PERSPECTIVES FOR AERONAUTICAL RESEARCH IN EUROPE

PARE

CHAPTER 9

Cooperation Beyond Europe's Borders

Final Report

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List of Acronyms

4DTs	- 4D trajectories
ABAS	- Aircraft based augmentation
ACC	- Area Control Centre
ADS-B	- Automatic Dependent Surveillance – Broadcast
AIM	- Aeronautical Information Management
AIP	- Aeronautical Information Publication
AIXM	- Aeronautical Information Exchange Model
ANS	- Air Navigation System
ANSP	- Air Navigation Services Provider
ASAS	- Airborne Separation Assurance System
ASBU	- Aviation System Block Upgrades
ASDE-X	- Airport Surface Detection System–Model X
ASIAP	- Aviation Safety Implementation Assistance Partnership
ASSC	- Airport Surface Surveillance Capability
AP	- Approach Control
ATC	- Air Traffic Control
ATFM	- Air traffic flow management
ATM	- Air Traffic Management
ATN	- Aeronautical Telecommunications Network

ATSAW	- Airborne Traffic Situation Awareness
BWB	- Blended Wing Body
CDM	- Collaborative Decision Making
CLRTAP	- Convention on Long-Range Transboundary Air Pollution
CNS	- Communication, Navigation and Surveillance
COI	- Communities of Interest
CONOPS	- Concept of Operations
COO	- Concept of Operations
CORSIA	- Carbon Offsetting and Reduction Scheme for International Aviation
CPDLC	- Controller Pilot Data Link Communications
DCB	- Demand and Capacity Balancing
DFDAU	- Digital Fight Data Acquisition Unit
DME	- Distance Measuring Equipment
DVOR	- Doppler VHF Omni-directional Range system (VOR)
EACCC	- The European Aviation Crisis Coordination Cell
EAD	- The European Aeronautical Information System Database
EANPG	- Th European Air Navigation Planning Group
EASA	- The European Authority for aviation safety
EC	- The European Commission
ECAC	- European Civil Aviation Conference
EGNOS	- European Geostationary Navigation Overlay Service
ENCASIA	- European Network of Civil Aviation Safety Investigation Authorities
EPAS	- European Plan for Aviation Safety
EUIR	- European Upper Flight Information Region
EUROCAE	- The European Organisation for Civil Aviation Equipment
EUROCONTROL	- European Organisation for the Safety of Air Navigation
FAA	- The Federal Aviation Administration
FAB	- Functional Airspace Block
FAR	- Federal Aviation Regulations
FF-ICE	- Flight & Flow Information for a Collaborative Environment
GANP	- Global Air Navigation Plan
GASeP	- Global Aviation Security Plan
GASP	- Global Aviation Safety Program
GNSS	- Global Navigation Satellite Systems
IAPs	- Instrument Approach Procedures

IATA	- The International Air Transport Association
ICAO	- International Civil Aviation Organization
ICOG	- Interoperability Consultancy Group
ICPTF	- International Certification Procedures Task Force
IFR	- Instrument Flight Rules
ILS	- Instrument Landing System
IM	- Interval Management
INS	- Inertial Navigation System
IPS	- Internet Protocol Suite
ITP	- In-Trail Procedures
IWP	- Integrated Working Plan
JAR	- Joint Aviation Requirements
KPA	- Key Performance Area
KPI	- Key Performance Indicator
MLAT	- Multilateration System
MOPS	- Minimum Operational Performance Specification
MoU	- Memorandum of Understanding
NAS	- National Airspace System
NAT	- North Atlantic
NCOIC	- Network Centric Operations Industry Consortium
NDOP	- Network Directors of Operations Group
NextGen	- Next Generation Air Transportation System (the FAA-led modernization of America's air transportation system to make flying even safer, more efficient, and more predictable)
NGATS	- Next Generation Air Transportation System
NM	- Network Manager
NMB	- Network Management Board
NOP	- The European Network Operations Plan
NOTAM	- Notice To AirMen
NSA	- National Supervisory Authority
PRR	- Performance Review Report
PSR	- Primary Surveillance Radar
QoS	- Quality of Service
RP	- Reference Period
RPAS	- Remotely Piloted Aircraft System
RTCA	- Radio Technical Commission for Aeronautics
SARPs	- Standards and Recommended Practices

SBAS	- Satellite Based Augmentation System
SES	- Single European Sky
SESAR	- Single European Sky ATM Research
SMR	- Surface Movement Radar
SOA	- Service Oriented Approach
SSC	- Single Sky Committee
SSP	- State Safety Programme
SSR	- Secondary Surveillance Radar
STAPES	- SysTem for AirPort noise Exposure Studies
SWIM	- System Wide Information Management
SWIM-SUIT	- System Wide Information Management Supported by Innovative Technologies
TBO	- Trajectory Based Operations
TBS	- Time Based Separation
TIS-B	- Traffic Information Service – Broadcast
TSFC	- Thrust-Specific Fuel Consumption
TWR	- Tower
UA	- Unmanned Aircraft
UAS	- Unmanned Aircraft System
UAS-AG	- Unmanned Aircraft Systems Advisory Group
UNFCCC	- United Nations Framework Convention on Climate Change
UTM	- Unmanned Aircraft System Traffic Management
VDL2	- VHF Data Link Mode 2
VFR	- Visual Flight Rules
VHF	- Very High Frequency
VOR	- VHF Omni-directional Range system
WAAS	- Wide Area Augmentation System
WAM	- Wide Area Multilateration System
WTO	- World Trade Organization

Chapter 9 – Cooperation beyond Europe's borders

There are many areas of aeronautics of common interest to the worldwide community, including education, research, industry, airlines, airports, service providers and ultimately passengers and the travelling public, and the governments and the national and international institutions representing them. Some of these areas that justify cooperation beyond Europe's borders are Air Traffic Management (ATM), harmonized certification rules, environmental effects, safety and security, fair trade and open markets and are considered next.

3.1 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. It is generally agreed that 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. 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.

The air traffic is densest in Europe and the north-eastern corridor of the US. Experience in these areas has shown that 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; (iii) associated with (ii) there is an increase in fuel consumption, and also increased pollution and noise, precisely near the airport areas where these issues are more sensitive; (iii) 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.

One of the most important problems requiring far-reaching reduction are delays in air transport. Air transport delays in the world and Europe are a major concern for the whole aviation industry. Not only is it a big inconvenience for the actors, but delays also induce large costs, for the airlines, their customers and the community as a whole. The airlines bear additional costs on the fleet, as well as flying and ground personnel since delays prevent them from operating in optimum conditions. They also must compensate for passengers for their experienced discomfort and prejudices. Also, according to their type of operations, airlines might experience specific costs (i.e. linked to hub operations). Additional long-term costs might also be observed such as a loss of competitiveness and the consequences of degraded social climate, which follows degraded working conditions. The delay-related costs for users are mostly airline passenger's opportunity cost, measured by their value of time. The delay-related costs for the community involve environmental costs as well as costs incurred by other actors involved in the air transport business such as hotels, travel agents, tour operators, airports, etc.

The main cause of delayed flights is the chained delay when one delay of a flight entails the delay of subsequent flights by a domino effect. But air transport delay is a very complex phenomenon and needs constant monitoring and investigations.

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 that 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 in Europe and NextGen in the US that are under some pressure to provide evidence of results and progress in the quest to keep air traffic capacity ahead of air transport growth and avoid the risk of massive flight delays and cancellations.

Progress in ATM is more marked in Europe and the US both because of the market pull of having the densest air traffic in the world and by the market push of being able to provide the most advanced relevant technologies, such as 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 situation is simpler in the US which as a single nation has the same procedures and compatible equipment under the auspices of the FAA that is both the only Air Navigation Services Provider (ANSP) and also the certification authority. In Europe: (i) there is a division in ATM sectors affected by national borders; (ii) the national ANSPs coordinate their activities through Eurocontrol and operate a diversity of hardware and software ;(iii) the membership of Eurocontrol is wider than that of the European Union and does not coincide with the certification authority (EASA) which groups the national certification authorities. The Single Sky is a given in the US and a work in progress in Europe. Despite all these factors Europe betters the US in most ATM performance metrics like timeliness of flights and achieves the same or higher safety standards.

While there is healthy and desirable competition in the supply of ATM equipment and systems, the requirement for seamless operation over continents and across oceans should be preserved. Also, many of the basic technologies are common and are implemented in many competitive commercial products. The seamless integration of SESAR and NextGen across the Atlantic Ocean is a good example of the need for and benefits of cooperation and coordination among the two world leaders in ATM technology. The benefits will be felt worldwide since the same issues of seamless air transport apply across national borders and the Pacific and Indian Oceans, and major suppliers of hardware are Europe and the US.

Considering the likely and needed progress in ATM (Key Topic T9.1), a comparison can be made between the two largest programs in the world (Key Topic T9.2): SESAR in Europe and NextGen in the US.

The coronavirus disease (COVID-19) outbreak in 2020 is of considerable concern to the aviation industry and poses specific challenges for the aircraft producers, airlines, airports and ATM system. In April 2020, the intensity of air traffic in the Europe area fell by almost 90%. Most European institutions connected with the aviation industry have been involved in activities aimed at reducing losses due to the spread of the COVID-19. EUROCONTROL developed The European Network Operations Plan (NOP) – 2020 Recovery Plan, which is a special version of the NOP to support the aviation response to the COVID-19 Crisis. The Plan provides for a consolidated European network view of the evolution of the air traffic and enables the planning of the service delivered in the recovery phase by ANSPs and airports to match the expected air traffic demand in a safe, efficient and coordinated manner.

The relationship with "Third Countries" was described in the European NOP 2019-2024 approved by the NMB (Network Management Board) in June 2019. The same working arrangements will be applied during the Recovery phase and across this NOP 2020 Recovery Plan. The relationship with ICAO was described in the European NOP 2019-2024 approved by the NMB in June 2019. During the COVID-19 Recovery phase, the relationship with ICAO primarily will be focused on actions aiming to support an effective recovery from the current situation. It may include:

- regional cooperation with the States within the EUR/NAT (Europe/ North Atlantic) region outside the NM (Network Manager) area of responsibility,

- inter-regional cooperation with the neighbouring ICAO regions (e.g. NAT),

- cooperation at the global level with ICAO and its agencies involved, which can contribute to the COVID-19 Recovery (e.g. WHO)

For the NOP 2020 Recovery Plan, a particular relationship is maintained with ICAO through their participation and contribution in the EACCC (The European Aviation Crisis Coordination Cell).

KEY TOPIC T9.1 EVOLUTION OF ATM IN EUROPE AND ELSEWHERE

Historically, Europe consisted of many countries that did not create uniform political, economic or demographic systems. Along with the development of closer political and economic cooperation within the European Union, the efforts have been made to harmonize the rules of ATC and ATM, which has led to the creation of a Single European Sky (SES) over Europe. Despite those activities, the ATC and ATM systems in Europe are fragmented and dominated by local ANSP that have a monopoly for running the ATC and ATM services. The border division of the airspace has made the European ATC and ATM system a kind of a mosaic of national ATC and ATM systems (EUROCONTROL, 2019; EUROCONTROL, 2016a; EUROCONTROL, 2016b; Lefebvre et al., 2010).

Europe is a unique region on Earth because of the very high population density and high intensity of flights performed on its territory. In 2015, more than 9.9 million IFR (Instrument Flight Rules) operations were carried out in Europe and forecasts predict their growth by 16% by 2022 (EUROCONTROL, 2016a). Currently, around 27,000 controlled flights take place in the European airspace every day. Europe is facing an airspace capacity crisis, as it is predicted that the number of flights will increase by as much as 50% in the next 10–20 years (EUROCONTROL, 2016a; EUROCONTROL, 2016b; Lefebvre et al., 2010).

Each year, over 1.6 billion passengers in Europe take one of 10 million flights. Passengers expect a safe and trouble-free journey, without any delays or cancellations and arriving on time with luggage in hand. In European Union, the legislation on passenger rights seeks to ensure that passengers enjoy a harmonised minimum level of protection, irrespective of the mode of transport used, to facilitate mobility and encourage the use of public transport (for Air transport: Regulations (EC) No 261/2004 and (EC) No 1107/2006). Meeting these expectations is the task of the European ATM system, which has so far managed safely and effectively the flow, traffic and density of traffic in the sky over Europe. However, with a forecasted increase in the number of flights to 16.9 million by 2030, the current ATM system needs to be improved using the latest technologies and revised operational procedures to avoid fragmentation and to meet the need for more flights in an efficient, safe and environmentally friendly manner. The modernized air transport system, characterized by innovative technology and the timely delivery of competitive products and services, will be of key importance to Europe's economy, society and cohesion (IATA, 2018).

T9.1.1 Steps Toward the Single European Sky (SES)

The Single European Sky (SES) initiative was launched at the beginning of the present century by the European Commission, mainly driven by important delays in aviation operation in Europe by the end of the 20th century. In other words, its primary goal was and is still to meet future capacity and safety needs through different tools, mainly legislation framework and research.

The first step taken was a legislative package drafted by the European Commission at the end of 2001 which was adopted by the European Parliament and Council in March 2004, since which the European Union has gained competences in air traffic management (ATM) and the decision-making process has moved away from an intergovernmental practice to a common European framework.

The legislative package adopted in 2004 comprised four basic regulations, which addressed the reinforcement of safety and air navigation services. The regulations provided the framework for the creation of additional capacity and improved efficiency and interoperability of the ATM system in Europe. These four basic regulations were [1]:

- Framework Regulation (EC N° 549/2004), which addresses the framework for the creation of the Single European Sky.

- Service provision Regulation (EC N° 550/2004), which addresses the provision of air navigation services in the SES.
- Airspace Regulation (EC N° 551/2004), which addresses the organization and use of airspace in the SES.
- Interoperability Regulation (EC N° 552/2004), which addresses the interoperability of the European ATM network.

These four regulations formed the SES I Package, and the result of its implementation was the insufficient progress in key areas hence deep modifications were needed. The key areas that needed to be developed were, mainly [2]:

- Performance review of service providers: The Framework Regulation foresaw Performance review of ANSP in which data gathering and benchmarking were expected to commence in 2008 in order to form a solid basis for the future development of the Single Sky initiative.
- Peer review of supervisory authorities: it was foreseen in order to ensure a uniform level of safety and even application of the Common Requirements. With the completion of the first Certification exercise by the NSAs (National Supervisory Authorities) in July 2007, the peer review was established with first visits in early 2008.
- Transparency of charging: the first review under the Common Charging Scheme Regulation was expected to guarantee greater transparency for the determination, imposition and enforcement of charges for air navigation services.
- Airspace design: the mandate process to Eurocontrol was initiated on several draft Regulations related to airspaces such as the establishment of a EUIR (European Upper Flight Information Region), airspace classification in the lower airspace or common principles for route and sector design. In this manner, progress in all three areas was slow and the Commission studied alternative mechanisms.
- FABs (Functional Airspace Blocks): a key element of SES was the establishment of FABs, which were foreseen as the mechanisms for ensuring maximum capacity and efficiency of the air traffic management network.

Back in 2007, SES did not deliver the expected results in some important areas. In general, the FAB approach was not producing the benefits hoped for in terms of improved flight efficiency, cost reduction and “defragmentation”. It was recognized that the creation of FABs was a new challenge and suffered from significant technical and organizational difficulties, sovereignty, particularly concerning Member States responsibilities and associated liability for their airspace and the involvement of the military remained an issue. Besides, even though the legislation had powerful tools to improve performance through: designation of service providers; unbundling of services; use of economic incentives; setting of user charges; changes in route structure; establishment of FABs; rationalization of infrastructure; etc., Member States did not make sufficient use of them to improve cost or operational efficiency of service provision [2].

In this manner, the SES II Package was defined in 2009 through Regulation EC N° 1070/2009 in which the main aim was to increase the overall performance of the air traffic management system in Europe, based on the insufficient progress in key areas from the start of the SES I Package, as explained above. Thus, the Commission adopted and implemented extensive and exhaustive implementing legislation in which more than 20 implementing rules and community specifications (or technical standards) were adopted by the European Commission to ensure the interoperability of technologies and systems [3]. Therefore, with the SES II Package, a step forward was made towards establishing targets in key areas of safety, network capacity, effectiveness and environmental impact.

This SES II Package was intended to accelerate the realization of the SES and its benefits with high-levels goals to achieve by 2020 relative to 2005. To achieve these goals the European Parliament established a framework of five pillars (Figure 9.1) based on technology, safety, performance-based regulation, airports and human factors. This framework is based on an integrated approach towards safety by the extension of the competencies of the EASA in the field of aerodromes, air traffic management and air navigation services, through the establishment of a joint undertaking (JU) on research & development, the SESAR JU (SESAR standing for the Single European Sky ATM Research). A Network Manager for the European ATM network has been created, while an independent Performance Review Body (PRB) supports the Commission in the development and management of the SES performance scheme in which Functional Airspace Blocks (FABs) have a key role to play [3].

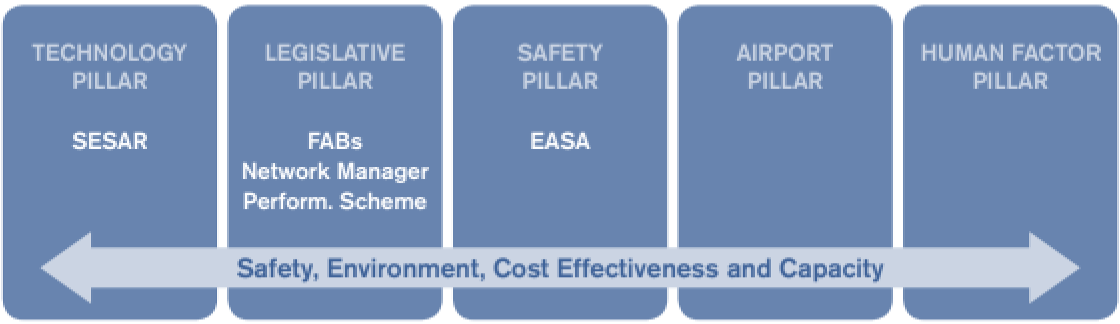


Figure 9.1 – SES implementation five pillars
Source: A Blueprint for the Single European Sky by IATA

Each one of these five pillars will help to achieve the overall SES objectives through a holistic approach, and they are specifically explained below [4]:

TECHNOLOGY PILLAR

The Single European Sky ATM Research (SESAR) program has been a strong focus for many stakeholders across the industry. At SESAR 2020, the successor of SESAR 1, about 1,6 billion of € has been committed to the development phase and is estimated that around 3,000 people are currently engaged in this unprecedented research and development effort to improve ATM efficiency. The encouraging results of this development phase have demonstrated that new concepts are feasible however the benefits will be much delayed and at a reduced level than originally planned. Additionally, SESAR deployment will only deliver a portion of the SES high-level goals and, if the technology component is not deployed in synchronization with the other pillars, it will lead to further waste and non-delivery of benefits.

SAFETY PILLAR

To date the SES, I and II packages focused on making progress in areas of safety and clarified the respective roles of regulators, supervision authorities and service providers. The evolution of the European Aviation Safety Agency (EASA) to cover ATM and airports is also an important step towards the supervision of safety across the entire air transport supply chain. However, at this point, it is considered that EASA must improve its cost-efficiency. Importantly, it is lacking some of the necessary resource capability to effectively perform new responsibilities, especially concerning appropriately experienced and skilled professionals. Reporting and transparency are also insufficient. For example, it is concerning that in the Performance Review Report (PRR) for the 2011 calendar year, that 12 European Civil Aviation Conference states did not submit safety template data to the Eurocontrol Safety Regulation Commission.

LEGISLATIVE PILLAR

The legislative pillar consists of three components which have close interrelationships; the Performance Scheme, the FABs and the NM.

PERFORMANCE SCHEME

The Regulation established that a Performance Scheme should be set up to improve the performance of air navigation services and network functions as much as the scheme aims to ensure that capacity is increased. As a result, flights will be significantly less delayed, saving unnecessary costs for airlines and passengers. Besides, the environmental impact of air traffic will be reduced due to more efficient and shorter flight paths. Air travellers should benefit from a punctual, greener and more cost-efficient mode of transport with a maintained or even enhanced level of safety. In this manner, the scheme should include Community-wide performance targets on the key performance areas of safety, environment, capacity and cost-efficiency. National plans to ensure consistency with this as established by this Regulation and Community-wide performance targets must be defined, and periodic review, monitoring and benchmarking of air navigation services and network functions should be conducted to ensure that targets are met. The Regulation also establishes reference periods (periods of validity and application of Union-wide performance targets and the performance plans): the first reference period, known as RP1, covered the calendar years 2012-2014, the current one, RP2, includes the calendar years 2015-2019 and RP3 has started on 1st of January 2020 and subsequent periods will cover five calendar years (ends on 31 st of December 2024). The European Commission adopted performance targets for air navigation services for the period 2020–2024 (Single European Sky Reference Period 3) on 29 May 2019. The targets determine the level of ambition for the entities responsible for air traffic management in Europe.

As an example of monitoring, en route Air traffic flow management (ATFM) delay has changed along the past years (see Figure 9.2). At the beginning of RP1, the average delay was lower than the target set for 2012 (0.63 vs 0.7) and, although the target has been even more restrictive every year, the average delay was also lower than the target in 2013 (0.54 vs 0.6). However, since 2014 until now, the average en-route ATFM delay has been higher than the target set and, even worse, the average delay has continued increasing until set the maximum difference in the current year (1.07 vs 0.5). Therefore, as an increasing trend is underway, air traffic stakeholders should implement mitigating measures to chase the fulfilment of the targets for each reference period during the following years.

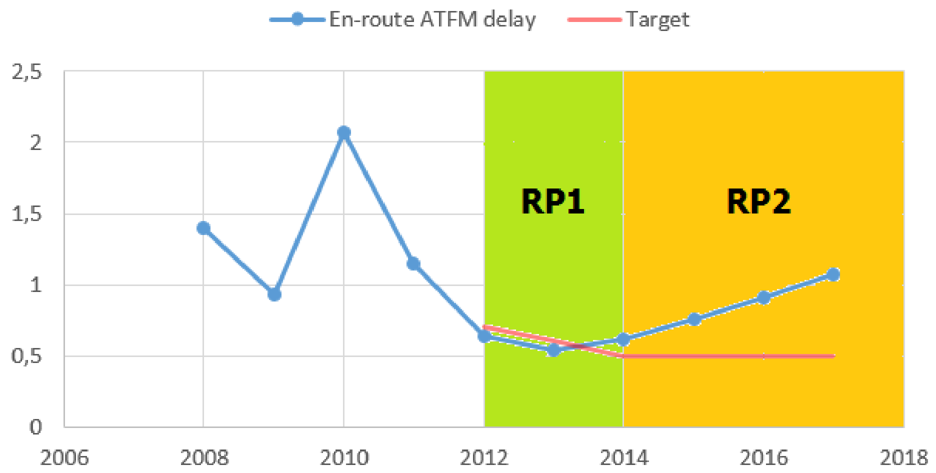


Figure 9.2 – En-route ATFM delay (RP1-RP2) (min/flight)

COVID-19 EFFECT

Due to the COVID-19 Crisis, it was developed a special version of NOP, The European Network Operations Recovery Plan–2020. Its development has been agreed by the Network Directors of Operations Group (NDOP) at its 25th meeting held on 17th March 2020 and endorsed by the Network Management Board (NMB) at its 27th meeting held on 2nd April 2020. The European Aviation Crisis Coordination Cell (EACCC) has been informed about and requested to contribute to the development of the Recovery Plan. The relevant information collected through the EACCC were being taken into account in this Recovery Plan –2020 as appropriate.

The European Network Operations Recovery Plan–2020 was based on the annual performance targets set by the Single European Sky Performance Framework for 2020 to 2024 (RP3), and the performance targets adopted by Single Sky Committee (SSC) at the ad-hoc session held on 1 April 2019, published in the Commission Implementing Decision 2019/903 of 29 May 2019 for RP3.

Given the situation at the beginning of 2020 and the impossibility to derive a full year traffic forecast then, the European Network Operations Recovery Plan–2020 didn't contain local en-route ATFM delay reference values and capacity increase requirements for whole 2020 year. Nevertheless, it aimed to achieve the lowest possible level of total ATFM delay (en-route + airports).

Concerning safety requirements, the European Network Operations Recovery Plan–2020 addressed the safety actions needed to ensure a safe and effective recovery of ATM operations.

FUNCTIONAL AIRSPACE BLOCKS

The FABs are a vital foundation element of the SES, designed to rationalize European ATM. There are currently 9 FABs established as can be seen in the following Figure 9.3:

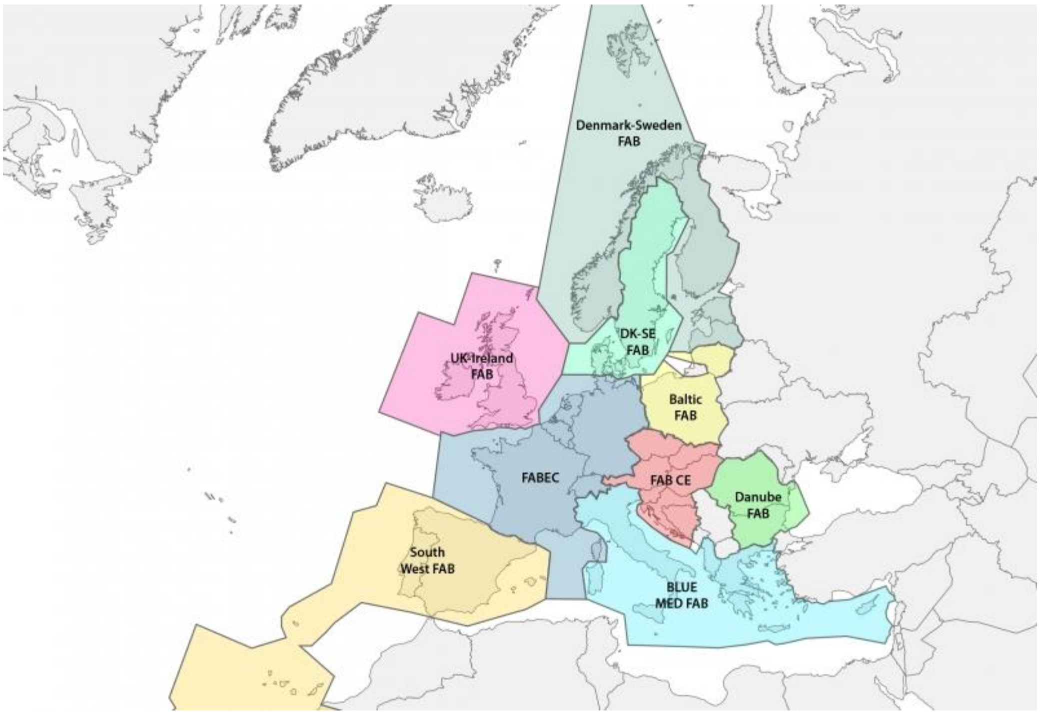


Figure 9.3 – Functional airspace blocks (FABs)
Source: EUROCONTROL

The establishment of Functional Airspace Blocks (FABs) is a key mechanism of the Single European Sky (SES) and represents the framework established by the Member States to enable this increased cooperation and integration leading to a more rational organization of airspace and service provision poised to meet the performance expectations of the airspace users and that of the European Union through its performance scheme [5]. In this way, route design has seen an increase in operational efficiency, however, major technical, cultural and industrials challenges still need to be addressed. Most European ANSPs continue to develop their ATM systems and their training capability, which leads to difficulty in standardizing EU-wide service delivery, inhibits staff mobility and adds significantly to overall costs.

In the COVID-19 Crisis, the NOP 2020 Recovery Plan involved all operational stakeholders, including FABs and related ANSPs, who were contributing to an effective recovery. The involvement of the FABs was achieved through the NMB.

NETWORK MANAGER

The Network Manager function was established at the beginning of 2012. The function has a governance structure supportive of airspace user needs and will be a useful tool to drive the implementation of SES operations towards increased performance. However, some unresolved matters relating to the on-going EUROCONTROL network technology research and development. To ensure the effectiveness of this role, the SES regulation should explicitly state that the Network Manager has the authority to enforce coordinated actions by ANSPs. Additionally, the Network Manager role needs to be strengthened to ensure that it can rationalize the network and identify opportunities for service quality improvement by FABs.

In 2020 during the COVID-19 crisis, NM received new tasks resulting from the current situation. At the 25th meeting held on 17th March 2020, the Network Directors of Operations Group (NDOP) drew the following conclusions concerning the NOP 2020 Recovery Plan:

- NDOP agreed that anticipation of traffic recovery shall be considered and that NM shall start developing the first elements of an effective COVID-19 NOP 2020 Recovery Plan in close cooperation with all operational stakeholders; the timing of such activity will take into account the evolution of the crisis;
- NDOP agreed that NM will work closely with the airspace users to take into account the latest traffic evolution and to have a daily update of the traffic demand outlook.

AIRPORTS PILLAR

The need to better integrate airport processes with airspace management using a standardized approach is evident if the capacity goals of the SES are to be realized and we are not to continue wasting €2.35 billion in additional costs attributable to the airport and associated terminal airspace.

Due to COVID-19 crisis, significant uncertainty in passenger terminal throughput due to likely state health requirements, available air and landside staff and uncertainty in airline schedules mean that all analysis made in 2020 has to be treated with caution.

HUMAN FACTORS PILLAR

Of all the pillars, the least tangible progress has occurred concerning the human factors and social issues involved in SES implementation. It is well recognized that this is a challenging area and will take commitment and diligence by ANSP management and staff to work through this transition. Without a successful human factors element to this transition, the SES will result in the deployment of new technology that will not be fully utilized and not deliver the anticipated benefits. A clear focus on better planning the engagement with ANSP staff is needed.

In conclusion, the experience gained with SES I since 2004 and SES II since 2009 has shown that the principles and direction of the SES are valid and warrant a continuation of their implementation. However, the initiative is experiencing significant delays in its implementation, notably in the achievement of the performance goals and the deployment of its basic elements (such as functional airspace blocks (FABs) or NSAs).

In 2009, when adopting the SES II Package, the legislator decided that SES II would be done in two stages and invited the Commission to come back to do an alignment of SES and EASA regulations after the initial set of EASA implementing measures and audit experiences concerning ANS was in place. A recast of the legislative package was therefore already foreseen, primarily aiming at simplifying and clarifying the borderline between EASA and SES legal frameworks.

The process of recast also allows assessing the effectiveness of the existing legal provisions in light of the lack of timely implementation of the SES initiative. This process of revision of the SES legal framework, known under the abbreviation of SES 2+, is intended to accelerate the implementation of the reform of air navigation services without departing from its original objectives and principles.

The purpose of the SES 2+ Package is to introduce improvements in oversight of rules, the performance scheme, the customer focus of the service providers and in overall performance. Besides, the SES 2+ Package will simplify the legislation by eliminating certain overlaps in the existing framework. Concerns have been raised about several overlapping areas existing in the SES framework and there is also a need to clarify the roles of the various actors at EU-level. This alignment between the four SES Regulations and the EASA Basic Regulation is a purely technical adaptation measure already required by the legislation. Due to the extent of overlap between the Regulations, a recast of the remaining parts of the four SES Regulations into one is a logical consequence of that adaptation [6].

Relationship with 'Third Countries'

In the context of the Network Manager Implementing Regulation, 'Third Countries' are non-EU States that are either members of EUROCONTROL, or that have concluded an agreement with the EU on the implementation of SES, or that participate in a FAB.

Many of these States are members of EUROCONTROL, thus have already been involved in and are committed to the activities directly related to meeting the EU-wide performance targets.

The NM geographical borders do not confine network management activities and the Network Manager will work with the operational stakeholders in the areas interfacing the European airspace, to ensure that they do not experience capacity shortfalls due to incompatibility of the systems and procedures with the adjacent ANSPs. To this end, EUROCONTROL/Network Manager has undertaken a series of activities to reinforce cooperation with the North African and Middle East states in the areas of airspace and route network enhancements, capacity determinations and ATFM.

Most of the adjacent ANSPs have already established operational relations with Network ATFM Operations (Azerbaijan, Iceland, Belarus, Russian Federation, Lebanon, Egypt, Morocco and Israel).

The European Aeronautical Information System Database (EAD), as a supporting function of the Network Manager, is a centralised repository of worldwide NOTAM (Notice To AirMen) information, ECAC AIP (Aeronautical Information Publication) documents library and quality assured AIP data in AIXM 4.5 & 5.1 format. EAD aims to make high-quality, harmonised electronic aeronautical information constantly available and to meet users' requirements for data quality and timeliness. The service allows other AIS Providers to enter and maintain their data in a central repository; users can retrieve and download AIS data in real-time. In December 2018 EUROCONTROL was re-certified as a pan-European Aeronautical Information Service Provider under the Single European Sky legislation. This certification was awarded after a positive evaluation by EASA.

EAD has been providing AIS services for more than 15 years. To date, 37 States have fully aligned themselves with the EAD processes and systems in their Aeronautical Information Management solutions. 4 States are in the process of migrating and a further 12 States have plans to fully join the EAD service. EAD users include the European States, but also countries such as Canada, the Philippines and South Africa.

At the COVID-19 Crisis, the same working arrangements (described above) were applied during the Recovery phase and across this NOP 2020 Recovery Plan.

RELATIONSHIP WITH ICAO

The relationship with ICAO covers two fields: a) participating in work of specific groups that have significant relevance to the functions of the NM; and b) coordinating proposals for amendments to the ICAO document relevant to the European Network Management functions.

The NM is participating in the following main working arrangements being part of the European Air Navigation Planning Group (EANPG):

- RDGE – Route Network Development Group - East
- ATMGE – ATM Group – East
- AWOG – All Weather Operations Group
- FMG – Frequency Management Group
- COG – EANPG Programme Coordinating Group
- BSTF – Black Sea Task Force
- AIRARDTF – Advanced Inter-Regional ATS Route Development Task Force
- ICARD 5LNC TF – ICAO EUR/NAT Regional Database_5 Letter Name Code Task Force.

The coordination of the proposals for amendment focuses on the documents with the relevance to the European network, such as:

- Regional Supplementary procedures – Doc.7030
- Air Traffic Management – Doc. 4444
- Airport Planning Manual – Doc. 9184
- European Air Navigation Plan – Doc. 7544.

The NM also participates in the preparation of the Air Navigation Conferences and the ICAO Global Air Navigation Plan (GANP) Multidisciplinary Vision Team.

The NM is using applications developed and managed by ICAO, such as ICARD (International Codes and Route Designators), and SAFIRE (Spectrum and Frequency Information Resource) in the execution of some of the functions. ICAO is using the ERNIP Database to ensure coherent airspace planning at the interfaces.

The NM also follows the European Regional Aviation Safety Group (RASG-EUR). The annual SMS Standard of Excellence measurement conducted by EUROCONTROL/CANSO on behalf of ICAO for the EUR Region is presented to the EUR-RASG and COG.

During the COVID-19 Recovery phase, the relationship with ICAO primarily focused on actions aimed to support an effective recovery from the situation at the time. The actions included, among others:

- regional cooperation with the States within the EUR/NAT region outside the NM area of responsibility,
- inter-regional cooperation with the neighbouring ICAO regions (e.g. NAT),
- cooperation at the global level with ICAO and its agencies involved, which could contribute to the COVID-19 Recovery (e.g. WHO)

For the NOP 2020 Recovery Plan, a particular relationship was maintained with ICAO through their participation and contribution in the EACCC.

T9.1.2 World-leading innovative programmes for air transportation system improvement: SESAR and NextGen

Within SES framework, particularly on the technology side, SESAR Programme supports the technological development to provide advanced technologies and procedures to modernize and optimize the future European ATM network. These technological solutions are aimed to increase the performance of Europe's ATM system and they contribute to the implementation of the SES. This modernization and harmonization of ATM systems are expected to be achieved through the definition, development, validation and deployment of innovative technological and operational ATM solutions.

Figure 9.4 – SESAR main pillars
Source: SESAR webpage

As one of its pillars (Figure 9.4), SESAR is defined in the European ATM Master Plan which is the agreed roadmap that connects ATM research and development activities with deployment scenarios to achieve the SES performance objectives. These development and validation activities are carried out by SESAR Joint Undertaking (SJU) and they are deployed through Common Projects. All three of these pillars (definition, development and deployment) are components of a virtual lifecycle that actively involves the stakeholders and the Commission in different forms of partnerships.

While the SES packages (I and II) were defined, two SESAR programs were also established. These SESAR programs are named SESAR I and SESAR 2020.

The Programme for SESAR 2020 is structured into three main research phases, beginning with Exploratory Research, then is further expanding within a Public-Private-Partnership (PPP) to conduct Industrial Research and Validation then further exploits the benefits of the PPP in Demonstrating at large Scale the concepts and technologies in representative environments to firmly establish the performance benefits and risks.

On the other hand, the Next Generation Air Transportation System (NextGen) is the Federal Aviation Administration (FAA)-led modernization of the United States' air transportation system to make flying even safer, more efficient, and more predictable, according to NextGen webpage.

In this manner, NextGen is composed of a comprehensive suite of upgrades, technologies and procedures that improve every phase of flight and enable aircraft to move more efficiently from departure to arrival. For example, one of the most important goals in NextGen is to use satellite technology to enhance navigation and surveillance, deploy digital systems for communication, and improve information management. Since the first demonstrations, trials and initial deployments of new systems and procedures, national airspace system (NAS) operators and users are benefiting from NextGen.

Globally, each one of these development programs (SESAR and NextGen) are focused on the specific problems that each region has. On the one hand, SESAR is mainly focused on the technological development that allows setting a common framework for the entire European Union from a holistic point of view. This common framework is intended to remove the fragmentation present in European aviation (for example each Member State has its supervision authorities and air navigation service providers) in such a way that the functioning is as uniform as possible in the whole EU regardless of the Member State where the service is provided. On the other hand, the United States is not as fragmented as the European Union (the US only has a unique air navigation service provider) hence its development program is focused on improving the performance through new technologies that allow reducing delays produced in its airspace and airports and also to increase its capacity.

Likewise, these differences between SESAR and NextGen make sense if the US and Europe ATM-related operational performance are compared. For example, according to 2010 data (see Figure 9.5), some areas are pretty similar and other areas are too different. In this manner, with similar-sized airspace (11.5 million km^2 for Europe, 10.4 million km^2 for the US), a comparable number of airports (450 in Europe for 509 in the US) and with very similar service levels, the US ATM system allows to manage 67% more flights (15.9 million flights in the US compared to 9.5 million flights in Europe) with less air traffic controllers (14600 in the US for 16700 in Europe) and 38% less staff (35200 in the US for 57000 in Europe). The main drivers behind such difference are the fragmentation of the European ATM system as there were 38 ANSPs in Europe (for only one in the US) and 63 en-route centres in Europe (for 20 in the US).

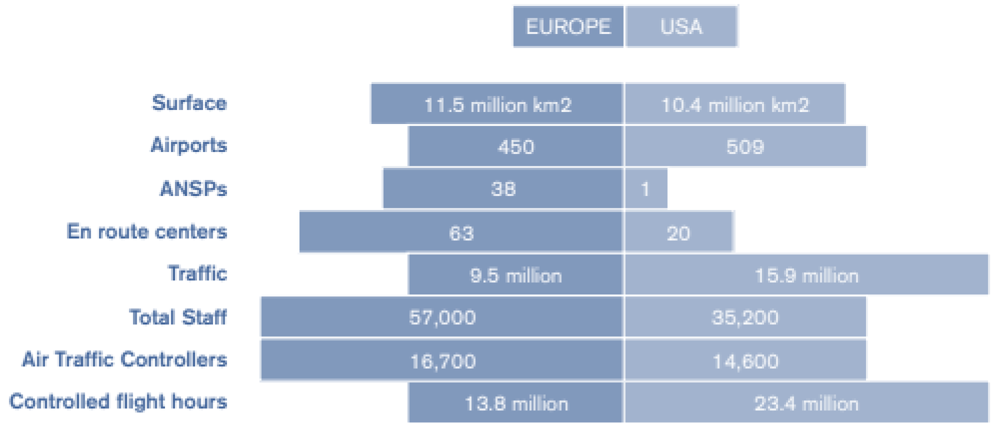


Figure 9.5 – 2010 U.S./Europe Comparison of ATM-Related Operational Performance
Source: A Blueprint for the Single European Sky by IATA

Comparing to more recent data, 2010 figures have remained almost undisturbed through the years. Although the US and the European ATM system are operated with similar technology and operational concepts, there is still a key difference: the US ATM system is operated by one single service provider (ANSP) which uses the same tools and equipment, communication processes and a common set of rules and procedures. However, even though ATFM and ASM in Europe are provided and coordinated centrally by the Network Manager, at the ATC level the European system is much more fragmented, and the provision of air navigation services is still largely organised by State boundaries [7].

In total, there are 37 different en route ANSPs of various geographical areas which have been operating different systems under slightly different sets of rules and procedures, and also different tools and equipment.

Therefore, as since 2004 the SES initiative of the European Union aims at reducing this fragmentation, SES 2+ Package is also addressing these issues.

Thus, the first problem addressed in SES 2+ Package is the insufficient efficiency of air navigation due to Air Navigation System (ANS) provision remains relatively inefficient in terms of cost and flight efficiency as well as the capacity offered. The main issues to be solved are the shortcomings in setting up and enforcing the performance scheme, ineffective supervisory authorities and the disproportionally high amount of support staff in the service providers.

The second key problem addressed in SES 2+ Package is a fragmented ATM system. The European ATM system consists of 27 national authorities overseeing in total over a hundred Air Navigation Service Providers (ANSPs) – en route, approach and aerodrome providers-, with the associated variance in systems, rules and procedures. There is a large number of additional costs caused by the fact that Europe has a large number of service providers, each procuring their systems, mostly training their staff, creating their operating procedures and being limited territorially to providing services in small airspace. To overcome fragmentation, the SES has introduced the ideas of cross-border Functional Air Blocks (FABs) and the centralised Network Manager to run certain network-level services. However, FABs and the Network Manager remains too weak hence developments should be carried out in these areas [6].

T9.1.3 The World Market for ATM Equipment

Firstly, ATM service and infrastructure have to be differenced. The ATM service is organized through a certain form of the supply chain: most of the service providers are state-owned companies which buy systems (radar stations, navaid stations, control centres, communication systems) from equipment suppliers. These systems form a cluster of tools that help to provide ATM thereby they are considered as part of the ATM infrastructure.

From an economic point of view, international rules set up by the International Civil Aviation Organization (ICAO) prevent the transformation of the ATM service into a real market. In this manner, a state is not authorized to raise money in selling the access to its sky in such a way that it can only ask airlines to pay for the services given to their aircraft passing through its sky: communication, surveillance, navigation, airspace design, control and flow management.

To be able to deliver the service, ANSPs have to be equipped. Providing ATM service requires different equipment such as radars to determine the position of the aircraft, navaid stations to help aircraft knowing exactly where they are, communication systems to secure exchanges between controllers and pilots, avionics systems, and so on. However, new technologies are allowing that exchanges between controllers and pilots are partly automated and managed by satellites (via datalink), moreover nowadays aircraft usually navigate using their position obtained by satellite instead of ground navaid stations (via performance-based navigation), thereby the equipment market is also adapting to new technologies [8].

In this context, the ATM equipment market is "small" in the sense of that equipment development and manufacturing companies are few so everybody in the market knows everybody. Some of the main companies involved are BAE Systems Plc, Northrop Grumman Corp., Indra Sistemas SA, Thales SA, Intelcan Technosystems Inc., Frequentis and so on.

Some of these companies are focused on specific equipment. For example, Toshiba only manufactures Primary and Secondary Surveillance Radar systems (PSR/SSR systems), VORs (VHF Omni-directional Range system) and DMEs (Distance Measuring Equipment) whilst Frequentis is focused on communication and information systems. On the other hand, other companies are focused on a wide market. This is the case of Thales or Indra. For example, the last one manufactures many systems such as digital voice communications control system, signal multichannel recorders, DVORs (Doppler VOR), DMEs, ILSs (Instrument Landing System), integrated ATC automation systems, ACC (Area Control Centre), APP (Approach Control) and TWR

(Tower) simulators, PSRs, 3D Radars, monopulse SSRs, SMRs (Surface Movement Radar), ADS-B (Automatic Dependent Surveillance-Broadcast) ground stations and so on [9].

As ATM equipment is made of complex systems in which connections, electronics and reliability are key factors, its development and manufacturing entail many complications and usually needs an important investment from the company hence it is difficult to enter in the market for new interested companies. Thus, some segments of the market are run by what seems to be a duopoly. This is the case of the ILS systems in whose market two companies are the main suppliers in the world: Indra and Thales. On the one hand, Thales has sold more than 700 ILS systems worldwide whilst Indra has sold more than 1200 ILS systems worldwide.

KEY TOPIC T9.2 COMPARISON OF SESAR WITH NEXTGEN

T9.2.1 Introduction

For both the SESAR and NextGen, the change to operations includes shared situational awareness for more collaborative decision making and trajectory-based operations for safer, more efficient airspace utilization. This requires transforming the procedures and regulations as well as the organizations' fundamental concepts and technologies. Net-Centric Operations allow migrating functionality among actors and facilities to improve the efficiency of the system as a whole but require that basic tenets be changed. In the case of ATM, this means changing the paradigm from extrapolating the aircraft intent based on radar data to the aircraft explicitly sharing it.

SESAR

Supporting the entire ATM system, and essential to its efficient operation is a netcentric, System Wide Information Management (SWIM) environment that includes the aircraft as well as all ground facilities. It will support collaborative decision-making processes, using efficient end-user applications to exploit the power of shared information. Interoperability between civil and military systems will also be a key enabler to enhance the overall performance of the ATM network.

By 2040, an increasing number and variety of air vehicles will be taking to Europe's skies. The SESAR vision aims to deliver a resilient and fully scalable ATM system capable of handling growing air traffic made up of a diverse range of manned and unmanned air vehicles in all classes of airspace, in a safe, secure, sustainable manner.

Fundamentally, SESAR operational concepts place the business trajectory at the core of the system, to execute each flight as close as possible to the intention of the user. This is seen as a move from airspace to trajectory focus while introducing a new approach to airspace design and management. The collaborative planning will continuously be reflected through a common shared Network Operations Plan (NOP). Integrated airport operations will contribute to capacity gains and reduce environmental impact. New separation modes will allow for increased capacity. Using these new integrated and collaborative features, humans will be central in the future European ATM system as managers and decision-makers.

SESAR and NextGen vision of the future ATM System (network, technologies, and procedures) is that it should facilitate the increasing multi-dimensional air transport demand safely and efficiently, be guided and driven by a performance framework addressing quality of service, societal needs and other areas, and in which safety is a paramount and continually improving Key Performance Area (KPA). KPA is a way of categorising performance subjects related to high-level ambitions and expectations. In compliance with ICAO specification, SESAR has defined 11 KPAs. The KPA determined by SESAR, set initial levels of performance targets by 2025, defining the broad spectrum of ATM performance, represented by these 11 key ICAO performance areas (KPA).

The KPA targets represent initial values (working assumptions), subject to further analysis and validation. Most KPAs are interdependent and will be the basis for impact assessment and consequent trade-off analysis for decision-making.

The defined 11 KPAs are as follows: Capacity, Cost-Effectiveness, Efficiency, Flexibility, Predictability, Safety, Security, Environmental Sustainability, Access and Equity, Participation, Interoperability. These have been further categorised into High, medium and low visibility areas based on their scope. Those that are highlighted, below, are the KPAs that SESAR sees as directly linked to the achievement of the proposed SESAR Vision.

Although there is no human factor among these key performance areas, it does in ATM as in all industries, human capital is a critical and an integral element of the system. Changing demands on ATM require a radical increase in the dynamics of the system to secure its scalability (up and down) and resilience, ensuring that all air traffic is handled safely and efficiently, even under the highest traffic growth forecast or during stagnation or unexpected downturn. To achieve this goal, digitalisation and automation will play a central role. In this context, the role of the human and of human interface with machines — making optimal use of the strengths of humans and their capacity to control the tools, use the support provided by machines to manage situations, and quickly and safely react to the unexpected — will require careful consideration. Therefore, human performance analysis is an integral and one of the most important elements of analysis under the SESAR program.

To measure the KPAs, Key Performance Indicators (KPIs) were to be used. KPI is the quantitative expression of actual progress in achieving performance objectives i.e. Current/past performance, expected future performance. Since indicators support objectives, they should not be defined without having a specific performance objective in mind. Indicators are not often directly measured. They are calculated from supporting metrics according to clearly defined formulas, e.g. cost-per-flight-indicator = Sum(cost)/Sum(flights). Performance measurement is therefore done through the collection of data for the supporting metrics."

SESAR performance indicators are in accordance with the European ATM Master Plan, which defines the overarching objectives. The performance ambitions were categorised according to the SES KPAs: capacity, safety, environment and cost-efficiency. Two additional KPAs, namely operational efficiency and security, have been identified as important contributors to SESAR performance and also have been included to European ATM Master Plan.

Performance ambitions for 2035 for controlled airspace are shown in table 9.1.

Key performance area	SES high-level goals 2005	Key performance indicator	Performance ambition vs. baseline			
			Baseline value (2012)	Ambition value (2035)	Absolute improvement	Relative improvement
Capacity	Enable 3-fold increase in ATM capacity	Departure delay[4],min/dep	9.5 min	6.5-8.5 min	1-3 min	10-30%
		IFR movements at most congested airports[5], million	4 million	4.2-4.4 million	0.2-0.4 million	5-10%
		Network throughput IFR flights[5], million	9.7 million	~15.7 million	~6.0 million	~60%
		Network throughput IFR flight hours[5], million	15.2 million	~26.7 million	~11.5 million	~75%
Cost efficiency	Reduced ATM services unit costs by 50% or more	Gate-to-gate direct ANS cost per flight[1]· EUR(2012)	EUR 960	EUR 580-670	EUR 290-380	30-40%
Operational efficiency		Gate-to-gate fuel burn per flight[2], kg/flight	5280 kg	4780-5030 kg	250-500 kg	5-10%
		Additional gate-to-gate flight time per flight, min/flight	8.2 min	3.7-4.1 min	4.1-4.5 min	50-55%
		Within the: Gate-to-gate flight time per flight[3], min/flight	(111 min)	(116 min)		
Environment	Enable 10% reduction in the effects flights have on the environment	Gate-to-gate CO_2 emissions, tonnes/flight	16.6 tonnes	15-15.8 tonnes	0.8-1.6 tonnes	5-10%
Safety	Improve safety by factor 10	Accidents with direct ATM contribution[6], #/year Includes in-flight accidents as well as accidents during surface movement (during taxi and on the runway)	0.7 (long-term average)	no ATM related accidents	0.7	100%
Security		ATM related security incidents resulting in traffic disruptions	unknown	no significant disruption due to cyber-security vulnerabilities	unknown	-

1 Unit rate savings will be larger because the average number of Service Units per flight continues to increase.
2 "Additional" means the average flight time extension caused by ATM inefficiencies.
3 Average flight time increases because the number of long-distance flights is forecast to grow faster than the number of short-distance flights.
4 All primary and secondary (reactionary) delay, including ATM and non-ATM causes.
5 Includes all non-segregated unmanned traffic flying IFR, but not the drone traffic flying in airspace below 500 feet or the new entrants flying above FL 600
6 In accordance with the PRR definition: where at least one ATM event or item was judged to be DIRECTLY in the causal chain of events leading to the accident. Without that ATM event, it is considered that the accident would not have happened.

Table 9.1 – Performance ambitions for 2035 for controlled airspace (European ATM Master Plan, 2019)

Capacity:

A 3-fold increase in capacity, while reducing delays on the ground and in the air (en route and airport network), is necessary to be able to handle traffic growth well beyond 2030. The ATM system is to accommodate a forecasted 73% increase in traffic by 2030 from the 2015 baseline while meeting the targets for safety and quality of service.

Cost-Effectiveness:

2030 Target: Halve the total direct ATM costs. The ATM Performance Framework provides a common basis to ensure the effectiveness of the ATM system through a dynamic relationship between the European States, institutions and regulations ("Institutional and Regulatory Framework"), and all aircraft operators, air navigation service providers and airports working in partnership to match the targets ("Business Management Framework").

Safety:

To improve safety levels by ensuring that the numbers of ATM induced accidents and serious or risk-bearing incidents decrease. The traffic increase to up to 2030 requires an improvement factor of 3, and for the long term a factor of 10, in case of the threefold in traffic.

Environment:

As a first step towards the political objective to enable a 10% reduction in the effects flights to have on the environment by emission improvements through the reduction of gate-to-gate excess fuel consumption, minimizing noise emissions and their impacts for each flight to the greatest extent possible, minimizing other adverse atmospheric effects to the greatest extent possible.

Despite the coming crisis in air transport, the airlines and aviation industry have to meet in the long run very ambitious environmental goals of the European Green Deal. These objectives will also modify the ecological objectives of the SESAR program. The European Green Deal launched by the European Commission in December 2019 aims to create the world's first climate-neutral bloc by 2050. The demonstrations in this category will aim to showcase solutions that can enable "zero CO2 waste" trajectories and can protect green flights from unnecessary deviations or constraints.

NEXTGEN

NextGen is focused on ATM System Transformation via trajectory-based operations with an emphasis on user needs. It endeavours to increase efficiencies and decision making to account for the growing demand and diversity of airspace participants and eliminate limitations caused by human decision making based on verbal communications. Transformation is enabled through distributed decision making, international harmonization, optimized division of human/automation roles, net-enabled probabilistic weather, integrated into automated decision tools, environmental sustainability, integrated safety management systems, and layered adaptive security. NextGen establishes principles and definitions of desired end-states in the varying domains associated with these services. This chapter does not discuss specific implementations or standards or methodologies of achieving these end-states or adhering to these principles.

T9.2.2 Net-Centric Commonalities

NEXTGEN

While the NextGen Concept of Operations (COO) uses different language to discuss desired performance improvements, the intent is very similar to the SESAR use of the KPAs. NextGen specifies Transformation Objectives in detail, in the Integrated Working Plan (IWP) and the domain chapters of the COO, for each area of the ATM system, and describes the fundamental goals of NextGen as the following:

- Meet the diverse operational objectives of all airspace users and accommodate a broader range of aircraft capabilities and performance characteristics;
- Meet the needs of flight operators and other NextGen stakeholders for access, efficiency, and predictability in executing their operations and missions;
- Be fundamentally safe, secure, of sufficient capacity, environmentally acceptable, and affordable for both flight operators and service providers;

NextGen also references the general goals of ATM Transformation from the Next Generation Air Transportation System (NGATS) Integrated Plan (2004). Six national and international goals and 19 objectives for NextGen are described. These are:

1. **Retain U.S. Leadership in Global Aviation**

   a) Retain role as the world leader in aviation;
   b) Reduce costs of aviation;

c) Enable services tailored to traveller and shipper needs;
d) Encourage performance-based, harmonized global standards for US products and services.

2. **Ensure Safety**

a) Maintain aviation's record as the safest mode of transportation;
b) Improve the level of safety of the U.S. air transportation system;
c) Increase the level of safety of the worldwide air transportation system.

3. **Ensure our National Defence**

a) Provide for common defence while minimizing civilian constraints;
b) Coordinate a national response to threats;
c) Ensure global access to civilian airspace.

4. **Expand Capacity**

a) Satisfy future growth in demand and operational diversity;
b) Reduce transit time and increase predictability;
c) Minimize the impact of weather and other disruptions.

5. **Protect the Environment**

a) Reduce noise, emissions, and fuel consumption
b) Balance aviation's environmental impacts with other societal objectives

6. **Secure the Nation**

a) Mitigate new and varied threats;
b) Ensure security efficiently serves demand;
c) Tailor strategies to threats, balancing costs and privacy issues;
d) Ensure traveller and shipper confidence in system security.

