector and the women's self-confidence in STEM (Science, Technology, Engineering and Mathematics) subjects; the gender stereotypes that women are exposed to in the educational context and the gender imbalance in STEM education; the inequality of employment opportunities, the gender imbalance in STEM jobs, the unequal treatment and labour conditions.

Generating Interest in Aerospace and Building Confidence

Evidence suggests that women are underrepresented in some areas of work, notably those where some knowledge of STEM subjects is required. Main reasons for this pattern include a lack of encouragement from friends, family and teachers; a lack of awareness, this is, reduced prior knowledge of STEM as a career option; and a lack of young women's self-confidence in STEM roles, which in its turn is partially caused by the societal bias that girls face since childhood. Considering this, it is fundamental to counter family and societal bias discouraging girls from the interest in vehicles, be it cars or planes (objective 49).

Key Findings:

- The European Institute for Gender Equality (EIGE) defends, in a report entitled "Study and work in the EU" (from 2018), that positive STEM experiences and development of "STEM identities" start from an early age, even before children enter formal education, through family relations (*e.g.* a strong bond with fathers increases women's likelihood to enter STEM studies) and choices (*e.g.* providing caring toys such as dolls for girls and exploring toys such as cars and planes for boys);
- Girls and boys also start understanding gender stereotypes or societal bias regarding gender as early as age two and they learn to adjust their behaviour according to internalised gender stereotypes by age four. The assumption that "girls play with dolls and boys play with cars/planes" and other predominant stereotypes with relation to gender and STEM (*e.g.* "boys are better at math and science than girls" or "science is for men, not for women") makes it particularly challenging for girls to see STEM as a potential career choice and, on the other hand, may equip boys with easily available and pre-established roles in science and technology;
- To understand why more Europe's girls and young women aren't studying STEM, Microsoft commissioned a Europe–focused research in 2017 involving 11.500 school girls (ages 11 to 18) and young women (ages 19 to 30) from 12 European countries. The research concluded that most European girls become interested in STEM between the ages of 11 and 12, but that interest drops off significantly between the ages of 15 and 16 (by the time girls are in high school). On average, 57% of girls rejected the idea that they will never be as good at STEM subjects as boys (expressing in general confidence in their STEM skills) but all of them acknowledged that men and women are treated differently in STEM-related roles and this perceived inequality is putting them off further STEM studies and careers;
- A study commissioned by the European Commission (EC)'s Directorate-General for Mobility and Transport (DG MOVE) identified 10 specific communication good practices and strategies able to be transferable across the full spectrum of transport sectors in the Member States and believed to promote transport jobs effectively to young women and men. These are: 1) Using research to confirm the approach; 2) Taking a strategic approach (a long term plan with specific targets); 3) Going into schools, colleges and universities; 4) Providing opportunities to experience the job; 5) Showcasing real people as role models; 6) Working with men to engage women; 7) Communicating with young people on their terms; 8) Building in careers advice provision to promotional strategies; 9) Using networks & mentoring to support female retention; 10) Using existing resources & networks to increase cost-effectiveness;
- Policymakers can help fight gender stereotypes and bring behavioural change regarding gender equality through an effective gender mainstreaming, which is a strategy that involves the integration of a gender

perspective into the preparation, design, implementation, monitoring and evaluation of policies, regulatory measures and spending programmes.

Key Actions: to achieve this objective, PARE recommends making available on-line and accessible to primary schools and parents, children stories and cartoons involving flying that are both entertaining and educational.

Implementing Changes in the Educational Context

In the EU, despite an average of half of the pupils that enter in the primary schools are female and continue studying further into secondary education, in tertiary education/university men are more likely to obtain a degree in a STEM field of studies. Research suggests that there is little no difference in boys' and girls' average ability at STEM subjects, which means that to attract more girls to STEM subjects at schools and universities, the solution is to tackle the stereotypes that they are exposed to from primary and secondary education until university graduation. In practice, it is necessary to give girls and boys in primary schools the same opportunities to choose their games and entertainment (objective 50) and to encourage more girls to take aeronautical engineering degrees (objective 51).

Key Findings:

- As said before, teachers play an important role in influencing girls and young women in studying and pursuing STEM fields. Some measures that have been adopted so far in Europe include:
    - 1) making available on the internet and to primary school's children stories and cartoons where girls drive cars and fly aeroplanes as much as boys do and let them play with vehicle models or ask for them as presents;
    - 2) developing a toolkit for primary and secondary school teachers to fight gender stereotypes and raise awareness about transport professions among young people;
    - 3) have a gender-neutral environment in classes that help young women to participate and feel engaged;
- According to a report made by Deloitte UK, in 2016, almost as many girls and boys sat the General Certificate of Secondary Education (GCSE), a qualification in a specific subject typically taken by school students aged 14 – 16, in STEM subjects. However, 40 per cent fewer girls than boys continue studying STEM subjects in A - level, which is the level that students who pass on the GCSE exam go to. This result corroborates with the findings of the Microsoft research that girl's interest drops between the ages of 15 and 16 and is not a cause of girls' performance in these subjects;
- According to the EIGE "*Study and work in the EU*" report, in ten years (2004-2015), women's share among STEM graduates in the EU barely changed and instead of slightly improving, has fallen from 23% to 22%. In engineering, manufacturing and construction-related studies, this percentage decreases to almost 16%;
- The article "Girl Power" published in 2018 in the *Social Sciences* open access journal states that women in engineering majors enter college with the same levels of interest and intent to persist in the major as male peers, but the majority face negative experiences such as male favouritism and differential treatment and sexual harassment from classmates and faculty; that make it difficult to persist and succeed in their majors. Those who have positive via supportive faculty members and peers, research experiences or participation in engineering organizations are more likely to continue taking STEM classes, complete degrees and continue on to post-baccalaureate STEM careers in comparison to those who do not.