In addition to these key performance goals, NextGen sets forth guiding principles for the development and implementation of the enterprise. While not goals, they do establish important achievement markers for the industry as the system moves towards the future. The principles are:

- Frequency Bandwidth/Spectrum Capacity Supporting Stakeholder/ Communities of Interest (COI) Information Sharing Needs – (i.e. adequate communications capacity and QoS (Quality of Service);
- Voice by Exception and Improved Where Necessary;
- Protocol Resolution – Sufficient/Dynamic addressing, secure end-to-end connectivity;
- Data Availability – Push/Pull and Publish/Subscribe capabilities between COIs;
- Content Understanding – metadata tagging and federated search;
- Technology for Timely Decision Making – Data is relevant for action by COIs;
- No Single Point of Failure – an enterprise solution that dynamically allocates resources to continue operations (transport and services);
- Data Interface Oriented – via a Hardware Interface model, this software and customizable COI interface facilitates ease of improvement and upgrade;
- Information Assurance – Appropriate access to information by authorized COIs
- Cross-Domain (i.e. Multi-Level Security or Multiple Levels of Security) Exchange/Gateway Capability;
- A key element of both SESAR and NextGen is System Wide Information Management (SWIM), which is a focus on how the technologies and systems will enable shared awareness for operations;

- The planned technology is very similar – ADS-B, Data Link, Extended Conflict Detection
- Both Systems recognize the primacy of data communications to the cockpit and amongst ground systems ("voice by exception") while maintaining the requirement for the voice for emergency purposes, back up, and for communications with less completely equipped aircraft;
- Both systems embrace a network-centric infrastructure with shared services and distributed data environments interacting semi-autonomously to achieve system-wide efficiencies.

T9.2.3 Differences

SESAR and NextGen differ in their implementation frameworks because they are tied to very different European and US industry structures. NextGen tends to be closely tied to the government in a hierarchical framework whereas SESAR appears to be a more collaborative approach, including, but not limited to, ATM ground activities. NextGen, while having a longer timeline to implement, takes a broader approach to transforming the entire air transportation system, including ground activities.

T9.2.4 Flow Management

SESAR

In parallel with all the phases of individual business trajectory planning, a Collaborative Decision Making (CDM) process is in place in which all stakeholders share the necessary information to ensure the long and short-term stability and efficiency of the ATM system and to ensure that the necessary set of ATM services can be delivered on the day of operation.

The key tool used to ensure a common view of the network situation will be the European Network Operations Plan (NOP). It is a dynamic rolling plan for continuous operations, rather than a series of discrete daily plans which draw on the latest available information being shared in the system. The NOP works with a set of collaborative applications providing access to traffic demand, airspace and airport capacity and constraints, scenarios to assist in managing diverse events and simulation tools for scenario modelling. The NOP aims to facilitate the processes needed to reach agreements on demand and capacity.

The NOP, in its initial phase, enables collaborative Demand and Capacity Balancing (DCB) through an integrated airspace/airport organization and management in accordance with the nature of the traffic being handled. The NOP supports layered planning on local, sub-Regional and Regional level.

Long-term ATM planning starts with traffic growth forecasts, including user business strategy development, and planned aircraft procurement. The required new assets can be considered as available resources for DCB only when their date of delivery becomes firm. Airspace Users will then declare their intentions through Shared Business Trajectories possibly including the requirement for airspace reservations. Network Management, working collaboratively with all partners will assess the resource situation regarding potential demand. Network Management will facilitate dialogue and negotiation to resolve demand/capacity imbalances collaboratively. Tools will be used to assess network efficiency.

NextGen

The US version places a great deal of emphasis on the collaborative and/or automated decision-making process between the Flight Operations Centres (FOCs)/cockpit and ground Air Traffic Management. The Key Characteristics paragraph of the COO states, "[t]o the maximum extent possible, decisions in NextGen are made at the local level with an awareness of system-wide implications. This includes, to a greater extent than ever before, an increased level of decision-making by the flight crew and FOCs."

Traffic information is available via the network to the ground and onboard displays, thus allowing pilots to collaborate with ground control operators on the best strategy for their preferred trajectory. More importantly, NextGen envisions a set of Infrastructure and Information services that, when provided; enable automated collaborative planning systems to achieve efficiencies for individual airlines and the overall system.

T9.2.5 Weather

The primary difference between SESAR and NextGen concerning weather is the way the information is acquired. In NextGen, a centralized government-run weather service is anticipated, and in SESAR the information will be derived from a variety of traditional sources. A more net-centric solution would be to allow each carrier to be able to choose whatever information is available from certified sources to provide maximum safety.

SESAR

The information will be derived from a variety of (traditional) sources including an Increased reliance on remote sensing systems, aircraft derived data and satellite-based weather information. With enhanced digital communications services, the provision of Metrology (MET) information will encompass ground-based and potentially airborne automation systems and human users.

NextGen

NextGen foresees weather as moving from a stand-alone display to an integrated decision-making element. A primary objective of NextGen is the establishment of a single authoritative weather service available to all systems communicating within the network. While little is said about how this service will be run, great detail is provided on what type of service will be available. The service will draw data from traditional weather reporting systems, aircraft and other sensors in route including UAVs specifically deployed for weather collection, commercial weather services which will augment the system at the basic provision rate and presumably at premium rates as a choice of individual carriers and aircraft and potentially airborne automation systems and human users as well as from weather national service.

T9.2.6 Infrastructure Service Domains

SESAR

SWIM is supported by a set of architectural elements (so-called SWIM architecture) allowing the exchange of data and ATM services across the entire European ATM system. SWIM is based on the interconnection of various automation systems. The SWIM architecture aims at providing specific value-added information management services: the SWIM services. They will:

- Support flexible and modular sharing of information, as opposed to closely coupled interfaces;
- Provide transparent access to ATM services likely to be geographically distributed;
- Assure the overall consistency.

SWIM services will be required to comply with potentially stringent Quality of Service (QoS) parameters, such as integrity, availability, latency, etc. The full impact of those QoS on the proposed architecture will require significant R&D activities. For instance, not all users will have permission to access all data within a domain because of operational, commercial or security reasons.

SWIM integrates Air-Ground and Ground-Ground data and ATM services exchange. The scope extends to all information that is of potential interest to ATM, including trajectories, surveillance data, aeronautical information of all types, meteorological data etc.

NEXTGEN

NextGen establishes the requirement for the provision of a robust infrastructure on which the entire system will rely. The services provided across the enterprise are:

- Information Sharing Services: Enabling operational entities, COIs, services, and applications throughout the NAS to collaborate in a seamless information infrastructure with Air Navigation Service, airport, and flight operations, Shared Situational Awareness, compliance and regulation oversight, and security, safety, environmental, and performance management services.
- Ground Services: Providing surveillance, communications, and flight data management to any service provider regardless of its physical location, thus removing geography as a limiting factor for air assets and ground control.
- Air-Ground Network Services: Frequency-to-airspace sector mapping is abandoned in favour of a dynamic network environment – the "intelligent network." Data communications are central to Trajectory Based Operations, including the use of 4D trajectories (4DTs, pushback and taxi inclusive) for planning and execution on the surface, automated trajectory analysis and separation assurance, and aircraft separation assurance with situational awareness of the 4DTs and short-term intent of surrounding aircraft.
- ANSP Infrastructure Services: Summarized with the term "virtual tower." Such services provide the ability to locate ANSP facilities where optimal, without limitation to airspace proximity (similar solutions were developed within SESAR 2020 PJ05 "Remote Tower for Multiple Airports" and SESAR 2020 PJ05-W2 "Digital technologies for Tower")
- Aircraft Data Communications Link: Allowing aircraft and ground assets to connect to the data network for collaborative purposes
- Infrastructure Management Services – Insuring QoS
- Mission Support Services - provide information assurance, protocols, and standards applicable to the Net-Centric Infrastructure Services (Access, Connectivity, Processing, Posting, and Pulling).

T9.2.7 Information, Data and Information Services

INFORMATION AND DATA IN SESAR AND NEXTGEN

A difference between the two documents lies in the treatment of information. While both indicate that data and information are key to integration and net centricity, SESAR, being a more decentralized model, calls for the establishment of a Reference Model for data and data normalization and standardization. NextGen, envisioning a more centralized government-run approach, goes further, describing not only data but the provision of "information services" in a service-oriented and networked environment. Both concepts call for systems to make use of centralized and decentralized services, delivered in a network-enabled, Service-Oriented Approach (SOA) environment, with NextGen suggesting a more centralized approach than SESAR. Collaboration on the development and fielding of these services and agreement on the standardization of data reference models could provide great efficiencies to both SESAR and NextGen efforts.

SESAR and NextGen both place a great deal of emphasis on the information enabling the processes, interaction and automated support of the ATM enterprise. While there are differences in terminology and a core difference in how the information elements are described, the content of the information and that content's purpose are very similar. NextGen describes information elements in the terminology of "services" - using a service-oriented architecture context to describe the automated and ubiquitous nature of the key information elements serving the overall system. SESAR describes the information elements in terms of data models associated with different domains (flight, weather, surveillance, etc) and describes a reference model architecture that, when used, makes the data and information available for use by the system participants.

Key to the continued comparison of the two systems will be an in-depth comparison and integration of the data models and the network-centric services. Each system should be able to use the data and information available within the other to execute the integrated, collaborative, and automated analytical and decision-making functions necessary to execute this transformational ATM.

SESAR

ATM Information Reference Model:

- Within the SWIM, Interoperable ATM information will be precisely defined by a Reference Model;
- Application independent and not constrained by implementation solutions;
- Addresses different domains of information as needed by the Users and expressed in business terms;
- Consistently describes cross-domain data;
- Allows fulfilling the SESAR overall information sharing requirement, across ground and air heterogeneous systems.

The information to be exchanged needs to be modelled explicitly, to allow a precise and concrete definition to be agreed.

Interoperability Models:

SWIM is first introduced for En-route/Approach ATC and Network (NIMS) interactions, and later including interactions with Airports, AOC and the Aircraft. Flight information is accessible through SWIM services around 2013. Airspace, Demand & Capacity data are accessible through SWIM services around 2016.

The SWIM services will be organized around 5 data domains:

- Flight Data (including detailed trajectories);
- Aeronautical Data;
- Meteo Data;
- Surveillance Data;
- Capacity & Demand Data (including Air Traffic Flow and Capacity Management Scenario).

NextGen

In addition to the Network Centric Infrastructure, Chapter 5 of NextGen discusses the centralized provision of Information Services across that infrastructure. This is a central component of the NextGen Transformation – that is, the provision of a set of data and information services (a "service-oriented environment") from which each participant in the ATM system can draw capabilities, whether that is to access data for their application uses or to use another application provided as a service to execute flight operations. The development of these services will be a challenging task, especially given the different data models in use across the industry. Collaboration with SESAR on the reference data models discussed in SESAR may benefit NextGen transformation efforts – just as collaboration on the development of centralized services might benefit SESAR participants.

In addition to the Network Centric Infrastructure, Chapter 5 of NextGen discusses the centralized provision of Information Services across that infrastructure. These are:

- Weather Information Services;
- Robust Precision Navigation Services;
- Surveillance Services (Cooperative and Non-Cooperative);
- Flight Plan Filing and Flight Data Management Services;

- Flow Strategy and Trajectory Impact Analysis Services;
- Aeronautical Information Services (AIS);
- Geographical Information System Services (GIS).

The development of services to support flight operations will be a challenging task, especially given the different data models in use across the industry. Collaboration with SESAR on the reference data models discussed in SESAR may benefit NextGen transformation efforts – just as collaboration on the development of centralized services might benefit SESAR participants.

T9.2.8 Aircraft Participation in SWIM

SESAR

The introduction of an Air to Ground Data Link Ground Management System, which is a SWIM node and offers the aircraft a single point of access on the ground with filtering of the shared information that is needed by the aircraft and the update of onboard databases while the aircraft is still at the gate. Benefits are expected through simplification of connectivity functions and on saving multiple connection infrastructures. Safety requires high availability of the A/G Datalink Ground Management System as a failure of a system at the sub-regional level would jeopardize the complete communication with the aircraft in that sub-region.

NEXTGEN

SWIM is an integral part of the NextGen concept, with the aircraft serving as a node on the network. SWIM encompasses the ability of aircraft and ground assets to collaboratively participate within an enterprise that is providing automated information cockpit-to-cockpit, cockpit-to-ground, ground-to-cockpit, and ground-to-ground. NextGen envisions a virtual network in which each node represents a part of the system –so all information is "system-wide." Each node participates in the system all the time – and user access and automated tools and services are used to ensure adequate data provision and QoS.

T9.2.9 CNS Development and Impacts

Much ground-based equipment in Europe will reach the end of life by 2018 – this is a major driver. Proposing 4 stages – Stage 1 is ADS-B out – then ATSAW (Airborne Traffic Situation Awareness), then self-separation (2020 to 2025) and finally the possible need for another link for advanced applications like ASAS (2025). There will be a focus on R&D for possible future applications that might require a better link than the 1090 MHz CASCADE program fits into the SESAR process. A Joint Undertaking will take place. NextGen and SESAR are working together on joint R&D and hold regular progress meetings.

SESAR

In its simplest form, the 2030 CNS (Communication, Navigation and Surveillance) baseline can be characterised as follows:

Communication:

- Communication technologies that enable improved voice and data exchanges between service actors within the system, such as those necessary to support the SWIM functionality and CDM process, for example:
  - Ground-Ground
    - An IP based ground-ground communications network supporting all the ATM applications and SWIM services, together with VoIP for ground segments, including VoIP for the ground segment of the air-ground voice link.
  - Voice

    - 8.33KHz is the standard for voice communications;
    - SATCOM voice for oceanic and remote areas.
  - Air-Ground Datalink
    - VDL2/ATN (VHF Data Link Mode 2 / Aeronautical Telecommunications Network).
  - Airport
    - A new Airport datalink to support surface communication, using a derivation of the IEEE 802.16.

Navigation:

- Navigation technologies that enable precision positioning, timing and guidance of the aircraft to support high performance, efficient 4D trajectory operations in all phases of flight, for example:
- Primary aircraft positioning means will be satellite-based for all flight phases.
- Positioning is expected to rely on a minimum of two dual-frequency satellite constellations (Galileo, GPS L1/L5 and potentially other constellations, assuming interoperability) and augmentation as required:
  - Aircraft based augmentation (ABAS) such as INS (Inertial Navigation System) and multiple GNSS (Global Navigation Satellite Systems) processing receivers;
  - Satellite-based augmentation (SBAS) such as European Geostationary Navigation Overlay Service (EGNOS) and Wide Area Augmentation System (WAAS);
- Terrestrial Navigation infrastructure based on DME/DME is maintained to provide a backup for en route and TMA;
- Enhanced onboard trajectory management systems and ATS Flight processing systems to support the trajectory Concept.

Surveillance:

- Surveillance technologies that enable precision monitoring of all traffic to assure safe and efficient operations, including enhanced Traffic Situational Awareness and Airborne Separation Assurance System (ASAS).
- For the airspace, Cooperative surveillance will be the norm, complemented as required by Independent Non-Cooperative surveillance to satisfy safety and security requirements. For the Airport both Cooperative and Independent Non-Cooperative surveillance systems will be necessary.
  - PSR will provide Independent Non-Cooperative surveillance;
  - Since aircraft will have the necessary mode S and ADS-B equipment, the choice of Cooperative surveillance technology (Mode S, ADS-B, MLAT - Multilateration) remains flexible, with the service provider determining the best solution for their particular operating environment, based on cost and performance;
  - SMR will provide the Independent Non-Cooperative airport surveillance
- ADS-B-In/Out is provided by 1090 ES;
- With a mandate of 1090 ES-ADS-B-Out, TIS-B (Traffic information service – broadcast) will not be needed in the transition to support ASAS applications;
- Satellite-based ADS-C for oceanic and remote areas.

CNS beyond 2030

Communication

- Datalink becomes the primary means of communications. Voice remains as a back-up;
- Common inter-networking transport mechanism to support the various datalinks, managing an end to end Quality of Service;

- Post-2030 implementation of new communications components, comprising terrestrial (wide or narrowband) and space-based components in the complement of VDL2/ATN to support the new most demanding data-link services.

Navigation

The availability of other constellations enables increased accuracy and availability. Multi constellation receivers can exploit available constellations/satellites (e.g. China, Russia) if the benefits outweigh the added complexity compared to a basic GPS + Galileo combination. Ground-based augmentation (GBAS) for Cat II/III approach and landing with backup provided by ILS/MLS, and specific GBAS features may be necessary to meet high-performance guidance requirements for airport surface navigation

Surveillance

- PSR is replaced by cheaper forms of Independent Non-Cooperative surveillance;
- The 1090 ES system supporting ADS-B-In/Out is improved and/or complemented with an additional high-performance data link.

SESAR

CNS is formulated for 2030 that builds on 8, 33 kilohertz, VDL2/ATN for communication. Navigation builds on satellites for position determination Surveillance system has four fundamental principles that build on primary radar, SSR model S, Wide-area Multilateration, ADS-B (builds on 1090 MHz) and monitoring in the aeroplane.

ADS-B equipment has been extensively and successfully tested in operational environments and is an example of a developed SESAR and NextGen technological component.

NextGen addresses transformation as a function of changes to the operational concepts and capabilities between the current state (2018) and 2035. There are interim transformation steps for various sub-domains, but no timelines are discussed for those interim steps to total transformation.

T9.2.10 Anticipated Risks

SESAR

SWIM (including the A/G Data Link Ground Management System) may not meet the required quality of service (which is still to be defined), e.g. concerning integrity, consistency.

Stakeholders may fail to achieve the required certification of their systems since they will need to carry out a safety analysis of a system that is connected to other stakeholders' systems via SWIM.

Many problems remain particularly with data quality and interoperability.

A key limitation has been the absence of a globally accepted aeronautical information exchange format, but this is now being addressed by AIXM V5.0 (Aeronautical Information Exchange Model)

NextGen

Automated tools, communications and enterprise management, and improved information flow will naturally provide for increases in efficiency and effectiveness regarding the ATM System. The overall concept is not, however, without risks. NextGen COO addresses these risks within the appendixes describing additional policy and research needs. Some of the major ones are listed below:

- NextGen assumes a fully available (very high QoS) and robust enterprise network supporting ground, surface, and air assets through all stages of every flight operation. If this network is not reliable, if communications paths and data integrity are not adequately assured, then the automated decision making will not happen, and the efficiencies will not be achieved.
- Moreover, should the system rely heavily on Trajectory Based Operations (TBO) and Flow Management in dense environments and then suffer an outage or data compromise, serious safety or security implications may arise.
- New capabilities and technologies may over-burden the cockpit operation.
- New policies and standards may be needed to ensure data and information security.
- Transformation to "virtual towers" and satellite-based Instrument Approach Procedures (IAPs) may present new difficulties in very low visibility conditions.
- There are changing rules, policies, security protections, responsibilities, and authorities for Safety Assurance and Safety Data Information sharing.
- Stakeholders must ensure data integrity across such a wide range of information services, weather, navigation, route planning, etc.)

COMPARISON

- Both need to ensure that architectural differences do not impact, for example, how the aircraft is included in the network.
- The investment side of things is a major challenge; stakeholders will need to be convinced that the benefits outweigh the costs.
- Achieving and providing safety for SESAR/NextGen is an enormously tough challenge.

T9.2.11 Contradictions and Major Concept Differences

- NextGen assumes a fully available (very high QoS) and robust enterprise network supporting ground, surface, and air assets through all stages of every flight operation. If this network is not reliable and if communications paths and data integrity are not adequately assured, then the automated decision-making will not happen, and the efficiencies will not be achieved.
- The SESAR Operational Concept time horizon is 2020+: NextGen time horizon is 2025;
- The SESAR Concept essentially has a strict ATM focus: NextGen also deals with other elements that may impact ATM either directly or indirectly (for example Homeland Security);
- The SESAR Concept adopts a largely Gate-to-Gate view with a window on the turn-round process that provides an Enroute-to-Enroute view through shared situational awareness of the status of the process. NextGen adopts a Curb-to-Curb view that encompasses all aspects of airport terminal and passenger operations.
- The SESAR Concept deals with certain issues, for example, Safety and the Environment, through some high-level statements and at the KPA level and the detail is the responsibility of other Work Packages: NextGen deals with these issues in detail within the Concept.
- Europe seems to be ahead of the U.S. in data communication, and the U.S. is ahead in defining ADS-B Out.
- Both systems emphasis the increased use of underutilized airports, however, there are minor differences. For example, NextGen includes an Airports Preservation Program to "increase community support and protect against the encroachment of incompatible land use", while SESAR states that capacity goals can be met in airspace but that airports are limiting factor.
- SESAR and NextGen differ in the way that Europe comprises several member states that must agree and the US is one nation from the start.
- SESAR and NextGen differ in their implementation frameworks because they are tied to very different European and US industry structures.

- The primary difference between SESAR and NextGen concerning weather is the way to acquire the information. In NextGen, it seems to be a centralized government-run weather service and SESAR considers the Weather information provision services as outside its scope of work (even it requires that it can use a variety of sources).

NextGen concepts are developed in anticipation of a widely expanding air traffic environment, but also anticipation of greater technological capabilities for aircraft, ground control systems, surveillance, networks, and automated decision support systems. The overall vision is widely applicable to all operations related to air travel in the US Airspace - from commercial routes and passenger planning through ATM and ground support operations.

T9.2.12 Harmonisation of NEXTGEN and SESAR

In 2011, the U.S. and the EU signed a Memorandum of Cooperation (MoC) on Civil Aviation Research and Development (R&D). In December 2017, the MoC was amended to cover the full lifecycle of SESAR and NextGen programmes, including deployment under a new Annex 1 for ATM modernisation containing three appendices on R&D (appendix 1), performance measurement (appendix 2) and deployment coordination (appendix 3). The cooperation aims to ensure the necessary harmonisation of the two programmes and to secure global interoperability, in particular for airspace users. Each appendix is implemented through coordination plans detailing terms of reference, goals and the activities to be undertaken under the MoC. These coordination plans also help to mitigate identified risks and allow for the engagement of stakeholders as part of the process (FAA, 2018).

Both NextGen and SESAR recognise the need to integrate the air and ground components of their respective ATM systems. This requires greater efficiency in the planning and execution of flight trajectories and the seamless and timely sharing of accurate information. The U.S.-EU harmonisation work aims to ensure that modernisation in air navigation systems worldwide supports a high-performing aviation system over time, based on global cooperation leading to seamless operations and safe and efficient practices for the airspace users and the travelling public.

The U.S. and Europe are modernising their ATM systems through the NextGen and SESAR programmes respectively that develop new capabilities introducing new enabling technologies and operational procedures. Specifically, these modernisation efforts are enabling a move from a ground-based ATM system, using radar and voice communications, to an integrated air-ground aviation and ATM system using satellite-based navigation and digital data communications. The goals on each side of the Atlantic are to improve overall aviation and ATM system performance, particularly in the areas of flight efficiency and the environment, while also meeting expected demands for increased capacity and continuing to maintain the highest levels of safety.

While NextGen and SESAR are the two largest ATM modernisation efforts in the world, parallel initiatives are being implemented in other regions. ATM modernisation is a complex task, but aviation industry stakeholders seek to harness the benefits of all of these initiatives, especially as traffic levels in civil aviation increase and new demands are placed on the system. To provide the greatest operational and performance benefits, these modernisation initiatives must harmonise to achieve seamless operations on a global basis. ICAO is supporting the modernisation and standardisation requirements of NextGen and SESAR and recognises them as global leaders of ATM modernisation while maintaining its commitment to the broader global civil aviation community. These complex and comprehensive initiatives are therefore ensuring alignment with the Global Air Navigation Plan (GANP; ICAO, 2016) and supporting the Aviation System Block Upgrades (ASBU) programme.

Following negotiations between the U.S. and EU, an amended MoC was signed on 13 December 2017. Under the amended MoC, an Annex for ATM Modernisation was created with an Executive Committee established to govern and oversee the activities of three appendices dealing respectively with:

- SESAR-NextGen cooperation for research, development, validation and global interoperability;
- Collaboration on ATM performance measurement; and
- SESAR-NextGen cooperation for deployment activities and global interoperability.

This State of Harmonisation document covers the activities of the first and third appendices, which both relate to NextGen-SESAR cooperation. In the future, the aim is to integrate the work on performance measurement more fully into the cooperation between NextGen and SESAR to provide a more comprehensive view of this collaborative ATM modernisation arrangement.

ICAO Global Air Navigation Plan (GANP) and Aviation System Block Upgrades (ASBU)

Both the U.S. and Europe were instrumental in supporting ICAO initiatives in the development of the GANP and the ASBU programme. The ASBUs provide a series of measurable, operational performance improvements, organised into flexible and scalable building blocks, modules and elements. The elements can be introduced as needed and implemented as each State and/or Region determines feasible based on their respective needs, capabilities and resources. The ASBUs provide the basis for ICAO's GANP 15-year outlook and are arranged as five-year time increments starting in 2013 and continuing through 2028 and beyond. These dates indicate when the standards and regulations need to be in place to support regions and States in modernising their aviation and ATM systems, thereby contributing to the modernisation of the global aviation system.

The newest, sixth edition of the Global Air Navigation Plan (GANP) responds to turn the challenges stemming from a new era in aviation into opportunities so that aviation can continue to boost social well-being worldwide. Furthermore, it is a call for action to all aviation stakeholders, at global, regional and national levels, to join efforts towards a common vision through the implementation of an evolutionary transformation of the air navigation system driven by performance. In aviation's fast and ever-changing landscape, achieving sustainable growth of international air transport strongly relies on a high-performing and seamless global air navigation system. With the GANP, ICAO brings the aviation community together to achieve an agile, safe, secure, sustainable, high-performing and interoperable global air navigation system.

Developed in collaboration with and for the benefit of stakeholders, the GANP is a key contributor to the achievement of ICAO's Strategic Objectives and has an important role to play in supporting the United Nations 2030 Agenda for Sustainable Development. A central goal for the GANP is SDG 9: Infrastructure, industry and innovation. In addition to the GANP, ICAO has developed global plans for the specific areas of safety and security: the Global Aviation Safety Plan(GASP, Doc 10004) and the Global Aviation Security Plan (GASeP, Doc 10118). The three global plans are complementary.

On 17 June 2019, the Council approved the sixth edition of the GANP, which is available in an interactive format on the GANP Portal (https://www4.icao.int/ganpportal). Also, a revised Assembly Resolution A39-12 on global planning for safety and air navigation is presented in the appendix hereto. The U.S. and Europe supported ICAO in developing the next sixth edition of the GANP during preparation for the 40th ICAO Assembly in 2019. The GANP 2019 including the supporting ASBU framework was restructured into a layered plan. The U.S. and Europe coordinated with each other to help develop the vision, conceptual roadmap (providing the scope of ASBU Blocks 3 and 4) and performance ambitions, which will be included in the executive part of the new GANP.

Coordination between the U.S. and Europe was ongoing to support the GANP update for 2019. It was important for this development to remain aligned with the NextGen Implementation Plans, the European

ATM Master Plan, and the SESAR Deployment Programme in order to reflect the needs of the U.S. and European systems.

Communications, navigation and surveillance (CNS) infrastructure and SWIM

The U.S. and the EU have each established roadmaps for the development and implementation planning of communications, navigation and surveillance (CNS) capabilities and SWIM. These roadmaps, based on their respective ATM modernisation programme results, business and operational performance needs, and budgets, have been developed in consultation with stakeholders and in accordance with their required regulatory arrangements. The joint harmonisation and interoperability strategies balance short, medium- and long-term requirements to understand the interoperability risks related both to current deployment plans and to the options for developing and implementing solutions in the medium and longer-term.

Work under the MoC on a joint U.S.-EU air/ground data communications strategy was launched in 2016 and led to the delivery of an agreed strategy document to the Executive Committee in December 2017.

An updated version of the joint U.S.-EU air/ground data communications strategy has been developed. This updated strategy identifies the harmonisation targets and risks, proposes concrete actions to mitigate risks of divergence, and considers transition aspects. Standards development organisations from the U.S. and Europe are together developing the standard for aeronautical telecommunication network using internet protocol suite (ATN IPS) work which is expected to be completed in 2020.

The joint navigation systems roadmap is being updated to align with NextGen and SESAR current capabilities and future strategies. The roadmap describes the expected and planned sustainability and evolution of the ground-based and satellite-based navigation infrastructure to support performance-based navigation (PBN) and precision approaches in both regions.

Wake vortex re-categorisation

New modernised wake vortex separation provisions developed in the U.S. and Europe are yielding significant improvements in efficiency and throughput at airports, especially those with capacity constraints. The U.S. and Europe have been collaborating on an initiative called RECAT to "re-categorise" wake turbulence separation standards as a contribution to the ICAO Wake Turbulence Working Group (WTWG). Currently, this work is split into three phases:

- RECAT-1: Introduction of a new categorisation scheme, optimising the existing ICAO wake turbulence separation classes;
- RECAT-2: Deployment of a static 'pair-wise' regime, whereby each aircraft pair has its appropriate wake turbulence separation minima; and
- RECAT-3: Dynamic pair-wise separation, where actual conditions, such as aircraft mass and atmospheric/meteorological conditions, are considered when establishing the required wake turbulence separation minima.

Recently, en-route wake has become a major and visible issue at ICAO. The U.S. and Europe developed an approach to this topic in the 2018 work programme.

Both the U.S. and Europe have implemented RECAT-1 which divides the current ICAO heavy and medium categories into two sub-categories and sees the creation of a new super-heavy category (different variants exist in the U.S. and Europe). Benefits from 3% to 17% additional throughput have already been achieved.

The U.S. has also implemented RECAT-2 at four sites, increasing the benefits above those achievable with RECAT-1 through the use of categories that leverage pair-wise separations to better optimise RECAT for airport fleet mix. Meanwhile, in Europe, RECAT-EU was deployed with Time Based Separation (TBS) in 2018, the first step towards RECAT-3.

In late 2017, the U.S. and Europe representatives developed a common proposal for a 7 category ICAO RECAT solution. A draft proposal for amendment (PfA) to ICAO Doc 4444 Procedures for Air Navigation Services – Air Traffic Management will be considered by the WTWG, leading to the initiation of an ICAO procedure for air navigation services (PANS) update to be delivered in 2020.

Work will continue to support the ICAO 7 category deliberations and refinement process to ensure delivery of the PANS update by 2020. The next phases of work will include the pairwise (RECAT-2) and dynamic pairwise wake vortex separation concepts (RECAT-3, more commonly known as time-based separation or TBS).

RECAT-2 will require understanding the common metrics for developing separation minima that can be used to prepare a RECAT proposal comprising a static pairwise matrix of separation minima for RECAT-2, together with guidance on grouping aircraft into six or more categories that take into account specific airport mix (RECAT-1).

RECAT-3 will involve sharing of knowledge on controller decision support tools that can be used to support the predictable delivery of arrival and departure traffic using static pairwise separation minima and managing different operational and meteorological conditions.

Risk assessment

The establishment of the MoC between the U.S. and EU has itself provided a successful means of identifying and managing the risks to interoperability arising from the NextGen and SESAR programmes. The MoC identifies the topics on which collaboration is necessary to secure interoperability and harmonisation. However, at the outset no formal risk management process was established. The U.S. and EU have now agreed to formally define such a process. The joint Harmonization Risk Issue Opportunity Management (HRIOM) Framework provides the means to identify, classify and respond to risks, issues and opportunities associated with ATM harmonisation and interoperability objectives. This new framework will be integrated into the internal processes in each technical area of cooperation.

Unmanned aerial systems (UAS)

The demand for UAS operations is steadily increasing, with the potential to generate significant economic growth and societal benefits. A drone traffic management system is needed to enable simultaneous drone operations safely and efficiently in all types of airspace and especially urban areas. U-space is the framework designed in Europe in response to the urgent need to support the safe integration of drones into airspace, in particular, but not only VLL airspace. U-space builds on ATM legacy, but it does not reproduce the current model for the provision of ATC services. By design, U-space is set to be scalable and will rely on high levels of autonomy and connectivity in combination with emerging technologies. U-space will encourage innovation, support the development of new businesses and facilitate the overall growth of the European drone services market while appropriately addressing safety, security and defence issues at EU level, in addition to respecting the privacy of citizens and minimising environmental impact.

NextGen and SESAR work together on the integration of UAS - a growing and significant category of airspace users - into the aviation system. The purpose of the collaboration between NextGen and SESAR is to initiate, coordinate, and prioritise the activities necessary to support the evolution of all UAS categories as fully integrated airspace users. The scope covers those remotely piloted aircraft systems (RPAS) that need to operate seamlessly within the ATM system, usually as instrument flight rules (IFR) airspace users. Also, it covers the development and integration of the rapidly evolving smaller drone environment, where potentially thousands of drones will be enabled to operate through the implementation of an entirely new management concept: UAS traffic management (UTM)/U-space.

Collaboration between NextGen and SESAR is underway, aimed at building on the ongoing activities in the US (FAA and NASA) and Europe to develop the UTM/U-space concept for civilian UAS operations in low-altitude airspace, as well as on the technologies and procedures needed to support the integration of all IFR RPAS. The outcomes of the EU Drone Outlook Study identified the potential economic impact of growth in drone operations. It confirms the anticipated integration challenges, which need to be addressed to support the projected growth.

The contribution from both the U.S. and Europe to ICAO panels and advisory groups in the area of RPAS and UAS are relevant and timely, given that dedicated and existing ICAO groups are addressing RPAS and UAS standards and guidance material. The U.S. and Europe have taken leading roles in developing standards and recommended practices (SARPS) and guidance for both international IFR operations of RPAS and domestic low altitude operations of UAS (UTM/U-space). The next steps will be to agree on how to integrate and coordinate both the more traditional IFR operations of RPAS and the emerging low altitude UAS operations to ensure safe operations with all other users of controlled and uncontrolled airspace.

Cybersecurity

Cyber resilience remains a major challenge for both the U.S. and Europe. The fundamental issues are to protect information and reduce the danger of disruption in the cyber environment and the critical infrastructures that depend upon it to avoid damage to the ATM system.

Harmonisation activities are underway related to the development of:

- Common standards and use cases for identity access management (IAM);
- Common security standards for internet protocol (IP) interoperability;
- Common framework and guidelines for sharing cybersecurity information between aviation stakeholders;
- Monitoring of the development of common standards and determination of their fitness for implementation into the respective FAA and SESAR infrastructures.

The aim is to make progress on several aspects, such as defining a possible common trust framework at ICAO level to secure the exchange of information relying on public key infrastructure (PKI) framework, which would be implemented regionally, and performing trials to demonstrate interoperability among regional PKIs. Activities to incept security at an early stage are conducted in the framework of Enterprise Architecture to secure by design future ATM systems.

The main objective of SESAR is to deliver a fully scalable system, fulfilling successfully the growing capacity needs while remaining even safer than today's system, striving to achieve the ambition of 'no ATM-related accident'. From a safety perspective, this means that all SESAR Solutions will be validated to deliver safety performances that, taken collectively, will make it possible to maintain or improve on the current high safety levels despite the increase in traffic.

System-wide information management (SWIM)

SWIM consists of standards, infrastructure and governance enabling the management of ATM-related information and its information exchange among multiple parties. The focus of the harmonisation collaboration is on standards, policy, procedures, and controls as part of SWIM's overall governance.

Progress has been made on standardisation in several areas of SWIM. A SWIM concept of operations (CONOPS) was prepared in a joint effort to support ICAO's ATM Requirements and Performance Panel

(ATMRPP), forming the baseline for the work of the ICAO Information Management Panel (IMP). Based on this CONOPS, SWIM is now further refined with major contributions from NextGen and SESAR, around the concepts of Services, Information, Technical Infrastructure and transversal considerations related to Cybersecurity and Governance. A next iteration of the ICAO SWIM Concept, called ASBU B1-SWIM for 2019-2025 was initiated in 2019, as a primary ICAO technical work program on information management to increase air navigation capacity and efficiency defines SWIM services (applications and infrastructure) and its implementation framework, building an aviation intranet-based standard data models and internet-based protocols to achieve interoperability.

The U.S. and Europe continue to collaborate making sure SWIM developments are jointly raised to the ICAO Information Management Panel (IMP) and ATMRPP, and Meteorology Panel (METP) when appropriate. On specific data domains, the following progress was made:

- Aeronautical information - developed jointly by the U.S. and EU, the aeronautical information exchange model (AIXM) has become a de facto global standard for the exchange of aeronautical information through new digital aeronautical information management (AIM) systems that are now being deployed globally;
- Meteorological information - the weather information exchange model (WXXM) developed jointly by the U.S. and EU, and the meteorological information exchange model (IWXXM), developed by ICAO and the World Meteorological Organisation (WMO) supported by the U.S and EU, cover all the latest ICAO requirements plus specific U.S.-EU needs;
- Flight and flow information - a globally applicable baseline flight and flow information exchange model (FIXM) have been established in support of flight and flow information for the collaborative environment (FF-ICE).

4D Trajectory (4DT) Management

Trajectory management aims to improve air traffic operations and increase the overall predictability to all users of the aviation and ATM system. This benefits all aviation partners and stakeholders alike.

A major component of the 4D trajectory management concept is Flight & Flow Information for a Collaborative Environment (FF-ICE), which supports TBO (trajectory-based operations) through the exchange and distribution of information. NextGen and SESAR are leading efforts with global partners to coordinate work in the area of 4D trajectory management and FF-ICE.

The joint US-EU avionics roadmap was updated in 2016 to reflect the impact of the latest regulatory guidance material. In parallel, operational capabilities are being addressed through joint RTCA (Radio Technical Commission for Aeronautics) / EUROCAE (The European Organisation for Civil Aviation Equipment) standards development activities. The roadmap will be updated to include new standards, including industry standards, as necessary when there are agreed results from other areas of U.S.-EU cooperation and in particular as a consequence of the air/ground data communications strategy.

Data communications (DataComm)

Both NextGen and SESAR are continuing to develop procedures requiring the integration of added air/ground data communications (DataComm) capabilities. Harmonisation work has concentrated on datalink applications and datalink technologies. This includes, but is not limited to, very high frequency (VHF) datalink, satellite communications, aeronautical mobile airport communication system (AeroMACS), future terrestrial datalink and internet protocols for air-ground data communications. In addition to DataComm applications and technologies, harmonisation efforts have focused on testing, benefits and metrics, end-to-end certification, monitoring and control, operational qualification, and operator and industry coordination.

A new version of the joint NextGen-SESAR air-ground DataComm strategy was developed within the framework of the MoC's transversal activities. The previous version of this strategy identified the target data communications environment that will ensure convergence between the US and EU and also described possible combinations of three elements, namely applications, networks and physical links, which are required for enabling interoperability. The updated version confirms the harmonisation targets for ATM operations in respective continental and oceanic airspace based on:

- ATN/IPS (Aeronautical Telecommunication Network / Internet Protocol Suite) for the network,
- Baseline 2 (B2) services for the ATM operational service applications, and
- A mix of current VDL Mode 2, new high bandwidth SATCOM and a new terrestrial datalink.

Navigation

A joint navigation systems roadmap is currently being updated, focusing on global navigation satellite systems (GNSS) such as satellite-based augmentation systems (SBAS), ground-based augmentation systems (GBAS) (including GAST-D and multi-constellation/multi-frequency-based systems), and performance-based navigation (PBN). It also addresses the interoperability of the PBN infrastructure regarding the redundant or alternative system to GNSS.

The navigation systems roadmap is being updated to depict current infrastructure along with planned capabilities and strategies for navigation evolution. The US and Europe will continue efforts to coordinate standards development activities through RTCA and EUROCAE.

Surveillance

Automatic Dependent Surveillance-Broadcast (ADS-B) is a surveillance technique that relies on aircraft broadcasting their identity, position and other information derived from onboard systems. This signal can be received for surveillance purposes on the ground (ADS-B Out) or on board of the aircraft (ADS-BIn).

Harmonisation work has continued in the areas of automatic dependent surveillance-broadcast (ADS-B), and the evolution of airborne separation assistance systems (ASAS) and applications that use ADS-B in the cockpit to support situational awareness, support airborne 'spacing' applications, and eventually the development of airborne 'separation' applications.

Harmonisation has been well managed in the area of ADS-B applications and technologies, with the publication of numerous RTCA and EUROCAE documents in the areas of Minimum Operational Performance Specification (MOPS) and safety, performance and interoperability requirements. Developments continue in this joint forum supported by NextGen and SESAR, including updates to the technical standards and development of further application standards. As part of the full lifecycle cooperation, the implementation of ADS-B is becoming a focus item for deployment cooperation.

The US and Europe will establish cooperation on the deployment of ADS-B. Cooperation will continue with respect to standards development through RTCA and EUROCAE. The outcome of the work will be feeding the ICAO processes to establish a harmonised approach on a global level.

The analysis of the data shows that most of the European airspace and main airports have ADS-B coverage, either by ADS-B stations or Mode S and WAM/MLAT (Wide Area Multilateration / Multilateration) systems. Furthermore, there are clear plans by the ANSPs to improve the overall coverage. It has to be noted that many ANSPs are, via WAM or ADS-B, capable to receive and process the ADS-B data and that some degree of operational use of the airborne ADS-B transmissions is already well established.

Beyond 2020, the total number of Mode S radars slightly increases, thus covering most of the European Airspace. ANSPs will continue to install/renew Mode S stations from 2021 to 2035. These stations will complement and/or replace the current infrastructure and will enhance the Mode S airport coverage in Europe. From 2020, the remaining average lifetime of the Mode S infrastructure is 17 years.

Airports (ANSPs and Airport operators) plan to install/renew 8 MLAT infrastructures between 2021 and 2028. These stations will complement and/or replace the current infrastructure and will enhance the MLAT coverage in airport areas.

In the US, the FAA has mandated that aircraft operating in most controlled U.S. airspace be equipped for ADS-B Out by January 1, 2020. ADS-B In, which is not mandated, offers additional situation awareness benefits to operators who equip with suitable avionics via the in-cockpit display of nearby aircraft.

For airlines, having ADS-B In allows pilots to use enhanced applications such as In-Trail Procedures (ITP) and Interval Management. ITP allows pilots to safely climb or descend with reduced separation on oceanic routes. Interval Management (IM), a key element in future Trajectory Based Operations in the NAS, allows pilots to meet tight time constraints when entering the terminal area in a queue with other arrivals. Avionics standards and certified equipment are available for ITP, with the FAA supporting the operations in oceanic airspace. IM is under development and the FAA is not yet supporting such operations.

A NextGen capability that can reduce the separation between equipped aircraft in often crowded transoceanic airspace is operational. ITP, an ADS-B In application, enables reduced separation between aircraft. ITP allows ADS-B-equipped aircraft to safely climb or descend with separation reduced to as close as 15 nautical miles compared to the normal in-trail separation distance of 30–80 nautical miles or more, depending on equipage capability, enabling pilots of transoceanic flights to access more optimal, fuel-saving altitudes.

In the US, ADS-B also plays an important role in airport operations through the Airport Surface Detection System–Model X (ASDE-X) and Airport Surface Surveillance Capability (ASSC) ground-surveillance systems. These systems combine radar, ADS-B and other data sources to enable controllers to track the surface movement of aircraft and airport ground vehicles, which helps reduce taxiway conflicts and runway incursions. ASDE-X is in place at 35 major airports across the United States. ASSC is operational at San Francisco and Cleveland and will be in place at a total of eight airports by January 2020. With ASDE-X and ASSC, controllers and pilots with ADS-B In and cockpit displays see aircraft and ground vehicles on the airport surface, and approach and departure paths within 2 miles of the airport.

T9.2.13 Conclusion

SESAR and the US NextGen both have the same basic aim – more efficient use of airspace and better air safety – 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.

SESAR tends to focus primarily on Air Traffic Management but has a nearer-term for completion. Network Centric Operations Industry Consortium (NCOIC) highly recommends that the sharing of approaches and lessons learned from each program be made a priority in the other program to improve efficiency and avoid stove piping and potential incompatibilities across the Atlantic.

Both organizations are embracing basic network-centric concepts. The way each is choosing to implement these is taking a different form.

The common vision is to integrate and implement new technologies to improve air traffic management (ATM) performance – a 'new paradigm'. SESAR and NextGen combine increased automation with new procedures to achieve safety, economic, capacity, environmental, and security benefits. The systems do not have to be identical but must have aligned requirements for equipment standards and technical interoperability.

SESAR:

- SWIM is a main feature of the SESAR ConOps.
- Information technologies are already available to support SWIM (Datalink may need further Development).
- Institutional barriers (property of data) will need to be mitigated through regulation (if not goodwill) before SWIM is possible.
- SWIM-SUIT (System Wide Information Management Supported by Innovative Technologies) will prove the concept using legacy systems using wrapper techniques;
- By the year 2025 new systems will be developed to be directly connectable to the SWIM infrastructure, interoperability will be the result.
- Each aircraft should be equipped so that it can achieve adequate end-to-end QoS by being able to receive the required data.
- Investment is a major challenge; stakeholders will need to be convinced that the benefits outweigh the costs.
- The SESAR Operational Concept time horizon is 2025+: NextGen time horizon is 2030+. As a result, all airlines with European routes will be required to harmonize with Eurocontrol solutions early, as each entity seeks long term interoperability solutions.
- Europe is now leading the world in controller pilot data link communications (CPDLC), with 15 airlines already using the service via the first operational implementation at Maastricht Upper Area Control Centre. But that lead is likely to be short-lived, thanks to the revival of US CPDLC plans through the FAA's budget allocation for a new Datacom system and the expected issuing of a notice of proposed rulemaking on aircraft equipage in 2022.
- A key element of both SESAR and NextGen is System Wide Information Management (SWIM), which is a focus on how the technologies and systems will enable shared awareness for operations. Some on-going initiatives such as ICOG (Interoperability Consultancy Group), D-AIM (Digital AIM), and SWIM-SUIT will enable legacy systems to operate in the SWIM environment.
- The planned technology is very similar – ADS-B, Data Link, Extended Conflict Detection. ADS-B equipment has been extensively and successfully tested in operational environments and is an example of a developed SESAR and NextGen technological component. The United States is further along on the surveillance part, known as Automatic Dependent Surveillance-Broadcast (ADS-B) Out, while Europe's SESAR is further advanced on datalink communications. Both Europe and the U.S. are moving toward the same goal, although the pace and emphasis during the transition to next-generation traffic management still must be worked out.
- Both systems embrace a network-centric infrastructure with shared services and distributed data environments interacting semi-autonomously to achieve system-wide efficiencies.
- Critical to consider global interoperability and harmonisation.

3.2 Harmonized Certification

The certification of an airliner is the final stage of the development process, and can also be the most complex, time-consuming and expensive. The certification of a modern airliner takes about 3 000 flying hours over 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. Although there has been much progress in ground testing and simulation, it is flight testing that is the ultimate proof that satisfies certification authorities. The increasing capabilities and complexity of successive generations of airliners mean that there are more hardware and software equipment and functions to test, and the progress is absorbed in performing increased testing in a comparable period.

The enormous progress over the past in-flight testing and certification is testified by the fact that most current programs reach production and service without a single fatal accident in the development process.

The days when a test pilot entered a prototype aircraft not knowing what to expect are long gone, and replaced by a much more scientific, disciplined, controlled and safer development process: (i) mathematical models are developed for the aircraft performance, stability and flying characteristics as a whole and of its constituent subsystems; (ii) the models are validated by extensive tests in aerodynamic wind tunnels, engine test facilities and ground test rigs covering structures and systems; (iii) the mathematical models are implemented in flight simulators giving test pilots many hours of experience before the real flight.

The main benefit of all this modelling, simulation and ground testing is that flight testing and certification are much more efficient, going through a larger number of test points in a shorter time, with almost complete safety, because: (i) the telemetry data from flight testing is compared in real-time with simulation models on the ground; (ii) in the case of an agreement it is possible to proceed to the next test point without delay as long as flight endurance allows; (iii) in case a discrepancy appears the testing is suspended until the cause is identified and corrected so that the incident does not become an accident; (iv) this process allows a faster exploration of the full flight envelope and operating conditions, starting from the safer central part and then gradually extending to the boundaries.

The extensive pre-flight testing does not mean that there are no surprises in-flight testing: (i) some phenomena like laminar to turbulent flow transition cannot always be predicted accurately in wind tunnel tests; (ii) similarly some engine operating characteristics cannot be fully simulated on the ground; (iii) complex systems can have many combinations of partial failure modes. Even considering only aerodynamics, CFD (computational fluid dynamics), wind tunnels and in-flight measurements can all show different results. The substantial effort in ground testing and simulation serves to reduce the risks of flight testing and allow certification with minimal upsets.

The discovery of major deficiencies in-flight testing or certification triggers a long and costly process: (i) identification of the cause(s) of the deficiency; (ii) design of a solution; (iii) testing of the design; (iv) implementation in at least prototype production; (v) incorporation in the existing prototype or additional aircraft; (vi) resumption of the flight testing and certification. This is an example of the fact that the later a deficiency is found the longer and the more expensive it will be to correct. The whole purpose of the development process is to use earlier and cheaper testing to identify and correct as many issues as possible so that less crop up at the last stage of flight testing and certification when the consequences in delays and cost will be greater.

The preceding account assumes that the certification process concerns only essential issues without duplication or unexpected requirements. That was not always the case in the past. There were instances some decades ago when different national certification required different tests for the same purpose, duplicating the effort and increasing cost with no benefit. The harmonization of certification standards avoids such costly duplications without benefit to safety or efficiency. 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.

Dissimilar certification rules or non-acceptance of other certification runs the risk of becoming disguised protectionism or lead to a non-level playing field. The acceptance of 'grandfather rights' allowed the second-generation Boeing B737 to keep earlier passenger evacuation rules, thus seating more passenger in a smaller cabin than the new Airbus A320 that had to meet more recent and stringent certification rules; this unfortunate episode had at least the positive consequence of the agreement between the FAA and EASA that 'grandfather rights' could not be invoked in the future. Another episode was the FAA requirement that in the event of an in-flight disintegration of an engine of the Airbus A340 there would be no possibility of severing fuel lines; this required a considerable redesign of the fuel lines in the wing of the aircraft; the EASA also raised some issues on updates to the Boeing B747, and eventually, a broader-based agreement was reached with FAA on certification rules, to the benefit of the worldwide aviation community.

The FAA and EASA certification rules are the 'de facto' world standard since aircraft that would not meet them could not fly in Europe and the US pre-empting much of the possible airline market. The EASA and FAA are an essential element in keeping aviation as the safest mode of transport, by making sure that all aircraft producers and their products deserve the trust of passengers. 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. The introduction of new technologies, and eventually of new aircraft configurations like flying wings or joined wings, will put new challenges on certification that must be addressed by close consultation between industry and the authorities, so that aircraft can be designed to meet all the requirements they will have to satisfy.

The harmonization of certification by EASA in Europe and the FAA in the US (Key Topic 9.3) sets the standard for these processes essential for the safety of air transport.

The certification process must be constantly monitored due to appeared unacceptable deviations and simplifications in the certification procedures, which can lead to tragic consequences. Within half a year, in 2018 and 2019 two new Boeing 737 Max aircraft crashed. As established, the reason for these disasters were errors made by Boeing, which were not disclosed in the process of certification tests of this type of aircraft. This happened because FAA delegated of safety duties to Boeing company. The FAA did not maintain adequate supervision and authority over the delegated representative. This caused the loss of trust in the FAA from the rest of the world, which can lead in the future to greater scrutiny for acceptance by different airworthiness authorities.

KEY TOPIC T9.3 HARMONIZED CERTIFICATION

T9.3.1 Coordination Between EASA and FAA

The overall framework for harmonized and coordinated certification between EASA and the FAA is currently established by the agreement between the US and the European Union on cooperation in the regulation of Civil Aviation Safety. This agreement entered into force on the 1st of May 2011 and this formalises the mutual trust that was built over the years between the US and EU in the fields of airworthiness approvals of civil aeronautical products; and approval and monitoring of maintenance facilities; environmental testing and approvals of civil aeronautical products; and approval and monitoring of maintenance facilities[1].

The agreement reflects the structure of a "classical" agreement in the areas of aviation safety, a "BASA" is being called the existing Bilateral Aviation Safety Agreements between the US and some EU Member States (EU MS). As in the cases of the BASAs, the agreement is based on mutual trust of each other's system and the comparison of regulatory systems. Moreover, the FAA and EASA at authority level prepared the so-called 3rd level texts (**Technical Implementation Procedures**, TIP for Airworthiness and Environmental Certification and the Maintenance Annex Guidance – MAG for Maintenance) that define how the Parties will implement and work to achieve the objectives set out in the Agreement and its Annexes).

The Agreement also establishes a series of committees/sub-committees ensuring its effective functioning:

- Implementation of the agreement, for handling disputes and the amendment and adoption of new annexes, will be the responsibility of the Bilateral Oversight Board (BOB). The Union will be represented in the BOB by the European Commission assisted by EASA and accompanied by the Aviation Authorities as representatives of the EU MS.

1 Information Note. Agreement between the United States of America and the European Union on cooperation in the regulation of civil Aviation Safety. EASA web page.

- Discussions at a technical level (FAA-EASA) and the development, approval and amendments of the TIP and MAG will be assured by the Certification Oversight Board (COB) and the Joint Maintenance Coordination Board (JMCB) respectively, being both boards accountable to the BOB.

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. Furthermore, the agreement supports the continuation of high-level regulatory cooperation and thus promotes a uniformly high degree of safety in air transport. This will facilitate trade in goods and services covered by its scope and limit as much as possible, the duplication of assessments, tests and controls to significant regulatory differences.

Its scope covers the airworthiness approvals and monitoring of civil aeronautical products, the environmental testing and approvals of civil aeronautical products and the approval and monitoring of maintenance facilities.

To complement this agreement, a series of guidelines have been commonly developed to establish the process through which the FAA and EASA intend to promote rulemaking co-operation in the early stages of the rulemaking process. The objectives of this rulemaking cooperation arrangement[2] are to:

- Exchange regulation intentions and priorities of the participants to align as much as possible their respective rulemaking programmes.
- Identify rulemaking initiatives of common interest that through regulatory collaboration would allow the FAA and EASA to avoid unnecessary divergence and duplication of work, maximize available resources and further harmonisation.
- Define the corresponding working methods to be followed by the participants when executing tasks which have been considered as of common interest.

The FAA and EASA rulemaking agreement foresee 3 possible working methods, as indicated in Figure 9.6, by which the participants will execute rulemaking tasks in the areas of common interest.

Working Method # 1 - EASA Takes the Lead	Working Method #2 - FAA Takes the Lead	Working Method #3 – Authorities Cooperation
• The general process is the EASA rulemaking procedure. • This working method aims at giving the FAA sufficient involvement in the EASA rulemaking project to understand the content of the draft rule and to be able to contribute to this process as necessary to allow it, where appropriate, to launch an equivalent Notice of Proposed Rulemaking ("NPRM") or take other equivalent rulemaking decision. • The EASA focal point should lead the rulemaking process in regular coordination with the FAA focal point.	• The general process is outlined in the FAA Office of Rulemaking's Rulemaking Manual. • This working method aims at giving EASA sufficient involvement in the FAA's rulemaking project to understand the content of the NPRM and be able to contribute to this process as necessary to allow it, where appropriate, to launch an equivalent NPA or take other equivalent rulemaking decision. • The FAA focal point should lead the rulemaking process in regular coordination with the EASA focal point.	• FAA and EASA intend to develop their rulemaking projects separately, but concurrently (to the extent practicable). • However, as appropriate, the FAA and EASA focal points may follow the process described in Working Methods #1 and #2 in sharing information during concurrent development of the rule.

Figure 9.6 – FAA and EASA rulemaking agreement foresee 3 possible working methods

[2] "Rulemaking Cooperation Guidelines for the Federal Aviation Administration and the European Aviation Safety Agency". FAA, EASA, 2013.

Finally, the agreement gives to the parties the possibility to agree on additional areas of cooperation by amendment of the agreement.

TECHNICAL IMPLEMENTATION PROCEDURES FOR AIRWORTHINESS AND ENVIRONMENTAL CERTIFICATION (TIP)

The last revision of this document was made in September 2017 called: Revision 6 Then two amendments were issued: Amendment 1(June 22, 2018) and Amendment 2 (April 02, 2019). The amendments do not significantly change the content of the document. They introduce small changes and corrections in the wording of several paragraphs.

The purpose of the TIP is to define the procedures for approving the design of civil aeronautical products and articles eligible for import into the U.S. and the EU, the process for obtaining eligibility for import, and the means for providing continued support of those civil aeronautical products and articles after import.

The TIP is based on continuous communication and confidence in the FAA's and EASA's technical competence and ability to perform regulatory functions within the scope of the TIP.

The FAA and EASA mutually recognize each other's aircraft certification systems, which includes EASA recognition of FAA's designee system and FAA recognition of EASA's design and production organization system.

T9.3.2 Grandfather Rights

According to sources such as Skybrary, grandfather rights are defined as the arrangement under which later derivatives of an initial aircraft type design can be manufactured under variations to the original Type Certificate thereby avoiding the more complex procedures involved in gaining approval under a completely new Type Certificate.

The effect of this is that although the standards applied to enable the issue of as Type Certificate have always progressively increased over time, in the light of experience and general technological progress, these benefits are not reflected in the certification of 'similar' aircraft by means of variations. There is no general time limit to these grandfather rights, and they can remain effective over a long period.

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.

This following Figure 9.7 shows how to determine the certification basis for derivative airlines types. The chosen method is a set of step-by-step guidelines for the certification of derivative types. These aim to enforce compliance with the latest regulations.

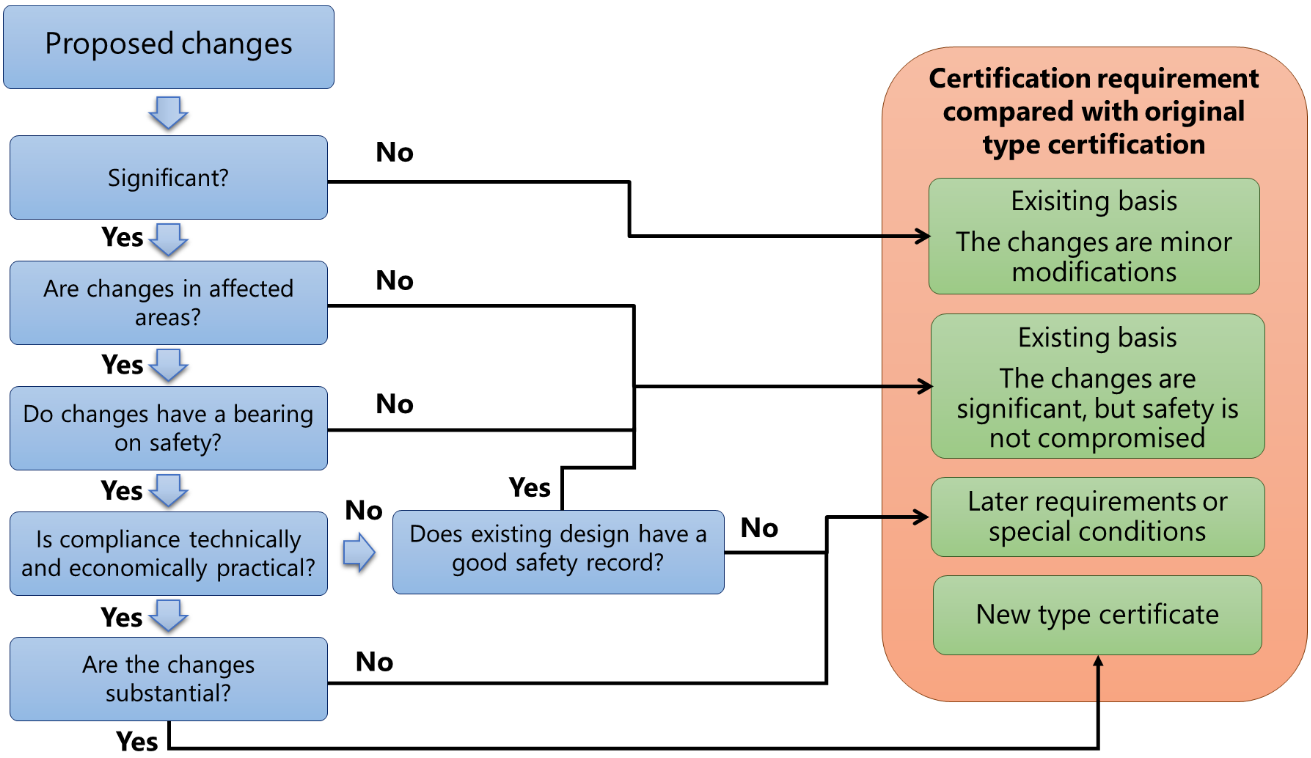


Figure 9.7 – Diagram about how to determine certification basis for derivative airliner types
Source: Boeing and the UK Civil Aviation Authority

Besides, grandfather rights are currently used in the European Union to allocate airport slots. Grand-fathered rights have also been established in the Commission Regulation 1702/2003, with the establishment of EASA. This grandfathering allows that now new type certificates for the related products need to be issued for certain type certificates dispensed before 28 September 2003 by Member States (JAA) following Regulation no 1702/2003.

Historical Perspective of Grandfather's Rights

Relevant Boeing and Airbus aircraft families have made extensive used of the grandfather's rights to avoid the burden of complex and expensive certification process according to new safety requirement.

Derivatives have not posed much of a problem to the European Authorities (JAA). Its first certification was awarded to Saab's SF340, in May 1984. That aircraft, and all those which have followed it, including the ATR series, the Airbus fleet from the A320 onwards and British Aerospace's 146/RJ series, have all been original aircraft certificated to standards which have required little amendments to comply with the latest - and proposed - changes to the JARs. The FAA, on the other hand, has had to deal with the Boeing and McDonnell Douglas (MDC) fleets, the derivatives of which include the world's best-sellers.

Without grandfather rights, the 747-8 would have not been certified as the passengers in the nose section of the main deck only have one way of exiting the plane in an emergency, whereas the new legislation required all planes to have 2 directions for all passengers to go in case of an emergency evacuation, front and backwards. European regulators insisted at that moment on Boeing to be required to undertake a full evacuation demonstration of the new 747 variant - something it avoided doing when the -400 was introduced in 1989. Although under previous 747 stretch development studies, such as the 747X of 2001, Boeing had intended to adopt an all-new certification path, it finally pursued certification for the 747-8I/8F under an amended 747-400 type certificate.

The 747-400 was itself approved as an amendment to the certification of the original 747-100 that was launched in 1966. European Joint Aviation Authorities') insisted in the 1980s that the cockpit/upper-deck floor of the Boeing 747-400 be strengthened to contemporary standards, to protect the flight-control runs which pass through it. Although at that moment the FAA disagreed, JAA insistence translated into that European-registered 747-400s having upper-deck floors built to a higher specification than those registered in the USA and elsewhere.

The latest issue concerns the Boeing 737-X series and whether, despite being a re-winged, re-engined, re-instrumented version of the previous series, it will gain any advantage over the A320 by virtue of grandfathering anomalies. The Boeing's 737-X series (the 737-600/700/800) complied with 362 out of 377 of the latest FAR (Federal Aviation Regulations)/JARs (Joint Aviation Requirements), and that the ten or so "reversions" (derivative privileges) granted complied with the ICPTF (International Certification Procedures Task Force) guidelines. By the end of 1995, Boeing had admitted that there were some five items yet to be clarified, but it is reluctant to list them. One of them was the issue of whether the 737-800 shall be permitted, given the limitations imposed by cabin emergency-exit regulations, to carry 179 or 189 passengers. A 737 has never been submitted to the JAA for certification - it was originally certificated by European national aviation authorities. The FAA, on the other hand, being the 737's original certificating authority, says that 189 is permissible under FAR grandfather rules.

On 2000 grandfather rights were finally killed on both sides of the Atlantic. A new US Federal Aviation Administration rule has replaced the regulation which allowed completely new aircraft models in a well-established family, like Boeing's 737 series, for example, to continue to be produced to some of the out-of-date certification standards in force when the first 737 was produced. The JAA upgrade also its previous regulation, that was a compromise solution requiring that new models in an existing family of aircraft do not have to meet the letter of the latest certification laws, provided that the new version could demonstrate "equivalent safety" by some other means. If it could not, the updated model had to satisfy the same certification standards that would apply to a completely new aircraft type.

FUTURE PERSPECTIVE OF GRANDFATHER'S RIGHTS

Besides this overall agreement on not application of grandfather rights, there are some challenges that problem might be reactivated in the future, as could have been happened with the upcoming application of new ICAO regulation for emissions.

On 8 February 2016, the International Civil Aviation Organization (ICAO) finalized a proposed performance standard for new aircraft that will mandate improvements in fuel efficiency and reductions in carbon dioxide (CO2) emissions. The standard, the first ever to impose binding energy efficiency and CO2 reduction targets for the aviation sector, was hammered out at the tenth meeting of ICAO's Committee for Environmental Protection (CAEP). It will apply to all new commercial and business aircraft delivered after 1 January 2028, with a transition period for modified aircraft starting in 2023. The standards will on average require a 4% reduction in the cruise fuel consumption of new aircraft starting in 2028 compared to 2015 deliveries, with the actual reductions ranging from 0 to 11%, depending on the maximum take-off mass (MTOM) of the aircraft.

If this standard would have been deeming to be applied only to new designs certified after the expected application date (instead of to all aircraft rolled out of a factory), in-service aircraft, those already flying before the date the standard takes effect, will not be affected by this new regulation. Most of the "future" aeroplanes that are already announced (B777X, A330neo, etc.) will acquire their type certificates well before 2024 and in essence would therefore grandfather in existing production lines and possibly derivative products as well, what could prolong the current period of limited efficiency improvements by delaying the introduction of new aircraft designs by manufacturers wishing to avoid triggering the standard[3]. If the grandfather clause would be adopted, then a standard applied in 2020 would cover only 5% of the global fleet in 2030.

In the future, it is expected that these grandfather rights may reappear as modifications to the new aircraft models are extended. Therefore, the procedure to be followed will be very similar to the current one since aircraft owners will try to achieve maximum use of their investment.

The conflicting issues which have to be resolved are, on the one hand, the need for safety regulation and environmental protection, to be able to advance, taking advantage of experience and technological improvement; and, on the other hand, the need for manufacturers to produce aircraft to approved designs which can remain unchanged long enough to be built, tested and put into operation, and then to achieve sufficient sales for a reasonable return on investment.

Risk arising from the use of Grandfather Rights through the example of B737 Max

In many cases, aircraft manufacturers try to continue the line of a particular type of aircraft for as long as possible. As an example is Boeing 737 envisioned in 1964. The 737 design is over 50 years old and has undergone countless changes between its 21 variations. While this may reflect well on the early 737 designs, this fact is a symptom of an aviation system that incentives amendments, grandfathering, and waivers. Boeing consciously acted to minimize changes to the 737-NG variants designs to certify the MAX as a 737 instead of under a new type certificate.

The first Boeing 737 design was created in 1965 and had its first commercial flight in April 1967. In the 1960s, stairs were the common method to load and unload passengers. The 737-100 had a set of metal stairs attached to its fuselage. This method of loading passengers required that the plane's fuselage be sufficiently low to the ground. The low fuselage did not pose a problem to the relatively small 1960's plane engines. Additionally, the low fuselage allowed bags to more easily be loaded and unloaded without the use of a conveyor.

However, in the 45 years after the launch of the first Boeing 737, the desire for more fuel-efficient engines would require Boeing to make a major change to keep up with its competition, as the larger engines would not fit on the airframe, and Boeing would realize it had exhausted all solutions based on modifications to the airframe. Since 1984, Boeing has had problems fitting larger engines, then the CFM56, onto the 737-300. To make the engines fit, Boeing had SNECMA make a custom version of the engine with a smaller fan, and Boeing relocated engine accessories and had to use non-round engine inlets. After Airbus announced a more fuel-efficient version of the A320, the A320neo, on December 1 2010, Boeing started to develop a more fuel-efficient 737.

To compete, Boeing focused its efforts to persuade the FAA to certify the MAX quickly and to reduce costs for air carriers. In contrast, the A320 started life designed around larger engines, specifically a full-sized version of the CFM56. Adding large, high-bypass, turbofans to the A320 did not require similar design solutions as in the B737. A320 was not limited by similar design boundaries to the B737.

Boeing found itself in a difficult situation because American Airlines planned a large order of new aircraft from Airbus. Bowing to financial pressure, Boeing scrapped its plan to build an entirely new plane. Instead, Boeing embarked on yet another version of the 737. Boeing promised the 737 MAX would be ready in six years, which would allow it to share the American Airlines contract between Boeing and Airbus.

[3] Efficiency Trends for New Commercial Jet Aircraft, 1960 to 2008. ICCT: International council on Clean Transportation

Boeing had to minimize certification time, certification costs, and any training and costs for airlines and pilots. Boeing had to convince the FAA that few enough changes were made to justifying certifying the MAX as a 737. Second, Boeing had to convince FAA that the changes made to the MAX would require little if any, additional differential training for 737 NG pilots.

Boeing engineers have twice reduced the time needed to develop technical drawings for the 737 NG. They worked under enormous pressure, conducive to making mistakes. Also, Boeing exerted pressure on FAA engineers that they quickly approved individual stages of the project. There was no complete and correct verification of documents. Verification was carried out to achieve specific certification dates. All changes were either hidden or minimized so that there would be no need for training differences for 737 NG pilots.

The 737 MAX's LEAP-1b engines have a diameter of 69 inches. These new engines did not fit on the 737's 1965 fuselage. Rather than recognizing that enough changes had been made to the 737 design and that safety would dictate a new type certificate, Boeing extended the pylons farther forward and higher to give the engines the needed clearance. Boeing also installed higher nose landing gear. The higher and more forward position of the engines generated greater lift for the aircraft, creating a tendency for the nose to pitch up.

To make the 737 MAX "feel" similar to the older 737s, Boeing installed MCAS, Maneuvering Characteristic Augmentation System. Boeing contracted the development of software systems to a firm that employed Indian software graduates at rates as low as $9 per hour. MCAS may have been only one of the software systems contracted out in this manner, given Boeing's decision at the time to lay off experienced engineers. Boeing's previous versions of the 737 had similar pitch-up problems, but those problems were solved with changes to the airframe rather than with software. During the certification process, Boeing withheld the existence of and the actual nature and strength of MCAS from the FAA and pilots.

Boeing's System Safety Analysis of MCAS contained at least three major flaws and mislead the FAA and pilots. First, the analysis understated MCAS' power by a factor of 4. The analysis stated that MCAS could only move the tail more than 0.6 degrees down. But in reality, MCAS could move the horizontal stabilizer more than four times as far, 2.5 degrees, each activation. Boeing programmed this higher limit after flight tests revealed that a stronger MCAS would be required. But the FAA believed the aeroplane was designed to the 0.6 limits, and that's what the foreign regulatory authorities thought, too.

The analysis classified the failure rating as "hazardous", one step below "catastrophic." A hazardous danger level requires input from more than one sensor. However, the 737s legacy autopilot architecture did not allow the operating Flight Control Computer (FCC) ready access to the other FCC's angle of attack sensor. As a result, the original MCAS implementation relied on just one angle of attack sensor. AOA sensors have high rates of failure, evidenced by the more than 216 reports of faulty AOA sensors reported to FAA since 2004.

A major failure requirement may rely on a single input sensor. These have a failure rating of less than one in 100,000. When the consequences of failure are deemed costlier, a hazardous failure requirement needs a failure rate of less than one in 10 million. Typically, this requires two separate sources of input.

Based on knowledge from the certification period, the FAA decided that 737 pilots only needed a one-hour iPad training course for the 737 MAX instead of any hands-on simulator training. And Boeing decided that pilots did not even need to know about MCAS.

On March 8, 2017, the Federal Aviation Administration (FAA) granted an amended type certificate to The Boeing Company (Boeing) for the 737-8 aircraft, the first of the 737 MAX family, which is the successor to the company's 737 Next Generation (NG) aircraft.

On October 29, 2018, Indonesian carrier Lion Air operating flight 610 from Soekarno–Hatta International Airport in Jakarta to Depati Amir Airport in Pangkal Pinang, crashed into the Java Sea 13 minutes after take-off, killing all 189 passengers and crew. Less than five months later, on March 10, 2019, in very similar circumstances, Ethiopian Airlines flight 302—another 737 MAX aircraft—crashed six minutes after take-off on a flight from Addis Ababa, Ethiopia, to Nairobi, Kenya, killing all 157 passengers and crew.

As a result of mistakes made and deliberate simplification and avoiding of certification procedures, there were two disasters in which 346 people were killed.

T9.3.3 Certification Challenges in China with the ARJ21 and C-919

Although China's government has had a great interest in manufacturing commercial aircraft, it has not had much success. Until recently, China's aircraft manufacturing industry's production was limited almost exclusively to serving the Chinese military. Consequently, almost all of China's commercial aircraft have been imported from foreign manufacturers. In 2008, the Chinese government consolidated its efforts to develop a commercial aircraft manufacturing industry by setting up a new state-owned commercial aircraft manufacturing company, the Commercial Aircraft Company of China (COMAC), to build two domestic aircraft: a regional jet, the ARJ-21, already under development, and a narrow-bodied aircraft, the C919.

In the 1970s, China made the first of several attempts to build a commercial jet. The most successful of these was the Y-10 jet transport, an aircraft broadly similar to the Boeing 707. Although several test flights conducted in the early 1980s were successful, the plane cost significantly more than western planes. For this reason, Chinese airlines found that it was more profitable to purchase aircraft from Boeing and Airbus. Only three Y-10 aircraft were built, and the program was discontinued due to design and cost problems.

Following the cancellation of the Y-10 program in 1983, China developed a plan to proceed from local production and assembly of foreign designs to local development with foreign assistance. The final step will consist of achieving completely independent local development without foreign assistance by 2010.

Following these objectives, an agreement was reached with McDonnell Douglas to assemble the MD-82 narrow-body airliner in Shanghai. Between 1986 and 1994, a total of 35 MD-82 were assembled. Then, the two partners planned to assemble 40 MD-90s, an upgraded derivative of the MD-80 series, but Boeing stopped producing the aircraft following its merger with McDonnell Douglas, and the program was suspended.

After the termination of the MD-80/90 attempt, in 1997, China persuaded a consortium that includes Airbus and Singapore Technologies to join AVIC in the development of a 100-seat regional jet, the AE-100. This program ended in 1999 when Airbus concluded that the program no longer fit into its strategic plan.

Subsequently, China focused on smaller regional jets and a consortium between several companies was formed in 2000 to develop and produce a regional jet, designed for flights of less than three hours and seating 70 to 105 passengers, known as the ARJ21.

In 2002, another Chinese aircraft manufacturer, the Harbin Aircraft Industries Group, formed a joint venture with Brazil's Embraer to assemble Embraer's ERJ-145 family of 30-to 50-seat regional jets in Harbin. However, the facility delivered only 41 ERJ-145 aircraft over seven years before production ended in 2011. Then the company started production Embraer Legacy 650. The first Chinese-built Embraer Legacy 650 took to the skies for the first time on 26 August 2013. The large-cabin business jet was assembled by Harbin Embraer Aircraft Industry (HEAI) - a joint venture between Embraer and Harbin's parent company, Aviation Industry Corporation of China (AVIC). The factory located in Harbin, which previously produced the ERJ-145 regional jet delivered the last Legacy 650 in March 2016. The company decided in June 2016 to end production of Legacy jet aircraft in China, bringing an end to a 13-year partnership with the Aviation Industry Corporation of China (AVIC). In 2017 Brazilian aeronautical company Embraer started the analysis of the possibility of building a factory in China to manufacture jet aircraft for the commercial aviation segment. Chief Executive Paulo Cesar de Souza e Silva said the board of directors intends to bring the E195-E2 to the market in 2019, before considering building a factory in China, which would be the first outside Brazil for the production of commercial aircraft. E195-E2 was certified on 28 February 2018.

China's first national jet, Comac's ARJ21, is a failure – it's heavy, technologically obsolete, and very late. After several decades of existence and four years of production, just a handful have been delivered to a few marginal Chinese airlines. However, in theory, it directly competes with Embraer's E175. It would be a remarkable – and unlikely – admission of failure for China to give up on that national jet, yet that would be the inevitable result of acquiring Embraer since the E175 is vastly superior [Richard Aboulafia, Forbes, 2020]

Recent reports indicate, however, the decreasing interest of the Chinese side in undertaking cooperation with Embraer.

More recently, the Chinese industry appears to have shifted its focus to larger aircraft in the 130-to 170-seat class. In 2008, a joint venture between Airbus and a Chinese consortium to perform final assembly of the Airbus A320.

Finally, China's indigenous commercial jet project known as the C919 was launched in 2008.

In the following image (Figure 9.8), it can be seen a timeline of China attempts to manufacture commercial aircraft:

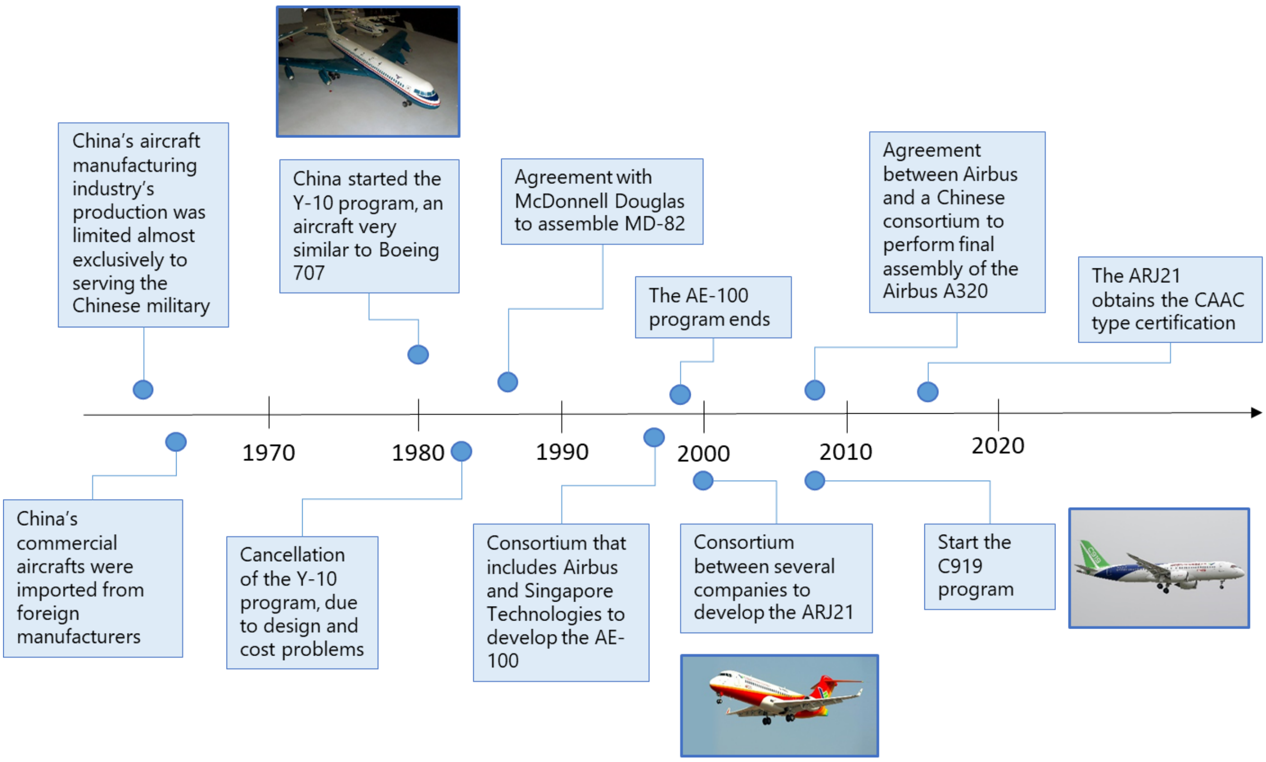


Figure 9.8 – China attempts to manufacture commercial aircraft

However, the China indigenous aircraft, the ARJ21 and the C919 have experience delays due to several problems during tests flights. A key problem of the delays has been a lack of systems integration skills. As several parts of the aircraft are produced by different manufacturers, the finished products are having compatibility issues during final assembly. Quality has also been a problem. Certain parts of the aircraft have failed to meet quality requirements.

Besides, one of the main problems in the construction of China indigenous aircraft is that there is no intellectual property protection, which implies that international companies often agree to transfer only dated technology. This issue has been a great problem for the ARJ21 and it may be a problem too for the C919.

ARJ21

The ARJ21 is a twin-engine regional jet, manufactured by the Chinese aerospace company COMAC.

This project started in 2002, and it has experienced significant delays compared to the initial plan. The first commercial flight took place in June 2016, six years later than planned. Up to 28th of April 2020, COMAC has delivered 24 ARJ21 aircraft, and the ARJ21 aircraft fleet has safely carried more than 810,000 passengers.

Depending on the version, the ARJ21 has a maximum seating capacity of 105 and a maximum range of 3,700 km, which makes it a direct competitor to Embraer E175 and E190, as well as to Bombardier CRJ900 and CRJ1000.

As it was said before, the ARJ21 has had several delays. In 2010, an ARJ21 wing failed to reach the predicted load rating during static testing. This wing's failure led the Civil Aviation Administration of China (CAAC) to limit the aircraft flight envelope during its flight test program. Also, other problems arose during the flight-testing program: two components of the testing program had not been completed, icing tests had been delayed and stall speed tests had not begun yet. These problems lead to delays in obtaining type certification. Wing cracks and avionics were other problems that contributed to the delays.

Obtaining an FAA type certification is a precondition for the ARJ21 to enter the global aviation market. Since 2003, the aviation authorities of China and the USA have been negotiating the ARJ21 application for FAA type without success.

However, the ARJ21 achieved the type certification from the Civil Aviation Administration of China (CAAC) in 2014, which allows the aircraft to carry out regional flights. On 29 November 2015, COMAC delivered the first ARJ21 to Chengdu Airlines and the first commercial flight took place in the Chengdu Shuangliu Airport on June 28 2016.

C919

The COMAC C919 is a narrow-body twinjet airliner developed by Chinese aerospace manufacturer COMAC. The programme was launched in 2008 and production and its first flight took place on 5 May 2017. The C919 can carry 156 to 168 passengers with a range of 3000 nautical miles. It is intended to compete primarily with the Boeing 737 and Airbus A320neo and it is planned to enter commercial service in 2021 with China Eastern airlines.

On the 24th November 2011, the preliminary design phase for the C919 ended and the assembly of the first C919 prototype began on December 2011. The flight testbed was expected to complete final assembly in 2014 and perform its first flight in 2015. However, there were several delays due to technical difficulties and supply issues. Finally, the first flight took place in 2017 and the first 150-seat C919 is scheduled to be delivered in 2021.

The C919 has not obtained yet a type of certification from CAAC, which will take about three to four years. In April 2017, the European Aviation Safety Association (EASA) agreed to help validate Chinese aviation authorities' certifying process of the C919's airworthiness. An EASA endorsement of the C919's airworthiness would increase its export prospects, especially in Asia and the Middle East. After EASA certification, the C919 could hope to win approval from the FAA.

A fourth prototype conducted its maiden flight on 1 August 2019 from Shanghai Pudong International Airport, with two further aircraft expected to join the test fleet before the end of 2019. A fifth prototype conducted its first flight on 24 October 2019, also from the aforementioned Shanghai airport. The fifth prototype is expected to undergo testing for extreme weather conditions, environmental control, drainage, and electrical supply. In 2020, despite the coronavirus pandemic, Comac is using six aircraft for flight testing and certification purposes and has scheduled 4,200 flight hours for completion of more than 700 test items ahead of the Civil Aviation Administration of China's certification of the C919 in 2021. The delivery of the first aircraft is planned for the next years.

C929

In 2016, COMAC and United Aircraft Corporation of Russia (UAC) signed an agreement to co-develop a 250-seat, 290-ton, 7,450-mile-range plane tentatively designated the C929. Its first flight is targeted for 2022, and it will potentially enter into service by 2025. The C929's construction will use large percentages of composite and titanium parts to reduce its weight, thus boosting payload, range, and fuel efficiency to compete with the Boeing 787 and Airbus A350. Like the C919, the C929 will likely use foreign parts, especially in the engines.

Initially, it was assumed that the aircraft would be equipped with a turbofan engine with a thrust of 77 000-88,000 pounds (340-390 kN). The engine was to be supplied by Rolls-Royce or General Electric that already had products in this class. However, CRAIC expected Thrust-Specific Fuel Consumption (TSFC) to be at least 10% better.

However, in 2017 it was signed a memorandum of understanding (MoU) between Russia's United Engine Corporation (UEC) and China's AECC Commercial Aircraft Engine Company calling for the joint development of a turbofan engine for the proposed new Russian-Chinese widebody known as the C929 in China and the LRWBA (long-range widebody aircraft) in Russia. The memorandum assumed at the beginning the initial joint research and customer requirements analysis and definition, then determining engine design and operating parameters before testing in 2022 and certification in 2027.

China has been working independently on the CJ-2000 engine. It could also use AI-38 engines co-developed by China and Ukrainian Ivchenko-Progress from the 225 kN Progress D-18T of the An-124/An-225. However, the MoU between Russian UEC and Chinese AECC makes this possibility unlikely.

T9.3.4 Certification of Novel Aircraft Configurations

The configuration of civil aircraft has evolved little since the 1920s. Almost without exception, passengers have been transported in a tubular fuselage, with the empennage at the rear and the engines mounted either under the wings or at the sides or/and top of the fuselage at the rear. Although major advances in aerodynamics and flight control systems have contributed greatly to improve the performance of the classic configuration, the advent of new design materials and design processes, along with a far better understanding of the aerodynamic and structural interactions that occur in different phases of flight, are driving some radical ideas for the future.

Regarding aircraft configurations, several options are being considered for the future:

- Development of integrated and interdisciplinary functional aircraft design methods, including systems, software and integration aspects considered from the conceptual design phase
- Integrated blended wing body and tail-mounted open rotor concepts
- Aircraft configurations regarding the type of energy (e.g. hydrogen, electrical propulsion…)

The following image (Figure 9.9) shows some different types of possible aircraft configurations based on the level of investment required (low, medium and high), as a function of time (2015, 2025 and 2050):

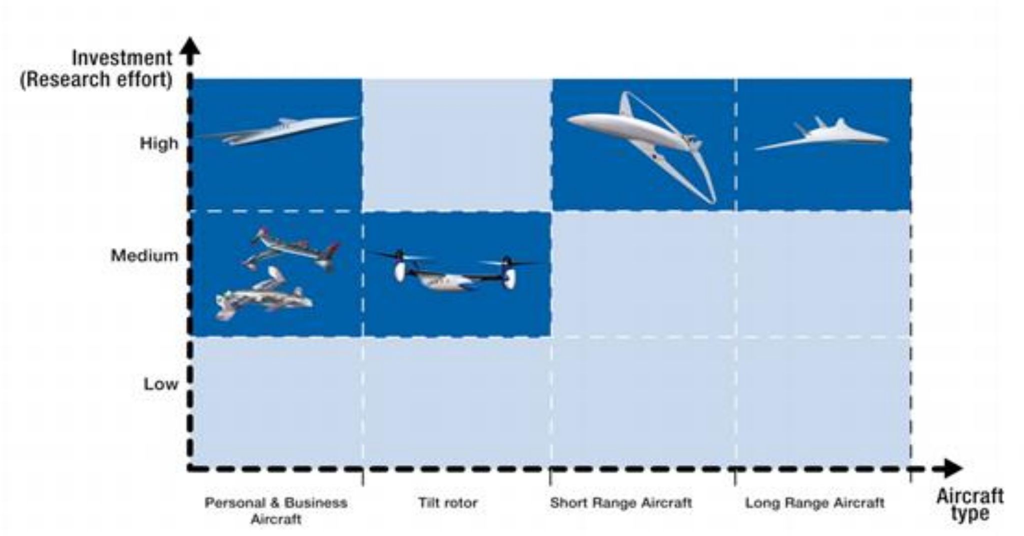


Figure 9.9 – Revolutionary aircraft configurations
Source 1: From Air Transport System 2050 Vision to Planning for Research and Innovation

Next are described as some of the revolutionary aircraft configurations that could be expected for the future:

- **Blended wing body (BWB)**: today's classical aircraft configurations feature separate structures for providing lift (wings) and carrying the payload (fuselage). This results in a heavier structure, additional wetted surface and associated viscous drag. The flying wing configurations are recognised as the most efficient aerodynamic solution, but presents challenges in many other areas, such as its great structural complexity, that could be mitigated with the development of advanced composite materials and production processes.

- **Prandtl joined-wing plane concept**: for a given wingspan and lift, the Prandtl-type biplane, with wings connected at the tip, could provide a theoretically lower induced drag during low-speed phases such as take-off, climb, descent and landing. Also, this radical change in configuration could provide a potential fuel burn reduction of 10%.

- **Flying-V**: promising flying wing-type concept that has recently attracted considerable attention, a V-shaped highly-swept double-wing configuration designed for a similar passenger number (314) and range as the A350. The two wings accommodate the passenger cabin, the cargo hold and the fuel tanks. With the same wingspan as the A350, it can use the same airport infrastructure. Similar to the BWB configuration, the Flying-V has a lower aerodynamic drag and is 20% more fuel-efficient than a comparable tube-and-wing aircraft. Based on an initial idea developed at Airbus, the Technical University of Delft in the Netherlands will continue to develop the concept further. The project is supported by KLM, which presented it at the 2019 IATA Annual General Meeting in Seoul.

- **Double-bubble fuselage**: as part of NASA's X-plane project, Aurora Flight Sciences designed the D8 aircraft concept, whose main feature is a "double-bubble" fuselage that can be thought of consisting of two blended side-by-side tubes. The wide flattened fuselage body generates additional lift. Therefore, the wings can be designed smaller and lighter to carry the aircraft weight, which leads to a significant fuel burn reduction relative to comparable conventional configurations. In addition, the engines attached at the rear of the fuselage allow the air to flow over the top of the aircraft and move through the engines which in return helps reducing the overall drag. This concept is known as boundary layer ingestion. The D8 configuration has the potential of achieving up to 20% of efficiency compared to the A320neo.

- **Tilt-rotor aircraft**: Tilt-rotors combine to some extent the hover advantages of helicopters with the higher-speeds of turboprop aircraft, overcoming the problem of helicopter speed being limited by the loss of main rotor efficiency at higher forward speeds. The next generation of tilt-rotors will feature a partially tilted wing to improve rotor efficiency at hover.

- **Personal air transport**: for personal air transport, short-range small aircraft that provide low emissions and easy handling could be used. Such aircraft would be operating along with others at lower altitudes and speeds with features as reduced weight, reduced fuel consumption, simpler maintenance or increased reliability. However, this concept will require the resolution of a number of major technological issues, including environmental control, ice protection systems and engine technology.

- **Supersonic business transport**: using supersonic business transport to link growing business metropolises in North America as well as in Europe and Asia would provide a potential reduction in flight time, being capable of travelling long distances in only a few hours. However, significant technological challenges remain, including:
  - Development of high-temperature carbon fibre materials;
  - Sonic boom overpressure on the ground;
  - Airport noise;
  - Easy to handle, reliable aircraft;
  - Low-emission, high-speed propulsion.

The previous aircraft configurations considered are only a few examples of the radical changes that are currently being studied. However, these revolutionary configurations could present challenges in the certification process as they present a great change compared to current configurations.

Aircraft certification is the process whereby an applicant requests approval from an aviation regulatory authority, such as the FAA or the European Aviation Safety Agency (EASA), for manufacturing a new aircraft model or making changes to an existing aircraft. Aircraft certification processes use approved standards, guidance, tests, methods, procedures as well as data submittals and plan documentation to achieve regulatory approval for aircraft type certification.

To certify the revolutionary aircraft configurations that are expected in the future, it will be necessary to improve current certification methods or to develop new ones to assure that these aircraft are safe and efficient. The certification methods that will be required are based on three pillars:

1. One pillar represents computational capabilities, which consist of high-speed supercomputers that can model the physics of air flowing over an object, be it a wing, a rudder or a full aeroplane. Improved computational tools would allow reducing costs, time, risk and it would provide a great increase in aircraft design efficiency and quality. Besides, unconventional configuration concepts could be explored more easily and with greater confidence during early design stages. Therefore, to certify new aircraft configurations through computational methods, it will be necessary to develop faster and more accurate algorithms.

   One of the main goals, which is expected to be achieved by improving computational tools, will be to certify new technology or vehicle concept with more limited use of ground or flight testing for validation. This will require the ability of the computational tools to predict absolute performance within known uncertainty bounds over the entire operating conditions.

2. A second pillar represents the experimental methods. In this case, scientists usually put a scale model of an object or part of an object (be it a wing, a rudder or an aeroplane) in a wind tunnel to take measurements of air flowing over the object. These measurements help improve the computer model, and the computer model helps inform about improvements to the aeroplane design, which can then be tested again in the wind tunnel. As the computational tools become increasingly reliable in predicting system performance, the role of wind tunnels should evolve towards physics-based testing for increased understanding of various flow phenomena and for developing extremely high-fidelity data for physical model development and code validation.

   Therefore, wind tunnels will continue to play a significant role in aircraft certification and testing, which will provide a significant reduction in costs and flight testing.

3. Finally, the third pillar is the flight testing of the design developed. The data recorded in the flight test can be used to validate and improve the computational and experimental methods used to develop the design in the first place.

   In the future, one of the main objectives will be to reduce the time required in this phase, since flight testing is the most expensive process and detecting errors in this phase could delay the whole certification process.

   The examples of new technologies given before applying in many areas like aerodynamics, propulsion, structures, materials, avionics, control and on-board systems as simulations, ground and flight test.

   Integration of all these technologies could be the greatest challenge and may require intermediate scale flight demonstrators before entry into commercial service of a certificated aircraft.

KEY TOPIC T9.4 CERTIFICATION PROCEDURES

The certification of an airliner is the final stage of the development process, and can also be the most complex, time-consuming and expensive.

The Type Certification (TC), i.e. the design approval for the model, should be complemented by the approvals by the Authority of the Design Organisation and of the Production Organisation (organisation demonstrates competence and compliance with regulatory requirements). The Authority empowered to approve products and organizations is an agency of an ICAO member state and is supposed to compile the respective requirements following Annex 8 to the ICAO Convention “Airworthiness of Aircraft” Part II Chapter 1 “Type Certification”. However, this is just the minimum requirements, so different countries might choose a range of levels of severity of the conditions.

To be granted the TC, the designer is asked to demonstrate the compliance to the Authority set of requirements, including analyses (aerodynamic, airframe loading, systems safety), structural tests, other ground tests (functional, fatigue, reliability), flight tests (performance, handling, flutter etc.). Applying for a TC is the start of the certification process and the timing is important because this is where the clock starts ticking. Part 23 aeroplanes generally have three years from the date of application to be certified; Part 25 aeroplanes have five years. The certification basis is structured in Mandatory Requirements, the applicable certification code in place at the time of TC application, e.g. CS-25 at Change 18. When a company applies for a type certificate, the rules that are in force at the time of application are the rules with which the applicant must comply. If, for example, the Authority changed the certification rules after someone applied for certification, requiring that icing tests be done with 100-micron freezing drizzle instead of the current 40-micron droplet size, the applicant would not have to meet that new regulation. This is where a protracted certification program can run into problems, because if there are delays that push the program beyond the three- or five-year limit, then the applicant has to apply for an extension and might have to comply with rules that took effect after the initial application. This is the case of the Japanese MRJ, still struggling after more than 10 years to complete the certification.

The flight testing for certification of a modern airliner takes about 3 000 flying hours over 3 to 5 years, involving 3 to 6 prototypes. Before the OEM flies a prototype of the design, the Authority will need to issue an experimental type certificate. Authority personnel will conduct a safety review and check that the aeroplane conforms to its design. A plan for test flying will cover all requirements. And before Authority test pilots fly in the aeroplane it must have flown through its full flight envelope. Flight testing is a challenging part of the certification program and it is difficult to compress without significantly increasing risks that could become delays and further costs. Although there has been much progress in ground testing and simulation, it is flight testing that is the ultimate proof that satisfies certification authorities. The increasing capabilities and complexity of successive generations of airliners mean that there are more hardware and software equipment and functions to test, and the progress is absorbed in performing increased testing in a comparable period.

Besides the certification programme for the aircraft, separate certification requirements are specified for engines as well as for propellers and Auxiliary Power Units (APUs). The time for the development and TC of a new engine is now around 5-6 years and about 10-15 test prototypes are employed (and sometimes destroyed) in-ground tests (including subassemblies tests), altitude bench tests and flight tests on the aeroplane equipped.

The preceding account assumes that the certification process concerns only essential issues without duplication or unexpected requirements from different certification responsible agencies. Before the 90s the standard recognized level worldwide was that of FARs, the regulations issued by US' FAA. The harmonization somehow existed, the first European unified JARs (e.g. JAR-25 'Large Airplanes') were nothing else than the declared transcription of the equivalent FARs. There are, however, several areas in which variations and additions to FAR Part 25 have been considered necessary to reach an agreement on a code acceptable to JAA participating countries, and these differences (Complementary Technical Conditions) were indicated into the specifications. After the creation of EASA in 2003, the requirements began to diverge, as can be observed in an ever-growing list of Significant Standard Differences (SSD) between U.S. Code of Federal Regulations (CFR), Part 25 and Joint Aviation Regulation (JAR), Part 25, or European Aviation Safety Agency (EASA) Certification Specifications (CS) 25 published by FAA (see www.faa.gov/aircraft/air_cert/design_approvals/transport/transport_intl/sd_list/ssd_nonssd_list/).

Similar negative effects would produce a proposal to grandfather in a large number of current aircraft designs in terms of emissions. If such a grandfathering clause is adopted, then any standard applicable beginning in 2020 would cover only 5% of the global fleet in 2030.

The "grandfathering right" is an Anglo-Saxon general legal principle, still controversially applied in aviation, besides in the certification practices, also in allocating airport slots. Another example of "grandfathering", this time perfectly justified, was introduced when EASA was established through Commission Regulation (EC) No 1702/2003 of 24 September 2003. It contains a grand-fathering mechanism for certain type certificates issued before 28 September 2003 by the Member States. These type certificates are deemed to have been issued following Regulation no 1702/2003 and, as a consequence, EASA does not need to issue new type certificates for the related products. However, since 28 September 2003, all changes to these type certificates or associated datasheet must be approved by EASA.

EASA delivers the primary certification for European aircraft models which are also being validated in parallel by foreign authorities for operation in their airspaces, e.g. the FAA for the US or TCCA for Canada. Conversely, EASA will validate the FAA certification of US aircraft models (or TCCA certification of Canadian models) according to applicable Bilateral Aviation Safety Agreements between the EU and USA, respectively Canada.

As an example, the existing "Agreement Between the United States Of America And The European Community On Cooperation In The Regulation Of Civil Aviation Safety" (EU_USA_BASA/en 1 - Revision 3_ March 2016) is continuously extended and improved to cover more situations and to provide regulatory cooperation and transparency. The parties established a Bilateral Oversight Board which is responsible for ensuring the effective functioning of the Agreement. Based on this, a more detailed "Technical Implementation Procedures for Airworthiness and Environmental Certification" (known as TIP) was signed between FAA and EASA, currently at Revision 6 from September 22, 2017. As part of the continued maintenance of confidence in each other's system, the FAA and EASA develop procedures to share and exchange information regarding airworthiness and environmental standards, certification systems, etc. The FAA and EASA recognise that certain approvals can benefit from mutual acceptance. There are specific approvals that will be accepted by the Validating Authority without the issuance of its approval, and therefore no application for validation is required. APPENDIX D of TIP lists 15 FAA and EASA mutually recognized airborne systems standards considered to be equivalent to issue approvals under TIP. This is a good start but far too modest. The reverse, the non-accepted differences, lead to extra efforts and spending in the certification process an avoidable waste.

A harmonisation programme, initialised years ago, should be accelerated to eliminate the differences, moving things toward the so-called WORLDWIDE harmonization.
A good step was achieved on September 16, 2015, when the leadership of the certification services/departments of the Agência Nacional de Aviação Civil (ANAC) of Brasil, European Aviation Safety Agency (EASA), Federal Aviation Administration (FAA), and Transport Canada Civil Aviation (TCCA) signed a charter establishing the CERTIFICATION MANAGEMENT TEAM (CMT). The CMT oversees and manages collaborative efforts to permit the development and implementation of regulatory and policy solutions common to certification issues and support greater harmonization. In May 2016, the CMT signed its Collaboration Strategy (see https://www.faa.gov/about/office_org/headquarters_offices/avs/offices/air/transformation/certification_strategy/media/cmt_strategy.pdf).
Also, the existing co-operation structure of 18 national agencies in the general field of safety, the Safety Management International Collaboration Group (SM ICG) might be extended as scope to cover Certification as well. SM ICG was founded by FAA, EASA and TCCA and is a cooperation between many regulatory authorities to promote a common understanding of Safety Management Systems /State Safety Program principles and requirements, facilitating their implementation across the international aviation community. (The current core membership of the SM ICG includes the Aviation Safety and Security Agency (AESA) of Spain, the National Civil Aviation Agency (ANAC) of Brazil, the Civil Aviation Authority of the Netherlands (CAA NL), the Civil Aviation Authority of New Zealand (CAA NZ), the Civil Aviation Authority of Singapore (CAAS), Civil Aviation Department of Hong Kong (CAD HK), the Civil Aviation Safety Authority (CASA) of Australia, the Direction Générale de l'Aviation Civile (DGAC) in France, the Ente Nazionale per l'Aviazione Civile (ENAC) in Italy, the European Aviation Safety Agency (EASA), the Federal Office of Civil Aviation (FOCA) of Switzerland, the Finnish Transport Safety Agency (Trafi), the Irish Aviation Authority (IAA), Japan Civil Aviation Bureau (JCAB), the United States Federal Aviation Administration (FAA) Aviation Safety Organization, Transport Canada Civil Aviation (TCCA), United Arab Emirates General Civil Aviation Authority (UAE GCAA), and the Civil Aviation Authority of United Kingdom (UK CAA). Additionally, the International Civil Aviation Organization (ICAO) is an observer of this group.
The main challenges to wider certification are not only agreeing on common standards but also ensuring that they are equally or at least equivalently applied by all parties.

3.3 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. The aims of the reduction of environmental impact can be either compatible or contrasting at the (i) local or (ii) global level. For example, the reduction of fuel consumption is beneficial in all cases because it reduces emissions. The design for high efficiency and low fuel consumption is different at low speeds (glider like configuration) and high speeds (swept wings) and thus lowering local emissions is a trade-off with lowering global emissions. Concerning the type of emissions, CO_2, NOx and particles that all result from the combustion process again compromises may be necessary among the amount of each that is produced.

The noise regulations of ICAO have long been the standard, although local airports can apply stricter standards that aircraft manufacturers cannot afford to ignore; in principle, a single noise standard that could be adhered to worldwide would be ideal. Concerning emissions, like other aspects of global warming and climate change, progress requires considerable international negotiation, with the European Union often the most active promoter. The emergence of the ICAO scheme on emissions is even more desirable than on noise because aircraft emissions are a global issue that cannot be solved at a local level like noise.

The environmental effects of aviation could be greater in regions of higher traffic density like Europe and the US; rightly so these are the regions of the world that apply stricter environmental standards, applying to new aircraft, and requiring older non-compliant aircraft either to be modified or retired from service. In the case when the modification of older aircraft for compliance with new environmental standards is not economical, many of them are sold to operate in other regions of the world. Thus, some less developed regions, with lower air traffic densities, operate older aircraft with larger environmental impact, that may or may not be felt locally, but certainly contributes to global pollution. These older aircraft can also pose some safety issues.

KEY TOPIC T9.5 AVIATION EFFECTS ON THE ENVIRONMENT

All transport, including air transport, causes deterioration of the natural environment and has a negative impact on people. The effects of aviation on the environment can be considered at two levels: locally as the emission and noise near airports; 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. The most important dangers which follow from the functioning of an airport are noise emission and air pollution, including unfavourable climate changes, both globally and locally. The reduction of environmental impact aims to either compatible or contrasting at the local or global level (IATA, 2018; IATA, 2019; ICAO, 2016; ICAO, 2017).

Impact of air transport on the environment analysed on the local level is mainly connected with the noise generated by taking-off and landing aircraft. On a regional level, the harmful influence of aviation is connected with polluting the air with reactive chemicals occurring close to the place of their emission. In global scale, due to an increasing number of air flights there occur climate changes in the whole globe connected with migration of pollution with compounds of small reactivity introduced to the environment at cruise altitudes, which is on the border of troposphere and stratosphere.

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. This is a cheap product of the distillation of crude oil, it does not require refining, thanks to which it has gained popularity in aviation. This type of fuel has the lowest freezing point of all the fuels (below minus 50°C) and properties facilitating the start of the cold engine, thanks to which it is safe for use in a cold climate. Typical exhaust gases from aviation engines contain 4 components: nitrogen (N_2), oxygen (O_2), carbon dioxide (CO_2) and water vapour. Moreover, a small volume of exhaust consists of a mixture of carbon monoxide (CO) and unburned hydrocarbons (UHC). As a result, there occur nitrogen oxides (N_2O, NO, NO_2 – further referred to as NyOx) which cause the occurrence of ozone and photochemical smog. Emissions of NyOx and other pollutions can be limited maintaining stoichiometric conditions of combustion in respectively low temperature, below 800°C. However, it is not possible regarding often changes of the power level of the engine, especially in the initial and final phases of the flight and providing high temperature which is necessary for steady combustion (Lefebvre et al., 2010).

Taking-off and landing aircraft are a source of noise which is considered to be environmental pollution following applicable legislation. Similar to chemical pollution, exceeding permissible standards of noise level has a negative impact on the surroundings and their inhabitants. A taking-off aircraft produces noise of about 120 dB, close to the threshold of pain (130 dB). There have been attempts to limit the noise emission by imposing decrease of aviation engines thrust during flights over populated areas and by introducing no flight zone (for example, over national parks). However, the obtained environmental effect would not balance the increasing number of flights.

Noise has a negative impact on the health of the people who live close to airports. This impact on human health can be divided into auditory health effects and non-auditory health effects. Auditory health effects include ongoing hearing loss connected with damages of the inner ear. However, non-auditory health effects include, first of all, cardiovascular diseases (such as high blood pressure, coronary heart disease). Long-term expose of inhabitants to permanent noise leads to the occurrence of neuroses, sleep disorders and low effective intellectual activities. It has been proved that people who live near airports bear health consequences recalculated at hundreds of USD per capita a year. For a sample airport with more than 400,000 operations a year, at the airport boundary, total yearly environmental damages range from $290 per person to $1200 per person ($860 mean) (Wolfe et al, 2014).

The noise regulations of ICAO have long been the standard, although local airports can apply stricter standards that aircraft manufacturers cannot afford to ignore; in principle, a single noise standard that could be adhered to worldwide would be ideal. Concerning emissions, like other aspects of global warming and climate change, progress requires considerable international negotiation, with the European Union often the most active promoter. The emerging of the ICAO scheme on emissions is even more desirable than on noise because aircraft emissions are a global issue that cannot be solved at a local level like noise.

Modern solutions directed to reduce aircraft impact for the environment was the subject of two biggest programs concerning aviation implemented by the European Union. One of them was SESAR JU (SESAR, 2006; WWW. SESAR JU) which supposed development of the solutions of a 10-time-increase of the safety level, a 3-time-increase of airspace capacity, reduction of costs connected with air traffic by 50% and decreasing of air transport impact on the natural environment by 10%. The other program was Clean Sky 2 (WWW. Clean Sky), a continuation of the Clean Sky program, 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) (WWW. SESAR JU).

T9.5.1 Contaminants

CONTAMINANTS FROM AIRCRAFT ENGINE EMISSIONS

- Commercial air travel is expected to double in the next 20 years, which will, in turn, increase the amount of contaminants emitted to the atmosphere. The following contaminants are emitted during the different phases of operation:

- NITROGEN OXIDES (NO_x) – which includes nitrogen oxide (NO) and nitrogen dioxide (NO_2);
- CARBON MONOXIDE (CO)
- UNBURNED HYDROCARBONS – which have almost been completed eliminated from the exhaust stream due to newer engine technologies
- SULPHUR OXIDES
- PARTICULATE MATTER (PM) – which leaves the exhaust as carbon black soot
- VOLATILE ORGANIC COMPOUNDS (VOCS) – such as benzene and acrolein
- OZONE (O3)– which is formed from the nitrogen oxides and volatile organic compounds emitted
- SEMI-VOLATILE ORGANIC COMPOUNDS (SVOCS)
- METALS

- NOISE – this contaminant is discussed in the Aircraft Noise section of the ICAO site ODOUR

Most of the focus of international efforts have been on the reduction of NO_x so far (ICAO has an engine certification standard for NO_x which is contained in Annex 16 — *Environmental Protection, Volume II — Aircraft Engine Emissions* to the Convention on International Civil Aviation). Further assessment of the impact of some of these contaminants (for example, particulate matter and metals) needs to be conducted to assess the risk to human health and to further the goal of reducing emissions.

Besides NO_x, ICAO has established limits for emissions of CO and unburned hydrocarbons in Annex 16, Volume II. This volume also contains provisions regarding smoke and vented fuel.

Auxiliary power units are also sources of contaminants. However, they are not certified for emissions and it is difficult to estimate emissions from these sources as manufacturers consider the emission rate information proprietary.

Aircraft engine emissions and auxiliary power units are the only sources under the remit of ICAO.

Contaminants from Airports and Associated Sources

Airports also release contaminants from activities such as:

- Ground service equipment;
- Motor vehicles (parking, road traffic);
- Construction;
- Boilers;
- Generators;
- Airport fire training facility;
- Food preparation;
- Engine testing;
- Electricity;
- De-icing;
- Fuel storage facilities.

The contaminants listed above can also be found emitting from airport sources. The VOCs emitted may vary for those emitted by aircraft depending on the fuels used in-ground service and road traffic vehicles, and fire training exercises.

HEALTH EFFECTS

Exposure to the contaminants listed above can result in serious health effects. Table 9.2 presented below lists some of these effects. Local and regional air quality officials are responsible for creating standards to protect human health from the adverse effects of these contaminants.

Pollutant	*Representative Health Effects*
Ozone	Lung function impairment, effects on exercise performance, increased airway responsiveness, increased susceptibility to respiratory infection, increased hospital admissions and emergency room visits, and pulmonary inflammation, lung structure damage.
Carbon Monoxide	Cardiovascular effects, especially in those persons with heart conditions (e.g., decreased time to onset of exercise-induced angina).
Nitrogen Oxides	Lung irritation and lower resistance to respiratory infections
Particulate Matter	Premature mortality, aggravation of respiratory and cardiovascular disease, changes in lung function and increased respiratory symptoms, changes to lung tissues and structure, and altered respiratory defense mechanisms.
Volatile Organic Compounds	Eye and respiratory tract irritation, headaches, dizziness, visual disorders, and memory impairment.