Key Actions: to achieve these two objectives, PARE recommends (respectively)

1) Including flight experiments equally accessible to boys and girls in primary and secondary school programmes and activities;

2) Reinforcing and accelerating visits to universities and industry, role models of success stories and the same fascinating technologies.

Improvement of the Employment Context

As the traditional masculine beliefs and values have been rooted in the aviation industry for a long period, despite several efforts made, the percentage of women pursuing a career in the field remains low, particularly in technical positions that require STEM skills. To oppose this, it is necessary:

- provide women with attractive careers in aeronautics in industry and academia (objective 52);
- discourage and prevent the continuation of abuse based on gender (objective 53);
- ensure that the protection of the family, maternity and parenthood is effectively implemented with its legal basis as a minimum (objective 54);
- give equal recognition of achievements regardless of gender, taking into account the circumstances (objective 55);
- see the differences between the genders as an opportunity for a symbiosis of distinct talents that furthers smooth progress (objective 56);
- increase the participation of women in aeronautics in the most effective way (objective 57); and
- recognise the historic achievements of women, including in aeronautics, in biased or unfavourable circumstances (objective 58).

Key Findings:

- In Europe, women make up 41% of aviation employees, but this percentage is deceptive because it reveals little of the skill distribution between the sexes or the extent of female presence in senior roles. For example, even though there is a high share of female cabin crew (a position that doesn't require STEM education), it is estimated that only around 4-5% of the world's commercial airline pilots are female. The same goes to technical positions that skew towards men;
- The gender gap in starting salary between men and women who have STEM qualifications and go on to take jobs in those spheres is smaller than in any other subject's studies. It is partly related to the fact that many women take time out from work for family reasons and may only take on a part-time job when they eventually return to work, which in general is paid less per hour than full-time work. Moreover, part-time work is not equally spread between women and men, since in the EU in 2017, 32% of women in employment worked part-time, compared with 9% of men;
- Women feel more supported in environments which recognize their range of skills they have, provide opportunities for progression and take a firm line on sexist behaviour. Concerning on-the-job treatment and preventing abuse, there are three main factors to take into consideration:
    1. Women mentoring programs: women mentors can support in efforts to make the industry and job functions more transparent, giving entrants a realistic depiction of how the industry works and what it is like in the work environment;
    2. Women job satisfaction determinants: on-the-job treatment should also consider women's determinants for job satisfaction and design their jobs ensuring these factors;
    3. Women networking: establishing networks of women to share experiences and promote opportunities are perceived to be an important element of improving working conditions.
- The protection of the family and children is a fundamental value of society that the law tries to ensure in all situations including employment. Instead of dismissing someone using collateral arguments, a change of type of work or a different assignment can make more compatible company priorities and family needs, by adjusting schedules or timetables;

- The recognition of professional achievements must be objective and fair, using the same criteria applied in the same way, regardless of gender, age or belief. However, fairness also means equal opportunities, and while applying the same final criteria, all should have the same opportunities to attain those objectives. The adjustment of working conditions or schedules or responsibilities to account for special individual circumstances of women or other groups is not a favour, but rather having an even playing field inside the company as the company would like to have in the market versus its competitors, promoting a loyal division of tasks within the organization;
- Women were present in aviation activities since the first flights. However, until the 70s their presence was, with rare exceptions, mainly as passengers on-board of male-piloted vehicles. Biased opinion persisted over decades, determining a large delay in pioneer women penetrating in male-dominated aviation professions. Examples of women that had remarkable successes in aviation despite modest recognition: Amelia Earhart, Hanna Reich, Jaqueline Cochran and Jaqueline Auriol. These notable exceptions were the effect of a combination of factors: outstanding qualities, the encouragement of a political system using women images for propaganda objectives, powerful support from families and luck;
- Women and men can have different sensibilities, distinct approaches to the same problem and complementary abilities that can be of benefit to the balanced and efficient performance of many tasks. Greater participation of women in aeronautics is not only an enlargement of the workforce in numbers, but it is also an enrichment in quality and talent, which are the foundations of inventiveness and competitiveness, on which depend the continuing European leadership in an ever more competitive world with new challenges.

Key Actions: to achieve these two objectives, PARE recommends (respectively)

1) Making all aspects of job recruitment, from the announcements to the interview to the benefits, gender-equal, and try to compensate for eventual gender differences;
2) Taking gender abuse as seriously as gross incompetence or major financial misconduct as concerns the consequences and leave no doubts on anyone's mind about this policy;
3) Taking family, maternity and parenthood in consideration in the assignment of tasks and giving a suitable working environment;
4) Avoiding direct and reverse discrimination or bias by judging and rewarding achievements in an even, transparent and fair way, that is not seen as gender bias;
5) Assigning positions and tasks using the best talents and skills available in both genders to promote creativity and efficiency;
6) Considering the greater numbers of women in aeronautics not just as a numerical enlargement of the workforce but also as a broadening of the talent available;
7) Considering the lives of outstanding women, including aviators and astronauts, not only from a biographical point of view but also recognising the challenges they had to overcome to realise their achievements.