Table 9.2A – Representative health effects of air pollutants

Pollutant	*Representative Environmental Effects*
Ozone	Crop damage, damage to trees and decreased resistance to disease for both crops and other plants.
Carbon Monoxide	Similar health effects on animals as on humans.
Nitrogen Oxides	Acid rain, visibility degradation, particle formation, contribution towards ozone formation.
Particulate Matter	Visibility degradation and monument and building soiling, safety effects for aircraft from reduced visibility.
Volatile Organic Compounds	Contribution towards ozone formation, odors and some direct effect on buildings and plants.

Table 9.2B – Representative environmental effects of air pollutants
Source: Evaluation of Air Pollutant Emissions from Subsonic Commercial Jet Aircraft, EPA

The following diagram (Figure 9.10) illustrates the percentage of deposition of particulate matter of a specified particle diameter that will reach different segments of the respiratory system.

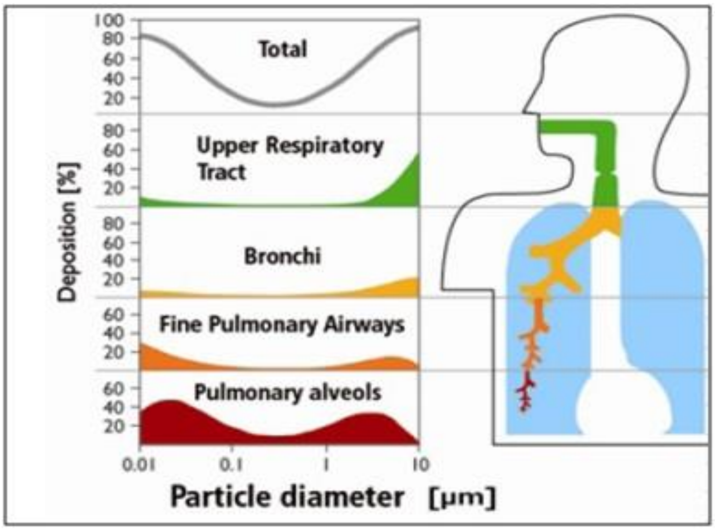


Figure 9.10 – Polluting particles matter
Source: ICAO Information Paper CAEP-SG/ 20082-IP/05

ENVIRONMENTAL EFFECTS

Aircraft and airport emissions can also have serious effects on the environment. These contaminants can affect crop productivity and ecosystem response. In particular, NO_x in the troposphere can contribute to ground-level ozone, excess nitrogen loads to sensitive water bodies, and acidification of sensitive ecosystems according to the U.S. Environmental Protection Agency.

Particulate matter contributes to visibility and soiling issues. They play a key role in creating the hazy smog often found surrounding cities on sunny, warm, dry days.

VOCs also contribute to ozone formation and damage plants, crops, buildings and materials when released at high levels.

ICAO Initiatives to Improve Local Air Quality

One of the initiatives that ICAO has undertaken to improve air quality is the creation (and continued updating) of the document Airport Air Quality Guidance Manual. The manual provides guidance to assist with the assessment of airport emission sources, emission inventories and emissions allocation. The first step to addressing local air quality is to obtain an accurate estimate of the types and amounts of contaminants being introduced to the airshed. Then efforts to reduce these emissions can be pursued.

ICAO is also promoting numerous mitigation measures to reduce local air quality emissions. These mitigation measures include technology and standards; operational measures; market-based measures; and alternative fuels.

AVIATION EMISSIONS

Aviation emissions in the context

In 2012, aviation represented 13% of all EU transport CO_2 emissions and 3% of the total EU CO_2 emissions. It was also estimated that European aviation represented 22% of global aviation's CO_2 emissions. Similarly, aviation now comprises 14% of all EU transport NO_X emissions and 7% of the total EU NO_X emissions. In absolute terms, NO_X emissions from aviation have doubled since 1990, and their relative share has quadrupled (Table 9.3), as other economic sectors have achieved significant reductions (Figure 9.11):

	Units	2005	2014	2017	2040 Base forecast	
					Advanced Tech	Frozen Tech
			(% change since 2005)			
Average fuel consumption of commercial flights	kg per passenger kilometre[1]	0.0355	0.0294	0.0270	0.0210	0.0238
	litres per 100 passenger kilometres[1]	4.4	3.7	3.4	2.6	3.0
			(-17%)	(-24%)	(-41%)	(-33%)
CO_2	million tonnes	141	148	163	198	224
			(+5%)	(+16%)	(+40%)	(+59%)
NO_x	thousand tonnes	669	749	839	972	1358
			(+12%)	(+25%)	(+45%)	(+103%)
HC	thousand tonnes	55	53	57	58	
			(-4%)	(+3%)	(+6%)	
CO	thousand tonnes	110	102	108	99	
			(-7%)	(-2%)	(-9%)	
volatile PM	thousand tonnes	4.1	4.5	4.9	6.6	
			10%	21%	61%	
non-volatile PM	thousand tonnes	3.2	2.9	2.9	2.9	
			-11%	-9%	-9%	

1 Kilometres represent the actual flown distance between origin and destination

Table 9.3 – Summary of emission indicators based on IMPACT data

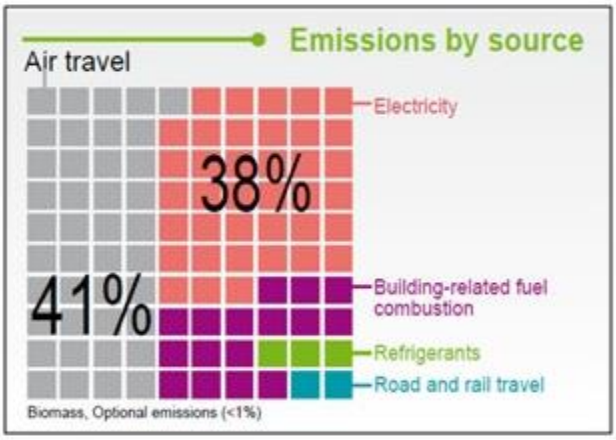


Figure 9.11 – Emissions by source (Source: ICAO).

Emissions are expected to increase further

The main aircraft engine emissions are considered here in terms of either full-flight (gate-to-gate), or a landing-take-off cycle below 3,000 feet for local air quality purposes.

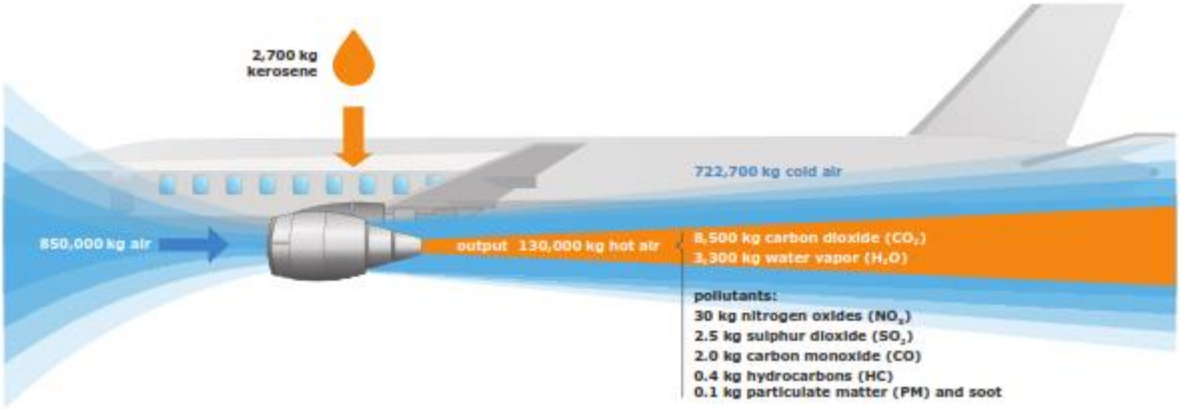


Figure 9.12 – Emissions from a typical two-engine jet aircraft during 1-hour flight with 150 passengers
Source: FOCA

Aircraft CO_2 emissions (Figure 9.12) increased from 88 to 156 million tonnes (+77%) between 1990 and 2005 according to the data reported by EU28 and the EFTA Members States to the United Nations Framework Convention on Climate Change (UNFCCC). According to data from the IMPACT emissions model, CO_2 emissions increased by 5% between 2005 and 2014. The increase in emissions is, however, less than the increase in passenger-kilometres flown over the same period (2005 to 2014). This was due to an improvement in fuel efficiency driven by the introduction of new aircraft, the removal of older aircraft, and improvements in operational practice. The average fuel burn per passenger kilometre flown for passenger aircraft, excluding business aviation, went down by 19% over this same period. However, projections indicate that future technology improvements are unlikely to balance the effect of future traffic growth. Under the base traffic forecast and advanced technology improvement rate, CO_2 emissions increases by 44% from 144 Mt in 2005 to 207 Mt in 2035.

NO_X emissions have also increased significantly: +85% (316 to 585 thousand tonnes) between 1990 and 2005 according to the Convention on Long-Range Transboundary Air Pollution (CLRTAP) data from the UN Economic Commission for Europe, and +13% between 2005 and 2014 according to IMPACT data. Where IMPACT is a model developed for use by the California Air Resources Board (CARB), to predicts concentrations on a regional grid. Under the base air traffic forecast and assuming an advanced NO_X technology improvement rate, emissions would reach around 920 thousand tonnes in 2035 (+42% compared to 2005).

Emissions of HC, CO and non-volatile PM have decreased between 2005 and 2014, while full flight emissions of volatile PM have increased by 7%. However, the total emissions of each of these pollutants are forecast to increase over the next twenty years.

Emissions Monitoring Plan

An Emissions Monitoring Plan (Figure 9.13) is a collaborative tool between the State and the aeroplane operator that identifies the most appropriate means and methods for CO2 emissions monitoring on an operator-specific basis and facilitates the reporting of the required information to the State. The State and aeroplane operator should maintain clear and open communication during the development of the plan. Working collaboratively during Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) preparation and implementation reduces potential errors and increases effectivity.

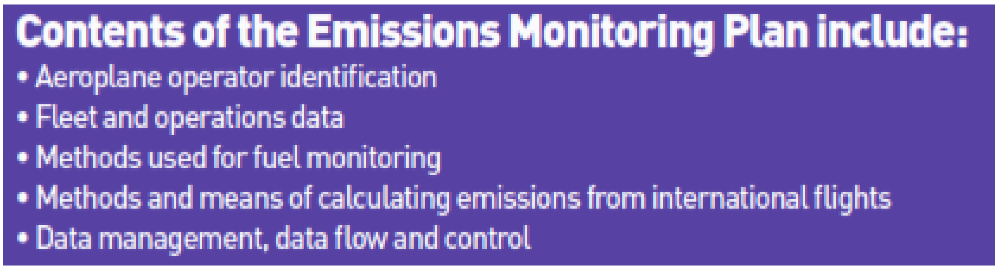


Figure 9.13 – Emissions monitoring

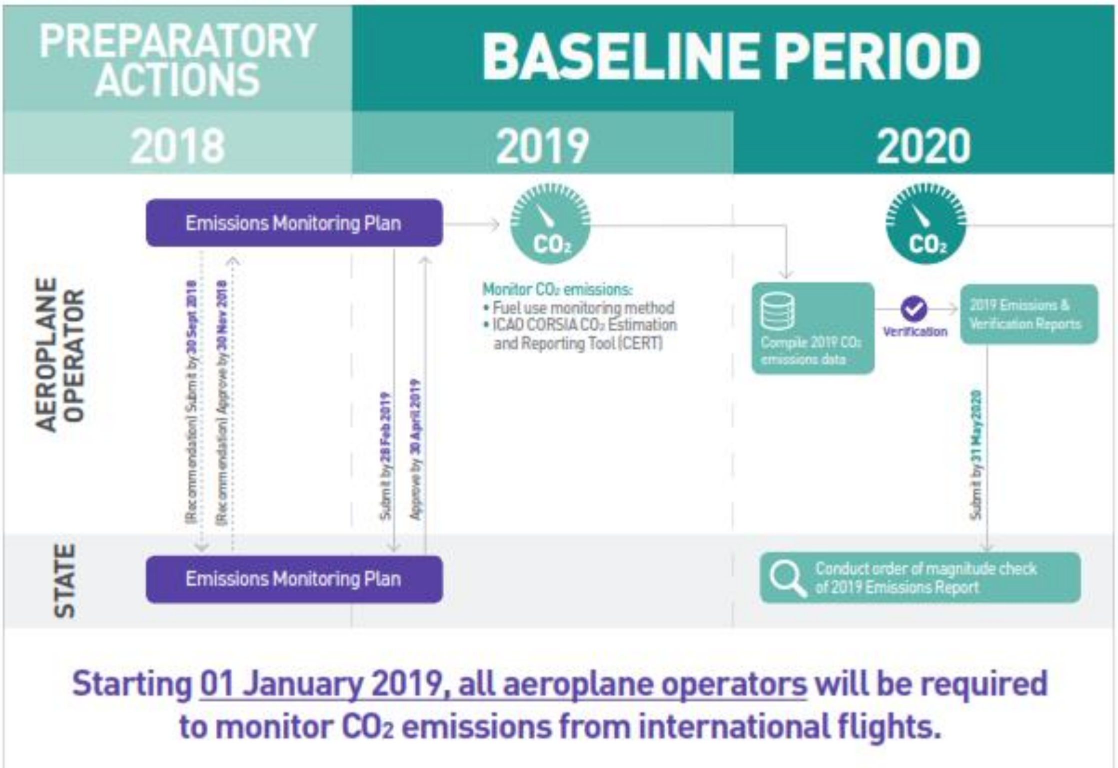


Figure 9.14 – Implementation of emissions monitoring

Emissions Monitoring Options

Draft CORSIA Standards and Recommended Practices (SARPs) request (Figure 9.14) an aeroplane operator to monitor and record its fuel use from international flights to determine its annual CO_2 emissions, following an eligible monitoring (Figure 9.15) method approved by the State to which it is attributed.

To simplify the estimation and reporting of CO_2 emissions from international flights for operators with a low level of activity in fulfilling their monitoring and reporting requirements, ICAO has developed the CORSIA CO_2 Estimation and Reporting Tool (CERT).

CERT also supports all aeroplane operators in determining if their CO_2 emissions are under the threshold to be exempt from the CORSIA reporting requirements (= 10 000 tonnes of CO_2 annually).

Aeroplane operators who emit = 500 000 tonnes of CO_2 annually in 2019 and 2020 from international flights, are not eligible to use CERT to monitor and report emissions and must choose one of the five eligible methods for Fuel Use Monitoring (the five methods are equivalent and there is no hierarchy for selecting a method).

However, all aeroplane operators can use CERT to fill in any CO_2 emissions data gaps, regardless of their emissions levels.

Emissions can be taxed (Table 9.4), depending on the airport (Table 9.5) and are generally higher for older aircraft (Figure 9.16).

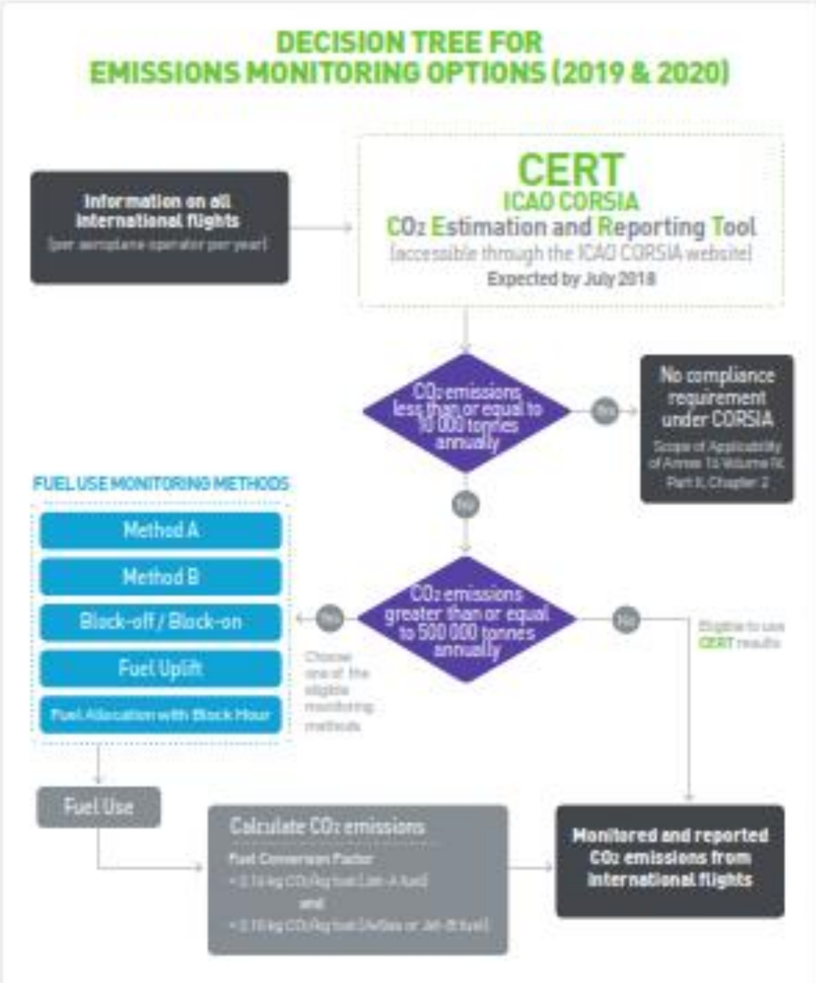


Figure 9.15 – Emission Monitoring Methods

Emissions Costs

Aircraft Type	Cost per LTO (Euros/LTO)	Aircraft Type	Cost per LTO (Euros/LTO)
B737	296	DH8	225
B757/767	583	ATR72	108
B787	872	ERJ-190	177
A320	254	MD-90	315
A321	375	MD-82/83	311
A330	756	Business jets	167

Table 9.4 – Average emission cost for commonly used aircraft types at Taipei Songshan Airport

Metropolitan Area	NO_x%	VOC%	$PM_{2.5}$%
Washington, DC	1.22	0.57	0.21
Philadelphia	0.64	0.35	0.20
New York	1.40	0.42	0.41
Denver	1.42	0.54	0.31
San Francisco	1.57	0.63	0.29
Dallas	1.76	0.58	0.23
Minneapolis	1.07	0.59	0.39
Chicago	1.27	0.49	0.36

Table 9.5 – Aircraft Emissions Contribution to Metropolitan Area Emissions Inventories

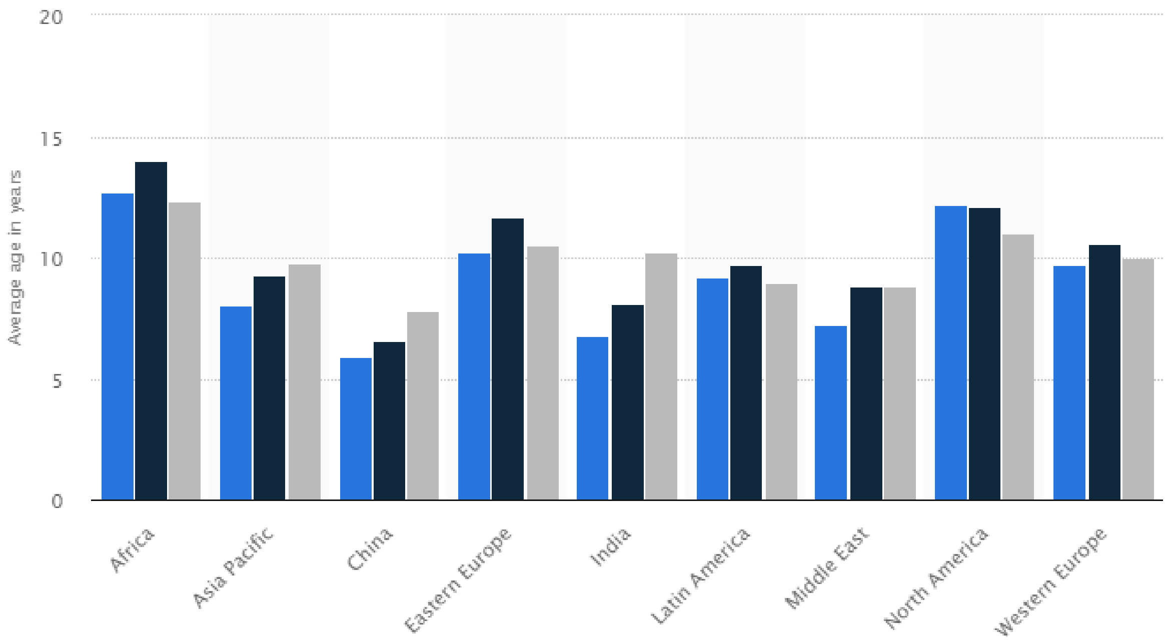


Figure 9.16 – Average age of the global operating aircraft fleet from 2018 to 2028, by region or country (in years)

Exhaust Emissions

For almost all types of emissions, narrow-body aircraft emit fewer greenhouse gasses per seat. Variations between single-aisle (narrow-body) and twin-aisle (wide-body) aircraft as well as between different airlines can be seen depending on the type of emission. Since the various airlines used many of the same aircraft types, variations within each emissions species are similar. Carbon Dioxide emissions followed the trend of fewer emissions from narrow bodies across all air fleets examined. The highest emitter of CO2 was American widebodies, 28.5534 kg of CO2 per seat. The lowest emitter was US Airways narrowbodies at 18.5989 kg per seat (Figures 9.17 – 9.22)

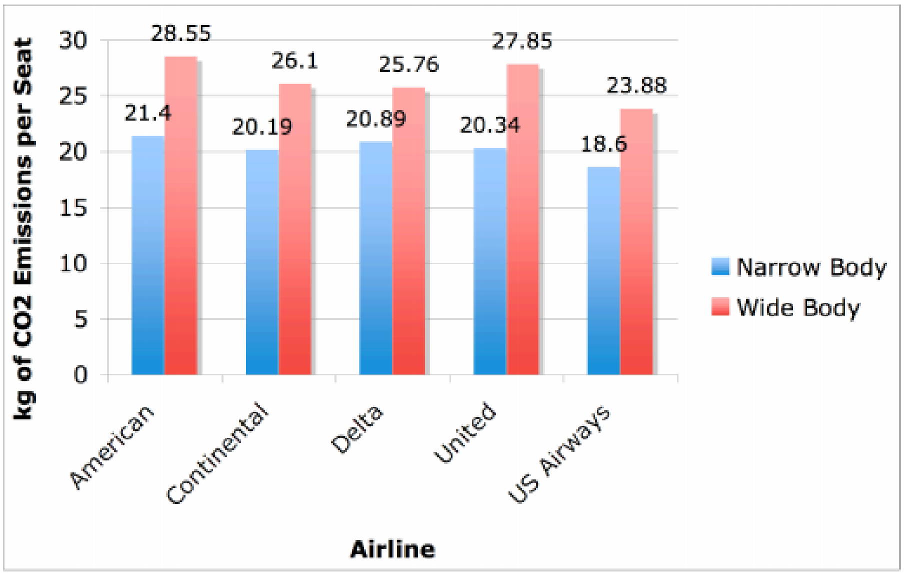


Figure 9.17 – Average CO2 Emissions per Seat for Narrow and Wide Body Aircraft for Each Airline

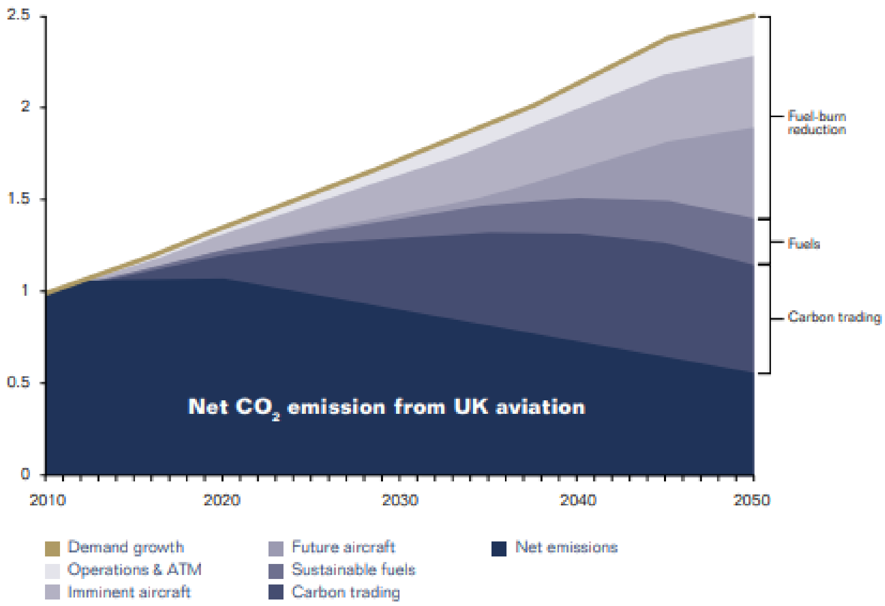


Figure 9.18 – Sustainable Aviation Carbon Roadmap (Source: Sustainable Aviation CO2 Roadmap)

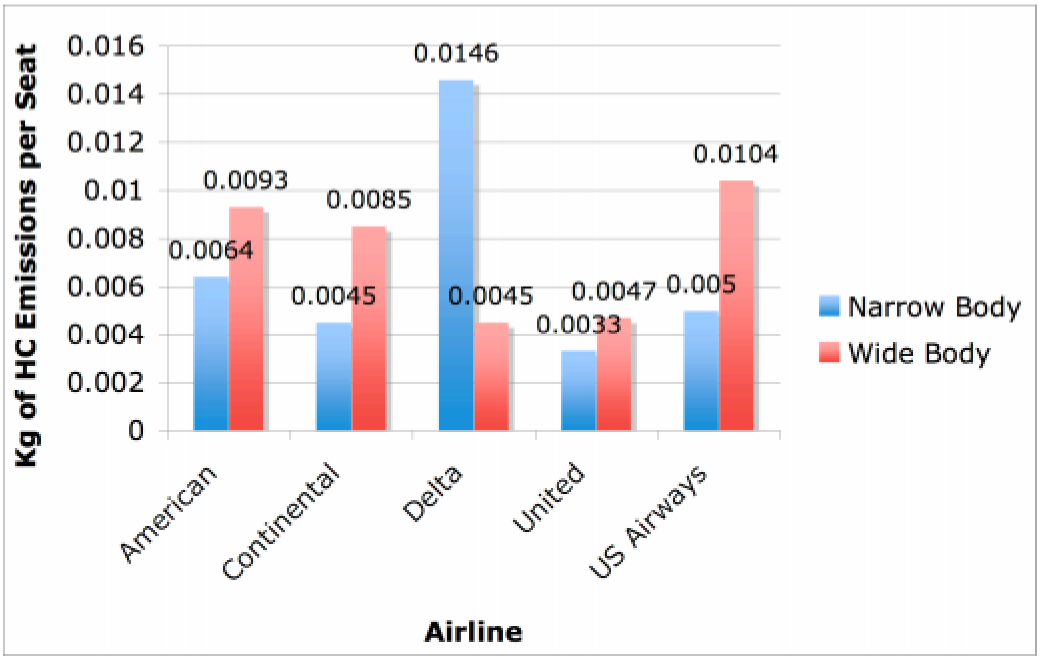


Figure 9.19 – Average HC Emissions per Seat for Narrow and Wide Body Aircraft for Each Airline

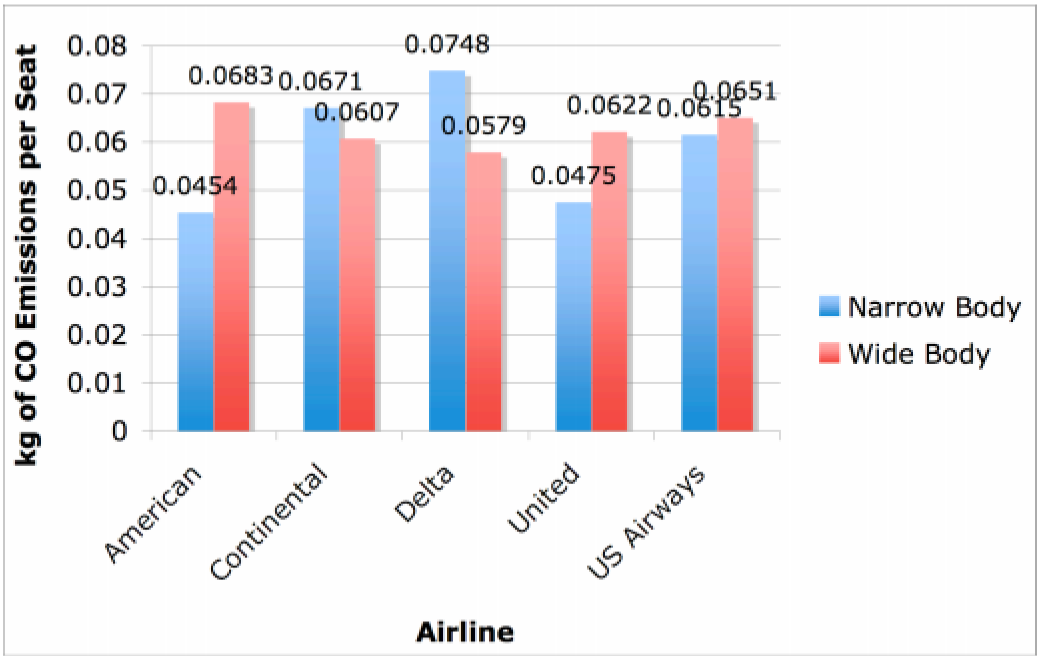


Figure 9.20 – Average CO Emissions for Narrow and Wide Body Aircraft for Each Airline

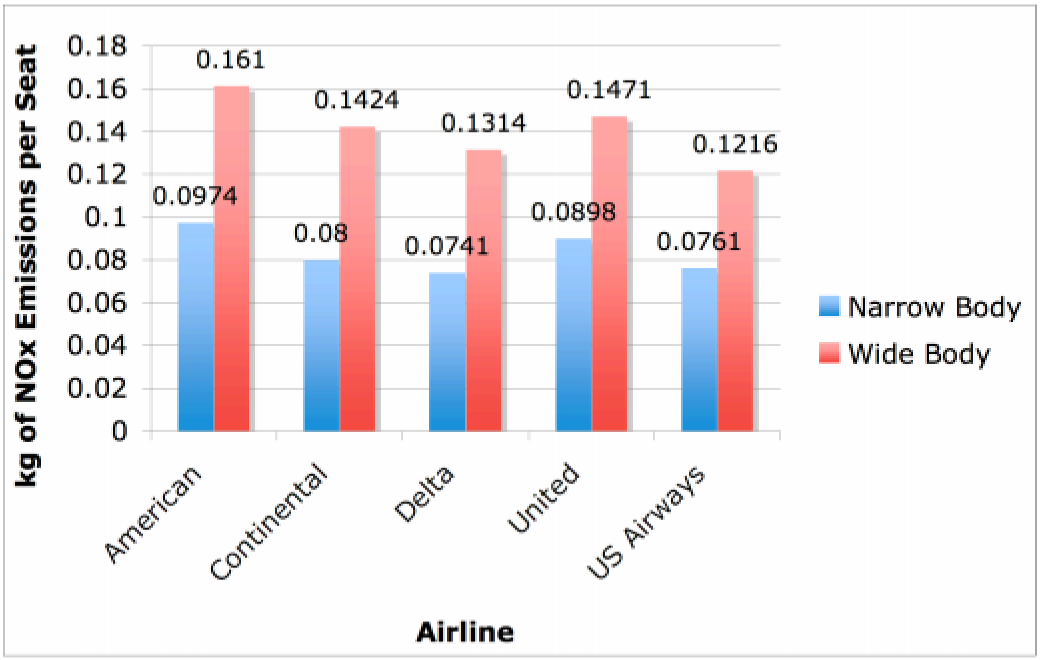


Figure 9.21 – Average NOX Emissions per Seat for Narrow and Wide Body Aircraft for Each Airline

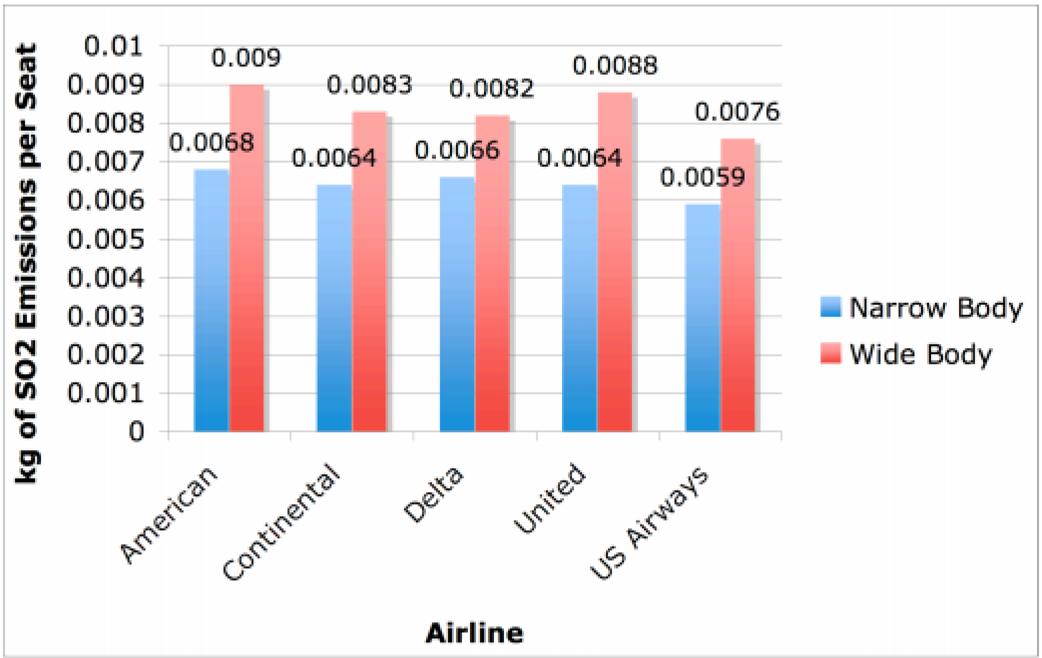


Figure 9.22 – Average SO2 Emissions per Seat for Narrow and Wide Body Aircraft for Each Airline

FUEL

The most basic of the results was which type of aircraft burned more fuel in an hour of operation. In overall fuel consumption for each airline, wide-body aircraft burned more gallons per hour for all airlines (Figure 9.23).

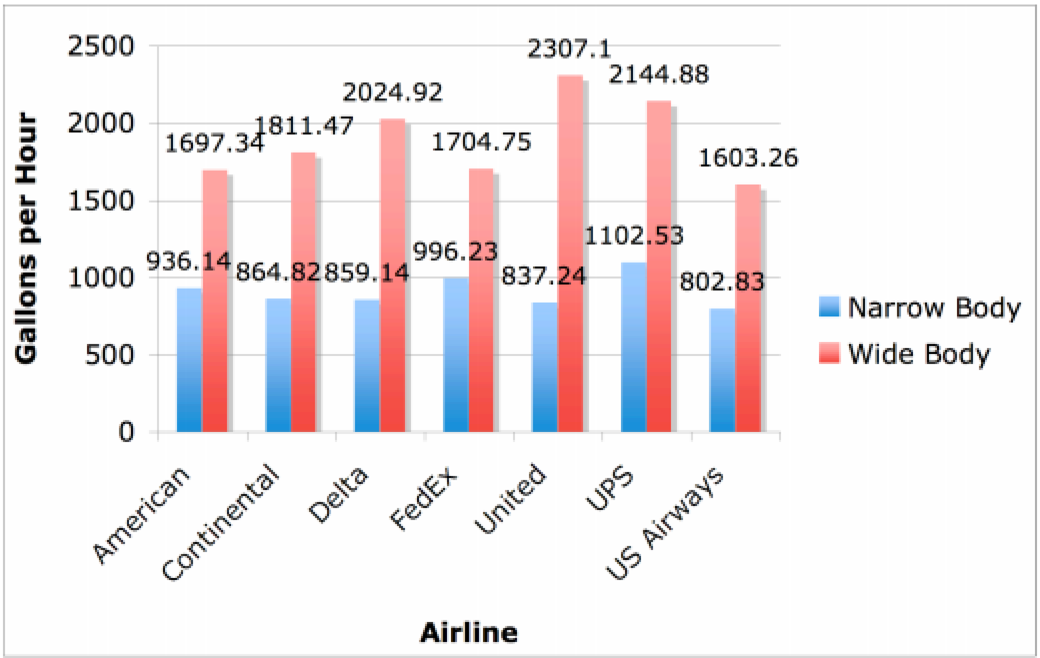


Figure 9.23 – Gallons of Fuel per Hour for Each Airline Broken Down by Narrow and Wide Body Aircraft

Fuel Efficiency

The fuel efficiency of aviation has developed continuously since the 1960s. Studies were undertaken by the International Council on Clean Transportation (ICCT)6 found that the gains were particularly large in the 60s and 70s, and though efficiency gains have slowed since 1990, they are estimated to be less than 50% of 1960 levels. A further study has been made by the International Coordinating Council of Aerospace Industries Associations (ICCAIA) using a metric of fuel burn per person per 100km. This interpretation suggests that fuel efficiency gains have continued since 2000, perhaps driven by a greater focus on improving load factors, which would not be accounted for in the ICCT model (Figure 9.24 – 9.26).

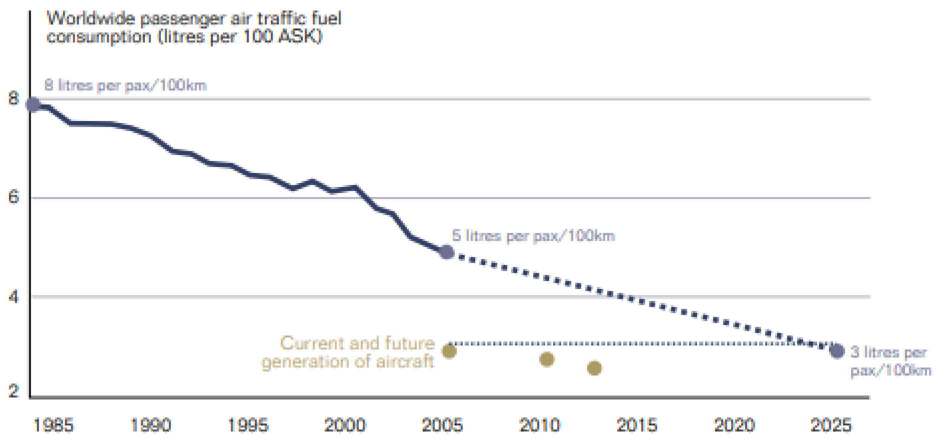


Figure 9.24 – Fuel Efficiency and Forecast v Today (Source: ICAO and ICCAIA)

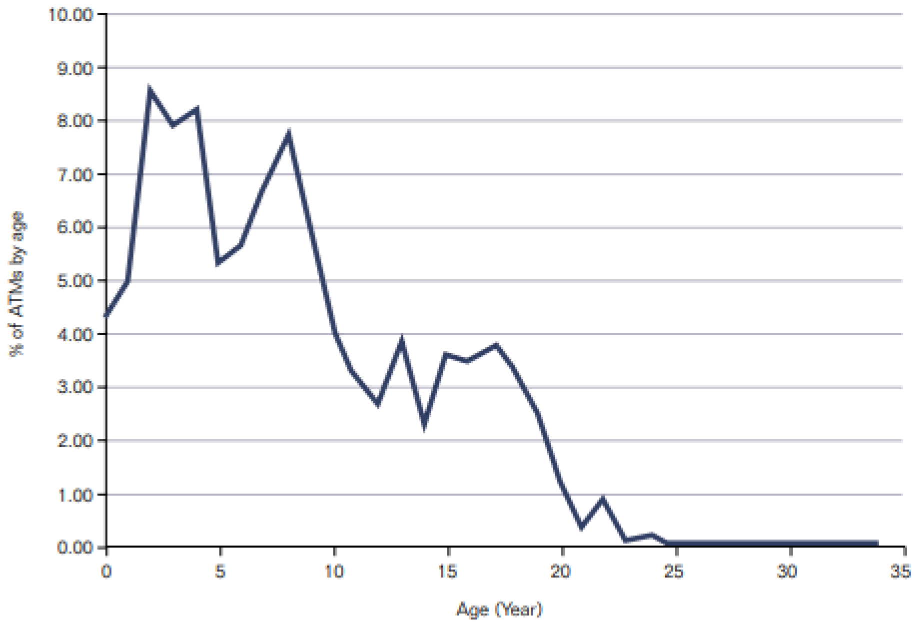


Figure 9.25 – UK Fleet, Average Age (Source: EMRC/AEA (for DfT)) Figure 9.26 - Europe to North America Proportion of Flights in 2015 by Technology Age (Source: Capstats.com)

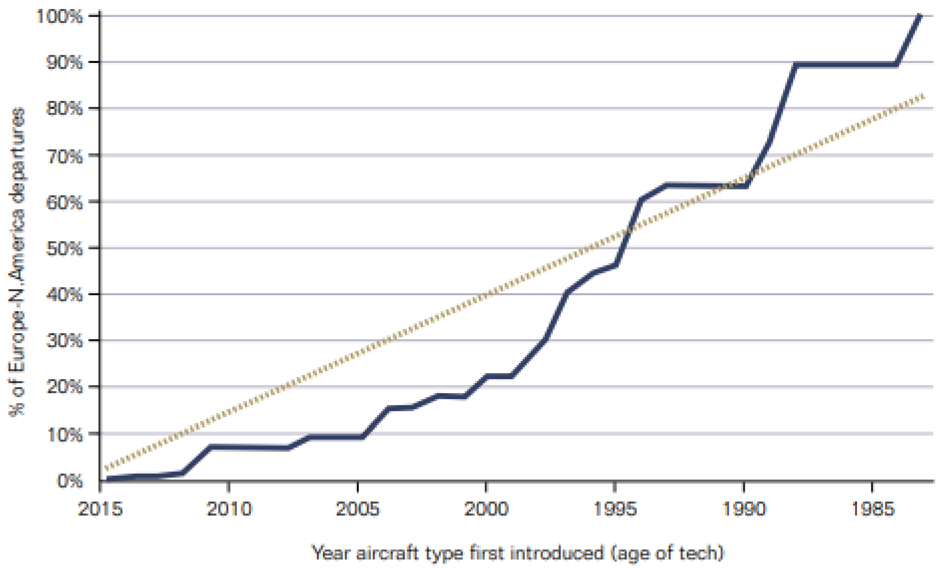


Figure 9.26 – Europe to North America Proportion of Flights in 2015 by Technology Age (Source: Capstats.com)

SUSTAINABLE FUELS

Over the past decades, significant technological developments have taken place in most areas of the aviation sector, except for the fossil-based fuel used by aircraft, which has remained relatively unchanged. 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. The last decade has seen considerable progress in developing Sustainable Aviation Fuels (SAFs) produced from bio-based feedstocks that have a lower carbon intensity, and which consequently could play an important role in mitigating the environmental impact of aviation.

Significant interest exists also for non-bio-based feedstocks, in particular, the so-called drop-in Power-to-Liquids 'electrofuels'. This pathway allows the production of synthetic alternative fuel to fossil kerosene through the use of renewable electricity to produce hydrogen from water by electrolysis and a combination with carbon from CO2 (ideally captured from the air). The Power-to-Liquid process can present a favourable greenhouse gas balance relative to conventional and bio-based aviation fuel streams with close to zero emissions. As of today, electrofuels are a technically viable solution to help decarbonise the aviation sector. However, few demonstrator projects are being brought forward because electrofuels are 3 to 6 times more expensive than kerosene. According to one study, using electrofuels to meet the expected remaining fuel demand for aviation in 2050 would require 95% of the electricity currently generated using renewables in Europe.

The price of bio-based aviation fuel relative to fossil-based kerosene is one of the major barriers to its greater market penetration. Today the feedstock price represents the major component of the final bio-based aviation fuel price, and its price volatility on the EU market can also create supply problems for fuel producers. While a typical price for fossil-based aviation fuel would be €600/tonne, the price of bio-based aviation fuel produced from used cooking oil can be in the range of €950-€1,015/tonne. Also, feedstocks that comply with sustainability requirements, such as used cooking oil and tallow used in the HEFA process, are in demand by the road fuel sector for biodiesel and green diesel production. It is expected that this competition between road and aviation will further increase in the coming years.

Bio-based aviation fuels may have lower GHG emissions in comparison with traditional fossil fuels. Indeed, the emissions from biofuel combustion are often considered as being zero, given that the fuels are produced from biomass. These are referred to as 'biogenic emissions', and they are assumed to be zero on the basis that the growth of the biomass absorbs the same amount of CO2 released during combustion.

The EU sees an important role for SAF in contributing to reduce the environmental impact of aviation. This is why it is taking action in several areas to support greater uptake of SAF within the European market, including research within the 'Horizon 2020' programme that supports the development and pre-commercial production of SAF. From 2013 to 2020, a total budget of €464 million is available to study advanced biofuels and other renewable sources, of which €25 million has been specifically allocated to SAF.

The UN International Civil Aviation Organization (ICAO) recognises SAF as an important element in reducing GHG emissions from aviation. Following ICAO's 39th Assembly in 2016, Resolution A39-2 requested Member States to put in place coordinated policy actions to accelerate the development, deployment and use of SAF. The second ICAO Conference on Aviation and Alternative Fuels in 2017 subsequently adopted a 2050 Vision for SAFs that called on States and all stakeholders to ensure that a significant proportion of fossil-based aviation fuels be substituted with SAF by 2050. Quantified targets are to be agreed at the next conference due to take place by 2025.

The current consumption of SAF remains very low in Europe. However, recent developments, including policy actions at the EU and global level, are intended to create incentives to increase the uptake of SAF in Europe. Nevertheless, the uptake of SAF is likely to remain limited to below 1% of total EU aviation fuel consumption in the near future, and its evolution in the mid/long term within the European market is still difficult to predict.

FUTURE REGULATIONS

The FAA is working through ICAO to evaluate policy options to limit or reduce greenhouse gas emissions from international aviation. ICAO has developed a range of standards, policies and guidance material for the application of integrated measures to address aircraft noise and engine emissions. Efforts include progress on new aircraft technology advancement, operational improvements and development and deployment of alternative fuels, as well as a commitment to developing a global market-based measure for international aviation and appropriate airport and land-use planning. Through the ICAO's CAEP, FAA is supporting the development of an aircraft CO2 emission standard. The standard is expected to reduce aircraft CO2 emissions by integrating fuel-efficient technologies into aircraft design and development. It has been developed such that effective improvements observed through the CO2 standard will correlate with reductions of CO2 emissions by aircraft during day-to-day operations. CAEP is developing an aircraft engine PM certification standard as well. In October 2013, the 38th ICAO Assembly adopted a comprehensive climate change resolution that includes a commitment to developing a global market-based measure to address GHG emissions from international aviation. The US is committed to pursuing the development of a global market-based measure (MBM) proposal. It has to be considered as a gap filler in the basket of measures that includes technology, operations and alternative fuels. These efforts contribute to achieving ICAO's aspirational goal of carbon-neutral growth by 2020 using a 2005 baseline. The U.S. is engaged both in supporting policy and technical work contributing to the proposal for a global MBM. Under this multidimensional regulatory and voluntary structure, aviation has made significant environmental progress. Given the complexity of the industry and the need for different strategies and technological approaches for different types of vehicles and equipment, a coordinated effort will continue between the aviation industry and the many regulatory agencies that share environmental responsibilities.

T9.5.2 Greener Aircraft Design

T9.5.2.1 NEW STANDARDS

The latest global environmental standards were adopted by ICAO in 2017. These cover both aeroplane CO2 emissions and aircraft engine non-volatile Particulate Matter (nvPM) mass concentration. EASA has subsequently supported the process to integrate these standards into European legislation [19] and will implement them as of the applicability date of 1 January 2020.

The CO2 standard provides an additional requirement into the design process that increases the priority of fuel efficiency in the overall aeroplane design. It is an important step forward to address the growing CO2 emissions from the aviation sector and will contribute to the climate change mitigation objectives of the United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement.

The nvPM mass concentration standard is expected to ultimately replace the existing Smoke Number requirement. ICAO is also working on future standards for both nvPM mass and nvPM number, which are based on the emissions that occur during landing and take-off operations. These proposed standards will be discussed at the CAEP/11 meeting in 2019. If agreed, it is expected that they too will be implemented into the European legislative framework.

T9.5.2.2 SUPERSONIC AIRCRAFT

Different types of new civil supersonic aircraft are currently under development and may be in-service as early as the mid-2020s. The design process to develop and certify such aircraft faces various environmental challenges.

Compared to subsonic aircraft, these supersonic aircraft will operate at higher cruise altitudes in the sensitive high troposphere and stratosphere (15-18 km altitude). Although future civil supersonic project aeroplanes will be more fuel-efficient than Concorde, their fuel burn is still expected to be higher in comparison with current subsonic aircraft of a similar size because drag increases with speed. Research also suggests that the climate change effects due to non-CO2 emissions from supersonic aeroplanes, operating at significantly higher altitudes, could be considerably greater than the non-CO2 effects from subsonic aeroplanes.

The noise and emissions produced from supersonic aircraft operations in and around airports is also a critical aspect. Engines optimised for supersonic operation typically have a trade-off between lower noise during take-off (high bypass ratio) and lower drag / higher fuel efficiency in supersonic cruise (low bypass ratio).

There are currently no noise or CO2 certification requirements for supersonic aircraft in Europe, and the existing supersonic engine emissions standards are considered to be outdated according to ICAO guidance material. Europe is therefore actively working to update these standards.

T9.5.2.3 New technology

The aviation industry is evolving into new areas, with existing and new start-up companies investing heavily in novel technology. In addition to recent developments of electric and hybrid engines, ideas to enhance urban mobility have also emerged including fully autonomous aircraft that can provide rapid point-to-point connectivity. New aircraft concepts and innovative types of operations have already applied for certification by EASA. These include the redesign of conventional aircraft as well as innovative electrical vertical take-off and landing (VTOL) aircraft. While the traditional noise certification procedure may be appropriate for the first category, drones and VTOL aircraft are more of a challenge. Based on an EASA Opinion, the European Commission is currently finalising proposals for noise requirements for drones that weigh less than 25 kg.

T9.5.2.4 Clean Sky

The Clean Sky 2 initiative (2014-2024), part of the EU Horizon 2020 programme, is a Joint Undertaking of the European Commission and the European aeronautics industry [32]. It builds on the original Clean Sky 1 programme (2008-2017) and contributes towards achieving the 'Flightpath 2050' environmental objectives set out by the Advisory Council for Aviation Research in Europe [33]. Bringing together the aeronautics industry, small and medium-sized enterprises, research centres and academia to drive forward innovative results, Clean Sky 2 also strengthens European aero-industry collaboration, global leadership and competitiveness. Clean Sky 2 has a total budget of €4 billion, and currently contains over 600 unique entities from 27 countries.

The Programme aims to accelerate the introduction of new technology in the 2025-2035 timeframe. By 2050, 75% of the world's fleet now in service (or on order) will be replaced by aircraft that can deploy Clean Sky 2 technologies. The direct economic benefits are estimated at €350-€400 billion and the associated indirect benefits of the order of €400 billion. Clean Sky 2 technologies are expected to bring a potential saving of 4 billion tonnes of CO2 between 2025 and 2050. This is in addition to approximately 3 billion tonnes of CO2 emissions savings that Clean Sky 1 should deliver.

T9.5.2.5 SESAR

When comparing the gate-to-gate actual trajectories of all European flights in 2017 against their unimpeded trajectories, there is an additional 5.8% gate-to-gate CO2 emissions at European level. The average excess CO2 emissions have remained stable over the last 6 years, even though traffic has increased.

It should be noted, however, that there are several reasons why the actual trajectory flew can vary from the unimpeded trajectory, and therefore 100% efficiency is not achievable (e.g. due to adverse weather, avoidance of 'Danger Areas', need to maintain minimum separation, lack of capacity leading to diversions, avoidance of relatively high route charges). Some inefficiency is unrecoverable due to necessary operational constraints and interdependencies.

The 2018 European ATM Master Plan ambition is to continue reducing the additional gate-to-gate flight time and additional gate-to-gate CO2 emissions to reach 3.2% and 2.3% respectively by 2035.

The total additional distance flown in 2017 within the SES area was 222.8 million kilometres, which resulted in approximately 3 million tonnes of additional CO2 emissions. The SES Performance Scheme includes two binding targets at the EU level for 2019 set at 4.1% for the en-route flight inefficiency of the last filed flight plan (KEP) and 2.6% for the actual trajectory (KEA).

The 2035 ambition level is to be reached by implementing various operational initiatives:

- Free Route Airspace
- Continuous Climb Operations / Continuous Descent Operations
- Implementation of Airport Collaborative Decision Making
- Further additional operational initiatives.

T9.5.3 Noise

Noise development to the present day: down by 80%. The most effective way of preventing noise is to invest in new aircraft technologies and to continually modernize existing aircraft. Major advances have been made in this area over the past few decades, with latest-generation aircraft 25 decibels, or around 80 per cent, quieter than 60 years ago (Figures 9.27 – 9.28).

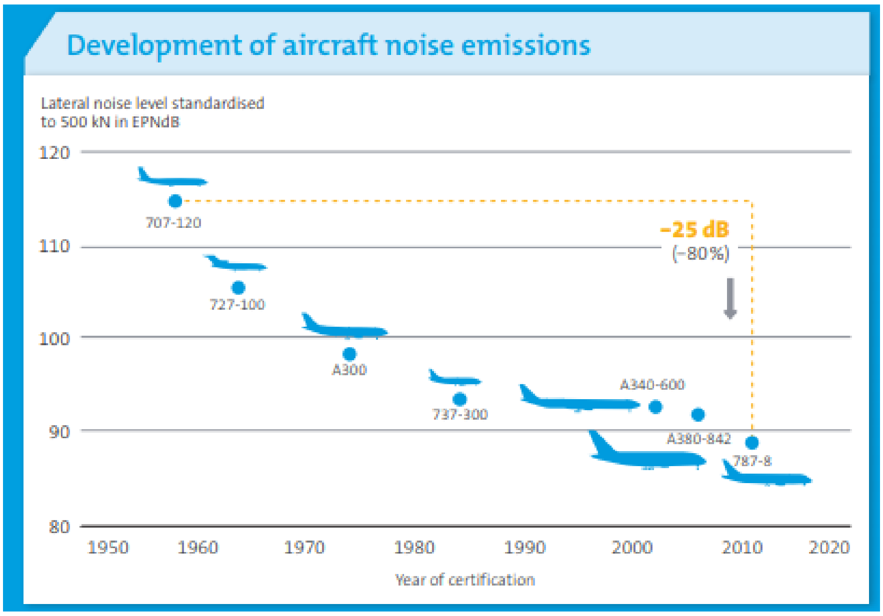


Figure 9.27 – Development of aircraft noise emissions

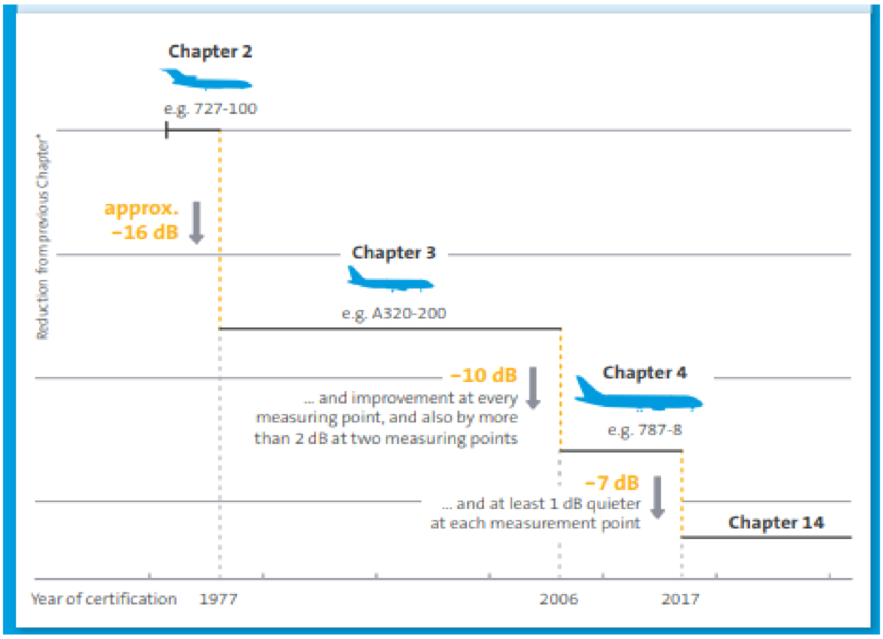


Figure 9.28 – Tightening of international noise levels

Many aircraft not only meet these limits but fall significantly below them (Figure 9.29). An Airbus A319-100, a Chapter 3 aircraft, is up to 19.4 decibels quieter than the limit for its Chapter. And some aircraft models fall well below the noise levels for Chapter 4. These include the Boeing 747-8, which is 15.6 decibels below the level, and the Airbus A380, which is 16.7 decibels below.

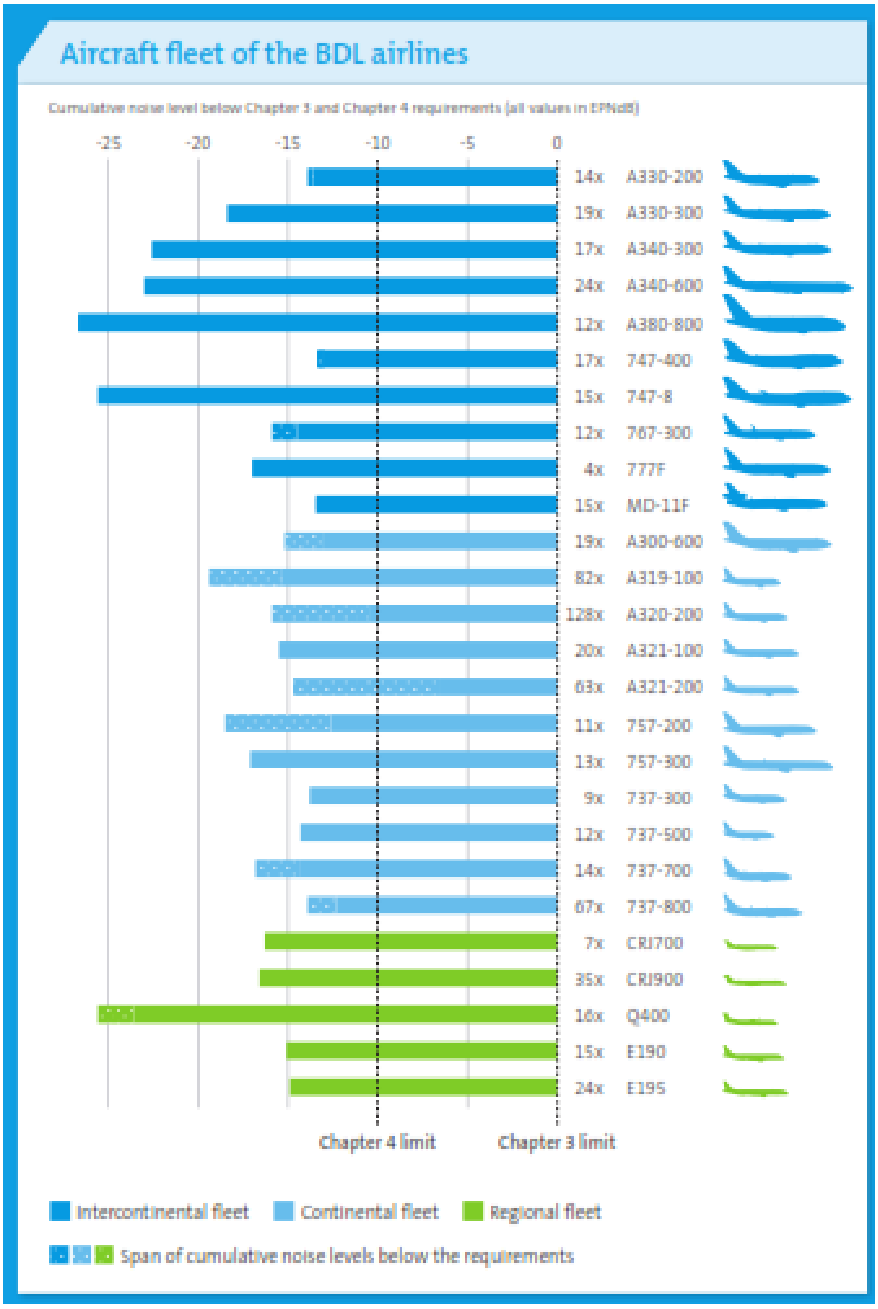


Figure 9.29 – Aircraft fleet of the BDL airlines

T9.5.3.1 Noise Reduction at Source

The most important method of noise reduction is the replacement of old, and therefore loud, aircraft with newer, quieter ones. An additional option is the upgrading of existing aircraft (Figure 9.30).

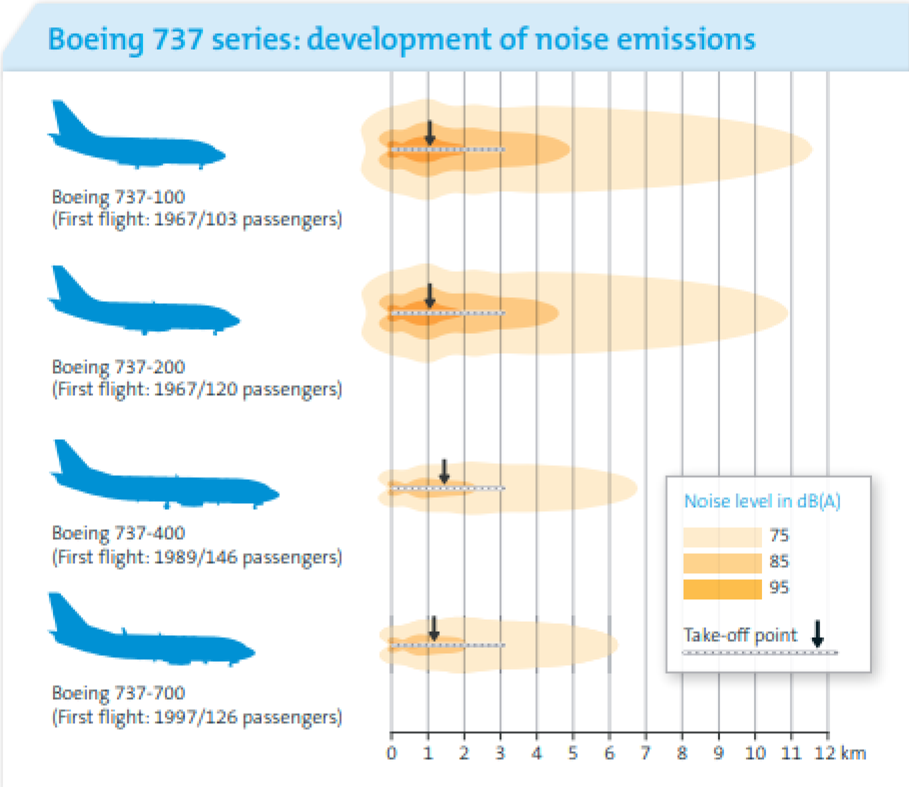


Figure 9.30 – Boeing 737 series: development of noise emissions
Source: Harris Miller & Hanson Inc.

Continued efforts may stabilize noise exposure by 2035 but it will continue to be a key challenge

Aircraft noise exposure is typically assessed by looking at the area of noise contours around airports, as well as the number of people within these contours. A noise contour represents the area around an airport in which noise levels exceed a given decibel (dB) threshold (Figure 9.31). The noise metrics and thresholds presented in this report are the LDEN 55 dB and Lnight 50 dB indicators, in line with what Member States are required to report under the EU Environmental Noise Directive (END). Total contour areas and populations were computed for 45 major European airports using the SysTem for AirPort noise Exposure Studies (STAPES) noise model. These two metrics were complemented by noise energy, which was computed for all airports in the EU28 and EFTA region (about 2100 airports in 2014).

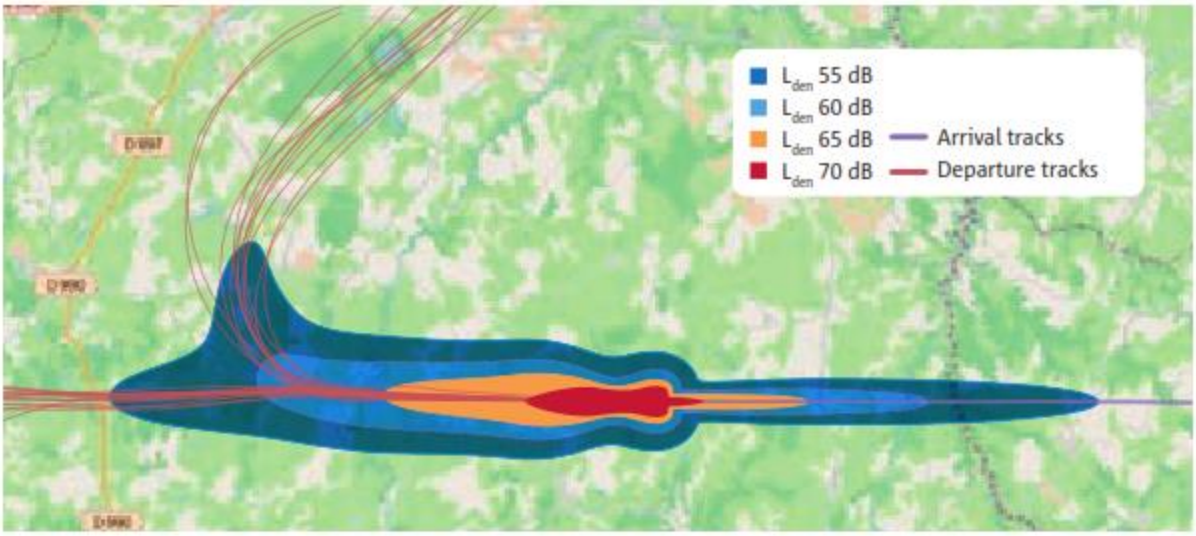


Figure 9.31 – Example of notional airport noise contours

Noise exposure has stabilized over the past ten years. The total population inside the STAPES Lden and Lnight contours decreased by only 2% (Lden) and 1% (Lnight) between 2005 and 2014, to reach 2.52 and 1.18 million people respectively in 2014 (Figure 9.28, Table 9.6). A similar trend is observed for the total noise energy in the EU28 and EFTA region, which decreased by 5% during the same period. This overall noise reduction is due to technological improvements, fleet renewal, increased ATM efficiency and the 2008 economic downturn. Fleet renewal has led to a 12% reduction in the average noise energy per operation between 2005 and 2014.

Under the base (most likely) traffic forecast continued 0.1 dB reduction per annum for new aircraft deliveries (low technology improvement rate) could halt the growth of the overall noise exposure in the 2035 timeframe, while a 0.3 dB reduction per annum (advanced technology improvement rate) could lead to a net reduction of the exposure compared to 2014 even under the high traffic forecast. However, in the absence of continuing technology improvements for new aircraft, the population inside the increased Lden 55 dB contour areas could reach 2.58, 3.54 and 4.29 million in 2035 under the low, base and high traffic forecasts respectively. The effects of different trends on total noise exposure are shown in Figure 9.32:

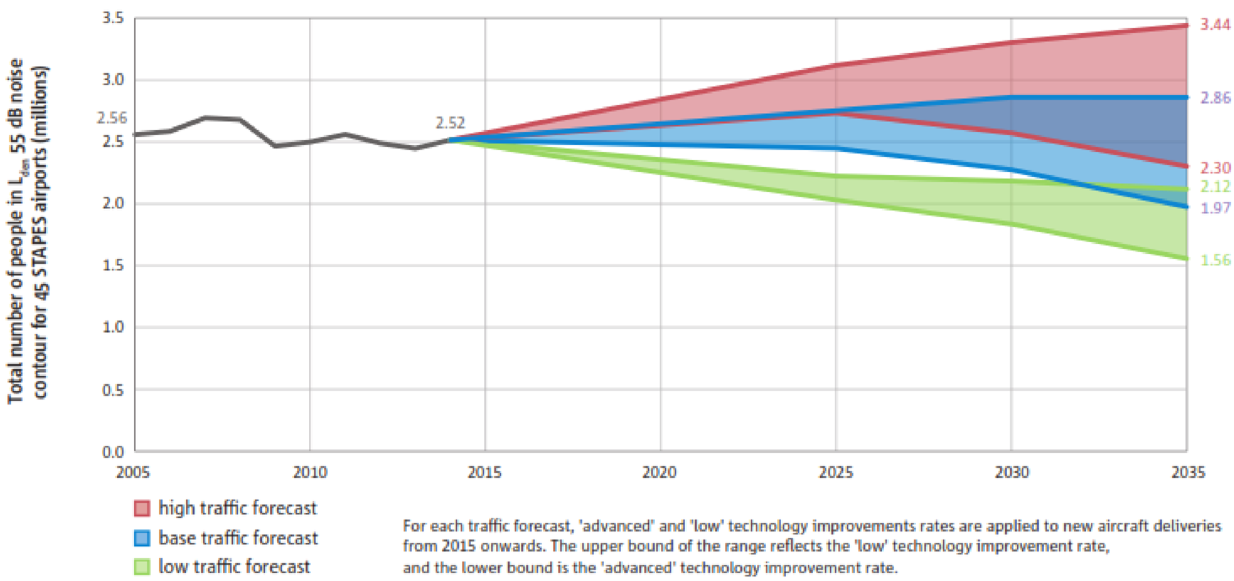


Figure 9.32 – Future technology improvements could stabilize overall aircraft noise exposure in the 2035 timeframe

T9.5.3.2 AIRCRAFT NOISE IN CONTEXT

Under the Environmental Noise Directive, aircraft noise data from 56 out of 91 airports having more than 50,000 movements/year, were reported by the EU Member States. These data showed that for these 56 airports 2.4 million people were exposed to noise levels of 55 dB Lden and above in 2012. An analysis was conducted on the remaining 35 European airports having more than 50,000 movements/year and, combined with the reported data, showed that around 5 million people in Europe were exposed to noise above 55 dB Lden that year.

World Health Organization (WHO) Noise Research

The Lden and Lnight indicators represent average noise over a given period, so they do not capture the specific characteristics of each noise event or differences between sources of noise (e.g. noise from single events are smoothed out).

To support the Member States, the WHO regional office for Europe is reviewing the latest scientific evidence and is expected to propose revised dose-response functions in 2016 to help better quantify the consequences of noise on health. As part of this work, WHO is also reviewing the harmful effects of aircraft noise at lower dB levels than the Lden 55 dB and Lnight 50 dB indicators used in this report. Past work on noise dose-response curves and health effects show that aircraft typically generate more annoyance and sleep disturbance than other sources at the same Lden levels.

	2005	2014 *(% change vs. 2005)*	Base forecast 2035 Advanced – Low Technology *(% change vs. 2005)*
L_{den} 55 dB area, 45 STAPES airports (km²)	2,251	2,181 *(-3%)*	1,983 – 2,587 *(-12%) (+15%)*
L_{night} 50 dB area, 45 STAPES airports (km²)	1,268	1,248 *(-2%)*	1,058 – 1,385 *(-17%) (+9%)*
L_{den} 55 dB population, 45 STAPES airports (millions)	2.56	2.52 *(-2%)*	1.97 – 2.86 *(-23%) (+12%)*
L_{night} 50 dB population, 45 STAPES airports (millions)	1.18	1.18 *(-1%)*	0.78 – 1.19 *(-34%) (+1%)*
Noise energy, all EU28-EFTA airports (10^{15} J)	9.60	9.16 *(-5%)*	9.37 – 12.9 *(-2%) (+34%)*
Average noise energy per operation, all EU28-EFTA airports (10^{8} J)	7.29	6.41 *(-12%)*	4.14 – 5.70 *(-43%) (-22%)*

Table 9.6 – Summary of noise indicators

T9.5.3.3 QUIETER AIRCRAFT DESIGN

The historic picture

There is no doubt that over more than fifty years of the jet age, technology has significantly improved aircraft noise performance, to the point that in 2012, the 57 dBA Leq aircraft noise contour area around Heathrow (Figure 9.32) covered just over a tenth of the area it did in 1974. Even considering significant population growth, 2012 saw a near ten-fold reduction in people within the contour compared with 1974. Gatwick has seen similar reductions (Figure 9.33), with the 57 dBA Leq contour area now around 20% of the size it was in

1979 when noise contours were first generated, and the population affected by that level of noise is just over 10% of the number it was in 1979.

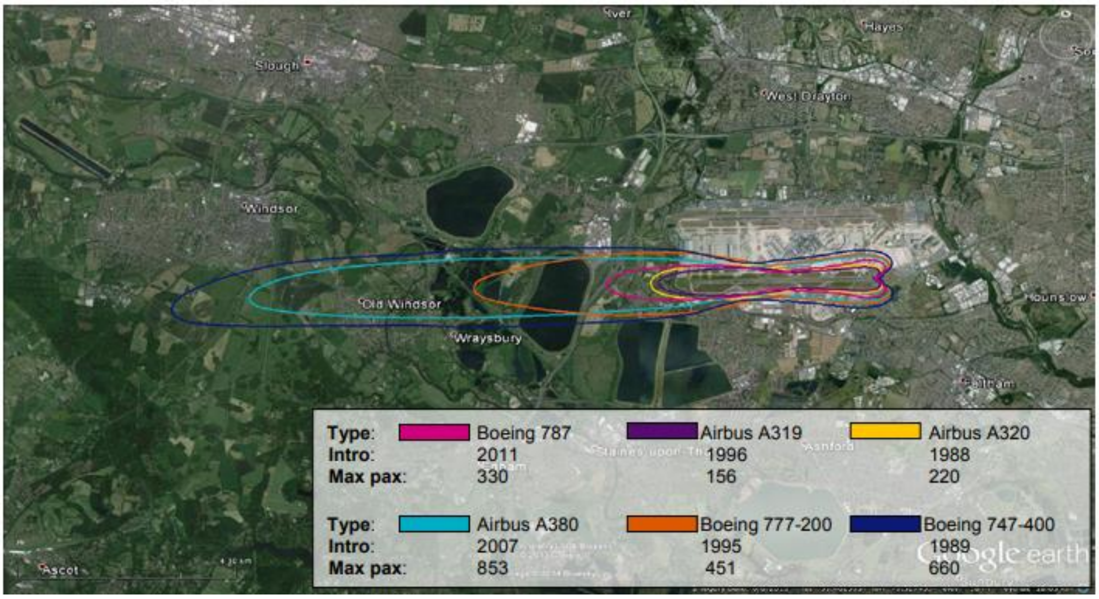


Figure 9.33 – Heathrow departure 90 dBA SEL contours on 27L CPT for selected aircraft

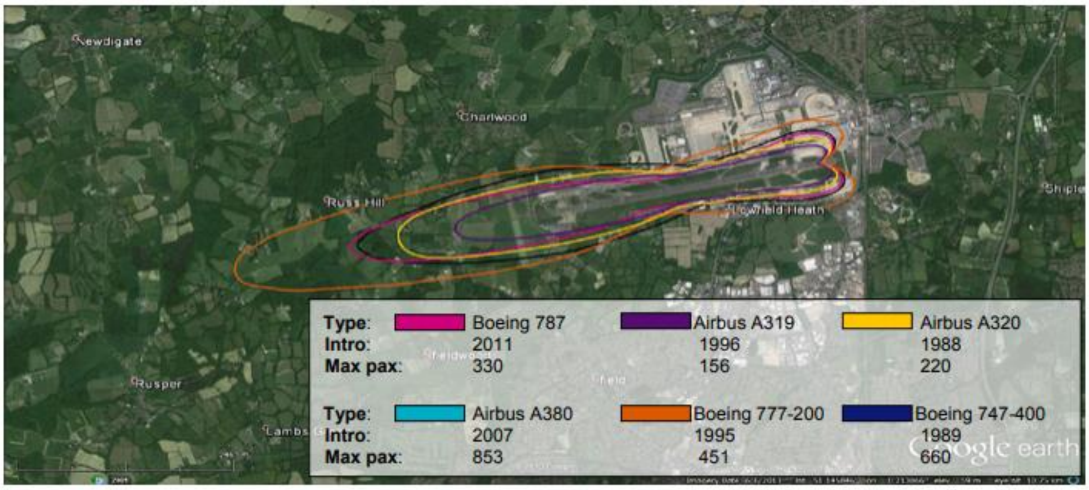


Figure 9.34 – Gatwick departure 90 dBA SEL contours on 26 SAM for selected aircraft

Despite the impact of the 2008 financial crisis and subsequent recession on passenger demand (and flight numbers at most airports), noise improvements over the past decade have been slower than in previous years. In part this is because following the retirement of the Concorde by both Air France and British Airways, the number of flights by extremely noisy, older aircraft from the 1960s and 1970s reduced to close to zero at Heathrow and many other UK airports. It may also be in part because the post-9/11 and financial crisis downturns, combined with the cyclical nature of airline fleet renewal and type introduction mean there hasn't been a significant number of new aircraft operating during the period, and in part, because there are fewer potential improvements in noise performance through manufacture following the step changes in performance over the previous 40 years. At Heathrow due to tightening capacity constraints, there has also been a steady increase in aircraft size, the proportion of long-haul flights has increased, and many domestic routes have reduced frequency or disappeared; all of which would have seen noise increasing without the accompanying technological and operational developments.

Today's technology

Airbus A380 The Airbus A380 entered service in October 2007 operated by Singapore Airlines and began flying into Heathrow in March 2008. In a typical configuration, it is capable of carrying around 525 passengers. If operated as a full economy class service, it would be able to carry over 850 people. The A380 is one of the quietest wide-body jet aircraft currently in operation, with only the newer and significantly smaller Boeing 787 being quieter. Throughout its design, there was a conscious focus on reducing noise, and ensuring that it was able to meet ICAO's Chapter 4 Standard adopted in 2001 and implemented in 2006. The focus on noise performance was in part to ensure that delayed departures could still operate during the night period at Heathrow Airport, where the Quota Count (QC) system imposes much stricter controls for night-time operations than ICAO's Chapter 4 standard, limiting operations for any aircraft with a QC/2 rating or higher from being scheduled between 2300 and 0600.

The A380 is rated (Figure 9.34) as 2 for departure and 0.5 for arrival noise, allowing its use within the total night period. By contrast, the 747-400 is rated as QC 4 for departure and QC 2 for arrival, meaning it is prohibited from being scheduled to depart from Heathrow after 2300 and before 0700, though it may operate as a delayed departure. The newer Boeing 747-8 model falls within the applicable QC limits.

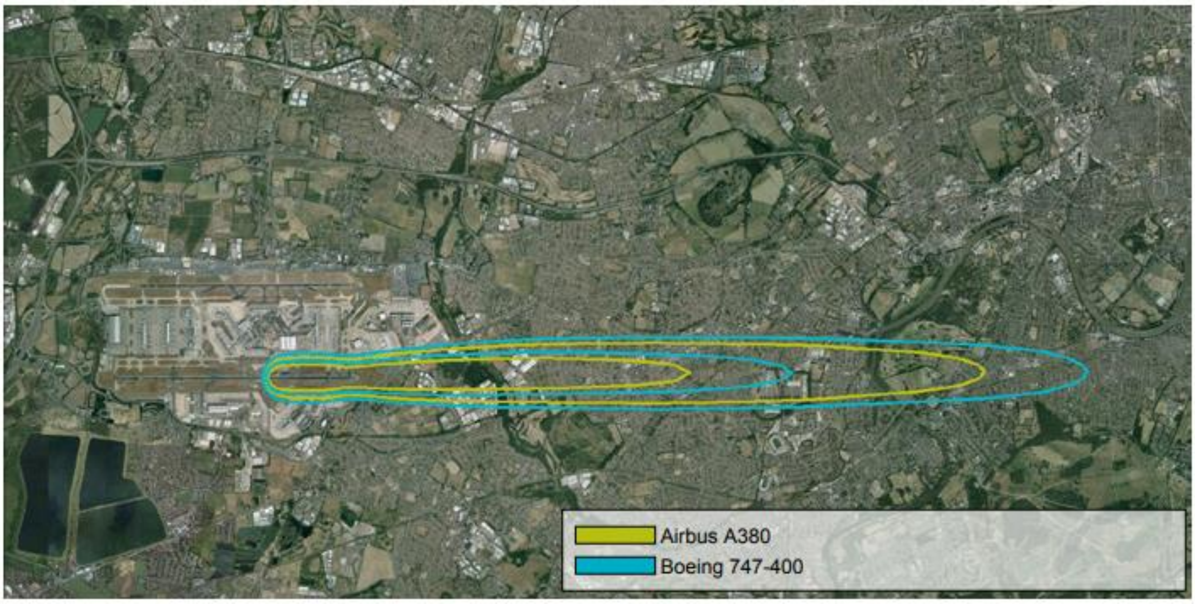


Figure 9.35 – Heathrow arrival 85 and 90 dBA SEL contours for an Airbus A380 landing 27L compared with a Boeing 747-400, the principle aircraft it is replacing

To put the A380's size and noise performance within its historical context, in a typical configuration, the aircraft allows for a seat capacity increase of 90% over 1992's A340-300, for no additional noise. This step-change underlines the potential for quota-based incentives to drive airline and manufacturer action to improve noise performance. Upon its introduction at Heathrow in 2008, operated by Singapore Airlines, the airline, airport, and NATS jointly trialled and implemented new departure procedures to reduce fuel burn and CO2 emissions while remaining within noise limits - highlighting the potential for noise to be managed within strict limits on other environmental impacts.

Boeing 787 Dreamliner although they were developed at a similar time, and introduced to service within five years of one another, the Airbus A380 and Boeing 787 Dreamliner are quite different types of aircraft. While the A380 is capable of carrying over 800 passengers, the 787 has a more traditional maximum passenger configuration of 330 people. The 787 is the world's first composite commercial transport aircraft and was designed to achieve fuel savings of up to 20% over the Boeing 767 which it replaces. Like the A380, the 787 also operates within Heathrow's strict Quota Count operational restrictions for night-time flying and is quieter than the aircraft types it aims to replace. Airbus A350 In 2004 Airbus began a programme of work to create a new wide-body aircraft capable of longer flights and with a similar capacity to the 787. This has grown into the A350 XWB (extra wide body), a twin-engined aircraft carrying between 250 and 350 passengers depending on the configuration. It is expected to begin commercial operations during 2014. Like the 787 it features a composite airframe and is designed to be very fuel-efficient. As with other new types, noise performance is promised to significantly improve over existing wide-body aircraft, but data is not yet available to quantify the gains. Improving existing types Introducing new aircraft types is a slow and typically cyclical process that can be fraught with delays and issues, as recent experience with the introduction of both Airbus and Boeing's new models, the A380 and 787, has shown. Even when new aircraft types are available, reflecting is a lengthy and expensive process for airlines, with significant resource impacts. Besides, despite the existing incentives to improve fleet noise performance, even at Heathrow, there has been no evidence that airlines have changed their normal fleet replacement cycles (for instance, in early 2014, British Airways' long-haul fleet consisted of four Airbus A380s, 55 Boeing 747-400s, 21 Boeing 767-300s and 55 Boeing 777s covering an age range of 0 to 25 years).

The introduction of newer models of existing types does offer the potential for improving noise (and other environmental and efficiency) performance, which, while still representing a significant outlay for airlines, reduces some of the costs and risks associated with purchasing brand new aircraft types. To put that in context, the latest version of Boeing's 747, the 747-8 Intercontinental, introduced in 2005, claims a 30% noise performance improvement over that of its predecessor the 747-400, originally introduced in 1989.

The future

Given the significant improvements in performance in the latest types of aircraft, and the general trend of slowing noise contour reduction over the past decade, in future when new types are introduced, the noise improvements may not be as significant as with previous generations of aircraft. In this context, we welcome the industry's ambition to drive further improvements, set out for instance in the Flightpath 2050 vision 20. Assuming a standard fleet life of 25 years, in line with usual depreciation assumptions, and take the last generation of aircraft as being purchased up until 2013 (which does not factor in continuing purchases of older aircraft by both legacy and low-cost carriers), we can expect to see significant noise improvements arising from normal fleet renewal exercises as airlines switch from older types to the latest aircraft until at least 2038. To provide context, the Figure 9.35 shows the ages of the fleet in operation at Heathrow during 2013 - significant numbers of aircraft predating the latest generation are still in operation, showing the potential for normal fleet renewal to improve noise performance.

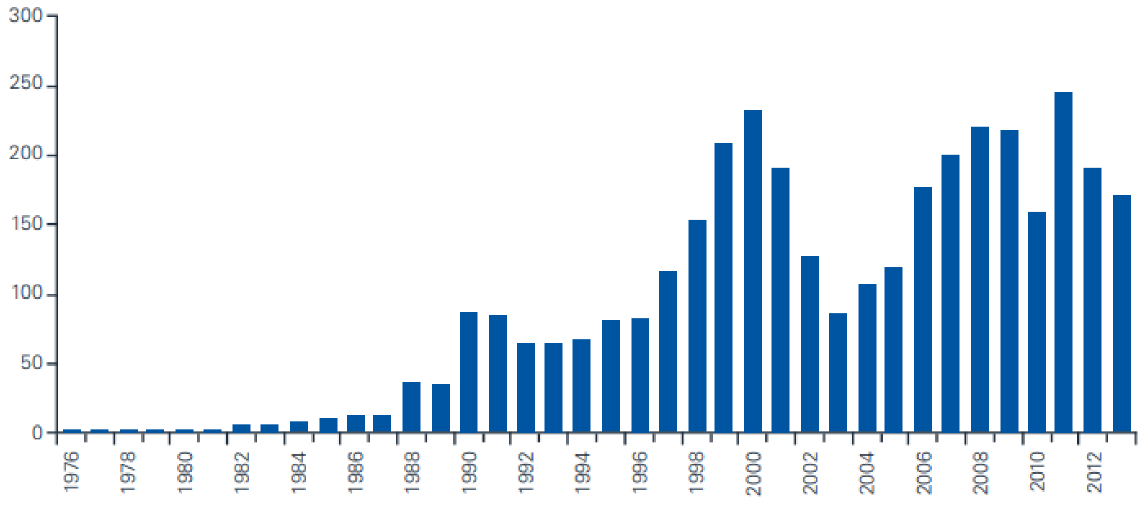


Figure 9.36 – LHR Aircraft fleet 2013 - No. aircraft vs. year built (Source: ERCD data)

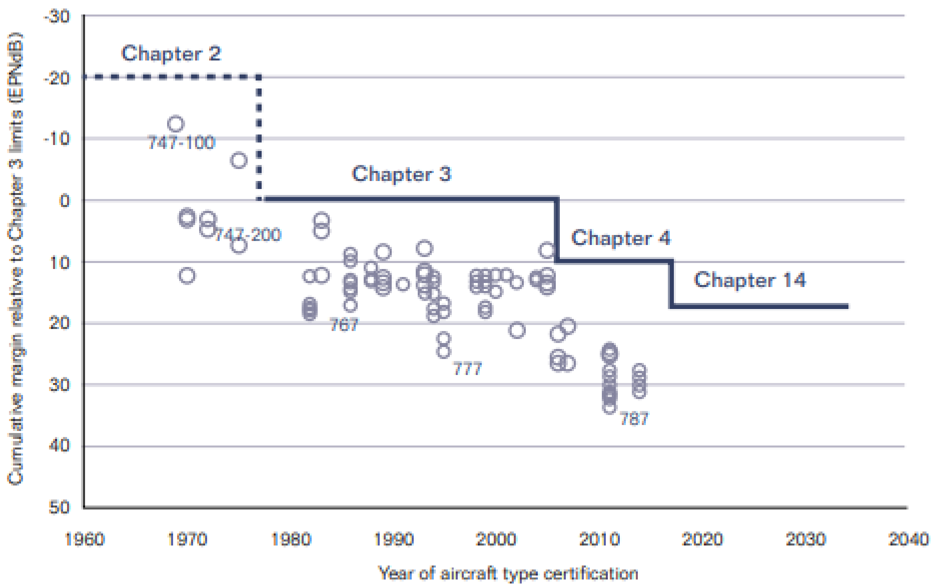


Figure 9.37 – ICAO noise chapter performance of wide-body aircraft since 1960 (Source: EASA European Aviation Environmental Report)

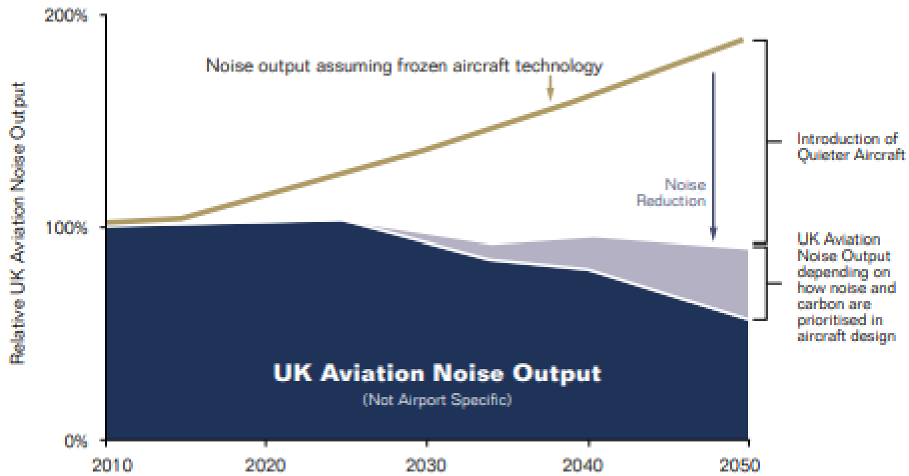


Figure 9.38 – Sustainable Aviation Noise Roadmap (Source: Sustainable Aviation Noise Roadmap)

The impact of quieter aircraft (Figures 9.36 – 9.37) can be illustrated from the noise maps of Heathrow and Helsinki airports, which are shown in Figure 9.38. Both charts show the size of the noise envelope over time and suggest that a combination of engine/airframe improvements and changes to navigation patterns can dramatically alter the shape of noise nuisance.

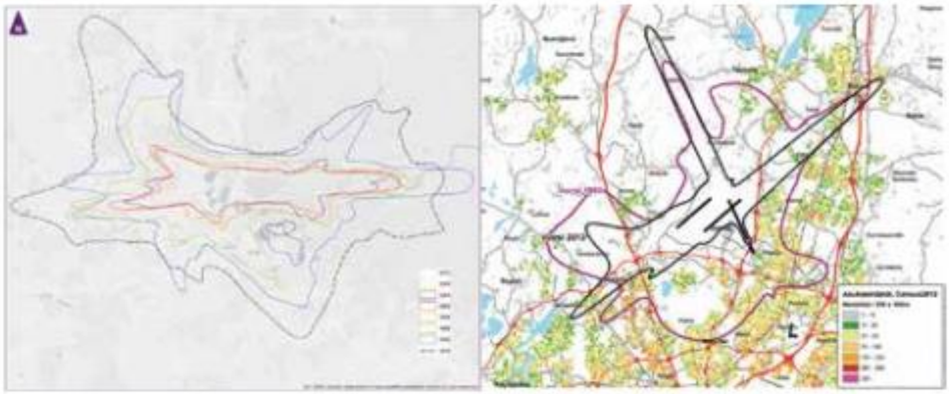


Figure 9.39 – Shrinking Airport Noise Contours: Heathrow, 1974-2012 (left) and Helsinki, 1990-2013 (right) (Source: Heathrow Airport Ltd, Helsinki Airport)

T9.5.4 Aircraft Design

The improvement in the efficiency of technology is frequently cited as the main source of improvements in sustainability for the industry.

The improvements in technology can be easily demonstrated by the diagram below (Figure 9.39), produced by the International Energy Agency (IEA). Whilst it is immediately apparent that the greatest increases in efficiency were made in the early years of the jet age, the industry is continuing on a steep path of improvement (Table 9.7).

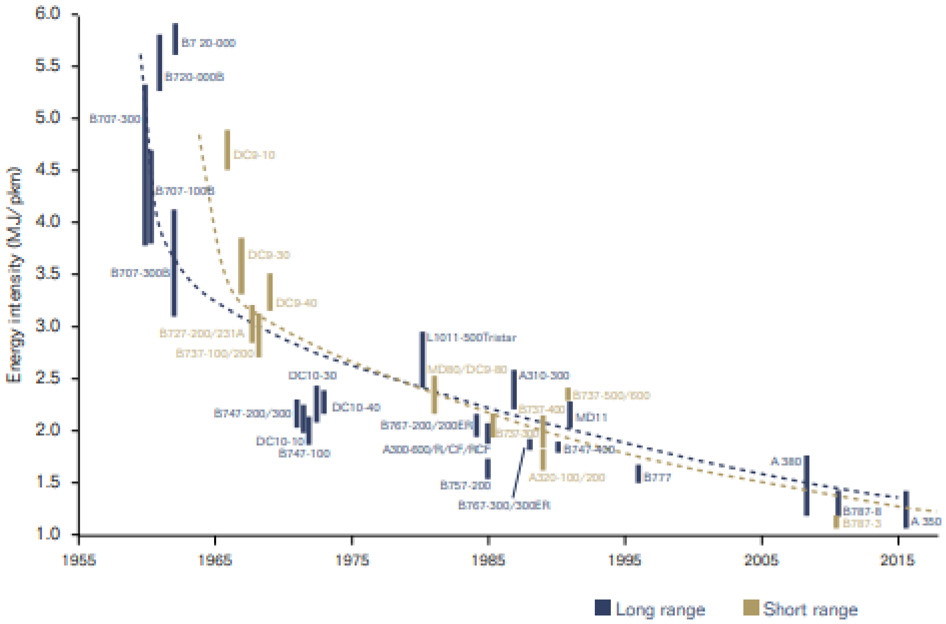


Figure 9.40 – Aircraft Efficiency Gains since 1955 (Source: IEA)

Airline Aircraft type	Engine Type	Takeoff EPNdB	Landing EPNdB	Total EPNdB
American				
MD-80	JT8D-217A/C; JT8D-219	91.4333	93.7	185.1333
737-800	CFM56-7B24/3	88.6	96.5	185.1
757-200	RB211-535E4B	85.7	95.2	180.9
767-200/ER/EM	CF6-80A	92.8	101.7	194.5
767-300/300ER	CF6-80C2B6	91.1	98.4	189.5
777-200/200lr/233lr (ER)	Trent 892	94	99.5	193.5
Continental				
737-300	CFM56-3B1	87.5	100.1	187.6
737-500	CFM56-3B1	87.3	100	187.3
737-700/700LR	CFM56-7B24	88.6	96.1	184.7
737-800	CFM56-7B26	85.6	96.6	182.2
737-900	CFM56-7B26	87.2	96.4	183.6
757-200	RB211-535	88.1	99.6	187.7
757-300	RB211-535E4B	88.4	95.4	183.8
767-200/ER/EM	GECF6-80C2B4F	88.5	96.5	185
767-400/ER	GECF6-80C2B8F	91.2	98.7	189.9
777-200/200lr/233lr (ER)	GE90-90B	91.3	97.8	189.1
Airtran				
717-200	BR700-715C130	82.1	91.6	173.7
737-700/700LR	CFM56-7B22	86.3	95.9	182.2
UPS				
757-200	PW2040; RB211-535E4	88.5	96.65	185.15
767-300/300ER	CF6-80C2B6F	90.9	98.5	189.4
A300B/C/F/-100/-200	PW4158	93.1	101.9	195
MD-11	CF6-80C2D1F; PW4462; PW4460	94.5333	104.1333	198.6666
747-400F	CF6-80C2B1F	99.7	101.4	201.1

Table 9.7 – Engine Type, Take-off, Landing, and Total Decibel Levels for Each Aircraft Type Within Selected Airlines

T9.5.5 Aviation's Contribution to Protecting from Air Pollutants

The aviation industry is working to reduce the level of pollutants emitted through improvements to aircraft and engine design, operational procedures and fuels.

Changes Made by Airlines

Airlines can help to improve air quality by:

- Switching off main engines on arrival and, where possible, limiting the use of aircraft auxiliary power units by using fixed electrical ground power, ground power units and pre-conditioned air.
- Delaying the switching on of main engines until necessary on departure.
- Whilst parked at aircraft stands, operating aircraft on the lowest possible energy draw (e.g. turning off unnecessary electrical systems such as In-Flight Entertainment).
- Reducing the number of engines used when taxiing.
- Applying reduced-thrust take-off.

Changes Made by Airports

Airports can help to improve air quality by:

- Providing fixed electrical ground power and pre-conditioned air for aircraft.
- Optimizing the most efficient flow of aircraft when moving between runways and stands.
- Investing in lower emission ground vehicles for use at the airport.
- Considering charging higher landing charges for aircraft with higher NOx emissions.
- Developing surface access strategies that encourage the use of public transport.
- Using electric towing of aircraft.

T9.5.6 Air Quality Policies

The EU Member States have set air quality targets through European legislation. Some of these targets are reflected as UK-wide objectives whilst others are devolved objectives with separate targets for England, Scotland, Wales and Northern Ireland.

Defra is the Government department with responsibility for setting national policy on air quality to meet these targets. At a local level, local authorities are required to assess air quality and Air Quality Management Areas (AQMAs) are declared if national air quality objectives are not being met.

Two of these targets are for average mean levels of 40µgm -3 for NO2 and PM10 in the UK. Data is available below for several UK airports in relation to both targets. There are no specific air quality targets for the UK aviation industry. Instead, air quality at airports is measured as part of a local authority's duties around air quality and any issues are dealt with between the airport and local authority.

Different airports have different obligations for monitoring and reporting air quality, with some reporting requirements necessary by law through planning obligations.

Solutions: Use of Next-Generation Biofuels

Table 9.8 shows which of the 15 airlines carrying the most passengers in the UK have a stated policy on the use of biofuels.

Airline	Commitment to biofuel development	Proposed feedstock source	Source
Aer Lingus	None stated		
American Airlines	None stated		
British Airways	Yes	Domestic waste	British Airways Corporate Responsibility Report 2012
EasyJet	None stated		
Emirates	None stated		
Flybe	None stated		
Jet2.com	None stated		
Lufthansa	Yes	A number of trials operated	Lufthansa Sustainability Report 2014
Monarch	None stated		
Ryanair	None stated		
Thomas Cook	None stated		
Thomson	Yes	Used cooking oil	Thomson Airways press release, Oct 2011
United Airlines	None stated		
Virgin Atlantic	Yes	Waste gases	Airline website
Wizz Air	None stated		

Table 9.8 – Publicly stated policies on the use of biofuels by the airline.
Source: airline websites

3.4 Safety

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. Airlines in Europe and the US have managed on more than one occasion to have a completely accident free year despite operating in the densest air traffic regionally as well as having international flights all over the globe in various weather and other conditions.

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.

Despite all these differences, the quest for higher safety across all operations must continue. The aviation authorities in the US first, and next also in Europe, have banned foreign airlines deemed not to meet adequate safety standards. This is necessary to protect the safety of those flying into and out of Europe and the US and also of residents that could become the victims of eventual accidents. 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. An effort to cooperate with aviation regulatory authorities worldwide, helping them to implement safety standards, would be a preventive measure leaving bans as the necessary last resort in fewer cases.

Safety in aviation (Key Topic T9.6) is enhanced by analysing accident/incident data (Key Topic T9.7).

KEY TOPIC T9.6 SAFETY IN AIR TRANSPORT

T9.6.1 Introduction

Safety is the top priority for all involved in aviation—and aviation is the safest form of long-distance travel. At 2016 there were over 40 million safe flights. It was made, among others, by a framework that incorporates respect for global standards, cooperation and the value of data. Global standards exist, but they are not being applied universally.

T9.6.2 Safety Standards in Different Regions of the World

The air transport industry plays a major role in global economic activity and development. One of the key elements to maintaining the vitality of civil aviation is to ensure safe, secure, efficient and environmentally sustainable operations at the global, regional and national levels.

A specialized agency of the United Nations, the International Civil Aviation Organization (ICAO) was created in 1944 to promote the safe and orderly development of international civil aviation throughout the world. ICAO promulgates Standards and Recommended Practices (SARPs) to facilitate harmonised regulations in aviation safety, security, efficiency and environmental protection on a global basis. ICAO is the primary forum for cooperation in all fields of civil aviation among its 191 Member States.

Improving the safety of the global air transport system is ICAO's guiding and most fundamental strategic objective. The Organization works constantly to address and enhance global aviation safety through coordinated activities and targets outlined in its Global Aviation Safety Plan (GASP). The Global Aviation Safety Plan or "GASP", is the document which supports the prioritization and continuous improvement of aviation safety. The GASP follows an approach and philosophy similar to that of the Global Air Navigation Plan (ICAO, Doc 9750), also referred to as the GANP. Both documents promote coordination and collaboration among international, regional and national initiatives aimed at delivering a harmonized, safe and efficient international civil aviation system. The GASP initiatives are monitored by ICAO's appraisal of global and regional aviation safety metrics based on established risk management principles — a core component of contemporary State Safety Programmes (SSP) and Safety Management Systems (SMS). In all of its coordinated safety activities, ICAO strives to achieve a balance between assessed risk and the requirements of practical, achievable and effective risk mitigation strategies.

Technical assistance is a major component of ICAO's "No Country Left Behind" (NCLB) initiative which focuses on assisting all States on priority basis to provide support for the implementation of ICAO SARPs under all ICAO strategic objectives. Building partnerships and pooling resources among States, international organizations, development institutions and industry is essential for collaboration on and contribution to technical assistance for effective implementation of SARPs and policies by States with sustainable results.

As part of this effort, ICAO established the Aviation Safety Implementation Assistance Partnership (ASIAP) during the Second High-level Safety Conference in 2015, as the platform for ICAO and its safety partners to coordinate efforts for the provision of assistance to States. Its members include Canada, China, France, Japan, Malaysia, Republic of Korea, Singapore, South Africa, United Kingdom, United States, Airports Council International (ACI), African Civil Aviation Commission (AFCAC), Airbus, Boeing, the Civil Air Navigation Services Organization (CANSO), the European Aviation Safety Agency (EASA), the International Air Transport Association (IATA), the World Bank and the Arab Civil Aviation Commission (ACAC).

Europe

In the last 25 years, the aviation sector in Europe has undergone a revolution that would have been unthinkable without key measures taken at EU level. Up to the late 1980s, air transport was fully controlled by State governments and overregulated by rather rigid bilateral agreements and obsolete international conventions. Since then, progressively, the European Union became a leading force and a respected policymaker in the field of air transport. Being highly successful in liberalising the aviation sector in the Member States, the EU took the opportunity to pursue its action further. Other important aspects – such as competition rules, traffic management, safety, security, airport capacity, environmental protection, passenger rights and external relations – were given similar attention. The term air safety designates technical aspects of flying, such as rules for construction and use of aircraft. Europe has a long tradition in rulemaking cooperation in aviation safety, with the first common standards developed around 1990 within the framework of the current no longer existing Joint Aviation Authorities (JAA). At that time, the European aviation safety authorities collaborated in the development of the Joint Aviation Requirements (JAR) and related procedures, initially in the field of aircraft manufacturing and design, and later also in respect of flight operations, maintenance and crew licensing. The current EU aviation safety system – a set of common safety rules – is based on close relations between the European Commission, the European Aviation Safety Agency (EASA), Eurocontrol, national civil aviation authorities, as well as aircraft manufacturers, airlines and other undertakings participating in the Single Aviation Market.

In 1991, the Council Regulation No 3922 – based on JAR – on the harmonisation of technical requirements and administrative procedures in the field of civil aviation safety – commonly referred to as EU-OPS – focused, in particular, on measures applicable to the operation and maintenance of aircraft and to persons and organisations involved in those tasks. It was updated in 2006 by Regulations No 1899 and 1900 of the European Parliament and the Council.

In 2002, the European Aviation Safety Agency (EASA) came into being with the adoption of the Regulation No 1592 of the European Parliament and the Council on common rules in the field of civil aviation and establishing a European Aviation Safety Agency. EASA was supposed to cover all aspects related to airworthiness and environmental certification of aeronautical products, parts and appliances, building on the experiences and cooperation of the former group of European aviation regulators (JAA).

The Regulation No 1592 has been amended in 2003 by the Regulation No 1643 of the European Parliament and the Council and repealed in 2008 by the Regulation No 216 of the European Parliament and of the Council that extended the powers of EASA to aircraft operations and crew licensing and training and also set safety rules on design, production, maintenance and operation of aircraft, certification of organisations and personnel in the aircraft sector and harmonisation and recognition of national certificates throughout the EU. The latest Regulation No 1108 of the European Parliament and of the Council, which was negotiated during the 2009 Czech Presidency, amended the Regulation No 216 in the field of aerodromes, Air Traffic Management and air navigation and enlarged further the powers of EASA to cover safety aspects of airport operations and provision of air navigation services and Air Traffic Management.

The extended duties of EASA are to help the European Commission to develop common standards on safety of civil aviation in EU legislation, ensure uniform application of these standards, issue certificates to EU companies in air transport and conduct inspections. These significant powers in the fields of airworthiness, environment, flight crews, aircraft operations, third-country aircraft, airport operations, air navigation services and Air Traffic Management was executed by a progressive adoption by 2013.

To improve air safety and prevent future disasters, it is essential to evaluate all aircraft accidents and incidents and come up with relevant conclusions. To this end, the Council Directive No 56 has been adopted in 1994, establishing the fundamental principles governing the investigation of civil aviation accidents and incidents, facilitating investigations and transposing into the EU legislation several fundamental international principles. In 2010, the Directive No 56 has been updated by the Regulation No 996 of the European Parliament and the Council on the investigation and prevention of accidents and incidents in civil aviation. The effectiveness of air accident investigations has been strengthened, cooperation between authorities facilitated and the rights of victims of air accidents and their relatives reinforced.

Due to the fact, that not only EU airlines fly the EU sky, the Regulation No 2111 of the European Parliament and the Council established in 2005 a Community list of air carriers subject to an operating ban within the Community and imposed the obligation to inform air transport passengers of the identity of the operating air carrier. The so-called European Blacklist of airlines with low safety standards, regularly updated, includes airlines banned from operating in the EU and airlines which are restricted to operating under specific conditions.

Air safety issues are mainly air carriers' concern. On one hand, airlines are in favour of achieving the highest possible safety performance and harmonising the rules across the Member States. On the other hand, they complain that the European Commission does not take due account of their professional views.

Europe plays a leading role as regards aviation safety. 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.

At the heart of this system is the concept of safety risks management, namely hazards identification, risks assessment and decision-making on the best course of action to mitigate those risks. The European Aviation Safety Agency (EASA), Member States (MS) and industry work closely together in this process. At European level, this process is coordinated by the EASA and documented in the European Plan for Aviation Safety (EPAS).

The fifth edition of EPAS covers the five years between 2016 and 2020 and is now an integral part of the EASA's programming activities. This means that the safety priorities identified in EPAS are addressed by specific actions in the EASA's rulemaking or safety promotion programmes, specific actions in the State Safety Programmes (SSPs) or through focused oversight activities performed either by the Agency or the MS.

In comparison with previous editions, the current one is more data-driven, providing a clear link with the Annual Safety Review (ASR) and with the EASA's Rulemaking Programme. An increased emphasis has been put on using safety promotion and focused oversight activities to mitigate safety risks.

UNITED STATES OF AMERICA

US aviation industry leaders, from the beginning, believed the aeroplane could not reach its full commercial potential without federal action to improve and maintain safety standards. At their urging, the Air Commerce Act was passed in 1926. This landmark legislation charged the Secretary of Commerce with fostering air commerce, issuing and enforcing air traffic rules, licensing pilots, certifying aircraft, establishing airways, and operating and maintaining aids to air navigation.

To ensure a federal focus on aviation safety, President Franklin Roosevelt signed the Civil Aeronautics Act in 1938. The legislation established the independent Civil Aeronautics Authority (CAA), with a three-member

Air Safety Board that would conduct accident investigations and recommend ways of preventing accidents. On May 21, 1958, Senator A. S. Monroney introduced a bill to create an independent Federal Aviation Agency to provide for the safe and efficient use of national airspace. Two months later, on August 23, 1958, the President signed the Federal Aviation Act, which transferred the Civil Aeronautics Authority's functions to a new independent Federal Aviation Agency responsible for civil aviation safety.

The FAA mission is to provide the safest, most efficient aerospace system in the world. Thanks to the work of FAA, it was created the safest, most reliable, most efficient, and most productive air transportation system in the world. To ensure aviation's future viability, FAA is now working with its federal and industry partners to develop a flexible aerospace system that fully responds to the changing needs of businesses and customers in the 21st century. The strength of the NextGen system depends on lower costs, improved service, greater capacity, and smarter security measures. That is why the FAA has defined a vision of the future that integrates achievements in safety, security, efficiency, and environmental compatibility.

The Federal Aviation Regulations, or FARs, are rules prescribed by the Federal Aviation Administration (FAA) governing all aviation activities in the United States. The FARs are part of Title 14 of the Code of Federal Regulations (CFR). A wide variety of activities are regulated, such as aircraft design and maintenance, typical airline flights, pilot training activities, hot-air ballooning, lighter-than-air aircraft, man-made structure heights, obstruction lighting and marking, and even model rocket launches, model aircraft operation, sUAS & Drone operation, and kite flying.

The rules are designed to promote safe aviation, protecting pilots, flight attendants, passengers and the general public from unnecessary risk. Since 1958, these rules have typically been referred to as "FARs", short for Federal Aviation Regulations. However, another set of regulations (Title 48) is titled "Federal Acquisitions Regulations", and this has led to confusion with the use of the acronym "FAR". Therefore, the FAA began to refer to specific regulations by the term "14 CFR part XX".

Bilateral Agreements

As globalisation advances, aviation safety is increasingly a cooperative, global effort. Civil Aviation Authorities from different countries or regions must cooperate in order to harmonize and coordinate joint efforts aimed at aviation safety.

As safety doesn't stop at European borders, EASA works with authorities worldwide to raise global standards. Being an authority itself, it can understand and address the challenges, and bring different stakeholders together.

In 2014, the Certification Management Team: ANAC (Agência Nacional de Aviação Civil), EASA (European Aviation Safety Agency), FAA (Federal Aviation Administration), and TCCA (Transport Canada Civil Aviation), agreed to greater collaboration between authorities „to more efficiently and effectively develop and implement regulatory and policy solutions to common certification issues". Globalization of aviation business and emerging countries trigger growing resource demands on authorities. Maximum use of the BASA (Bilateral Agreement of Safety in Aviation) and full recognition of certificating authorities 'capabilities are essential to reduce efforts in the validation.

The Technical Implementation Procedures (TIP) were authorized by Article 5 and Annex 1 of the Agreement between the Government of the United States of America (U.S.) and the European Union (EU) on Cooperation in the Regulation of Civil Aviation Safety. In accordance with Article 5 of the Agreement, the Federal Aviation Administration (FAA) and the European Aviation Safety Agency (EASA) have determined that the aircraft certification systems of each Authority for the design approval, production approval, airworthiness approval, and continuing airworthiness of the civil aeronautical products and articles identified in this document, are sufficiently compatible in structure and performance to support these procedures.

The TIP is based on continuous communication and mutual confidence in the FAA's and EASA's technical competence and ability to perform regulatory functions within the scope of the TIP. The FAA and EASA, when acting as the Authority for the importing State, shall give the same validity to the certification made by the other, as the Authority for the exporting State, as if they were made in accordance with its own applicable laws, regulations, and requirements. When a finding is made by one Authority following the laws and regulations of the other Authority and the TIP, that finding is given the same validity as if it were made by the other Authority. Therefore, the fundamental principle of the TIP is to maximize the use of the exporting Authority's aircraft certification system to ensure that the airworthiness and environmental requirements of the validating Authority are satisfied.

As required by the Agreement, the FAA Aircraft Certification Service and EASA Certification Directors have established the Certification Oversight Board (COB), consisting of management representatives from each Authority. The COB shall be responsible for the effective functioning, implementation, and continued validity of these procedures, including revisions and amendments thereto. The COB shall establish its own rules of procedure, its membership, and meeting schedules. The frequency of these meetings will be mutually agreed upon by the COB and will depend on the number and significance of the issues to be discussed between the authorities. These meetings will also be used to discuss and harmonize any major differences in standards and their interpretation that are identified during certification projects between the FAA and EASA and when significant differences are identified, formal proposals will be raised through the applicable rulemaking committee. The COB will invite management from the responsible policy office to participate in all discussions focused on operational issues (e.g. Maintenance Review Board and Operational Suitability Data).

T9.6.3 Safety Standards for Different Services

Business Aviation

Business Aviation has established a record as one of the world's safest forms of transportation. Professionally flown aircraft of all sizes are operated on unscheduled routes to all corners of the globe, yet the safety record continues to be excellent despite the very challenging operating environment. The exemplary safety record of business aviation can be attributed to professionalism and attention to safe operating practices. The business aviation community promotes safety through industry standards and good training, as well as through monitoring and analysing safety information to facilitate continuous improvement.

The global population (2013) of Business Aircraft consist of about 19,000 business jets and 14,500 Turbo Props. Business aircraft in North America represents 61.2% of the global fleet. South and Central America have approximately 11.6% and Europe 13.0% of the world's fleet. Other regions account for the remaining 14% of the fleet.

The 2013 summarized flight hour totals are as follows (2013): Business Jets – 7,700,000 hours and Turbo Props – about 4,000,000 hours. The flying hours in North America represents 63.4% of the total, Europe 13.2%, Central/South America 12.5%, and the rest of the world 11%.

At business aviation safety requirements are based on Regulation (EU) 376/2014 on the Reporting, Analysis and Follow Up of Occurrences in Civil Aviation, which was built on Directive 2003/42 and reporting and modern SMS requirements under IRs of BR216/2008. The Key Areas of the Regulation:

- Improved reporting and follow up of occurrences from both mandatory and voluntary reporting processes.
- Introduction of occurrence risk classification.
- Rules on confidentiality of the information and Just Culture.
- Provision of Guidance Material and other useful supporting information for the industry.

- Analysis-a key part Safety Risk Management process to use and share what is learnt.

The following concepts and actions are elements of safety culture that can be found in many organizations:

- Unqualified commitment to safety as a behavioural pattern and pervasive way of life by top management.
- Unambiguous expectations by each level of management as well as each peer group that, for all employees, safe life patterns and work habits are as normal as breathing and must be practised off the job as well as on the job.
- Availability of quality, standardized equipment with which to accomplish the assigned tasks.
- Clear, easily understood operating procedures, followed without deviation.
- Inclusive system of communications for collecting, analysing, and exchanging incident data related to safety.
- Non-retribution for submission of incident data.
- Retraining without penalty or stigma when safety is involved.
- System for tracking incident and accident data, analysis of trends, and feedback of results.
- Peer acceptance that accidents are preventable, regardless of operations.
- Peer acceptance that safety is a matter of lifestyle - a matter of culture.

PRIVATE AIRCRAFT

The sub-sector of General Aviation (GA) covers noncomplex aircraft operations with an emphasis on non-commercial operations. This embraces aeroplanes, helicopters, sailplanes (gliders) and balloons (including airships). Their uses range from pure sport and recreational activities to general private flying, owner-operators own business use through to some commercial activities such as aerial work, all of which are included in the scope of the non-commercial use.

The regulation for GA must be proportionate: specific activities should lead to specific requirements, just fit to mitigate for the risk. Consequently, the group chose to adopt a wide area of applicability, and principles and guidelines of a sufficiently general nature to be used as appropriate in different cases. This does not preclude that, when coming to specific regulation elaboration, it will be necessary to identify very precise boundaries for application.

GA should be treated differently to Commercial Air Transport (CAT) because it is important to recognise the differences between commercial and non-commercial environments from a safety management perspective.

- Control of Risk: end-use stakeholders in non-CAT aviation generally have much more ability to assess and control the risk of the operation. In many cases, except for very limited risk to third parties, the operators are the only stakeholders exposed to risk.
- Level Playing Field: in the competitive CAT market, driven by a profit motive, a level playing field between actors is necessary to ensure that safety does not enter a vicious downward spiral.
- Cost Burden and Economies of Scale: CAT operations are typically much more repetitive than non-commercial operations. CAT aircraft may fly up to 4,000 hours p.a. whereas non-commercial aircraft may typically fly only 50 to 100 hours p.a. This leads to significant economies of scale for CAT in dealing with fixed costs and other resource requirements including those generated by regulatory compliance.
- Flexibility: CAT operations are usually planned in detail in advance with a limited need for short-term flexibility. By contrast, non-CAT operations are often planned at relatively short notice, tend to be dynamic and may even be opportunistic (e.g. highly weather dependent).

- Private flying including sporting and recreational / leisure aviation as well as personal transport. This form of flying has only one thing in common with CAT, the 3-dimensional aspect and only three areas of overlap or adjacent proximity, which are the use of airspace, communications frequencies, and some airports.

GA must, therefore, be treated as a sector in its own right and not as a watered-down "Commercial Air Transport (CAT) by-product".

As highlighted by ICAO and for the reasons mentioned above, the level of safety expected for GA may not be the same as the one required for CAT. The available data in the various European States show that the currently observed level of safety for GA activities – the least complex ones - is currently indeed not as high as CAT's.

The public perception seems to accept the current levels of safety demonstrated by the GA community. It is however essential not to compromise that level of safety, by the modification of the regulatory approach.

The group considers that the regulatory approach is not the sole method of assuring a minimum acceptable level of safety, but that both education and the development of improved safety culture across the community are equally valid. A more liberal attitude to product approvals is also expected to promote innovation and to lead to the rapid introduction of more modern and safer equipment.

Applying safety management principles, careful monitoring of the evolution of the GA safety situation will be of high importance, to be able to take appropriate measures (not necessarily new regulations, as mentioned above) to ensure the safety level remains appropriate.

Transparency for the participants to GA activities will have to be increased: they need to be adequately informed that the level of safety they will encounter may not be the same as in a commercial air transport flight, in order for them to understand and accept the level of safety knowingly.

AGRICULTURAL AVIATION

Most aerial agricultural operations are flown in heavily laden aircraft, at a low level in challenging terrain. Specialised equipment and highly skilled people are needed to operate this sector. Apart from the obvious operational concerns, participants are also subject to many other factors affecting safety. These include business performance, local weather conditions, physical obstacles in low-level flights and personal issues. Despite the significant effort from the CAA (Civil Aviation Authority) and the aviation industry, the safety performance in this sector remains poor. The CAA and industry have agreed that a new approach to managing risk is needed.

It was seen the development of Safety Management Systems, known as SMS, as a positive approach to safety-related risk. When in place, the SMS structure ensures a proactive approach to risk identification and risk management. Risks can then be identified and treated before they lead to unsafe or dangerous outcomes. This is not only for safety but also for business enhancement. SMS is part of a global change to how regulators carry out their obligations – risk-based regulatory oversight.

The CAA is committed to the concept of adopting a risk-based approach to regulatory oversight. This is in line with the International Civil Aviation Organisation (ICAO) requirements for regulatory bodies to develop a State Safety Programme (SSP). The development of the SSP will be in accordance with ICAO Annex 19 Standards and Recommended Practices. This includes the implementation of a formal SMS by aviation organisations.

The aviation industry is dynamic and safety-risk factors also change. Without ongoing effort, there is a potential for risks to increase due to factors such as introducing new technology, and commercial pressures. The regulator and aviation organisations need to employ a risk-based approach to safety management. One of the main objectives of risk-based regulation for the CAA is to have structured means to effectively use resources. This ensures that the highest risk sectors of industry will be managed first.

This is one of the main reasons why the agricultural aviation sector was selected to undergo a Sector Risk Profile.

Risk can be defined as the chance something could happen, and risk management as the identification of safety risks enabling proactive control of the potential outcome of these risks.

Many risk elements can be identified in the agricultural aviation SRP. Placing them into risk levels ranging from Medium to Very High. These levels are determined by assessing the likelihood of the risk occurring and the possible consequences. Examples of identified risk elements include aircraft performance and maintenance; operator obligations; pilot training; and airstrip conditions.

T9.6.4 Air Carriers Operating Ban

EUROPEAN UNION

The list of air carriers banned in the European Union is a list of airlines failing to meet regulatory oversight standards of the EU, and which are banned from entering the airspace of any member state. All Member States and the European Aviation Safety Agency (EASA) have the obligation to communicate to the Commission all information which may be relevant to updating the list. This may include reports showing serious safety deficiencies of an air carrier (such as reports of Safety Assessment of Foreign Aircraft inspections performed at airports within the European Community), operating bans imposed by third countries, audit reports drawn up by the International Civil Aviation Organisation (ICAO) following safety inspections (in the framework of the Universal Safety Oversight Audit Programme) of the civil aviation authorities of the 189 Contracting parties to the Chicago Convention, as well as accident-related information or other serious incident-related information.

To update the list, the Commission is assisted by the Air Safety Committee composed by technical air safety experts from all the EU Member States (plus Iceland, Norway and Switzerland which, however, have no voting rights) and chaired by the Commission (the Commission does not have any voting rights). Acting on a proposal by the Commission, the Air Safety Committee adopts its opinion by a qualified majority, which is then submitted to the European Parliament before final adoption by the Commission and subsequent publication in the Official Journal.

The decision to include or remove a carrier (or a group of carriers certified in the same State) is taken based on the common safety criteria annexed to the "Basic Regulation" (Regulation 2111/2005/EC establishing a Community list of banned carriers). These criteria take into consideration, for instance, the existence of safety deficiencies on the part of an air carrier, or the lack of ability (or willingness) by an air carrier or authorities responsible for its oversight to address safety deficiencies, operating bans imposed by third countries, audit reports drawn up by third countries or international organisations (ICAO) and substantiated accident-related information. All criteria are based on international aviation safety standards.

If an airline considers that it should be taken off the list because it complies with the relevant safety standards, it can address a request to the Commission or a Member State, either directly or through its civil aviation authority. Only the Commission or a Member State may ask for the list to be updated. The Air Safety Committee will then assess the evidence presented by the airline and/or its oversight authority to substantiate its request for being withdrawn from the EC "blacklist" and formulate its opinion to the Commission.

The procedure of adding the airline to the list is the same as that for updating the list. If the Commission or a Member State acquires evidence indicating serious safety deficiencies on the part of an airline or its oversight authority anywhere in the world, they ask for the list to be revised immediately. Indeed, in such cases, the Member States must ask for the update of the "blacklist". A decision is then taken in the light of the common safety criteria for banning established by the "Basic Regulation".

Where the Commission is of the opinion that the continuation of operations into the Community of an air carrier is likely to constitute a serious safety risk and that such risk has not been resolved satisfactorily at the national level (by measures taken by the civil aviation authority of a Member State) it can take provisional measures, whereby the carrier is banned from entering the European air space. These measures are then presented to the Air Safety Committee for confirmation or modification.

As long as the air carrier is subject to a total ban, it cannot operate with its aircraft and personnel in the EC. The airline is placed on Annex A to the regulation whereby the "blacklist" is updated. Equally, as long as an air carrier is subject to a partial ban it can operate only with the aircraft stipulated in the Regulation and cannot expand its network. The airline is placed on Annex B to the regulation whereby the "blacklist" is updated.

Nevertheless, banned airlines can still fly their aircraft into the Community for maintenance (notably to resolve safety deficiencies in this area) without carrying any passengers or payload – the so-called "ferry flights". Also, banned airlines can use other airlines (their aircraft and personnel) based on contracts called "wet-lease agreements". In this way, passengers and cargo can still be transported but only by airlines which fully comply with the safety rules. Furthermore, aircraft which are used for government or state purposes (e.g. transport of the heads of state and/or government), escape the requirements of ICAO. Therefore, these aircraft are considered to be operating "state flights" and can, therefore, fly into the EC even if they are banned from operating commercial flights. Such flights need however a special authorisation as foreseen by ICAO, from all the Member States that the plane flies over as well as from the state of destination.

Finally, banned airlines cannot enter the airspace of any Member State and fly over their territory while they are banned (totally or partially).

Airlines which have been banned, or which are being investigated because of a potential ban, have the right to express their points of view, submit any documents which they consider appropriate for their defence, and make oral and written presentations to the Air Safety Committee and the Commission. This means that they can submit comments in writing, add new items to their file, and ask to be heard by the Commission or to attend a hearing before the Aviation Safety Committee, which then formulates its opinion based on these proceedings and the materials submitted before or during the hearing. The rules foresee that carriers and authorities are given a deadline within which they have to respond.

UNITED STATES OF AMERICA

In the US the equivalent of EASA is FAA (Federal Aviation Agency). FAA is the part of the United States Department of Transportation. It is the National Aviation Authority of the US. The FAA has a blacklist of sorts as well, but its list bans certain countries, not specific airlines, from entering U.S. airspace. This ban may be implemented due to a failure to meet international aviation standards for operations and maintenance (so, the criteria is somewhat similar to the EU list).

Under the International Aviation Safety Assessment (IASA) program, the FAA determines whether another country's oversight of its air carriers that operate, or seek to operate, into the U.S., or codeshare with a U.S. air carrier, complies with safety standards established by the International Civil Aviation Organization (ICAO). The IASA program is administered by the FAA Associate Administrator for Aviation Safety (AVS), Flight Standards Service (AFS), International Programs and Policy Division (AFS-50).

The IASA program focuses on a country's ability, not the ability of individual air carriers, to adhere to international aviation safety standards and recommended practices contained in Annex 1 (Personnel

Licensing), Annex 6 (Operation of Aircraft), and Annex 8 (Airworthiness of Aircraft) to the International Convention on Civil Aviation "Chicago Convention" (ICAO Document 7300).

IASA assessments determine compliance with these international standards by focusing on the eight critical elements of an effective aviation safety oversight authority specified in ICAO Document 9734, Safety Oversight Manual. Those eight critical elements include primary aviation legislation; specific operating regulations; State civil aviation system and safety oversight functions; technical personnel qualification and training; technical guidance, tools and the provision of safety-critical information; licensing, certification, authorization, and approval obligations; surveillance obligations; and resolution of safety concerns.

AIRLINE SAFETY RATING

If the airline has an International Air Transport Association Operational Safety Audit certification (IOSA), it earns two stars. This certificate is difficult to get, so either the airline didn't sign up to be assessed (which is a little suspicious) or they have failed. The International Air Transport Association awards this certificate biannually to the airlines that meet its standards of operational management and control systems. The IOSA certificate is worth two stars—double some of the other criteria—because the IOSA certificate is a pretty good indicator of an airline's safety rating. Airlines with an IOSA certificate had 77% fewer accidents than those without one in 2012.

If the airline is not on the European Union (EU) Blacklist, it receives one star. If the airline hasn't had one fatality in the past ten years, it receives one star. This includes passengers or crew and the fatality must be due to an accident, which does not include any fatalities due to terrorism or fatalities due to something out of their control (an unidentified object obstructing the runway, etc.). If the Federal Aviation Authority (FAA) has endorsed an airline, it receives one star.

If the country of airline origin has met all eight of the International Civil Aviation Organization (IACO) safety parameters, it receives two stars. They can receive partial credit here—if they meet at least five, they get one star. The eight parameters include Airworthiness, Accident Investigation, Air Navigation Service, Aerodromes, Legislation, Operations, Licensing, and Organization.

Two exceptions may cause an airline to lose a star, which are:

- If the airline operates only Russian-built aircraft.
- If the country of origin has grounded an airline's fleet due to safety concerns in the last five years.

Out of 449 airlines, 149 scored the highest safety rating (seven out of seven stars). Below are listed the top ten, each with a seven out of seven ratings. Qantas got the top spot, and the rest are listed in alphabetical order.

- Qantas;
- Air New Zealand;
- British Airways;
- Cathay Pacific Airways;
- Emirates;
- Etihad Airways;
- EVA Air;
- Finnair;
- Lufthansa;
- Singapore Airlines.

T9.6.5 References

Žabokrtský M., 2011, EU Air Transport Policy: Implications on Airlines and Airports, Současná Evropa 01/2011.

Regulations:

Council Regulation (EEC) No 3922/91 of 16 December 1991 on the harmonisation of technical requirements and administrative procedures in the field of civil aviation.

Regulation (EC) No 1899/2006 of the European Parliament and of the Council of 12 December 2006 amending Council Regulation (EEC) No 3922/91 on the harmonisation of technical requirements and administrative procedures in the field of civil aviation; Regulation (EC) No 1900/2006 of the European Parliament and of the Council of 20 December 2006 amending Council Regulation (EEC) No 3922/91 on the harmonisation of technical requirements and administrative procedures in the field of civil aviation.

Regulation (EC) No 1592/2002 of the European Parliament and of the Council of 15 July 2002 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency.

Regulation (EC) No 1643/2003 of the European Parliament and of the Council of 22 July 2003 amending Regulation (EC) No 1592/2002 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency.

Regulation (EC) No 216/2008 of the European Parliament and of the Council of 20 February 2008 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC.

Regulation (EC) No 1108/2009 of the European Parliament and of the Council of 21 October 2009 amending Regulation (EC) No 216/2008 in the field of aerodromes, Air Traffic Management and air navigation and repealing Directive 2006/23/EC.

Council Directive 94/56/EC of 21 November 1994 establishing the fundamental principles governing the investigation of civil aviation accidents and incidents.

Regulation (EU) No 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation and repealing Directive 94/56/EC.

Regulation (EC) No 2111/2005 of the European Parliament and of the Council of 14 December 2005 on the establishment of a Community list of air carriers subject to an operating ban within the Community and on informing air transport passengers of the identity of the operating air carrier, and repealing Article 9 of Directive 2004/36/EC.

Web Pages:

ICAO, International Civil Aviation Organization, www.icao.int, access: March 2018.

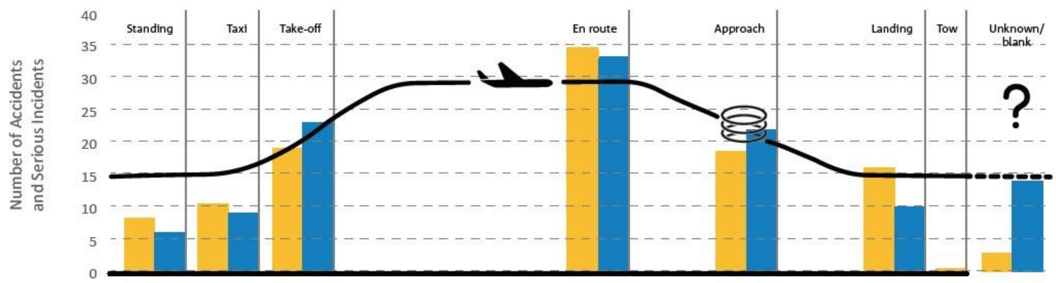
EASA, European Aviation Safety Agency, https://www.easa.europa.eu/, access: March 2018.

FAA, Federal Aviation Administration, https://www.faa.gov/, access: March 2018.

KEY TOPIC T9.7 ANALYSING INCIDENT/ACCIDENT DATA

For preventing risks related to safety, one opportunity is analysing accident/incident data and decide about which actions will be most effective by using new approaches. In fact, in the past, many aviation accidents have been attributable to non-sensitive and non-precise tools, malfunction of sensors, aircraft design, engines, detectors and so on. Nowadays, the use of the principle of active system control offers a good opportunity for further improvements in safety levels.

Statistically, the riskiest phases of flight are taking off and landing especially in bad weather conditions. As shown in the bottom sketch of Figure 9.41. The numbers for 2018 show a very similar distribution pattern of accidents and serious incidents to the 10 year average with a greater number in "En-route" due to the higher exposure (length of this phase of flight) and during approach, take-off and landing due to the critical nature of those flight phases. "Unknown/blank" flight phase corresponds to those occurrences where no data was available and it normally relates to the second aircraft in some of the occurrences (e.g. in a general aviation leisure flight leading to a loss of separation with an Airliner, the missing information on the specific flight phase may be for the general aviation flight).



	Standing	Taxi	Take-off	En route	Approach	Landing	Tow	Unknown/ Blank
Average 2008-2017	8.3	10.5	19.1	34.4	18.6	16	0.4	2.8
2018	6	9	23	33	22	10	0	14

Figure 9.41 – Number of Accidents and Serious Incidents by Flight Phase, 2008- 2018 (Annual Safety Review 2019, EASA).

Over the past 50 years, security and flight safety has improved significantly, and their level is expected to grow even in the presence of an increasing volume of air traffic foreseen for the future. 2016 and 2017 are the years with the lowest number of fatalities in aviation history, thanks to the continued improvements in safety across almost every operational domain. According to a preliminary EASA safety overview depicted in Figure 9.42, 2017 shows the lowest number of fatal accidents in modern aviation history for commercial air transport with large aeroplanes. 2017 was considered the safest year ever in commercial aviation history, nevertheless, the events in 2018 were a reminder that safety should not be taken for granted. Worldwide in 2018, there were 530 fatalities in 11 fatal accidents, setting us back to a level not experienced since 2015.

Over the past 5 years between 2014 and 2018, accidents and serious incidents involving large aeroplane commercial air transport operations most commonly involved the following Key Risk Areas, otherwise known as potential accident outcomes:

-Aircraft Upset.

-Runway Excursions.

-Technical Faults relating to Aircraft Pressurisation or Fire.

These Key Risk Areas are reflected in the European strategic safety priorities that are identified in the European Plan for Aviation Safety (EPAS). The EPAS identifies both the accident outcomes that have to prevent and the safety issues that it would be need to address through mitigating actions.

In Table 9.9 a recent overview of the statistical analysis in security and safety, performed by IATA, is depicted. However, even if we have seen an important advance in safety systems, the fatal accident occurrence demonstrates the importance of joining forces to improve safety in the aviation community.

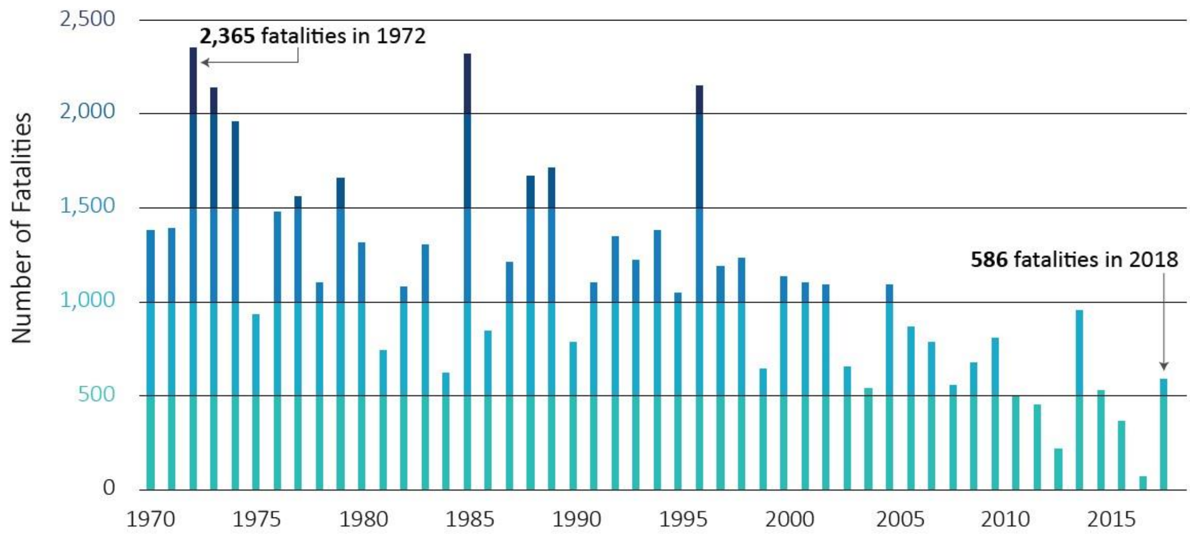


Figure 9.42 – Number of fatal accidents in aviation history for worldwide commercial air transport with large aeroplanes.
Source: Annual Safety Review 2019, EASA.

Rendement en matière de sécurité en 2017

	2017	2016	Moyenne sur 5 ans (2012-2016)
Décès à bord [i]	19	202	314,6
Nombre total d'accidents	45	67	74.8
Accidents mortels	6	9 [ii]	10,8
Risque de décès [iii]	0,09	0,21	0,24
Accidents mortels touchant des vols de passagers	2	3	5,6
Accidents mortels touchant des vols de fret	4	6	4,6
% des accidents causant des décès	13,3	13,4	14,4
Pertes de coque d'avion à réaction	4	13	10
Pertes de coque d'avion causant des décès	1	4	3,4
Pertes de coque de turbopropulseur	9	7	15
Pertes de coque de turbopropulseur causant des décès	5	4	7,2

Table 9. 9 – Statistical yield in security and safety in 2017 compared to 2016.
Source: IATA document 2018

SAFETY STANDARDS IN DIFFERENT REGIONS OF THE WORLD

In the USA, the major cause of aeronautic accidents is related to human factor (1468 accidents in 2000) and performance. These accidents records include lack of total experience, lack of recent experience, human performance and inadequate training. However, the USA is deemed to have the best safety management infrastructure developed so far, as illustrated in Figure 9.43:

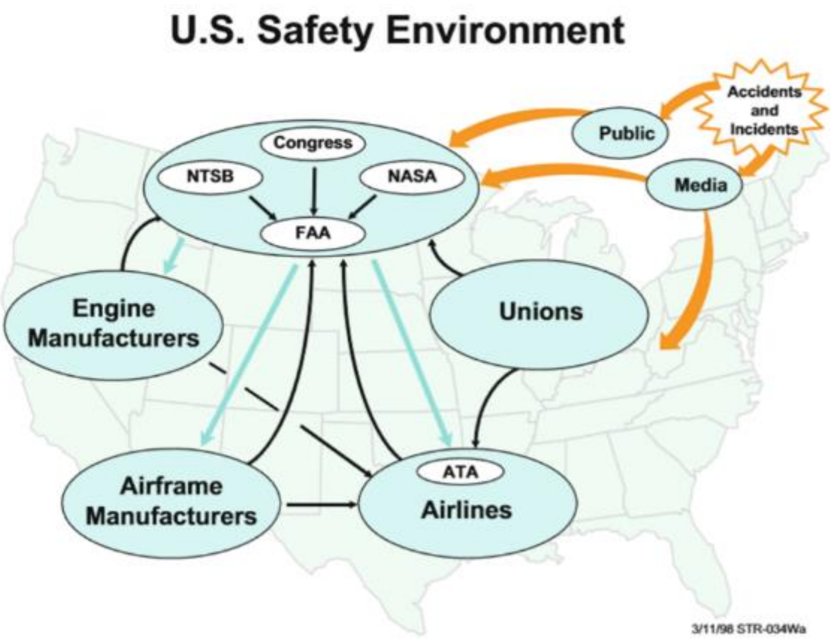


Figure 9.43 – Safety management infrastructure in the USA based on figures from Boeing.
Source: I. Schagaev, B.R. Kirk, Active System Control, DOI 10.1007/978-3-319-46813-6_1 Springer International Publishing AG 2018

In the US, the National Transportation Safety Board (NTSB) is responsible for investigations when an accident occurs and together with FAA and NASA provide recommendations, propose practical actions to avoid similar accidents in the future.

In 2010, the European Commission conducted a comprehensive review of EU legislation on civil aviation accident and incident investigations. This review resulted in the adoption of Regulation (EU) No 996/2010, which currently provides the legal framework for the conduct of civil aviation accident and incident investigations in the EU.

Following the entry into force of Regulation (EU) No 996/2010, civil aviation safety investigation authorities of EU Member States gathered on 19 January 2011 in Brussels to establish the "European Network of Civil Aviation Safety Investigation Authorities" (ENCASIA).

In each member state of the European Union, the investigation of aviation accidents is carried out by relevant government agencies.

In contrast to the USA, EU initiatives in aviation safety have been focused mainly on the human factor, e.g., training and inspections. However, in the past, this strategy has failed as it concerns the increase in safety levels.

The introduction of satellite links has provided an opportunity to store and analyse the flight data, evaluate the safety aspect of the flight in real-time, etc. as shown in Figure 9.44:

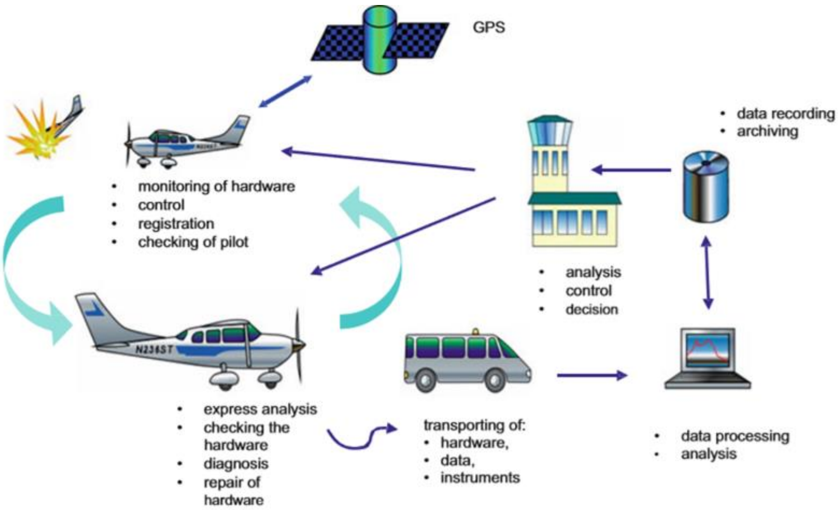


Figure 9.44 – Conventional cycle of information processing of flight information.
Source: I. Schagaev, B.R. Kirk, Active System Control, DOI 10.1007/978-3-319-46813-6_1
Springer International Publishing AG 2018

For long-term analysis, this innovation has allowed finding safety trends over several flights and elaborate new management schemes.

In this contest, an important point to be addressed is the pilot's and crew's training about the regulation protocols. Another safety issue is the mental health of the pilot related to the human factor. In this regard, many areas of medicine have looked to the aviation industry to develop improvements in safety through regulated, standardized practices. It is reported that the pilot's fatigue plays an important role in safety risks. A different meta-analysis confirmed that, in general, the mental health of pilots is a key element for improving safety in aviation (Fanjoy, R.O., Harriman, S.L., DeMik, R.J. 2010. International Journal of Applied Aviation Studies. Individual and environmental predictors of burnout among regional airline pilots).

According to the EASA Annual Safety Review 2019, it is possible to establish a list of safety issues based on the past performance of the system by counting high-risk occurrences, or the number of fatalities or through the aggregated risk score. This review provides a statistical summary of aviation safety in the EASA Member States (MS) and provides the possibility to understand, which the most important safety challenge is. The major top safety issues are:

- Perception and situational awareness;
- Icing in flight;
- Handling of technical failures;
- Turbulence;
- Airborne conflict;
- Flight planning;
- Decision making and planning;
- Experience, training and the competence of individuals;
- Wind-shear;
- Flightpath management;
- Mental health.

The European Plan for Aviation Safety (EPAS) is developed through the European safety risk management (SRM) process, which is articulated in five steps as shown in Figure 9.45:

Figure 9.45 – The European Safety Risk Management Process.
Source: EASA AST summary 2017

The EPAS is a key component of an integrated Safety Management System (SMS) and is constantly being reviewed and improved.

Safety standard in Europe is assured thanks to the efforts of EASA. The main issue is to apply these standards also outside Europe. EASA maintains close working relations with the International Civil Aviation Organization (ICAO) to support States in fulfilling ICAO safety standard. ICAO promulgates **Standards and Recommended Practices (SARPs)** to facilitate harmonised regulations in particular in aviation safety, and security, hence efficiency and environmental protection on a global basis. In 2015, ICAO established the **Aviation Safety Implementation Assistance Partnership (ASIAP)** to coordinate efforts for the provision of assistance to member States (depicted in Figure 9.46) and participating organizations. (https://www.icao.int/safety/Documents/ICAO_SR_2017_18072017.pdf)

Figure 9.46 – ASIAP State and Organisational Partners. Source: ICAO Safety Report 2017 Edition

Existing onboard checking systems are designed to improve aviation safety in future flights using as a reference the available and stored data recorded in-flight. With an on-board processing capability, it becomes possible to simultaneously record and analyse data making it possible to check the aircraft conditions in real-time. Signals are recorded by the **Digital Fight Data Acquisition Unit (DFDAU)** which can also accept digital inputs from sensors and other avionics equipment. So far, new standards and available technologies enable to store 2h of cockpit voice data and record 256 12-bit data words per second. Further plans for the development of flight recording are underway, *i.e.,* the use of flash memory which improves the reliability of these records.

Today the "black box" is the major tool and way to improve the existing safety system. In 1999, the FAA introduced new aircraft black box rules, and in 2004, the FAA requested a recording of controller pilot data link communication messages. In addition to voice and flight data recording, ICAO, EUROCAE and ARINC are considering video recorder. Moreover, by the end of 2006, the NTSB and FAA have requested video recorders and cameras in the cockpit, especially for small turboprops that do not currently have safety recorders.

Figure 9.47 shows some advanced international black box trends, and highlight that Europe is somewhat behind about the recent research focus on implemented and announced "black box" projects worldwide:

	NASA FAA mandates major aircraft "black box" upgrade http:// www.cnn.com/2008/US/03/10/black.boxes/
	China . . .and a new data recorder—a spacecraft black box—is also being tested. The black box is faster than its Shenzhou 5 counterpart and contains more storage space, but at only half the size, Xinhua reported (Xinhuanet, 05) (Malik, 05)
	USA • Time recorded, 25 h continuous • Number of parameters, 18–1000+ • Impact tolerance, 3400Gs/6.5 ms • Fire resistance, 1100°C/30 m • Water pressure resistance submerged, 20,000 ft • Underwater locator beacon, 37.5 KHz • Battery has shelf-life of 6 years or more • Capability upon activation with 30-day operation
	"Izmeritel" (Russia) new flight recorder • Time recorded, 25 h continuous • Number of parameters, 18–1000+ • Impact tolerance, 3500Gs/6.5 ms • Fire resistance, 1100°C/45 m • Water pressure resistance submerged, 20,000 ft • Underwater locator beacon, 37.5 KHz • Battery has shelf-life of 6 years or more • Capability upon activation: 30-day operation *http://www.izmeritel.smolensk.ru/spec1.html*

Figure 9.47 – Existing and developmental flight safety recorders.
Source: I. Schagaev, B.R. Kirk, Active System Control, DOI 10.1007/978-3-319-46813-6_4
© Springer International Publishing AG 2018

The next generation of black boxes has to be compact, extremely resilient, active, and with enhanced capability to improve recorded time. Moreover, the smaller size and the decreased weight could provide great improvements in such devices. However, these features, i.e., decreased weight and size and, at the same time, increased resilience, the survival of accidents, fires and the effects of an aggressive environment (seawater), durability and ability to be recovered still represent a great challenge.

The Global Aviation Safety Program (GASP) by ICAO provides a continuous improvement strategy for the implementation of effective safety oversight systems, State Safety Programmes (SSPs) and the development of advanced safety oversight systems, including predictive risk management. The GASP also sets out timelines for the global collective achievement of these near-, mid- and long-term objectives. These timelines are aligned with the established update process for the GASP and the Global Air Navigation Plan (GANP), which are revised on a triennial basis. The GASP is a high level, strategic, planning and implementation policy document developed in conjunction with the Global Air Navigation Plan (Doc 9750). Both documents promote coordination of international, regional and national initiatives aimed at delivering a harmonized, safe and efficient international civil aviation system [Global Aviation Safety Plan, Doc 10004, ISBN 978-92-9258-118-3].

ICAO has established five comprehensive strategic objectives, which are revised on a triennial basis. ICAO strategic objective dedicated to enhancing global civil aviation safety is focused primarily on the State's regulatory oversight capabilities in the context of growing passenger and cargo movements, taking into account efficiency and environmental changes.

More information on the Strategic Objectives can be found on the ICAO website at www.icao.int/about-icao/Pages/Strategic-Objectives.aspx.

The GASP objectives require that the States put in place robust and sustainable safety oversight systems leading to a more sophisticated means of managing safety. To meet these objectives, regional aviation safety groups (RASGs) and regional safety oversight organizations (RSOOs) should be involved actively in the coordination and harmonization of all activities undertaken to address aviation safety issues at a regional level, including the use of the global aviation safety roadmap by individual States or a group of States.

Figure 9.48 provides an overview of the GASP objectives and their associated timelines. The States must first establish an effective safety oversight system before implementing an SSP. It is expected that all States will continually progress implementation of Standards and Recommended Practices (SARPs) to achieve the GASP objectives and priorities set out in the GASP.

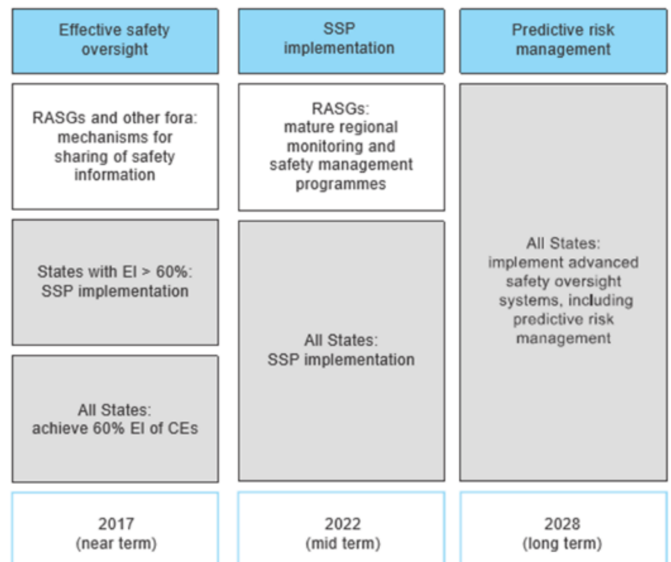


Figure 9.48 – GASP objectives and associated timelines.
Source: ICAO Doc 10004 Global Aviation Safety Plan 2017 – 2019

A target was set for all African States to attain 60 per cent effective implementation (EI) of the critical elements (CEs) of a State safety oversight system by 2017. This target was adopted by the ICAO Council and endorsed by the ICAO General Assembly as a global measure and formed the basis for the near-term objective included in the 2014-2016 edition of the GASP. It corresponds to a minimum level necessary for a State to perform effective safety oversight and move towards SSP implementation.

The near-term objectives, to be achieved by 2017, take into account the current level of safety oversight systems implementation at the regional and national levels.

The near-term objectives are as follows:

a) States lacking fundamental safety oversight capabilities are to achieve an EI of at least 60 per cent overall of the eight CEs of a State safety oversight system. States should prioritize the resolution of deficiencies or findings which have the highest impact in terms of safety improvements. The universal safety oversight audit programme (USOAP) protocols, used to assess the implementation of ICAO provisions, are categorized according to eight CEs (see Figure 9.49).

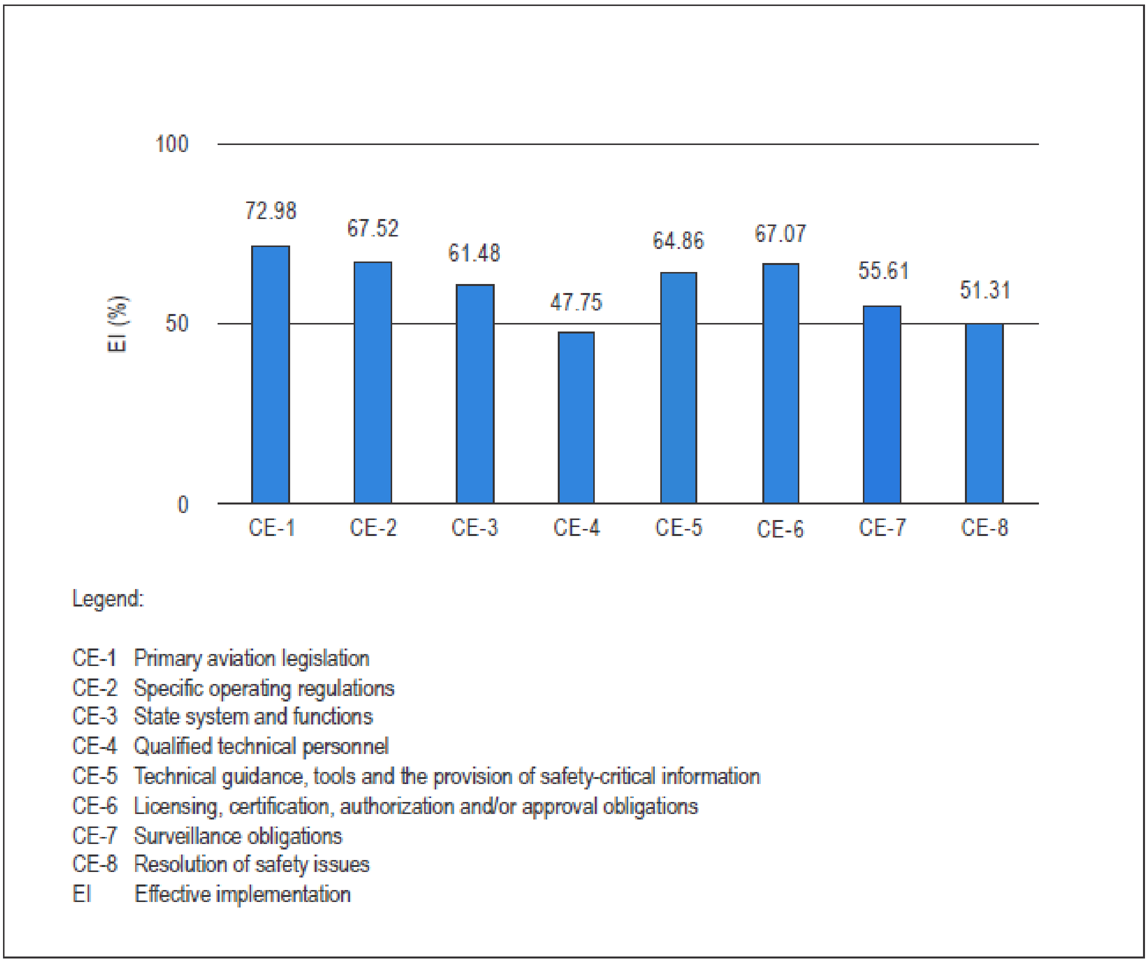


Figure 9.49 – Per cent effective implementation (EI) of the critical elements (CEs) worldwide

Source: ICAO Doc 10004 Global Aviation Safety Plan 2017 – 2019

Implementation of CE-6, which addresses licensing, certification, authorization and/or approval obligations, is fundamental to the reduction of accident rates. Furthermore, through a root cause analysis, deficiencies in CE-6 can be traced to protocol questions in CE-1 to CE-5, which establish a safety oversight system. Each deficiency in CE-6 should, therefore, be associated with a specific action plan for a State's improvement efforts. Effective execution of the action plan provides the basis for prioritized compliance.

b) States which have an EI of 60 per cent or greater should implement SSP, which will facilitate addressing risks specific to their aviation systems.
c) All States and stakeholders are encouraged to put in place mechanisms for the sharing of safety information through their RASGs and other regional or sub-regional fora.

An interesting and important ICAO SARPs is represented form Document namely "Manual for the Oversight of Fatigue Management Approaches (Doc.9966)" which support the approaches to fatigue management. Annex 6 (Operation of Aircraft) Part I – International Commercial Air Transport – Aeroplanes, which is related to flight and cabin crew. Annex 6 (Operation of Aircraft) Part II – International General Aviation – Aeroplanes, this section 2 applies to all international GA operation and Section 3 refers to all operator personnel involved in the operation and maintenance of large and turbojet aeroplanes in GA operations. Annex 11 (Air Traffic Services), which pertain to air traffic controllers.

In addition to the Safety Report, ICAO has created lists of State safety performance indicators (SPIs). A sample set of SPIs was presented at the second High-level Safety Conference held in 2015 (HLSC 2015), through an information paper (IP/01) entitled "Safety data, performance metrics and indicators". The HLSC 2015 recommended that ICAO improve and harmonize those SPIs, taking into account others that were currently in use. Metrics are the core of the SPI process. They constitute the basis from which indicators are drawn. Once a list of metrics is available, providing information such as a definition, the data source, update frequency, unit, scope and safety relevance, State or regional specific indicators can be defined which address the uniqueness of each situation but use the same metrics.

The usage of identifiable metrics allows benchmarking between States and regions even though their safety indicators may differ with regard to their scope, coverage or target. The collection of data is crucial to the development of SPIs. Data can be collected through various ways such as auditing, inspections or reporting.

Occurrence data is typically stored in a database such as the European Coordination Centre for Accident and Incident Reporting Systems (ECCAIRS). The collection of accident and incident data is a well-established aviation safety data collection process executed at the State level.

ICAO USOAP programme has evaluated whether States have effectively implemented an accident and incident database (protocol question 6.507). As of August 2014, only 42 per cent of all audited States have effectively implemented such a database. The regional implementation rates range from 64% in the European region to 13% in Africa as can be seen on the map in Figure 9.50:

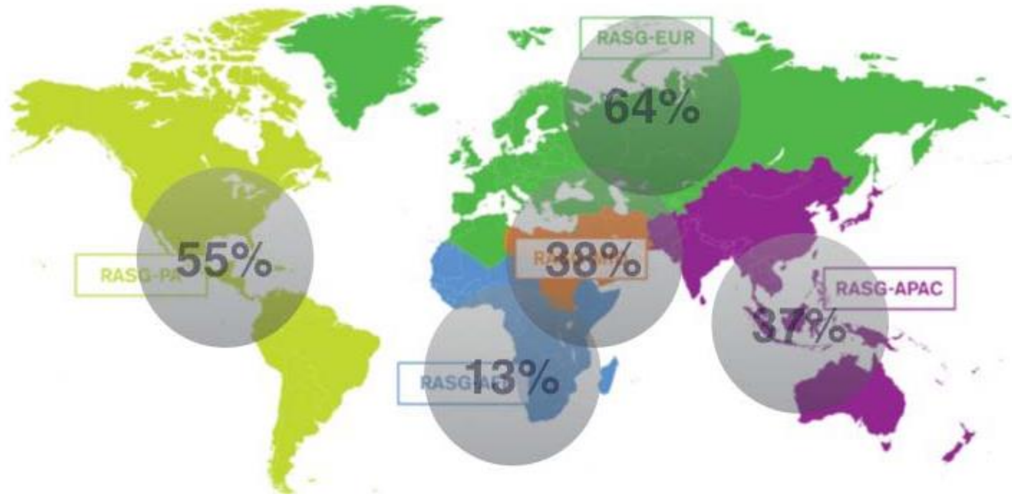


Figure 9.50 – Effective implementation of incident and accident databases
Source: ICAO Secretariat "Safety data, performance metrics and indicators".
Presented at 2015 High-level Safety Conference (HLSC 2015)

The list of safety indicators (see Table 9.10) has been defined which can be used by States for their safety monitoring programme and to establish baselines which can be used ultimately to define targets and acceptable levels of safety.

A- Safety Indicators

#	Indicators and Metrics	Type	Usage
1	**Effective Implementation of State Safety Oversight System** *Metrics:* • *USOAP EI Scores overall* • *USOAP EI Scores by technical area* • *USOAP EI Scores by critical element*	Predictive	Target
2	**Progress in SSP Implementation** *Metrics:* • *Percentage of completed gap analysis questions* • *Percentage of implemented gap analysis questions overall* • *Percentage of implemented gap analysis questions by element*	Predictive	Target
3	**Progress in SMS Implementation** *Metrics:* • *Percentage of completed gap analysis questions by operator* • *Percentage of implemented gap analysis questions overall by operator* *Percentage of implemented gap analysis questions by element and by operator*	Predictive	Target
4	**Frequency and Severity of Accidents and Incidents** *Metrics:* • *Number and distributions of occurrences by severity level (accident, serious incidents, etc.) and ADREP occurrence category* • *Number and distribution of fatalities by ADREP occurrence category* • *Occurrence per number of departures (rate)* *Note: Occurrences should be limited to specific categories of aircraft and operations like "aircraft above 5 700 kg operating scheduled commercial flights"*	Reactive / Proactive	Target
5	**Certification of Aerodromes** *Metrics:* • *Number and percentage of certified international aerodromes overall and by airspace*	Predictive	Target
6	**Significant Safety Concerns** Metrics: • *Number and duration of USOAP CMA significant safety concerns by technical area*	Predictive	Target
7	**Presence of notable hazardous conditions** *Metrics:* • *Number, duration and distribution of safety-related NOTAMS by Doc 8400 Q-code categories*	Predictive	Monitor
8	**Fleet Modernization** *Metrics:* • *Average age of all registered and operated aircraft and their distribution by operator* • *Percentage of all registered and operated aircraft above 20 years and their distribution by operator*	Predictive	Monitor
9	**Effectiveness of Foreign Operator Safety Assessment Programmes** *Metrics:* • *Compliance scores by foreign and national operator*	Predictive	Monitor
10	**Industry Certification** *Metrics:* • *Number and percentage of operators holding industry certificates by type (IOSA, ISBAO, ISAGO etc.)*	Predictive	Monitor
11	**Extend of Environmental Hazards** *Metrics:* • *Average terrain elevation around airports* • *Percentage of METARS indicating low ceiling or visibility by month and location*	Predictive	Be aware

Table 9.10 – Safety indicators
Source: ICAO Secretariat "Safety data, performance metrics and indicators".
Presented at 2015 High-level Safety Conference (HLSC 2015)

SAFETY STANDARDS FOR DIFFERENT SERVICES: AIRLINES, BUSINESS JETS, PRIVATE AIRCRAFT, AGRICULTURAL

Significant safety improvements have been made since the start of commercial aviation. The aviation industry continues to evolve, but its top priority is the same: getting passengers to their destinations safely.

Airbus is committed to safety standards and supporting the safe operation of all its aircraft and those that fly aboard them. Therefore, Airbus works to ensure safety in different levels from the design, to the materials/manuals supplied to customers to operate and maintain the aircraft; form the worldwide services delivered in support of the aircraft's operation to the training to the flight – cabin and maintenance crews.

Airbus works with its customers to introduce safety management systems (SMS) as part of its commitment to improving global flight safety and decreasing accidents. Moreover, it is in constant contact with other aircraft manufacturers, airlines and air safety organisation around the world. Furthermore, Airbus Helicopters develops Safety Information Notices and other technical publication to provide customers with valuable information relates to the company's products and services and to improve safety control.

Airbus Helicopters customers can consult the entire library of technical publications through the company's Technical Information Publication on Internet (T.I.P.I) according to their subscription. The European Helicopter Safety Team (EHEST) regularly releases guidance to improve helicopter safety.

Airbus Helicopter's activities are focused on meeting industry safety standards and supporting the safe operation of its aircraft. In the 1960s, this company developed the Fenestron® shrouded tail rotor which introduced a new level of helicopter safety on the ground and in the air. It is important to share safety information to continue enhancing safety and preventing accidents.

Airbus has several safety-information sharing initiatives such as Project "**Destination 10X Together**", a platform upon which Airbus and operators can collaborate to propose pragmatic solutions to key identified safety issues; ***Safety First*** magazine, that shares lessons-learned with operators and the wider aviation community, and highlights new safety enhancements that Airbus or others have made available; "**Statistical Analysis of Commercial Aviation Accidents".** Focusing on all Western-built aircraft since the beginning of the commercial jet age, this statistical analysis of the air transport sector examines the evolution of hull-loss and fatal accident rates during revenue flights from 1958-2016.

(http://www.airbus.com/company/safety.html#commercialjetlinersafety).

According to IATA's Six Point Safety Strategy, a comprehensive data-driven approach to identify organizational, operational and emerging safety issues such as reducing operational risk i.e., Loss of Control In-Flight (LOC-I), Controlled Flight Into Terrain (CFIT), lithium batteries and integrating remotely-piloted aircraft systems (RPAS) into airspace, and Runway Safety.

In addition to other areas of operational risk, IATA support consistent implementation of SMS, Flight Management System, Cabin Safety, Fatigue as well as enhance quality and compliance through their programs such as IATA Training Qualification and Initiative programs (**SAFETY STANDARDS: CHRONIC CHALLENGES AND EMERGING PRINCIPLES Ibrahim Habli).**

International aviation safety standards are the product of U.S. and EU aviation leadership. These standards are reported in ICAO Annexes and Manual, and since 2013, the number of annexes has grown to 19. Indeed, this last annex was created to improve safety systems. However, standards vary dramatically, as safety analysis is an ongoing process. Safety standards are regularly revised and updated, and typically include a mandatory part covering the requirements for compliance. The creation and the process of news SARP are shown in Figure 9.51. This entire process takes about two years from initial proposal to formal adoption of a SARP within an annex or procedure for air navigation service (PANS) manual. Since the Chicago Convention, ICAO has incorporated over 12,000 SARPs within the 19 annexes and five PANS, along with supplementary and guidance materials.

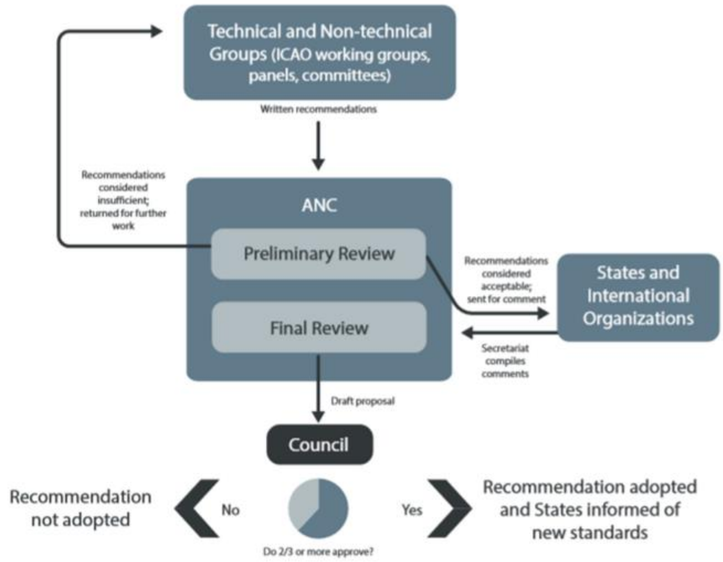


Figure 9.51 – Standard making process.
Source: Suzanne K. Kearns Fundamental of International aviation. Routledge, Taylor and Francis.

In accordance with ICAO Standards and Recommended Practices (SARPs), States must develop its safety oversight capabilities and implement SSPs. The Global Aviation Safety Plan (GASP) provides a strategy to enhance the implementation of the safety initiatives presented in the global aviation safety roadmap and to assist States to meet their safety responsibilities.

However, States' priorities should be coordinated through the Regional Aviation Safety Group (RASGs) to address specific safety concerns in line with global safety priorities and standards. In addition, States and regions should prioritize initiatives associated with the safety performance enablers to first establish effective safety oversight and then address safety risks effectively. Furthermore, States have an obligation under the Chicago Convention to provide timely notification to ICAO when their national regulations or practices differ from those established by SARPs. By this way, States enhance safety by implementing SARPs through the development, publication and implementation of harmonized regulations at the international, regional and national levels. Similarly, the implementation of industry best practices serves to enhance standardization among service providers (ICAO -2017-2019 rod, in ICAO folder document).

RASGs serve as regional cooperative for an integrating global, regional, sub-regional, national and industry efforts in continuing to enhance aviation safety worldwide. RASGs develop and implement work programmes that support a regional performance framework for the management of safety based on the GASP. The Regional Offices of RASGs are the following:

- Bangkok: Asia and Pacific (APAC) Office
- Cairo: Middle East (MID) Office
- Dakar: Western and Central African (WACAF) Office
- Lima: South American (SAM) Office
- Mexico: North American
- Nairobi: Eastern and Southern African (ESAF) Office
- Paris: European and North Atlantic (EUR / NAT) Office

Industry stakeholders- i.e., ICAO, States, international and regional organizations, industry representatives, air navigation service providers, operators, users, aerodromes, manufactures and maintenance organizations- are involved to continually improve safety (Figure 9.51). They are encouraged to review the roadmap to identify safety initiatives and actions that support national and regional programmes and work collaboratively to enhance safety in a coordinated manner.

General-purpose aviation includes various kinds of aircraft application: administrative, business, air-taxi, tourism, medical, life-saving, agricultural, prospecting, sporting, training, and experimental. Users of GA aircraft, in turn, can be private and corporate owners as well as state and local administrative bodies such as police or fire departments.

Safety standards for GA must be elaborated in different manner respect the CA and military one. This feature need not have expensive smart devices and no prof. data the record for GA respects the other. In any way, to improve safety in aviation safety standard should be elaborate internationally and commonly.

Safety Management Failings by Cause	%
Airframe and Power Plants	32.90
Pilot/Owner and operator licensing	12.97
Past overhaul time	3.78
Past or no 100 hour inspection	3.24
Past or no annual inspection	1.62

Figure 9.52 – Percentage of failures in the practice of Safety management.
Source: Aviation: Landscape, Classification, Risk Dataaleas

IEC 61505 is one of the most widely used standards in the safety domain. One of the key objectives of the IEC 61505 standard is to provide a basis for the development of domain-specific standards and covers all safety lifecycle activities. One safety standard evolving form this is IEC 61508, which include standards in health care, machinery, nuclear, and automotive. A recent similar and derivate of IEC 61508 in the automotive functional safety standard is ISO26262, which provides full coverage of the safety lifecycle activities. The ISO 26262 standard is focused on the development activities at the system, hardware, and software levels. It is important to note that safety standards underline is the need to demonstrate the integration between the development processes and the safety activities.

The lack of existing and published rationale results in making safety standards is one of the major cause of companies' mistakes in this field, due to a poor understanding of the directive that the authorities aim to assess and/or due to lack of experience, *i.e.* due to turnover of staff or lack of engagement with the standardization community. Both researchers and practitioner are working to overcome this challenge.

The lifecycles in both IEC 61508 and ISO 26262 start with a definition and an analysis of the system and environment.

Another important safety standard: the Guidelines for Development of Civil Aircraft and Systems, the ARP4754A safety assessment model, emphasizes the bidirectional relationship between the main development activities (function definition, system architecture, and implementation) and the primary safety analyses, namely: functional hazard assessment (FHA), preliminary aircraft safety assessment (PASA), preliminary system safety assessment (PSSA), system safety assessment (SSA), and aircraft safety assessment (ASA). Independence between functions, systems, or items is often used as a key risk-reduction strategy.

The relationship between safety at the design stage and safety at the operational stage is illustrated in the Federal Aviation Administration's (FAA) framework for Safety Management Systems (SMS) (AC 120-92A) (FAA, 2010), depicted in Figure 9.53:

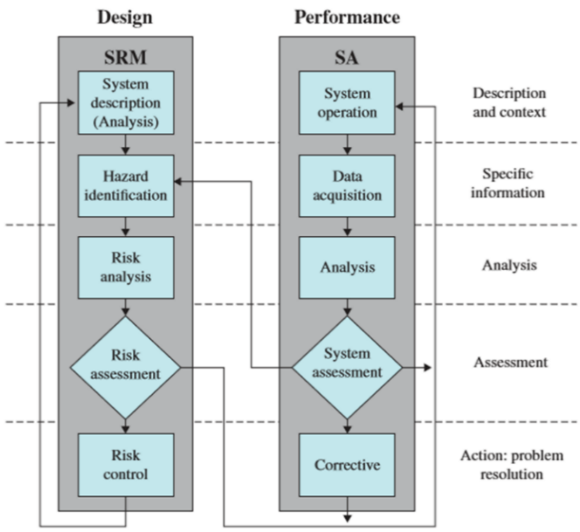


Figure 9.53 – FAA SMS framework – Feedback between SRM and SA.
Source: FAA 2010

The feedback between SRM and SA is used for providing ongoing safety assurance, and as a means for understanding design and operational weaknesses and improving the effectiveness of the safety controls, aiming to help institutionalize learning and evolving safety culture.

HOW DO THE FAA AND EASA BAN FOREIGN AIRLINES OR REMOVE THE BAN?

The European Commission with the support of the European Aviation Safety Agency (EASA) chairs the EU Air Safety Committee (ASC). The Commission is constantly looking at ways to improve air safety standards by working with aviation authorities worldwide. According to the International Aviation Law Institute, safety standards are not being met globally. As an example, ICAO has identified Latin America, Africa, and Asia as disproportionately responsible for airline accidents. Moreover, other concerns have been raised by the absence of transparency and accountability in the growing Chinese aviation market.

In Europe, the Blacklist program began, in December 2005. The EU Member States identify carriers subject to operating bans within their territory. Then, the FAA and EASA, in coordination with the EU Commission evaluates on common criteria the carriers and publishes at least every three months the EU Air Safety List in the Official Journal of the European Union. This includes one list of all airlines banned from operating in Europe and another one includes airlines that are restricted from operating under certain conditions in Europe. The EU Air Safety List helps to maintain high levels of safety in the EU, but it also helps affected airlines and countries to improve their levels of safety, making the EU Air Safety List a major preventive tool. In fact, banned carriers can request a compliance review from the Commission to be removed from the list.

The EU Air Safety List contains two lists. The first list (Annex A) includes all airlines banned from operating in Europe. The second list (Annex B) includes airlines that are restricted from operating under certain conditions in Europe. Both lists are updated regularly and published in the Official Journal of the European Union. Before taking any action based on the information in these lists, all users should ensure they have the latest version. A total of 115 airlines were banned from EU skies, according to the EU Air Safety List that was updated at the end of 2019 by the European Commission.

The European Commission in Nov. 2017 updated the list of non-European airlines that do not meet international safety standards and are therefore subject to an operating ban or operational restrictions within the European Union. Following this last update, a total of 178 airlines are banned from EU skies:

- 109 airlines certified in 15 states, due to a lack of safety oversight by the aviation authorities from these,
- 6 individual airlines, based on safety concerns concerning these airlines themselves.

There are also three airlines which have operational restrictions at the beginning of 2020 when operating in EU airspace and therefore can only use certain types of aircraft.

According to the Commission, the EU Air Safety List not only helps to maintain high levels of safety in the EU but also helps affected airlines and countries to improve their levels of safety, for them to eventually be taken off the list. Also, the EU Air Safety List has become a major preventive tool, as it motivates countries with safety problems to act upon them before a ban under the EU Air Safety List would become necessary.

It is important to note that, the civil aviation authorities of the Member States of the European Union are only able to inspect aircraft of airlines that land at each Union airport. Therefore, the fact that an airline is not included in the list does not automatically mean that it was compliant with all safety standards. With this in mind, it is necessary to improve the international safety standard as the assessment is made against them, and notably, the standards promulgated by the International Civil Aviation Organization (ICAO). (http://europa.eu/rapid/press-release_IP-17-4971_en.htm).

EASA is, therefore, implementing technical cooperation projects with partner countries and regions. An example is the "Improving air transport in Central Africa" (ATA-AC) project, where EASA works with several African states on several aspects of aviation safety.

In light of this, there are several ways to improve safety such as the need of a new approach, better if it will be dynamic rather than static, to safety management and modelling accident analysis/prevention, which takes account of the varying risks during the different phases of flight and dynamically adapts the safety strategy accordingly. The "soft" regulation of aviation and the lack of strict enforcement also constrain improvements in safety management. These existing schemes of safety management in aviation, easily avoidable by GA aircraft owners and users, are mostly focused on after flight. The "human" factor being the weakest link in the chain hence it should be better investigated.

The US ("country-based" approach) list is distinct from the EU ("carrier-based" approach). The US approach to Blacklist, ensure that all foreign air carriers that operate to or from the U.S. are properly licensed and with safety oversight provided by a competent Civil Aviation Authority (CAA) following ICAO standards. In this regards the FAA look at the foreign CAA's capability for providing safety certification and at the foreign CAA's ability to provide continual oversight of its carriers. A country's failure to meet ICAO standards is published by the FAA. Moreover, in the US the Flight Safety Foundation, which is an international non-profit organization, performs research, inspection, advice, and publishing to improve safety since 1947. This organization has helped protect everyone who benefits from air travel, everywhere in the world and works closely with other aviation organizations, including the Airline Pilots Association, Air Transport Association of America, ICAO, IATA, etc. The Foundation is in a unique position to identify global safety issues, set priorities and serve as a catalyst to address these concerns through data collection and information sharing, education, advocacy and communications.

SAFETY ACTIVITY DEVELOPMENT

Worldwide cooperation on safety issues is based on assumptions and actions initiated by ICAO. The Global Aviation Safety Plan (GASP) is ICAO's top strategic safety document. The GASP, including the global aviation safety roadmap, serves as an action plan to assist the aviation community in achieving the objectives presented in the Plan, through a structured, common frame of reference for all relevant stakeholders. The 2017–2019 edition of the GASP has three main objectives:

- All States to reach an effective implementation (EI) score of 60 per cent for the eight critical elements (CEs) of a safety oversight system by the end of 2017;
- All States to implement a State Safety Programme (SSP) by 2022; and
- All States to implement advanced safety oversight systems, including predictive risk management by 2028.

The implementation status of 2017–2019 edition of the GASP as of 31 May 2018. For the first objective on effective implementation of safety oversight, 69.19% of States is above 60% EI and the global average EI score sits at 65.51%. Despite the marked trend of improvement, the first objective was not met by the end of 2017. For the second objective on SSP implementation, 85% of all States with EI higher than 60 per cent (122 States) have started implementing their SSP. 37% (46 States) has established a plan for SSP implementation and 3 States have declared that they have fully implemented an SSP. Based on this data, this objective is on track. For the third objective on predictive risk management, States struggle to achieve this as a standalone goal, mainly because it requires full SSP implementation. A proposal was made to merge this objective into the SSP one (not as standalone) for the 2020–2022 edition of the GASP since it is part of implementing an SSP. So there are some difficulties in achieving this objective.

UNMANNED AIRCRAFT SYSTEM (UAS)/ REMOTELY PILOTED AIRCRAFT SYSTEM (RPAS)

Unmanned aircraft (UA) includes a broad spectrum of aircraft from meteorological balloons that fly freely to highly complex aircraft piloted from remote locations by licensed aviation professionals. The latter is part of a category referred to as remotely piloted aircraft (RPA) and operate as part of a remotely piloted aircraft system (RPAS). ICAO has been leading the development of a regulatory framework to enable the safe and efficient integration of RPA into non-segregated airspace and at aerodromes for over 10 years. In particular, through the work of the Remotely Piloted Aircraft Systems Panel (RPASP), ICAO is engaged in a detailed study of the International Convention on Civil Aviation (the "Chicago Convention") and its 19 Annexes to develop international Standards and Recommended Practices (SARPs) and guidance material applicable to RPA engaged in international navigation under instrument flight rules (IFR).

ICAO's initial work on RPAS has led to the amendment of Annex 2 – Rules of the Air, which now contains high-level provisions regarding certification, licensing, operating rules and special authorizations; Annex 7 – Aircraft Nationality and Registration Marks, to define RPA as unmanned aircraft and ensure nationality and registration marks can be applied regardless of size or configuration of aircraft; and Annex 13 – Aircraft Accident and Incident Investigation, extending the definition of "accident" to include unmanned aircraft. In March 2015, ICAO published the Manual on Remotely Piloted Aircraft Systems (Doc 10019) to direct the development of future SARPs. In October 2017, an RPAS Concept of Operations (CONOPS) for International IFR Operations was published. The RPAS CONOPS aims to describe the operational environment of manned and unmanned aircraft, thereby ensuring a common understanding of how the subset that is remotely piloted can be expected to be accommodated and ultimately integrated into the national airspace. The scope is currently limited to certificated RPAS operating internationally within controlled airspace under IFR in non-segregated airspace and at aerodromes in the 2031 onward timeframe. In March 2018, ICAO adopted an amendment to Annex 1 – Personnel Licensing on remote pilot licensing, competency-based training and assessment – the first in a series of amendments planned for the remaining Annexes. This will become applicable on 3 November 2022. The development of guidance material in support of this amendment is currently underway.

In 2016, the 39th Session of the ICAO Assembly expanded the scope of the Organization's work programme to include the regulation of all UA, including small UA typically engaged in domestic operations. Accordingly, the Unmanned Aircraft Systems Advisory Group (UAS-AG) was established in 2016 to provide guidance and best practices to States, regulatory bodies and stakeholders to enable the safe and efficient operation of UA. The UAS-AG is comprised of UAS regulatory and operational personnel, ATM and related industry technical experts from geographically diverse Member States, international organizations, industry and academia. The UAS-AG's first order of business was to develop an online Toolkit to assist States that have no, or limited, regulations or guidance material. The Toolkit offers not only helpful information and resources, but also serves as a platform for the exchange of global best practices, lessons learned, and effective governance approaches.

In March 2017, in response to events involving the operation of small UA by uncertified, untrained recreational users, ICAO issued State letter AN 13/55-17/38, reminding the Member States as a matter of urgency of their obligation under Annex 2 – Rules of the Air, to establish and enforce regulations mandating that aircraft not be operated negligently or recklessly or in such proximity to other aircraft as to create a collision hazard, including at international aerodromes.

In May 2017, recognizing that a variety of UA is set to be used in lower altitude, domestic airspace, ICAO announced a Request for Information (RFI) calling for solutions from industry, States and stakeholders to establish a harmonized global framework for a new concept under development known as UAS traffic management (UTM), which intends to serve as a highly automated ATM-like system for areas with high-density UA operations. The RFI focused on solutions for the registration, communications and geofencing-like systems needed to enable UTM. In February 2018, ICAO announced a second RFI seeking solutions to enable the safe and efficient transition between future UTM and concurrent ATM systems. The UAS-AG is in the process of developing a framework to ensure the global harmonization and interoperability of UTM systems based on these RFI submissions.

Based upon the results of the assessments of submissions from States, industry and academia to ICAO's 2017, 2018 and 2019 RFIs, ICAO invited various submitters, which best addressed the various problem statements in the respective RFI, to present their information to a global audience at DRONE ENABLE, ICAO's Unmanned Aircraft Systems (UAS) Industry Symposia in 2017, 2018 and 2019. The most recent RFI has recently been approved and selected submissions will be shared at DRONE ENABLE/4, 9-11 September 2020, in Rio De Janeiro, Brazil.

The UAS-AG Phase II will support the Secretariat in guiding ICAO Member States with establishing a common global framework for, and core boundaries of, unmanned aircraft system traffic management (UTM), to allow further UTM developments to focus on better-defined issues, whether technical, operational or legal.

Through these activities, ICAO continues to lead the development of a comprehensive and harmonized regulatory framework for unmanned aviation that is implemented in a harmonized manner in Europe and other countries around the world.

IATA has also collaborated closely with ICAO, civil aviation authorities and key industry partners to develop a toolkit that provides states with operational guidance and regulations to ensure the safe and efficient integration of Unmanned Aircraft Systems (UAS) into shared airspace.

The SESAR Joint Undertaking has defined the U-Space Blueprint. U-space is a set of new services relying on a high level of digitalisation and automation of functions and specific procedures designed to support safe, efficient and secure access to airspace for large numbers of drones.

On 19 October 2019, the European Commission launched the European Network of U-space Demonstrators to support U-space projects and solutions.

The network is a forum to share knowledge on how to keep drone operations safe, secure and green. It focusses on U-space: a system that connects all drones flying in the air and that makes all drones visible for authorities and citizens.

Led by the European Commission, EUROCONTROL is part of the Network's support cell, which bundles together the regulatory competence of EASA, the R&D management expertise of the SJU and our air traffic management expertise.

The network focuses specifically on projects with a clear business case that build on mature technologies but need some further operational and regulatory demonstrations before starting commercial operations.

The network also supports the competent authorities in processing the numerous applications expected once commercial businesses start. The network is open to all U-space projects that help to open the European drone services market. All SESAR U-space related projects and all projects within the European Innovative Programme (EIP), Smart Cities and Communities (SCC), Urban Air Mobility (UAM) initiative are automatically part of the Network.

At the end of 2019, SESAR JU and its partners have completed 19 research and demonstration projects, addressing everything from the concept of operations for drone operations, critical communications, surveillance and tracking, and information management to aircraft systems, ground-based technologies, cyber-resilience and geo-fencing. The results of these projects have been summarized and published, and are the basis for further plans for the integration and development of unmanned systems in Europe.

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3.5 Security

Security is a global issue at least as much as safety because passengers can fly to airports worldwide, outside the jurisdiction of the authorities that apply stricter standards like Europe, the US or Japan. Many of these are popular tourist destinations besides important business hubs. The tendency for some airports to attract smuggling facilitates the infiltration of security threats. As for safety, the regions with higher safety standards like Europe and the US could support security cooperation with other countries, especially those chosen as business or tourist travel destinations of its citizens.

Besides airport security, another aspect is airways security about which each state should provide adequate warning. The shooting down of Malaysian Airways MH370 over the Donbass region of Ukraine is a tragic example of how easy it is to fail in this domain. The Ukrainian rebels were armed with shoulder-fired surface-to-air missiles that had been used to shoot down several Ukrainian military aircraft. The Ukrainian air force had restricted flying to altitudes above 9 km above the reach of such missiles. They did not know that longer-range vehicle-mounted surface-to-air missiles had been deployed in the region and considered airline flights safe at typical cruise altitudes of around 10 km.

Ukrainian air force transport aircraft was also flying at those altitudes, and the missile was intended as a surprise shooting down of one of them and was advertised at the internet as such. When it was realized that the target had been an airliner the internet announcement was quickly withdrawn, and a long process of denial, obstruction and destruction of evidence was started, including jamming of investigators communications near the crash site and hacking of their office in the Netherlands. Several airlines had simply decided not to overfly Ukraine, which in retrospect was a far better decision. Ensuring the security of air travel may require cooperation with intelligence services that can inform airlines on measures to safeguard their passengers, by evaluating the risks that their nationals could incur in certain regions of the world.

KEY TOPIC T9.8 ASSISTANCE PROGRAMMES TO IMPROVE AIRPORT SECURITY

Integrating security systems and operations into the planning and design of airport construction and refurbishment projects can be a very complex task. The term "security system" covers a broad range of equipment, technologies, procedures, and operational approaches that need clear and concise guidelines. The task is further complicated by 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. Finally, 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.

Airports tend to be in a constant state of change in terms of their physical layouts, operations, and tenants. Even as the industry has seen significant mergers of domestic and international airlines, new, alternative carriers are entering the market. 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.

All these points emphasize that there is not a single, one-size-fits-all solution to the unique problems encountered at each airport when designing and integrating security systems, nor is there a single planning and design approach for the physical space and facilities that can be universally applied to all airports.

In response to September 11, 2001, terrorist attacks in the United States, and with the potential for future attacks, the President signed into law the Aviation and Transportation Security Act (ATSA) on November 19, 2001. The creation of the DHS (Department of Homeland Security) by the Homeland Security Act of 2002 realigned a patchwork of government activities into a single department with the primary mission to protect US homeland, resulting in the most significant transformation of the U.S. government since World War II.

There are numerous advantages to incorporating security concerns into the airport planning and design process at the earliest phases of planning and development.

Timely consideration of such needs will result in less obtrusive, less costly, and more effective and efficient security systems. Such systems are less likely to provoke passenger complaints or employee resistance and are more able to fully meet regulatory and operational requirements. Proper planning can also result in reduced manpower requirements and consequential reductions in airport and aircraft operator overhead expenses. A careful review of the prevalent threat environment, and applicable security standards and countermeasures prior to finalization of construction plans, will help determine an airport's most appropriate security posture. Such a review may also help to reduce reliance on labour-intensive procedures and equipment, which is common when an airport is required to quickly retrofit security.

Inclusion of security experts early in the planning process will result in a better coordinated and more cost-effective approach to security.

Planning for security must be an integral part of any design project undertaken at an airport, including physical structures and IT systems, among others. The most efficient and cost-effective method of instituting security measures in any facility or operation is through planning and analysis at the start of the design process, supported by monitoring and amendment of those analyses, if required, throughout the project. Selecting, constructing, or modifying a facility without considering the security implications for the protection of the general public, the facility, passengers, and airport and air carrier personnel can result in increased risk to persons and assets, as well as have a costly impact on facility modifications, or cause project delays.

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.

Perimeter protection (e.g., fences, gates, and patrols) is the first line of defence in providing physical security for personnel and property at a facility. Some more advanced technologies can reach outside the fence to identify approaching threats or may be used in an environment where there is no fence or physical barriers, such as a water boundary or swamp.

The second line of defence and perhaps the most important is interior controls (e.g., access control and checkpoints). The monetary value and criticality of the items and areas to be protected, the perceived threat, the vulnerability of the facility, and the cost of the controls necessary to reduce that vulnerability, will determine the extent of interior controls.

The primary objective of facility protection planning is to ensure both the integrity and continuity of operations and the security of assets. Any area designated as requiring control for security and/or safety purposes must have identifiable boundaries for that area to be recognized and managed. In some cases, boundaries must meet a regulatory requirement to prevent or deter access to an area. In many instances, however, boundaries may not be hard physical barriers, such as fences or walls; they might instead be painted lines, lines marked and monitored by electronic signals, grass or pavement edges, natural boundaries such as water or tree lines, or simply geographic coordinates. The distinctions between these different areas must be understood by the design team, such that they are clear on how the physical design of space and structures relates to the physical and virtual boundaries.

To implement security at an airport, it is necessary to understand and quantify the degrees of security into three key issues:

1. What is the threat to the airport?
2. What is an airport's level of vulnerability relative to each element of that threat?
3. To what extent is the threat/vulnerability likely to change, and why?

A vulnerability assessment is an excellent tool and the primary means for determining the extent to which a facility may require security enhancements. It serves to bring security considerations into the mix early in the design process, which reduces the risk of a more expensive retrofit after the design or construction has begun. Many tools and methodologies are available; all are subjective to varying degrees, largely because, in every case, one must first have a thorough understanding of both short- and long-term threats to understand and respond to the three key issues noted above. With this in mind, the planning and design team's response to these points will be a recommendation of a combination of security measures, both physical and procedural, to provide enhanced security and ease of movement for both passengers and employees.

The Airport Security Committee may offer recommendations that consider the following:

- Known threat(s) specific to the airport and/or to the airlines serving it;
- History of criminal or disruptive incidents in the area surrounding the facility, but not primarily directed toward airport operations;
- Domestic and international threats and the general integrity of the transportation system;
- Facility location, size, and configuration;
- The extent of exterior lighting;
- Presence of physical barriers;
- Presence of access control and alarm monitoring systems, closed-circuit television systems, and other electronic monitoring systems;
- Presence and capabilities of onsite staff, law enforcement, and/or security patrols;
- Other locally determined pertinent factors, such as general aviation, commercial operations, and intermodal transportation facilities.

Airport and aircraft operators provide protection through a combination of mobile patrols or fixed posts staffed by police, other security officers, or contract uniformed personnel; security systems and devices; lockable building entrances and gates; and cooperation of local law enforcement agencies. The degree of normal and special protection is determined by completion of a vulnerability assessment and a crime prevention assessment.

The local police department may collect and compile information about criminal activity on or against property under the control of the airport, provide crime prevention information programs to the occupant and federal agencies upon request, and conduct crime prevention assessments in cooperation with appropriate law enforcement agencies.

In addition to physical protection, airport operators also need to keep records of incidents, personnel access, or other activities. Some of the records (such as personnel access) may be collected automatically. Recordkeeping needs, including some video applications, may affect IT systems, cable designs, and equipment locations, as well as require secure data storage. These needs should be coordinated early in the design process.

It is important to consider security systems and procedures from the beginning of the design phase through completion, so that space allocation, appropriate cabinetry and furnishings, conduit runs and system wiring, heavy-duty materials, reinforcing devices, seismic requirements, and other necessary construction requirements are provided in the original plans.

The first step toward integrating security into airport planning, design, or major renovation is the analysis and determination of the airport's general security requirements. The range of available options, configurations, and functions is very broad. There is no single solution, and with a very little examination, it is apparent that there are a large number of issues that must be addressed before the best approach and optimal solution can be achieved at any given airport.

The place to start is defining operational requirements, and most common views on the development of a Concept of Operations characterize the process in terms of eight basic questions:

- *What does the project involve: an update of existing infrastructure, a move or expansion into new facilities, operational reorganization, new interfaces with airport departments and government agencies, or mutual aid?*
- *Why is this project happening? What is the impetus: system integration, physical expansion, growth forecasts, outdated technology, new regulatory requirements, inadequate or failing infrastructure, or administrative restructuring?*
- *Who are the users and stakeholders, both internal and external to the organization? What are their operational goals, and what information do they require?*
- *What infrastructure exists? What threats and vulnerabilities exist?*
- *Which new technologies will be most appropriate to best serve the different priorities and interactions among user groups?*
- *What human factors need to be accommodated, such as ergonomics, lighting and noise levels, sightlines, design factors for dealing with multiple technologies and/or multiple events, and certain staffing and training criteria?*
- *What is the realistic budget and where it is coming from? What are the additional related costs, such as those for staffing and long-term training, operations, and maintenance?*

Asking the question "what?" seeks to identify the depth and breadth of security functionality to meet appropriate user requirements. What array of services is the facility expected to offer? What information is it expected to provide, to whom, and for what purposes? This can include a range of points, all needing early identification, as they will drive the detailed approaches to plan and design. What systems and services are needed to meet the user requirements? This is limited to a high-level definition of systems in operational terms rather than in technical terms. Unless there is a specific reason for identifying details of a system, this should initially be generalized. The reasons to identify a new or upgraded system or service may include: a legacy system may exist and continue to be used; or the owner of the facility may have other operational, legal, policy, budgetary, physical space or contractual constraints that limit the ability to make changes to or replace a system. Developing a description of the appropriate level of functionality requirements will serve as the foundation for a more detailed design of the systems.

Answering "Why?" will lead to the identification of the objectives of the security system project. Why is it needed? For airport expansion and growth projections or consolidation of operational and administrative functions? For outdated or failing technologies and infrastructure, or possibly new regulatory requirements that address operational gaps and user needs? Or, perhaps, for all of the above? As a subset to this, the answer should also identify operational and administrative issues, policies, and constraints affecting the facility, which inform the planning process in determining how the project will be executed to achieve its objectives.

This emphasizes the importance of having all stakeholders engaged in the development of the Concept of Operations. The comparison and contrast of views between the executive level and the operational level should identify gaps in the objectives; identify conflicts and redundancies to be addressed and resolved; allow for the identification and resolution of differing levels of criticality and priorities and provide a baseline for establishing near-term and long-term objectives.

"Who?" addresses the identity of stakeholders, e.g., individual or organizational, internal and external to the security system and its operational elements. It should address the user requirements as classes or descriptions of users who are meaningful to the organization. Also, it should include the operational requirements necessary for their primary responsibilities. This also begins to identify the support activities of stakeholders that arise beyond the anticipated operational activities—who owns the facility, who maintains it, who manages and pays for it—thus, also identifying persons or offices who, while not primary users, significantly influence how the project is ultimately designed and operated.

It should also provide the initial identification of the types of personnel, and the number and type of functions that will be located in the facility or interact with it in some form; identify the level and priorities of personnel or organizations that will be engaged in the process during design and development; and identify at a high level the roles and responsibilities of the stakeholders with a definition of their operational interactions, both internal and external.

For any security system, a typical stakeholder list might include the following groups:

- Management/executive staff;
- Communications staff/dispatchers;
- Law enforcement, contract security;
- Airside operations;
- Landside operations;
- Curbside and ground transportation;
- Airport facilities and maintenance;
- Airport development/engineering;
- IT;
- Risk Management;
- Air Traffic Control;
- Airlines;
- Military joint use;
- Adjacent commercial/industrial parks;
- Local/state/regional government;
- Surrounding community.

To answer "when?" one should realize that the development of a security system may not be an isolated project. It will frequently be a part of a larger effort such as a new or renovated terminal and affect many other related activities. It is essential to have a clear but flexible schedule to allow for coordination with related programs, conflict avoidance, and incorporation of opportunities for collaboration with other projects or actions. Often, the timing may be driven by a need to meet regulatory, policy, or other procedural requirements, the nuances of which must be thoroughly understood as part of the driving force behind development.

A preliminary project schedule should reflect at least the following five periods:

- Concept development period;
- Pre-design phase;
- Planning and design period;
- Construction or implementation period, including changeover;
- Useful life of the facility past construction or implementation – This element is often overlooked, but it can establish a basis for later planning for anticipated upgrades, replacement, or expansion, all of which must be reflected in long-term planning and budget considerations.

During the planning and design phases, this baseline schedule will be refined and enhanced by the design team based on budgets, resource availability, project scale, and other evolving factors.

Addressing where to locate a new facility can become somewhat complex, especially when the facility has special requirements, or future moves, additions, or changes are planned. These can include different requirements for physical separation or proximity to another facility. For example, regulatory or operational limitations on the facility site may reflect requirements for setbacks from another area for reasons of safety or security; limits in the amount or suitability of the space; infrastructure constraints; adequacy of IT capabilities in alternate locations; budget considerations; threats and vulnerabilities relative to its operations; and access requirements.

"How?" addresses how the facility can be successfully developed and implemented, based on the information developed throughout the process. It includes such issues as funding, personnel, integration of existing and planned infrastructure, architectural constraints, coordination of planning and design concerns, and a list of other locally unique activities and assets to be accommodated for the project to move forward. The resolution of "how" is a particularly critical element of the Concept of Operations as it establishes each sequential set of activities, to be set in place for the guidance to be fully effective.

This will vary depending on the particulars of each project, but, in general, should include a rough order of magnitude of "soft" costs such as planning, design, and consulting fees required to develop the project; a similar rough order of magnitude of the "hard" costs such as capital expenses for construction of facilities, IT and communications infrastructure expansion, equipment, labour, and related costs; internal and external professional resources necessary to complete and support the project, such as maintenance and training; and a proposed schedule of steps to be undertaken throughout the process, and milestones to be accomplished.

A key element of the Concept of Operations for the development of an airport security system is a Risk Assessment, the principal components of which are a determination of threats and vulnerabilities. The standard risk formula is risk = threat x vulnerability x consequences [R= T x V x C]. A risk assessment is necessary for the general development of airports and other mission-critical facilities and should be a standard element of the early supporting activities. The risk assessment can establish some starting points: what systems are in place, what changes are planned, what their strengths and vulnerabilities are with respect to a range of likely threats, and how the security planning and design process can address them in an optimal operational and cost-effective manner. The actions taken in response to the risk assessment will often include measures designed to increase the ability of a facility to respond to an event or multiple simultaneous events, as well as provide increased safety and security measures as the irregular operations evolve. As some of these measures can increase costs for the development of the security system, the assessment must provide a clear definition of the risks and vulnerabilities to be addressed during planning and design.

The key elements of a threat and vulnerability assessment include the following:

- Develop a clear perspective of the interrelationships among the facility, the organization, and its assets. Assets include property, systems, structures, business, information/data, and people.
- Identify the threats and vulnerabilities and the risks associated with each. An outside party, preferably a party with expertise in the risk assessment process, can do this initially. The approach used by the outside party may vary from the relatively benign to the very aggressive. Regardless of the approach, the external assessment should be combined with information on the range and probability of threats and vulnerabilities known to the facility owner.
- Quantify the probabilities associated with each of the identified risks. To the greatest extent possible, the probabilities should be based on factual data. Probabilities of risk can be gathered from a range of sources, including local, state, and national agencies that have experience with events and incidents.

Once a set of risks has been identified, planners should quantify the value of losses associated with each risk. This includes financial costs, costs due to loss of use of a facility or function, the cost to recover, loss of life, loss of earnings or revenue, and loss of goodwill and trust. The value of a loss resulting in direct relation to the risk needs to be measured against an established system of values.

Threats and vulnerabilities change over time, as does an organization's response to both. A risk assessment should not be a one-time activity but should be revisited when experiencing major organizational, facility, or operational changes. An airport operator should not go more than five years between thorough threat and vulnerability assessments; more often if changing conditions warrant.

SITUATIONAL AWARENESS

Situational awareness is the perception of events and activities in real or near-real-time seen by an individual or group, and their understanding of how those events and activities may be related. More simply stated, one should know what is going on from moment to moment so that the Security Operations Centre (SOC) operator can react if required.

Situational awareness can be developed through several different means. It can include:

- Direct observation of an event or situation;
- Observation reported by third parties;
- Observation through CCTV systems;
- Observation through sensing systems (e.g., fire alarms, security alarms);
- Observation related by news and media outlets.

Too much information, particularly if it is irrelevant or distracting from a critical event, can be detrimental to effective decision making by the SOC operator. Excess information can place such a high demand for human operators or responders that they cannot absorb or process it all and may miss or misinterpret critical points.

This is not to suggest that available information should be limited. A SOC should have access to information where it is appropriate and useful for decision making. Several approaches can be taken to avoid overloading the SOC without losing vital information:

- Disperse blocks of information to different people or teams, who filter critical data to a manager or team charged with decision-making.
- Establish levels of criticality for information or alarm conditions, such that more urgent concerns are elevated for attention sooner.
- Provide a smaller number of points to focus on, while allowing different information streams to be viewed. An example of this is a video wall with a limited number of screens but a high number of video feeds, allowing the SOC operator to select and change their primary views as the situation develops.

Key considerations and elements of effective situational awareness include:

- Good quality information delivered promptly;
- Where situational awareness drives organizational response to an event or activity, reliable bi-directional communications are essential;
- Flexibility to allow for changing conditions;
- The level of situational awareness required of the SOC staff drives the information sources that need to be delivered.

ICAO Global Aviation Security Plan (GASeP)

The air transport industry plays a significant role in the global economy. Secure air transport service enhances connectivity in trade, tourism, political and cultural links between States. Annual international air passenger traffic is expected to reach 6 billion by 2030 from about 3.3 billion today, while air cargo transported is expected to increase to 125 million tonnes from 50 million. With air traffic projected to increase significantly in the future, there is a need for a planning framework at the international, regional and national levels to manage growth in a safe, secure and efficient manner.

In September 2016, delegates at the 39th Session of the International Civil Aviation Organization (ICAO) Assembly agreed that there was a need for the accelerated development of a Global Aviation Security Plan (GASeP) as a future aviation security policy and programming framework. The GASeP, which replaces the ICAO Comprehensive Aviation Security Strategy (ICASS), addresses the needs of States and industry in guiding all aviation security enhancement efforts through a set of internationally agreed priority actions, tasks and targets.

The objective of establishing the GASeP is to help ICAO, States and stakeholders enhance the effectiveness of global aviation security. The GASeP, therefore, seeks to unite the international aviation security community and inspire action in this direction, taking into account that the threats and risks faced by the civil aviation community continue to evolve. It is also intended to achieve the shared and common goal of enhancing aviation security worldwide and to help States come together to fulfil the commitments set out in UNSCR 2309 (2016) and relevant ICAO Assembly Resolutions.

The overarching principles that support the GASeP's objective are:

- **No Country Left Behind**. To ensure that the implementation of security SARPs are urgently undertaken globally so that all States have access to the significant socio-economic benefits of safe, secure and reliable air transport.
- **Effective implementation and compliance**. Appropriate measures that are applied to ensure consistent outcomes, coupled with a robust security quality control and oversight system.
- **Sustainability**. Utilizing measures that are proportionate and realistic in the long term, duly coordinated with entities from other sectors (e.g. aviation safety, air navigation, facilitation).
- **Cooperation and information sharing**. Strengthen cooperation and sharing of information between and amongst States and stakeholders. To ensure that the principles of cooperation defined in bilateral and/or multilateral air services agreements, recognition of equivalent security measures, and focus on security outcomes continue to be the basis for international cooperation.
- **Security culture and human capacity development**. Establish a strong and robust security culture and develop human capital, skill and competency.
- **Innovation**. Encourage States and stakeholders to devise, establish and share new and innovative ways to implement security policies and measures.
- **Identifying, understanding and managing risk**. Enhance understanding of aviation security risks and take appropriate and effective action.

Central to the Plan is a Roadmap that outlines 94 tasks, accompanying 32 actions under 5 key priority outcomes, which set out objectives until the 40th Session of the ICAO Assembly in 2019. A set of indicators and target dates also accompanies each task. This Roadmap is a "living" document and shall be periodically reviewed and adjusted as necessary, taking into account new and emerging aviation security threats.

During 40th Session of the ICAO Assembly (24th September – 04th October 2019) States welcomed and endorsed the ICAO Cybersecurity strategy for the air transport sector, a first-of-its-kind response which features key goals relating to information sharing, improved coordination among all partnering government and enforcement entities, and timely and aligned responses to related risks and events.

They further endorsed ICAO's expeditious delivery of the GASeP, with over 160 States participating in the lively discussions, and supported the ICAO Secretariat's initiative to establish a mechanism for reporting implementation progress, which is critical in encouraging all States to reach the GASeP aspirational targets for 2020, 2023, and 2030.

In order to make rapid progress on its core objective of enhancing the effectiveness of global aviation security and improving the practical and sustainable implementation of preventive aviation security measures, the GASeP identifies five key priority outcomes where ICAO, States and stakeholders should focus their urgent attention, resources and efforts. These priorities derive from the main challenges that may face member states in delivering this objective. They are:

- **Enhance risk awareness and response**. Understanding risk is essential for policies and measures that are effective, proportionate and sustainable. Undertaking risk assessments will help to identify gaps and vulnerabilities, which can then be urgently addressed in the most practical way possible, and with optimal use of resources.
- **Develop security culture and human capability**. The promotion of effective security culture is critical to achieving good security outcomes. Strong security culture must be developed from the top management across and within every organization. The existence of a well-trained, motivated and professional workforce is a critical prerequisite for effective aviation security.
- **Improve technological resources and foster innovation**. Promoting and applying better technological solutions and innovative techniques can provide the tools for enhancing security effectiveness while ensuring operational efficiency.
- **Improve oversight and quality assurance**. Effective quality control and oversight processes globally, nationally, and locally are critical in delivering sustained effective aviation security.
- **Increase cooperation and support**. Increasing collaboration between and within States will enable the key security objectives to be achieved more quickly and efficiently.

The GASeP will bring together ICAO, States, industry, and other stakeholders in a holistic and coordinated effort to address current and emerging global aviation security challenges. Security is a critical pillar for the growth and sustainability of the global aviation industry. It is envisaged that the GASeP will serve as an important document to assist all stakeholders to strengthen international collaboration in aviation security, including the areas of harmonizing security principles, approaches and measures; information sharing; innovation and better use of security technology, and in aviation security training and capacity development. The GASeP will also move ICAO, States, industry and all stakeholders towards fulfilling the intent and direction of UNSCR 2309 (2016), and towards enhancing the level of global aviation security for the benefit of all States, as well as contributing to the wider benefit of strengthening economic growth and development across the world.

The Aviation Cyber Security Task Force (ACSTF)

Public and industry concern around vulnerabilities and risks associated with aviation cybersecurity continues to escalate. Additionally, state and non-state cyber actors are increasingly demonstrating their interest in targeting civil aviation systems, with intents ranging from proving antagonistic capabilities, stealing data and to disrupt the continuity of operations. Their interests also include civil aircraft as noted by paragraph 2.5 of HLCAS/2-WP/6 "Update on Aviation Security Threat and Risk". However, currently, aircraft systems are believed to remain highly resilient against attempted electronic interference. But, potential vulnerabilities are regularly highlighted, and regulators and industry must increasingly develop a pro-active, resilient and continuously evolving aviation cybersecurity posture as aircraft data optimization and connectivity efforts increase.

IATA has established an aircraft cybersecurity task force (ACSTF) reporting to the Security Group (SEG), tasked to develop high-level risk-based guidance and best practices for the digital protection of complex aircraft systems. Additionally, the ACSTF leverages existing guidance available to industry, such those published by the European Organization for Civil Aviation Equipment (EUROCAE) Working Group 72 (EU) and Radio Technical Commission for Aeronautics (RTCA) Special Committee (US), to make recommendations for an industry-led approach when addressing cyber-risks associated with the safe operation of aircraft critical systems.

3.6 Fair Trade

Trade disputes are not unknown in aviation at the highest level of the World Trade Organization (WTO). After having initially dismissed Airbus as a 'government aircraft', when it realized this was a serious competitor, Boeing tried to prove its claim at the WTO. The United States on behalf of Boeing filled a complaint that Airbus was subsidized by European governments since it received low-interest loans for aircraft development, refundable from subsequent sales. The counterargument was that Boeing benefitted from US Air Force and NASA contracts, for example, the Boeing 707 was based on the military transport C-135 and KC-135 tanker. The Air Force owns factories that it can lend to the industry at nominal or zero cost; the NASA contracts cover 100% of costs whereas in some EU research programs the industry pays 50%. It is unclear whether the protracted litigation was of benefit to anyone, certainly not to airlines that want competition between Airbus and Boeing, not a monopoly of either of them.

The reverse process occurred with the EU on behalf of Airbus filing a complaint with the WTO about the US export-import bank low rate loans in support of the exports of Boeing aircraft. The case was won by the European side that was allowed to apply penalties as compensation but may have elected not to do so. The response on the US side was to change the export support law, to one protecting employment in the US and discouraging delocalization of industrial activity abroad. The practical effect in terms of 'export subsidies' was the same except that they now covered a range of industrial sectors wider than just aviation. An example that WTO rulings can be sidestepped by new legislation that aggravates rather reduces the trading inequalities. At present, the future of the export-import bank in the US is under discussion despite the support of Boeing because it gives loans to foreign airlines competing with US airlines. In the meantime, Airbus has plentifully refunded the European governments for the former development loans and is healthy enough not to need them anymore.

The Airbus-Boeing duopoly of large airliners is not alone to come to WTO fillings since the Canadian government on behalf of Bombardier has accused Brazil of subsidizing Embraer. More recently the tables were turned around in the context of the sale of C-Series in the US at low prices after major cash injections of the Quebec government into Bombardier, that are suspect of financing dumping. Bombardier noted among other things that more than 50% by value of a C-series is American, and that percentage will go higher when the production line moves from Canada to the US as part of the deal with Airbus. Even some Airbus aircraft with American engines have more than 50% American content due not only to propulsion but also several other systems.

Boeing maximizes value in final production that takes place at three sites; the third in a southern state whose laws give less bargaining power than the trade unions have in Seattle. Airbus maximizes value at its partners and has the main two production lines in Europe plus final assembly lines in China and the US, the latter increasing local content. There is substantial international content both in the Airbus and Boeing aircraft, often starting with engine options and continuing with a worldwide supply chain. The airlines have no interest in trade disputes and the Boeing-Airbus competition suits well their bargaining power when buying new aircraft as the Bombardier-Embraer competition did. The link Airbus-Bombardier and Boeing-Embraer if they strengthen would mean that: (i) for more than 150 seats there would still be the choice of Airbus or Boeing and likewise, for jets of less than 100 seats a choice between Bombardier and Embraer; (ii) in the range 100 to 150 seats the choice might narrow down from 4 to 2, extending the duopoly to almost all the jet airliner market.

KEY TOPIC T9.9 FAIR TRADE

T9.9.1 Historical background

Boeing forayed into commercial aviation by launching its first aircraft, the B&W Seaplane, in 1916. The company went on to develop several small passenger and military aircraft in the two decades that followed, becoming a frontrunner in all-metal aircraft construction.

Boeing introduced its first commercial jetliner, the 707, in 1958. The launch of 747 long-range airliners with much larger seating capacity than other commercial aircraft in 1970 further strengthened Boeing's position in commercial aviation.

Airbus was founded in the late 1960s to consolidate of Europe's fragmented commercial jetliner manufacturing base, and growing it into an international competitor. At that time, the global market for large commercial jetliners was overwhelmingly dominated by American firms. Boeing, Lockheed and Douglas Aircraft controlled about 90% of the market. The governments of France, Germany, Britain and Spain recognized that to meet the challenge from the Americans and overcome the huge barriers to entry in the industry, they needed to combine their resources. In 1970 the Airbus consortium was officially established, and the governments of the four countries made major commitments for financial support of this enterprise. This support came largely in the form of loans at below-market rates to fund the bulk of the development costs for the A300, the first airliner produced by this consortium. The development of the Airbus A300 cost US$1.5 billion. Government loans were also provided to European suppliers of Airbus, particularly Rolls-Royce, which produced the engines that were used to power the Airbus aircraft.

Because Boeing has been present on the market for a long time, the Airbus, without state aids, would not be able to enter the market because the company would not stand any chance to make a profit.

This method of financing, called launch aid, has been utilized to support the development of the entire family of jetliners now produced by Airbus and has contributed significantly to the growth of Airbus. As time passed, this funding evolved from direct grants to reimbursable advances that were linked to sales. Under this system, loans from Europe's governments are repaid gradually with each aircraft or engine that is sold. However, if sales fail to reach specified goals, the loan is not fully repaid. Thus, the governments assume a portion of the market risk of developing new aircraft or engines. This arrangement reduces the market risk for Airbus and its suppliers and gives them the ability to borrow in the open market at lower rates than they would otherwise have to pay for additional financing that they might require.

As the Airbus developed, changes in the marketplace occurred on the other side of the Atlantic as well. Lockheed lost its position when its L-1011 wide-body jet failed to attain profitability, and the firm withdrew from commercial aircraft production in the early 1980s. Production problems with its DC-8 and DC-9 jetliners, along with the cost of development of the DC-10, forced Douglas to merge with McDonnell Aircraft, a major producer of military aircraft, in 1967. Douglas Aircraft operated as a separate unit within McDonnell Douglas, but continued to be plagued by production problems and low sales. Weakness in its commercial aircraft division ultimately caused McDonnell Douglas to seek a merger with Boeing, and the two firms merged in 1997. This merger left Boeing as the sole producer of large commercial jetliners in the United States and resulted in an effective duopoly in the global market, with Airbus as the only other major competitor.

As Airbus began to increase its market share and establish itself as a viable competitor, Boeing became increasingly vocal about the unfairness of the launch aid that Airbus received. Airbus responded by drawing attention to the indirect subsidies received by Boeing.

Although the U.S. government does not provide launch aid or loans to Boeing (nor to engine manufacturers such as General Electric or other Boeing suppliers) for new development programs, the Boeing has received "indirect" subsidies. For example, the National Aeronautics and Space Administration (NASA) supports aeronautics and propulsion research that is shared with Boeing, and NASA programs are 100% funded. Research sponsored by the Department of Defence creates technological spin-offs that are reflected in commercial jetliner innovation, most notably in aircraft engines and aircraft design. Furthermore, several state and local governments, particularly the states of Washington, Illinois and Kansas, provide tax breaks to Boeing, which has production facilities in those states.

As sales of the Airbus A-320 began to chip away at sales of the popular Boeing 737 in the latter part of the 1980s, the debate became much more heated. This resulted in both sides coming to the bargaining table, and in 1992 they agreed on limitations on the level of subsidies. Launch aid for Airbus was limited to 33 per cent of development costs and indirect subsidies to Boeing were limited to 3 per cent of revenue.

However, as Boeing continued to lose market share to Airbus in the ensuing years, trade frictions intensified once again. In 2004, Boeing accused Airbus of violating the provisions of the 1992 pact and renounced the agreement. Trade representatives from the United States and the European Union attempted to negotiate a settlement to the dispute in 2005, but their efforts were unsuccessful. Boeing filed a suit at the WTO, claiming that Airbus received illegal subsidies from European governments. Airbus immediately retaliated by filing a suit against Boeing, claiming that the federal and state subsidies received by Boeing were illegal.

Today, two producers of large commercial aircraft (more than 120 seats) dominate the market. In 2019, the Boeing Company manufactured 380 aeroplanes while its European competitor Airbus delivered 863 aircraft. The world's civil jet planes fleet currently totals 25,326. aircraft (2018). 22,363 of them are large commercial aircraft. The base of large commercial aircraft splits up in 11,463 Boeing aircraft and 9,681 Airbus aircraft. Hence, Boeing controls a market share of 51.26 per cent while Airbus accounts for 43.29 per cent of the global fleet of large commercial aircraft. The remaining aeroplanes are mainly McDonnell-Douglas types.

Airbus' revenues are better diversified and are from markets that have high growth potential such as the Asia Pacific, especially China. The company earns more revenue from Asia Pacific (36.6%) than Europe (27.9%) and the two regions together contribute approximately 65% to its gross revenue.

Although Boeing too earns a similar chunk of its revenues (70%) from just two geographic areas namely the US (44.2%) and the Asia Pacific (25.6%), its revenues are more concentrated in the US, unlike Airbus, which has a better diversification. Airbus also earns higher revenue from the Asia Pacific, which Boeing too recognises to be a crucial market for its future growth.

Similar to the market for large civil aircraft, the market for the regional jet with 30 to 120 seats is currently dominated by two manufacturers: Canada-based Bombardier and Embraer from Brazil. The world's regional jet fleet consists of 3,559 aircraft (2018). The total Bombardier-made fleet amounts to 1,275 aircraft which corresponds to a market share of 35.8 per cent. Embraer sees 1,851 aircraft in service (52.0 per cent market share). Hence, Bombardier and Embraer together make up about 87 per cent of the global regional jet fleet. The remaining 13 per cent are aircraft manufactured by Bae, Fokker, Fairchild and Sukhoi. The first three manufacturers have ceased aircraft production years ago, however. Bombardier and Embraer are today's only remaining regional jet manufacturers. However, three newcomers are currently entering the market and have received their first firm orders: Russia's Sukhoi Superjet 100 (developed in cooperation with Ilyushin and Boeing), China's AVIC I Commercial Aircraft Company (ACAC) ARJ21 and Japan's Mitsubishi MRJ.

Having already conquered the North American domestic and some European countries with its Canadair Regional Jet series (CRJ), Bombardier saw an opportunity to build a larger aircraft. Called the Cseries, the plane was designed to replace ageing DC9/MD80, Foker 100 and the BAe146. Unlike its CRJ Series of jets, the new plane would have twin wing-mounted engines and a 2-3 seat configuration.

Throughout its development, Bombardier had to keep asking the Canadian government and the government of Quebec for financial aid to stay in business. With orders on the books and the thought of thousands of workers being laid off, the money was forthcoming. Bombardier was now under financial pressure and mired down with a trade dispute with Boeing. Therefore, it offered a stake in the CSeries to Airbus.

Knowing the value of the CSeries planes, Airbus jumped at the chance and acquired 50.1% of the CSeries program in October 2017. Now with a controlling interest, Airbus said that it would move the manufacturing of the CSeries aircraft to its facility in Mobile Alabama, a move designed to thwart threats of massive tariffs from the United States. By doing this, Airbus could now market the plane to American carries as an aircraft built by American workers in the USA.

The manufacturer knew that there would be added value in incorporating the CSeries with the Airbus brand. Therefore, it decided to rename the planes the A220-100 and A220-300.

The Airbus incorporation of the Bombardier CSeries as A220 is beneficial for both: (i) Airbus completes its aircraft range at the bottom end with a modern and efficient A220; (ii) the A220 benefits from the bargaining power of Airbus with suppliers (lower costs), plus the vast Airbus worldwide support network.

Despite the current aviation corona-crisis, the Airbus A220 will be one of the first aircraft airlines turn to as they start flying again. It is anticipated that the A220 aircraft will be an advantage to airlines as they adjust to new demand in a post-coronavirus market is supported somewhat by the aircraft's utility during the crisis. Delta Air Lines has kept all 31 of its fleet of A220s flying, despite grounding more than half its fleet during the crisis.

AirBaltic, which had made the A220 an integral part of its growth strategy when the aircraft was still produced under the Bombardier name, announced in April 2020 that the A220 remains core to the airline's survival strategy going forward. AirBaltic plans to initially resume operations using its 22 Airbus A220-300 aircraft, with reduced capacity for 2020 and 2021, and foresees a return to growth by the end of 2020, supported by a fleet of up to 50 Airbus A220-300 aircraft.

T9.9.2 International Content in Airbus, Boeing, Bombardier and Embraer Airliners

Aircraft manufacturing is arguably the most contested industry in international trade governance. This is due to the great financial expenditures to be incurred for the development of a new type of a large aircraft. There is no aircraft manufacturer in the world which can do this without state support. Significant static economies of scale which result from high R & D as well as from investments in production plants characterize the civil aircraft industry. The development of the first Airbus type A300, for example, cost US$1.5 billion while Airbus had to invest US$3 billion in the development of the A330/A340. The research & development efforts for the new flagship, the A380, exceeded €15 billion and the new twin-aisle A350XWB family, entered to service in 2015 cost up €11 billion. On average, R & D expenditures make up 50 per cent of the total costs of an aircraft programme. Since most of these expenditures are specific, as the R & D outcomes can only be used for building aircraft (families), investments in R & D in this industry are sunk costs which act as barriers to market entry.

The two lead actors in this topic are Boeing and Airbus for long-range aircraft, and Bombardier and Embraer and others for regional aircraft. Ever since Airbus emerged some 40 years ago to challenge Boeing's position as the world's dominant aircraft manufacturer, governments have been accusing one another of illegitimately propping up their respective national champions, while simultaneously professing their innocence in providing support.

The traditional tools of trade governance are particularly ill-suited to aircraft manufacturing. 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. The problem is, when it comes to aircraft manufacturing, there has never been anything close to a perfectly competitive, distortion-free market: It is politics and subsidies all the way down. 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.

Thus, the aircraft market consists of governments subsidizing production by their national champions, then lobbying other governments to buy their planes, often linking these procurement decisions to diplomatic relationships. There is not a good methodology to reasonably price this subsidy. Moreover, this points to the larger problem in trying to arrive at a “fair” outcome in the aircraft subsidy complaints: Given how governments are so deeply and fundamentally involved in the industry, asking what a jet would cost in the absence of government distortions to the market is an impossible question.

Furthermore, the aircraft manufacturing industry shows both the strengths and limits of the rules-based, legal approach to global economic governance. The WTO has made a valiant attempt to discipline some of the more direct subsidies governments provide to their aircraft manufacturers. But the legal record shows it has been a long, drawn-out fight, with no signs of easing. And the institution is not cut out to weigh into the informal, indirect subsidies provided by defence contracts, let alone adjudicate how much diplomatic pressure is appropriate in pushing for a jet sale.

Meanwhile, looming on the horizon is a bigger and potentially far messier aircraft subsidy fight. Recently, China’s COMAC, a state-owned aircraft manufacturer, completed a successful first flight test of its new jetliner, designed to compete with Boeing and Airbus. Comac has repeatedly tried (and failed) to strong-arm the FAA into giving Comac aircraft certification. Comac too has tried to strong-arm the EASA. Instead of trying to coerce them, Comac has resorted to blackmail which also failed. This failed for both ARJ21 and C919. Meaning that as of its release in 2021, the C919 probably won’t be able to fly in the EU or US. Whereas the ARJ21 has limited certification in China, and flies with restrictions there. When eventually China obtains certification for their airliners, which they have failed for more than a decade, the risk of subsidies is considerable, judging from well-known export practice.

For now, neither Boeing nor Airbus wants to take an aggressive stance against COMAC, as the two Western companies don’t want to risk losing out on lucrative sales to China’s domestic airlines. But ultimately, they, along with their government backers, will need a strategy for dealing with this new challenger. Perhaps this will finally prompt Boeing and Airbus to aim their attacks away from one another and toward a common threat, just as Siemens and Alstom recently joined forces to take on the China Railway Rolling Stock Corporation, China’s state-backed train maker that’s winning more and more contracts overseas.

The current situation is even more complicated than before. Top aircraft manufacturers Airbus, Boeing, Embraer and Bombardier have complex relationships that result from cooperative relationships. This demonstrates that subsidies granted by national governments to domestic aircraft manufacturers are increasingly less effective in the ever more inter-nationalized aircraft industry.

The strategic trade policy concept is based on the assumption that subsidies raise the national income if the rents shifted as a result of the subsidy exceed their budgetary costs. But in highly internationalized industries it cannot be taken for granted that domestic subsidies will solely benefit domestic producers without any welfare reducing “leakage” to the benefit of foreign producers or consumers.

It has to be questioned that both Boeing and Airbus are still pure “national champions”. Boeing, for example, has outsourced large parts of the B787 production process to six major suppliers in three countries. Boeing itself will realise only 35 per cent of the 787 work share. About two-third of the design, development and fabrication work was out-sourced to suppliers from the United States, Europe and Japan.

Each of the competing companies, Boeing and Airbus, is aware of the fact that it cannot manufacture the aircraft entirely by itself. It must more or less reach for the services of subcontractors. Outsourcing is mainly used to reduce production costs. However, it can be a source of various problems. For Airbus and Boeing, their supply chains overlaps so much that they come to the same supplier and basically make the same demands for components.

Supply chains which provide everything from jet engines to the overhead compartments for the carry-on bag may not be able to ramp up production fast enough if needed. It creates serious bottlenecks because the same manufacturers make parts for both Boeing and Airbus companies.

Boeing executives admit that it can be tough to find the right balance between what it makes at its plants and what it acquires from outside companies.

The company has conceded it tipped too far in the wrong direction with the 787, which is undergoing test flights some two years behind schedule. Boeing relied extensively on other companies to both design and build 787 components, in part to alleviate the burden of financing such a big project. But the extensive outsourcing led to communication snafus and delays.

Aviation analysts believe that the lesson from "the great fiasco of the 787" is that it's not just what is outsourced, but also how it is outsourced. Boeing failed by giving outsiders too much responsibility for designing integral parts of the aircraft.

It doesn't mean it's a bad idea to divide the work — and share the cost — of building an aircraft. The aeroplane makers always rely on outside suppliers to build engines, one of the most important components in an aircraft, and the system has been highly successful.

The comprehensive outsourcing strategy has given to the Boeing company the opportunity to attract widespread support from governments outside the US. To be more precise the Chicago-based company managed to extract substantial financial support from the Japanese and Italian governments. In 2005 it was estimated the Japanese support at US$1.588 billion, which splits up into 30 per cent for non-repayable grants and 70 per cent for repayable loans. The repayment scheme of the granted loans follows arrangements very similar to those criticized by the US government in its WTO case against the EC. "Ironically it seems that whilst Boeing complains about this system being used by its competitor, it is happy to see the same or an even more generous system used by its Japanese suppliers to reduce its manufacturing costs for the 787" (Pritchard, D./MacPherson, A. (2005): Boeing's Diffusion of Commercial Aircraft Design and Manufacturing Technology to Japan: Surrender-ing the US aircraft industry for foreign financial support, Canada – United States Trade Center Occasional Paper No. 30). Concerning Italy, Boeing profited from government aid worth US$590 million (€500 million) which were granted for upgrading one of Alenia's plants in southern Italy. Hence, "a substantial portion (46 per cent) of the estimated $13.4 billion in launch funding consists of actionable/prohibited subsidies under both the 1994 WTO-SCM Agreements and the 1992-EU Agreement on Trade in Large Civil Aircraft." (Pritchard, D./MacPherson, A. (2004): Industrial Subsidies and the Politics of World Trade: The case of the Boeing 7e7, in The Industrial Geographer, Vol. 1 (2), pp. 57-73). Regarding the launch aid likely to violate WTO agreements, 60 per cent was granted by the state of Washington, 26 per cent by the Japanese government, 9.6 per cent by Italy and 3.3 per cent by the state of Kansas for Boeing's Wichita facility.

Airbus has awarded manufacturing work contracts to a wide range of suppliers as well. It is worth pointing out in this context that about 40 per cent of the contracts Airbus concluded with external suppliers for the A350XWB program were with US-based companies. These contracts are worth US$24 billion, representing around 80 per-cent of all outsourcing contracts so far.

The A350XWB-programme is not the only Airbus program subject to the outsourcing of key component and stages of production. Even though major fuselage sections and components of the A380 are designed, developed and manufactured by Airbus entities in France, Germany, the United Kingdom and Spain, a number of US firms participate substantially in the A380 production. The engines, for example, are made by General Electric, and Goodrich takes responsibility for the main landing gear, the evacuation systems and the interior lighting system. The navigation equipment is delivered by Northrop-Grumman, and Honeywell is Airbus' partner for avionics. In total, nearly half of the components of the A380 are assembled by US companies, mostly in US facilities. Since 1990, Airbus has spent about US$ 50 billion in the United States, and 120,000 jobs in the US aircraft industry depend on Airbus (2012).

The same trends are unfolding in the regional aircraft industry. The two leading manufacturers, Bombardier and Embraer, have built nearly global supply chains as well. Initially, a program of CSeries aeroplane – designed to seat 100 up to 149 passengers was planned in cooperation with China Aviation Industry Corporation (AVIC)'s affiliate Shenyang Aircraft Corporation. The purchase of majority stake by Airbus and the change of the program name to A220 modified these plans. Alenia Aeronautica from Italy has won the contract to manufacture the horizontal and vertical stabilizers. The fixed leading edge of the wing is made by the Belgium-based Sonaca in cooperation with the Czech Aero Vodochody. US-firms like Rockwell Collins, Goodrich, Honeywell and C&D Zodiac have signed delivery contracts for the avionics and cabin interiors, respectively.

In the Embraer 170/190-programme, external suppliers deliver whole systems which only have to be integrated on the final assembly line. In doing so, suppliers have been taking about one-third, in figures US$ 850 million, of the total launching costs. US companies dominate Embraer's external supplier list (57 per cent), followed by European-based suppliers (27 per cent share) and Japanese companies (8 per cent share). The remaining 8 per cent spread out over firms from other countries.

T9.9.3 Europe/ Airbus versus US/Boeing at the WTO

Before the US took on Canadian subsidies to Bombardier, it had long been decrying the "launch aid" European governments gave Airbus to help it bring new models to market. The Europeans, for their part, complained about the indirect subsidies Boeing received in terms of inflated defence procurement contracts and NASA research expenditures. The two sides reached something of a truce in a 1992 agreement that set limits on subsidies, but that deal broke down in 2004, and since then the two sides have been fighting it out in a series of seemingly never-ending World Trade Organization (WTO) disputes.

In the agreement in 1992, the parties recognised a formula for balancing US financial grants to its aircraft industry with repayable loans to the European aircraft industry. While the EU, in good faith, met its commitments under this agreement, the US repeatedly disregarded the established limitations, both in terms of amounts and types of subsidies. One example was the unprecedented package of subsidies granted by Washington State for the 787 and other Boeing commercial aircraft, which amounted to more than USD 3 billion. The State of Washington made it very clear at the time that the incentive package was designed to help "Boeing to beat Airbus." Independent commentators noted that the Boeing Incentive Package was an "unprecedented" deal that has "never been done for any company by any state."

Following the withdrawal from the 1992 bilateral EU-EC agreement, the United States initiated two complaints with the WTO regarding measures affecting trade in large civil aircraft. The first request was submitted on 6 October 2004 while the second was filed on 31 January 2006. Both requests are complementary. In the second complaint, the US government has provided a list of measures by several European governments which – from the US perspective – constitute illegal subsidies.

The EU was left with little choice but to respond with a parallel WTO challenge to US government support of the US aerospace industry (i.e., Boeing) by federal, state and local authorities. This included benefits to Boeing under the so-called US Foreign Sales Corporation Scheme, which the US government had continued to provide to Boeing, despite these subsidies having repeatedly been found to violate WTO rules.

These two parallel WTO challenges, the "Airbus case" (DS316: the US challenge of EU support for Airbus) and the "Boeing case" (DS353: the EU challenge of US support to Boeing), and have followed different timetables.

The Airbus case

The US claimed that Airbus receives billions of Euros in subsidies that are prohibited or otherwise inconsistent with WTO rules. This claim has been largely rejected by the WTO. The reality is that the financing Airbus received from the Member States is repayable with interest, as agreed to by the US in the 1992 Agreement.

In the original proceedings, the WTO panel found that financing by the Member States in the form of repayable launch investment ("RLI") does not constitute a subsidy per se, in contrast to grants or industry-specific tax breaks. Instead, specific instances of RLI involved subsidies only to the limited extent that the interest due fell short of market rates. Moreover, the WTO confirmed that RLI does not constitute a prohibited subsidy.

Ultimately, however, the WTO found that individual instances of RLI, historic capital contributions to Airbus made in the 1980s and early 1990s, and a small number of infrastructure support measures, constitute subsidies that cause competitive harm in the market place. Specifically, the WTO attributed a small number of sales that Airbus won and Boeing lost, as well as market share losses by Boeing in a small number of markets, to the EU support. The WTO directed the EU to remove these adverse effects of the subsidies or to withdraw the subsidies.

Initiated at the request of the US the compliance proceedings concluded on 15 May 2018. The Appellate Body established that the EU demonstrated that, because of the passage of time, non-subsidised investments by Airbus in the competitiveness of its products, and other market developments, there were no longer any adverse effects attributable to the subsidies and that withdrawal had been achieved.

The Airbus case essential facts

- Consistent with the 1992 Agreement, financing by the Member States of Airbus aircraft through repayable launch investment (RLI) is limited and repayable with interest. The WTO confirmed that RLI does not per se constitute subsidies; instead, individual instances of RLI have involved subsidization in the form of interest rate shortfalls from market benchmarks for RLI. This distinguishes RLI from most US support to Boeing in the form of grants and tax breaks, which do per se constitute subsidies and are never repayable.
- The WTO confirmed that RLI does not involve export or local content contingencies, and therefore does not involve prohibited subsidies.
- The WTO also confirmed in the original proceedings that all R&D programmes in the EU (European, national and regional) are fully compatible with WTO rules. This finding is especially relevant when compared to the WTO findings in the Boeing case that NASA and Department of Defense R&D subsidies caused adverse effects in the market.
- The WTO also rejected the US challenge to support the A380 production site (Aéroconstellation) in Toulouse, France. While the WTO previously found that support for the A380 production site in the Mühlenberger Loch facility in Hamburg, Germany, was a subsidy that contributed to adverse effects, Airbus has since agreed to increase rental payments, and the United States, therefore, abandoned its challenge. The WTO reversed previous findings stating that the EU has fully complied with respect to all pre-A380 subsidies. While the Appellate Body found that RLI for A380 and a tiny portion of A350XWB continued to cause adverse effects in the market, the measures submitted by the EU to the WTO in late May 2019 address these in full and puts an end to 14 years of WTO litigation against subsidies to Airbus.

The Boeing case

In its WTO case against the US, the EU has challenged various the US federal, state and local subsidies benefitting Boeing, totalling—as confirmed by the Appellate Body report—USD 5-6 billion in WTO-inconsistent subsidies disbursed between 1989 and 2006. In March 2013, the EU estimated that subsidies granted to Boeing after 2006 amounted to billions of additional dollars.

To support EU arguments, it can be cited the US President Barack Obama statement from 2012 (visit to Boeing's production facility in Everett): "This plane (a Boeing 787) was first designed virtually using the same technology that was developed by NASA. Government research helped to create this plane.", and "a lot of those ideas came out of government research.".The US provided no evidence whatsoever of any real compliance with WTO findings and recommendations, which prompted the EU, on 11 October 2012, to request the establishment of a WTO compliance panel. That panel published a report in June 2017 in which it agreed with the EU that the illegal subsidies granted by the US to Boeing have not been removed. Instead, following the publication of the panel's findings in 2012, the US has provided additional illegal subsidies to Boeing.

The compliance panel report agreed with the EU's demonstration that the harm that these measures caused to Airbus since 2012 is at least USD 15-20 billion.

The compliance panel's findings were appealed and, on 28 March 2019, the Appellate Body issued a report which rejected the US's arguments and preserved the EU's win before the panel. The Appellate Body also went a step further and broadened the scope of the EU's victory by finding that additional US federal and state programmes constitute subsidies.

The Boeing case essential facts

- Washington State tax breaks granted for the period 2006-2024 amount to a subsidy valued at approximately USD 3 billion. These tax breaks were subsequently extended through the State's 777X incentive package, valued at an additional USD 8.7 billion which is the largest ever state-level subsidy package in the history of the United States. Industry specialists consider that these amounts could be sufficient to cover the entire cost of design and development of the 777X, essentially giving Boeing a "free ride" by offsetting completely its costs of developing and bringing the aircraft to market.
- The City of Wichita (Kansas) granted almost USD 500 million in the form of tax abatements on Industrial Revenue Bonds between 1989 and 2006, subsidies from which Boeing continues to benefit.
- Boeing was eligible for USD 2.2 billion in Foreign Sales Corporation export subsidies, despite previous WTO rulings that these are prohibited subsidies under WTO law. Eligibility continues today for certain Boeing transactions.
- The Appellate Body (AB) has confirmed that the Washington Tax subsidies and Foreign Sales Corporation subsidies, as well as the Wichita subsidies, enabled Boeing to win orders in the "single-aisle" 100-200 seat market (Boeing 737 vs A320) over Airbus.
- NASA has provided Boeing with more than USD 2.6 billion in subsidies through eight NASA-funded federal research programmes, through direct payments and free access to facilities, equipment and employees. These subsidies continue to this day.
- The AB confirmed that the above programmes provided subsidies in the form of a direct transfer of funds or the provision of goods and services by NASA to Boeing, for which no fee is payable and for which Boeing acquired the commercial IP rights.

Next steps

In light of the WTO findings regarding US subsidies and the harm caused to Airbus, the EU has requested the resumption of arbitration concerning the amount of annually-recurring countermeasures it is permitted to take against US imports.

The EU, Member States, and Airbus have always publicly and vocally favoured resolution of the conflict through negotiation rather than litigation. The European side has made several concrete offers to the USTR and Boeing to this end.

Currently (2020) dispute between Airbus, Boeing, Europe and the U.S. lasts for 16 years. Both sides were partially successful in 2019 (have won in court). The US side has received the right to compensation of $7.5 billion from the EU. But the WTO in mid-2020 will announce how much Europe can collect in return.

Initially, Boeing used to favour seeing the WTO process fully carried out and had deflected long-running Airbus entreaties to talk about an agreement. But, the COVID-19 outbreak, China trade war and finally the 737 MAX crisis significantly changed the situation. In mid-2020, it can be seen a slight trend of Boeing to try to craft some kind of a deal.

In the first quarter of 2020, the Donald Trump administration took action to force a settlement with the Airbus and the EU. The new legislation was introduced for consideration in Washington state that would dial back tax benefits to Boeing worth about $ 100 million a year. Officially, Boeing supports these steps. On the other hand, the administration announced on Feb. 14 that the tariffs applied to large commercial aircraft from Europe imported into the U.S. will rise from 10% to 15% on March 18.

Currently, Airbus has a bit more to lose in this battle, because of the export plans to the U.S. All the fast-growing U.S. airlines purchase Airbus jets, including Frontier, Spirit, Jet-Blue, Allegiant and Delta.

Potential settlement in the airliner dispute depends on many factors, such as the WTO position, the EU position, the Boeing-Embraer deal and the President Trump reaction.

The US still allege that the low interest loans have given Airbus an unfair advantage, enabling it to capture 50% of the global market for large commercial aeroplanes, at America's expense, when in fact Airbus has repaid all loans with a profit to the European governments that acted as lenders.

T9.9.4 Canada/Bombardier versus Brazil/Embraer at the WTO

Brazil and Embraer have also brought their complaints against Bombardier, which are very similar to the grievances alleged by Boeing, to the WTO, which ended with a positive ruling for the US side in October 2019. All in all, aircraft manufacturing is arguably the most contested industry in international trade governance.

The Airbus-Boeing duopoly of large airliners is not alone to come to WTO fillings since the Canadian government on behalf of Bombardier has accused Brazil of subsidizing Embraer.

Therefore, the main problem between Canada / Bombardier and Brazil / Embraer centres on a conflict over the Canadian government's aid to Bombardier. The aim is to prevent the poisoning of bilateral relations, which recently recovered completely from the impact of a similar struggle in the past.

The conflict has reached the point that the Canadian government threatened to use hundreds of millions of dollars in trade sanctions against Brazil for the use of short-term loans for Embraer, a direct competitor of Bombardier in the global aerospace market.

T9.9.5 The Saga of the C-Series Scale to Eastern Airlines

The Bombardier C Series is a family of narrow-body, twin-engine, medium-range jet airliners by Canadian manufacturer Bombardier Aerospace. The C Series models are the CS100 and the CS300, which have been built with leading-edge technology and systems integration, advanced materials and aerodynamics. They have been designed specifically for the 100- to 150-seat single-aisle market. They are very efficient and economic aircraft, thanks to significant reductions in fuel burn and operating costs. The CS100 aircraft carries between 100 and 135 passengers and offers great flexibility for many airline business models. On the other hand, the CS300 aircraft is a good solution for mid-sized markets with up to 160 passengers per flight. The CS100 and the CS300 have a range of 3100 and 3300 nautical miles respectively.

According to Bombardier market forecast, in the next years, China will be a region with one of the largest fleets in the 60-to 150-seat segment. It is expected that the passenger traffic in cities away from the main hubs of Beijing, Shanghai and Guangzhou grows significantly, which is an opportunity for convincing airlines to opt for the 110-150 seat C Series planes.

Nowadays, Bombardier has a strong presence in the Asian-Pacific region, with 40 airlines that operate 330 Bombardier regional and small single-aisle aircraft, which a great success in the 100-70 150-segment. The launch customer for the C Series in Asia was Korean Air, who ordered 10 CS300 with 10 options. Korean Air has taken delivery of two CS300 aircraft to date and had their first revenue flight from Seoul to Ulsan on January 20, 2018. Therefore, one of the objectives of Bombardier will be keeping the focus on the China market and obtaining deliveries from Chinese airlines.

In the following Figure 9.55, it can be seen the number of C series orders in recent years:

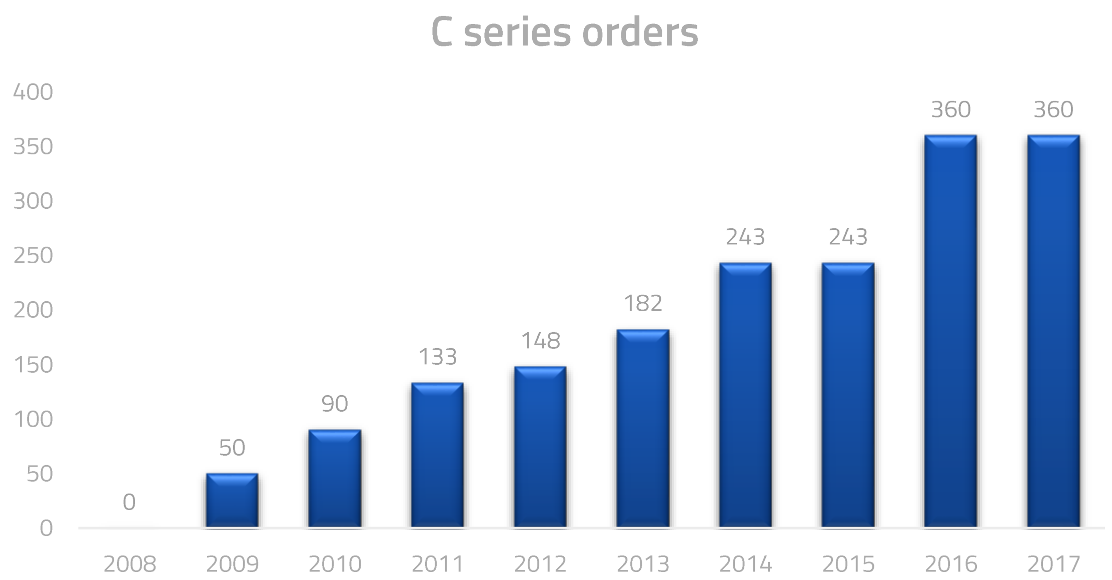

Figure 9.54 – C series orders, cumulative by year
Source: Bombardier web page

As can be seen from the previous image, the number of orders of the C series has increased in recent years. The first Bombardier C series deliveries were carried out in 2016, five CS100 to Deutsche Lufthansa and two CS300 to airBaltic. In 2017, a total of 24 C series aircraft were delivered, eight CS100 and seven CS300 to Deutsche Lufthansa, seven CS300 to airBaltic and two CS300 to Korean Air.

In 2016, Bombardier and Delta Air Lines announced that they had executed a firm agreement for the sale and purchase of 75 CS100 aircraft, which meant the largest C series order, as it can be seen in the next Figure 9.56:

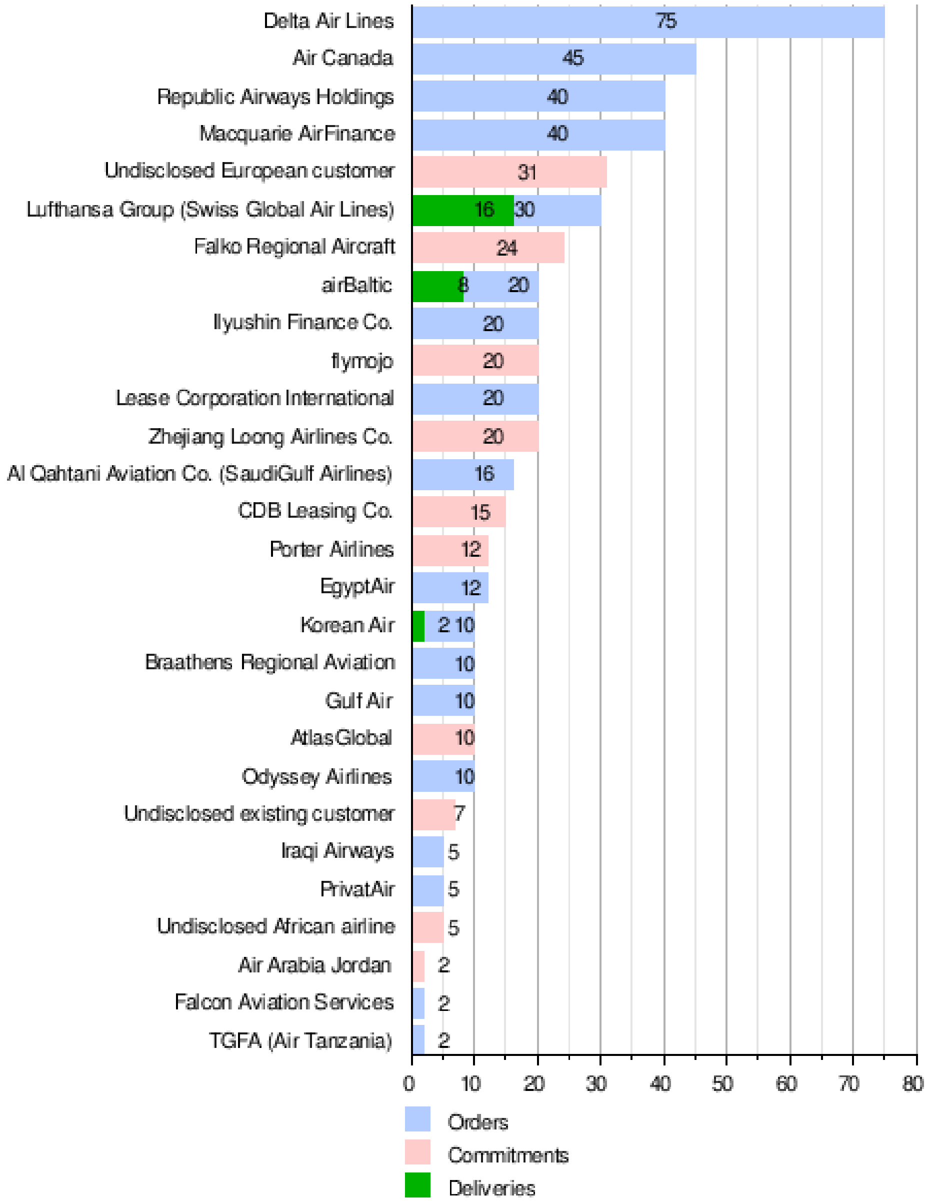

Figure 9.55 – C series orders and deliveries by customer
Source: Wikipedia web page

In addition, in 2017 Airbus and Bombardier signed an agreement through which Airbus would manufacture the C series. Being a part of the model manufactured in US soil, Bombardier wanted to avoid the tariffs of 300% recently imposed by the US Government on C series aeroplanes. In 2018 the US International Trade Commission (ITC) voted unanimously against Boeing in favour of its Canadian rival Bombardier after Donald Trump's administration had threatened to impose duties of 292%. The agreement between Bombardier and Airbus allow to share resources, costs and technology with Airbus, which will be a relief for its deteriorating finances.

This agreement will be very beneficial for both sides since it will allow Airbus to compete against Boeing, which is its biggest rival. The agreement will be continued even though Boeing lost the case.

The orders from the C-Series pale by comparison with the 10,000 deliveries of the B737 and 8,500 of the A320, both much longer in the market.

T9.9.6. The Saga of the Boeing & Embraer Joint Venture

In 2017 Boeing and Embraer confirmed that a potential combination was being discussed, with a transaction subject to approval by the Brazilian government and regulators, the two companies' boards and shareholders. Aviation industry analysts saw the potential deal as a reaction to the Airbus–Bombardier deal on the C-Series.

On December 22, 2017, Brazilian President Michel Temer said the sale of Embraer to Boeing was "out of the question", adding that the government was in favour allowing other companies, like Boeing, to establish partnerships with the company, but warning that it would veto changes in stock control. On December 28, 2017, defence minister Raul Jungmann opposed transferring control of the parent company Embraer S.A., because he believed that Embraer's defence business could not be separated from its commercial operations, but would welcome a deal maintaining local control of the company. On January 2, 2018, Brazilian financial newspaper Valor Econômico reported that the companies were now looking at forming a joint venture to avoid changing control of Embraer to appease Brazilian regulators.

On July 5, 2018, a Memorandum of Understanding was announced for a strategic partnership: for $3.8 billion Boeing would have an 80% stake in a joint venture with Embraer, which would produce and service Embraer's commercial airliners (the ERJ, E-Jet and the E-Jet E2), a business that at the time was valued at $4.75 billion and offer $150 million worth of corporate synergy opportunities. Under the proposed joint venture, Embraer would retain its executive business jet and its defence industry businesses, but the two companies could explore a second joint venture for the C-390 Millennium defence aircraft. Boeing would control the new company, which would be managed from Brazil with leaders who report to Boeing's CEO. A lock-up agreement would prevent Embraer or Boeing from selling their shares for 10 years. A put option would protect the minority stake value, allowing Embraer to sell its shares at the same price, inflation-adjusted. At the time of the announcement, the deal was expected to be approved by shareholders and government regulators by the end of 2019.

On February 26, 2019, the partnership was approved by Embraer's shareholders. It was to be followed by antitrust reviews in Brazil, the EU, the US and China for an expected closure by the end of 2018. The joint venture should have $3.5 billion assets against $1.4 billion liabilities, for a $2.1 billion equity value.

On May 23, 2019, Boeing announced that the division would be known as "Boeing Brazil–Commercial," dropping the Embraer name but had not yet decided whether to rebrand the aircraft as Boeing models. The joint venture also confirmed that airliner production would remain at the São José dos Campos factory, to be taken over by Boeing Brazil.

The EU antitrust investigation was set to issue findings from its preliminary review on October 4, 2019, and intended to conduct a full investigation thereafter which could last up to five months. By then, Boeing and Embraer were expecting the transaction to close in early 2020. On November 12, 2019, Embraer confirmed the delay until at least March 2020. In January 2020, the partnership was approved by Brazilian authorities, and only the European Commission approval was lacking. The deal was expected to close after June 23, 2020.

On November 18, 2019, the two companies officially announced a second joint venture known as "Boeing Embraer – Defense" to promote and develop new markets for the C-390 Millennium. Embraer would keep a 51% stake in this proposed joint venture, which would also need to be approved by shareholders and government regulators.

On April 25, 2020, Boeing announced that it has terminated its Master Transaction Agreement (MTA) with Embraer, under which the two companies sought to establish a new level of strategic partnership. The parties had planned to create a joint venture comprising Embraer's commercial aviation business and a second joint venture to develop new markets for the C-390 Millennium medium airlift and air mobility aircraft.

Under the MTA, April 24, 2020, was the initial termination date, subject to extension by either party if certain conditions were met. Boeing exercised its rights to terminate after Embraer did not satisfy the necessary conditions.

Embraer has rejected Boeing's reasons for the termination of the deal and said the company "has manufactured false claims as a pretext to seek to avoid its commitments" because of its financial condition after the **737 MAX groundings** and "other business and reputational problems".

Industry analysts said that the $4.2 billion deal became unbalanced as Embraer's market value fell to less than $1.1 billion as air travel demand dropped as a result of the impact of the 2019–2020 **coronavirus pandemic** on aviation. Industry analysts speculated that Boeing may have also cancelled the deal because it had recently been awarded a U.S. government **pandemic** relief loan, and wanted to avoid making the impression that funds intended to support U.S. jobs were instead used to secure a deal with a Brazilian firm.

The planned partnership between Boeing and Embraer had received unconditional approval from all necessary regulatory authorities, with the exception of the European Commission.

Boeing did not have much choice and therefore had to terminate the contract with Embraer. Although Boeing officially referred to alleged failures by Embraer, the main reason for terminating the contract was to save 4.2 billion dollars. Boeing was currently unable to finance the takeover. And even if it had: How could Boeing have argued to apply for state aid in the United States and lay off employees while making a huge investment abroad?

Even loss in court and potential penalties are better for Boeing than continuing the take-over.

The main reason for the planned takeover was that the American aircraft manufacturer wanted to do something about it when Airbus took over Bombardier's C-Series and turned it into the Airbus A220. Embraer's new E2 family was a perfect fit. On the other hand, Boeing also wanted to secure access to Embraer's highly praised research and development – as well as to the more favourable production costs in Brazil. None of this is going to happen now.

Thus, Boeing will not be able to use Embraer's engineering capabilities to develop a New Middle of the Market aircraft, a Future Small Airplane or any other new aircraft. At the same time, it is clear that without Embraer's regional aircraft, the aircraft manufacturer will have only three commercial passenger jets in the foreseeable future: the Boeing 737 Max for short- and medium-haul flights and the 787 and 777 for long-haul flights.

It is unclear what will become of the new generation 777X, for which Boeing has only collected just over 300 orders. In addition, the recovery in the long-haul business after the Corona crisis is likely to be slow in general. So Boeing – and this is probably the most important consequence of the failed Embraer's deal – will depend more than ever on a successful return of the 737 Max.

In the race with Airbus, Boeing will most likely fall behind. The US manufacturer can currently do nothing to counter the Airbus A220, nor the high-range LR and XLR versions of the A321. And smaller aircraft could be particularly important now. «It is becoming increasingly clear that the recovery is starting with the smallest aircraft – turboprops and regional jets. Boeing's smallest aircraft is the Max 7, which nobody wants. That's why Boeing will wait the longest for a recovery,» said Air Insight analysts. The US-based company only has an advantage in the freighter segment, where Boeing 767-300 F, 777 F and 747-8 F are available.

Under these omens, the analysis portal Leeham predicts: «The 2020s will be Boeing's lost decade.» Should it really come to that, the question arises whether another manufacturer besides Airbus will be able to use this. There is already speculation that the Chinese aircraft manufacturers Comac or Avic could keep an eye on Embraer.

Embraer, which is the third-largest aircraft manufacturer in the world, is currently (2020) open to new business partners after Boeing Co ditched a $4.2 billion deal which has been prepared for years. Embraer plans new contracts would be smaller in scope than the failed venture with Boeing.

Embraer is no longer looking for a partnership of the size that the company had with Boeing. According to Embraer, it would be faster and more efficient to have partnerships by the project. Embraer begins to undo the costly separation process that readied Embraer's profitable commercial jet division for Boeing's takeover.

The two companies are now engaged in competing arbitration proceedings, having each filed claims against the other separately over whether the necessary conditions for the Embraer-Boeing deal were met.

When Boeing cancelled the planned deal in April 2020 just as the coronavirus ravaged the travel industry, Embraer was left with no plan B. Embraer is only now drafting a five-year business plan for the commercial jets division which Boeing would have run. Embraer drew up similar plans last year (2019) for its defence and executive jet units which were going to remain independent from Boeing.

Company management is now remaking Embraer as a company focused on finding smaller, more targeted partnerships. A new turboprop aircraft that Embraer wishes to develop but no longer has the cash to finance could potentially spawn one deal.

Reuters reported in July 2020 that China, India and Russia were evaluating potential partnerships with Embraer.

Boeing and Embraer will maintain their existing Master Teaming Agreement, originally signed in 2012 and expanded in 2016, to jointly market and support the C-390 Millennium military aircraft.

Major exceptions to open markets in civil aviation do exist, generally uncontested. Perhaps the most visible and long-standing is that the Japanese airlines tended to buy Boeing aircraft more often than from Airbus, though the difference has reduced over time. The reason is that Japan to the US trade surplus, that the Japanese government tries to reduce through various measures, including airliner purchases. The Japanese airlines are happy and willing to oblige by buying Boeing aircraft, as long as it is in the national interest, but not otherwise. A possibly isolated instance of the latter was the indictment of former Prime Minister Kokuei Tanaka for prompting some Japanese airlines to buy Lockheed Tristars instead of other American widebodies. When this became known through the enquiry of the US congress on the Lockheed bankruptcy, Tanaka was still prime minister and refused to resign; his party, that had a majority in parliament, voted him and itself out of power with a non-confidence vote.

Boeing has consolidated its hold in the Japanese market by including Japanese industry in the production of its aircraft; it has gone further with Japan financing part of the development of the B787 together with some American states. The Japanese have limited their indigenous production to regional aircraft or smaller, for example, the Nanc YS-11 in the past and the Mitsubishi MRJ-100 and Honda business jet at present. China has apparently tried to use airliner purchases as a political instrument, depending mostly on its relations with the US, buying more Boeing aircraft during the up periods and less in the down periods. The Airbus final assembly line for the A320 in China is a more stable prospect. It is also possible to find the opposite example of Japan, with Italy and other certain producing assemblies for Boeing and Airbus.

The times when the US market was closed to Airbus are long gone, and most airlines make the most they can of the Airbus-Boeing competition. In the past Boeing could charge high prices for the Boeing 747, when it was the only jumbo available, possibly financing the rest of the range. More recently in the twin-aisle long-range market, the preference of major airlines for a twin-engine instead of the Airbus A380 may have allowed Boeing to charge high prices for the B777X stretch. In most sectors of the airline market, the Boeing-Airbus duopoly is desirable not only to give airlines bargaining power to keep prices in check; it also promotes technological progress and efficient air travel ultimately for the benefit of airline passengers.

The development of a modern long-range airliner costs over 10 B€ over 5 years and more. An aircraft manufacturer needs big, sustained profits to finance the development and production until break-even is reached. Bank loans at commercial rates of interest are hardly viable when break-even is 10 or more years away.

The Boeing 787 is an example. Optimistic predictions put development at 10 B$ over 3 years. At the end of an 8 years development program, Boeing had accumulated a 30B$ debt. Despite favourable conditions from the US states where the facilities are located and a sizeable contribution (20-40%) from Japan.

The B787 was the most successful airliner programme ever, with over 1,000 orders before entering service. Boeing is not stating when the 30 B$ debt will be covered. With unit prices of around 300 M$ a 10% profit percentage of 30 M$ a piece would cover the debt with 1,000 sales, less than those already achieved.

The development of the A380 costs over 16 B€. It is not clear if it will ever be recovered or even if its low rate production is self-sustaining. It has now become clear that the costs spent on the development of the A380 can never be recovered because the decision to stop the production has been made. And more and more airlines are making decisions to phase-out of Airbus A380 from their fleet. Yet with a backlog of more than 5,000 aircraft costing 100-450 M$ each, both companies can survive some large holes in their balance sheets.

KEY TOPIC T9.10 OPEN MARKETS

T9.10.1 The Japanese Market Captive of Airbus

For more than half a century, Boeing has been the top provider of commercial jetliners to Japanese airlines and a major supplier of military equipment and aircraft to the Japanese Ministry of Defence (JMoD). Boeing opened its doors in Japan in 1953, just two years after Kawasaki Heavy Industries and Showa Aircraft were contracted by the US government to maintain US military aircraft, a move that restarted Japan's aircraft industry.

The US's relationship with Japanese industry started in 1956 when Mitsubishi Heavy industries commenced the licensed production of the North American F-86 Sabre Jetfighter. The relationship continued to grow over the coming years in both the defence and commercial areas, and Boeing expanded the number of programs on which it collaborated with Japanese Industry, as well as the number of partners. During those years, Boeing transferred new technology to Japan and, in turn, Japan used that acquired technology in support of Boeing programs.

Today, Boeing retains deep supplier, customer and partner relationships across Japanese government, industry and civil society.

In the following sections, it will be described the relationship between Boeing and Japan in the military and commercial areas in the past years. The following Figure 9.57 summarizes this relationship:

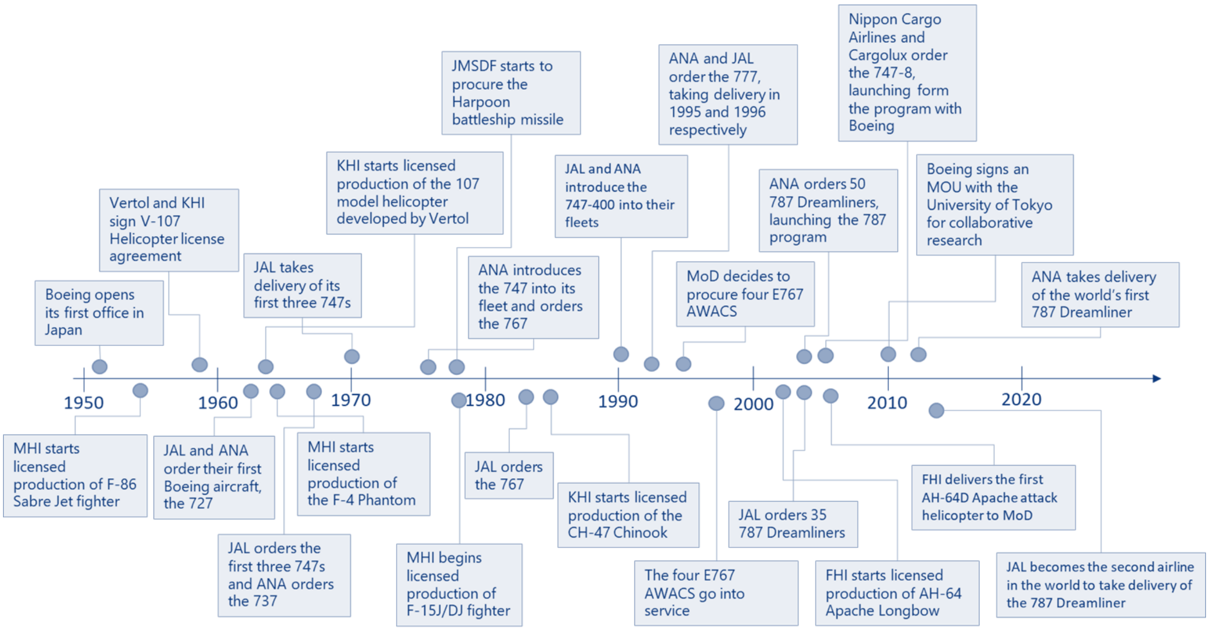

Figure 9.56 – Relationship between US industry, including Boeing and Japan timeline
Source: Boeing

COMMERCIAL AIRPLANES

Japan has long served as one of the largest financial international markets for Boeing Commercial Airplanes. Over the past 50 years, Japanese carriers have ordered more than 970 Boeing jetliners, and Japan is one of Boeing's largest twin-aisle markets.

In the past decade, nearly 80% of the commercial aircraft ordered by Japanese customers have been Boeing products. Japan is the single biggest customer for the 787. Japan Airlines (JAL) purchased more 747s than any other airline customer and All Nippon Airways (ANA) is the largest international customer for the 767's family of aeroplanes. Together, Japan's major carriers make Japan one of the largest international customers for the 777, with more than 100 ordered.

Japan also plays an important role in launching major new programs. Japan's Nippon Cargo Airlines, together with Cargolux, launched the 747-8 Freighter in 2005. In addition, Japan Airlines and All Nippon Airways were among a number of carriers with whom Boeing held intensive discussions to define and develop the 777 configurations. All Nippon Airways was also a 777 launch customer and became the first Asian operator. Moreover, Japan airlines served as launch customers for the 767-300, 767-300 Boeing Converted Freighter and 737-700ER.

In 2004, All Nippon Airways (ANA) launched the 787 Dreamliner with 50 orders, which represented the largest launch order for a Boeing commercial aeroplane at the time. In addition, Japan Airlines (JAL) selected the 787 Dreamliner as its next-generation midsized twin-aisle aeroplane and joined the 787 launch team with an initial order of 35 aeroplanes. All Nippon Airways (ANA) and Japan Airlines (JAL) both collaborated with Boeing in the development of the Dreamliner, sharing their expertise in passenger amenities, aeroplane performance and aircraft maintenance. All Nippon Airways and Japan airlines became the first customers to fly the 787 Dreamliner in September 2011 and April 2012, respectively. Since then, both airlines have made incremental 787 orders that include all members of the Dreamliner family: 787-8, 787-9 and 787-10. Japan has more than 90 787's flying today, more than any other country.

MILITARY AIRPLANES

Boeing Defence, Space and Security and Japan's Ministry of Defence (MoD) have a long history of working together to meet Japan's defence needs. This cooperation dates back to 1956 and the licensed production of the F-86 Sabre by Mitsubishi Heavy Industries (MHI). Boeing continued collaboration with the Japanese industry through licensed production of the Vertol 107 helicopter and the F-4 Phantom.

In 1981, the first non-US delivery of 10 F-15 Eagles began under the Peace Eagle program. Four more F-15s were delivered to Japan in 1983, and in total, Mitsubishi Heavy Industries (MHI) built nearly 200 F-15J/DJ Eagles under licensed production. Today, Japan operates the second-largest fleet of F-15s in the world. Boeing is currently involved with Mitsubishi Heavy Industries in upgrading the F-15J/DJ aircraft to fulfil Japan's desired mission effectiveness well into the 21st century.

The F-1 and F-2 fighters developed by Japan involved the American companies and technology transfer to the US.

Defence, Space and Security have provided many other defence solutions to Japan's Self-Defence Forces. In 1978, the Japan Maritime Self-Defence Force first placed orders for Harpoon anti-ship missiles and, currently, it is second only to the US Navy in terms of the number of Harpoon missiles in its inventory.

Boeing began delivering CH-47 Chinook helicopters to the Japan Air and Ground Self-Defence Forces in 1984. Since then, Kawasaki Heavy Industries (KHI), under license by Boeing, has manufactured and delivered 100 CH-47s to Japanese forces, providing Japan with the world's second-largest operational Chinook fleet.

Other deliveries provided by Boeing have been 13 AH-64D Apache Longbows, with the first of them delivered in March 2006, through a license agreement with Subaru. Boeing has also delivered four KC-767 tankers and four Airborne Warning and Control System (AWACS) aircraft to JASDF and continues to provide ongoing support and upgrades for these platforms.

There is close cooperation between the US and Japan in the area of ballistic missiles defence systems due to North Korean and Chinese threat.

BOEING PARTNERS IN JAPAN

Around 150 Japanese companies are suppliers to Boeing across its commercial and defence product lines. Mitsubishi Heavy Industries, Kawasaki Heavy Industries and Subaru produce components for Boeing commercial models and manage licensed production of Boeing defence products (Figure 9.58). These companies designed and developed 35% of the 787 Dreamliner airframe structure, including the main wing box (the first time that the design and build of such a critical part were entrusted outside the company). Together, they also supply 16% and 21% of the 767 and 777 airframes, respectively, and have contracted with Boeing to provide 21% of the 777X.

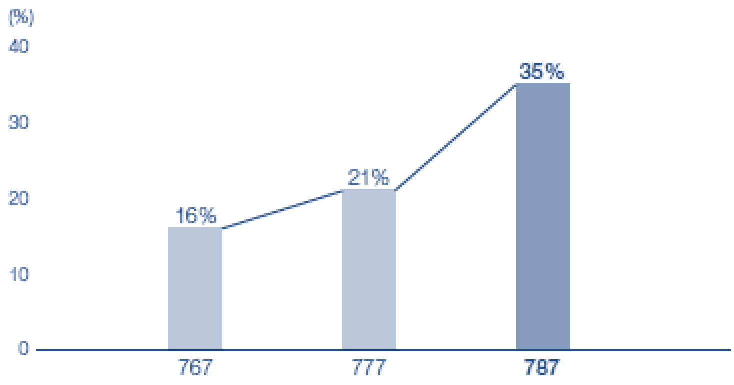

Figure 9.57 – Japanese Industry Work-Share Growth
Source: Boeing

Other components provided by Japanese firms include tires, gearboxes, trailing-edge flaps, lavatories, flight deck interiors, altimeters, actuators, valves and video entertainment systems. In addition, Toray Industries is providing composite materials for the 787.

Boeing's partnerships in Japan extend well beyond the above examples. In fact, the company has meaningful collaborations in the technology and environmental areas with Japanese universities, research institutions and various government agencies.

In addition, Boeing also maintains close relationships with the Government of Japan's Ministry of Land, Infrastructure Transport and Tourism (MLIT) and the Japan Civil Aviation Bureau (JCAB) to help ensure ever safer air transportation. The Ministry of Economy, Trade and Industry (METI) is another key partner in terms of Boeing's collaboration with Japan's aerospace industry, as the Aeronautics and Space Research Agency (JAXA).

AIRBUS IN JAPAN

In recent years, Airbus has significantly strengthened its position in the Japanese commercial aircraft market. Japan airlines' major order for the A350 XWB was an important breakthrough and it was soon followed by orders from All Nippon Airways Holdings for the A320 family and, early in 2016, for the A380. The first of All Nippon Airways' three A380s it is expected to be delivered in 2019. In addition, over 20 major Japanese companies work with Airbus on various commercial aircraft programmes. For example, the A380's forward and rear cargo doors come from by Mitsubishi Heavy Industries while the vertical tail plane's (VTP) leading and trailing edge are manufactured by Fuji Heavy Industries.

In relation to defence and space, Airbus is contributing to Japan's successful space sector by supplying state-of-the-art components for Japanese satellites. Moreover, some of Airbus space technologies were developed in Japan.

T9.10.2 Competition between Airbus and Boeing

The commercial air transport industry of the last 20 years has been characterized by the duopoly competition between Boeing, the American aircraft manufacturer, and Airbus, the European aircraft manufacturer.

In relation to orders and deliveries, there has been a strong competition between both companies, as can be seen in the following figures:

Figure 9.58 – Airbus vs. Boeing net orders from 2007 to 2018.

In terms of orders, during the 1980's and 1990's decade, it's clear that Boeing deliveries considerably exceeded that of Airbus. By 2000, little difference remained between both companies. However, during the last few years (Figure 9.59), Airbus has received more aircraft orders than Boeing.

In terms of deliveries (Figure 9.60), Boeing has a clear lead against Airbus in the 6 years, from 2012 to 2018. Boeing has delivered more jets than Airbus for each of the past seven years, before 2019. But with 737 delivers halted since March 2019, Boeing delivered less than half as many jets as its European rival in 2019.

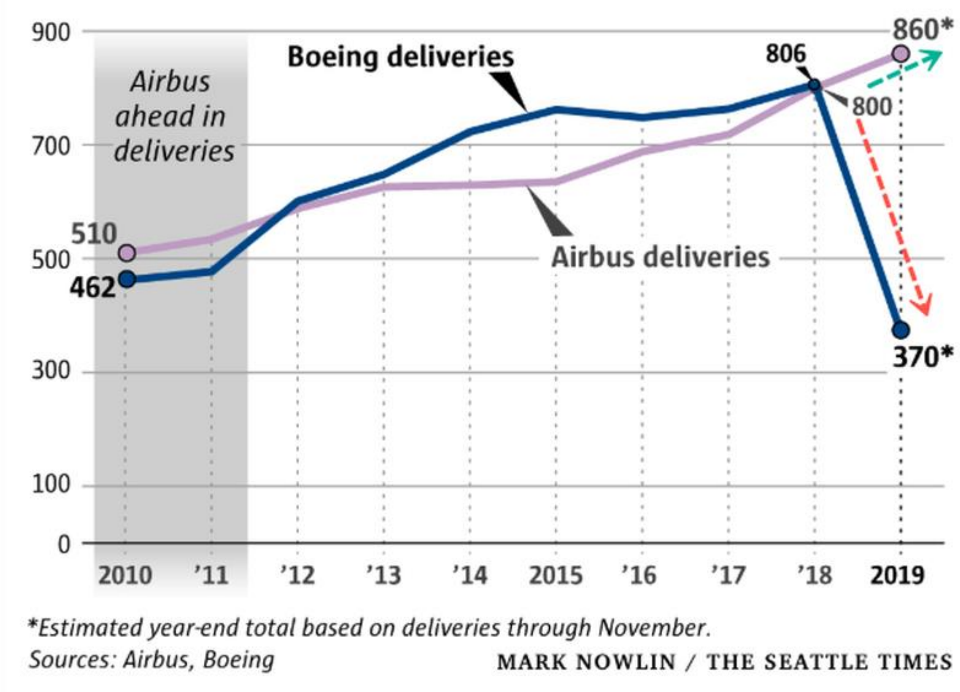

Figure 9.59 – Airbus vs. Boeing deliveries

If it is compared to Airbus and Boeing, orders between similar aircraft, the following results are obtained:

A320 FAMILY VS. B737 FAMILY

The Airbus A320 family consists of short-to medium-range, narrow-body, commercial passenger twin-engine jet airliners manufactured by Airbus that was released in the 1980s. The family includes the A318, A319, A320 and A321. The aircraft family can accommodate up to 236 passengers and has a range of 3100 to 12000 km, depending on the model. The A320 family competes directly with the Boeing 737 family, a short-to medium-range twinjet narrow-body airliner developed and manufactured by Boeing that was released in the 1960s. The B737 family is composed of several models with capacities from 85 to 215 passengers.

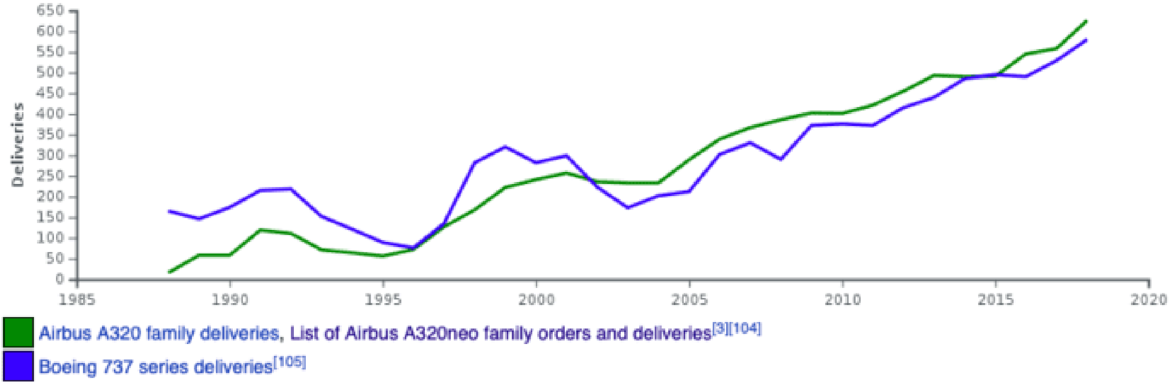

Figure 9.60 – A320 vs. B737 deliveries
Source: Wikipedia web page

In the previous image (Figure 9.61), it is compared to the A320 family and the B737 family deliveries of past years. Taking into account orders and deliveries, the 737 series is the best-selling commercial jetliner in history, with a total of 14543 orders and about 9895 deliveries. In comparison, Airbus has delivered 7979 A320 series aircraft and has received 8125 orders. The B737 has been 55 years on the market and the A320 'only' 40 years.

The A320 Family is the world's bestselling single-aisle aircraft family and is the preferred choice with traditional airlines and passengers, as well as with the fast-growing low-cost carrier market for which it is now the aircraft of choice.

A320neo Family is the market leader capturing around 60% of the market with over 6,100 orders from 100 customers.

The A320neo is the most advanced A320 version as Airbus continues to invest over 300 million Euros a year in innovation and upgrades for the A320 Family to maintain its position as the most advanced and fuel-efficient single-aisle aircraft Family. The A319neo, A320neo and A321neo models, launched in December 2010, have a choice of two new engines (the Pure Power PW1100G-JM from Pratt and Whitney and the LEAP-1A from CFM International) and feature large wingtip devices known as Sharklets. Together they deliver a 15% fuel burn reduction per seat right away when the aircraft enters into service, and 20% reduction per seat by 2020 achieved through cabin innovations and efficiency improvements. The A320neo is also more eco-friendly, with 5,000 tons less CO2 emissions per year per aircraft and nearly 50 per cent reduction in noise footprint compared to previous generation aircraft.

The Airbus A321XLR, the Xtra-long-range version of the single-aisle A320neo Family aircraft, is enjoying a keen interest among the airlines. Following the long-awaited launch during Paris Air Show 2019, this aircraft has already managed to secure hundreds of orders.

During the second half of 2019, 22 operators and two aircraft leasing companies ordered, committed or converted their existing orders to over 450 aircraft of the newest type.

The aircraft is scheduled to enter final assembly line in 2021, while first deliveries are about to begin in 2023.

Actually, the A321XLR is a derivative from the Airbus A321LR, where LR stands for "long-range". The LR planes are already being delivered.

With a new program, Airbus targets to fill in the gap between ordinary single-aisle planes and small widebodies, meaning that the A321XLR will become a good match for the operators looking for a widebody range with a single-aisle efficiency.

The A321LR is capable of flying 15% further than a simple A321neo. Whereas the A321XLR could fly 15% further than the A321LR.

A350 FAMILY VS. B787 FAMILY

The Airbus A350 is a family of long-range, twin-engine wide-body jet airliners developed by Airbus. The family includes the A350-800, A350-900 and A350-1000. The aircraft variants can accommodate 280 to 366 passengers and have a range of up to 9,700nm. The A350 family competes directly with the Boeing 787 family also with B777, which are a long-haul, mid-size wide-body, twin-engine jet airliners made by Boeing. The family variants can seat 242 to 335 passengers and their range varies from 7,000nm to 8300nm, depending on the model.

In the following graphics, it can be seen a comparison between A350 and B787 orders (Figure 9.62) and deliveries (Figure 9.63), cumulative by year:

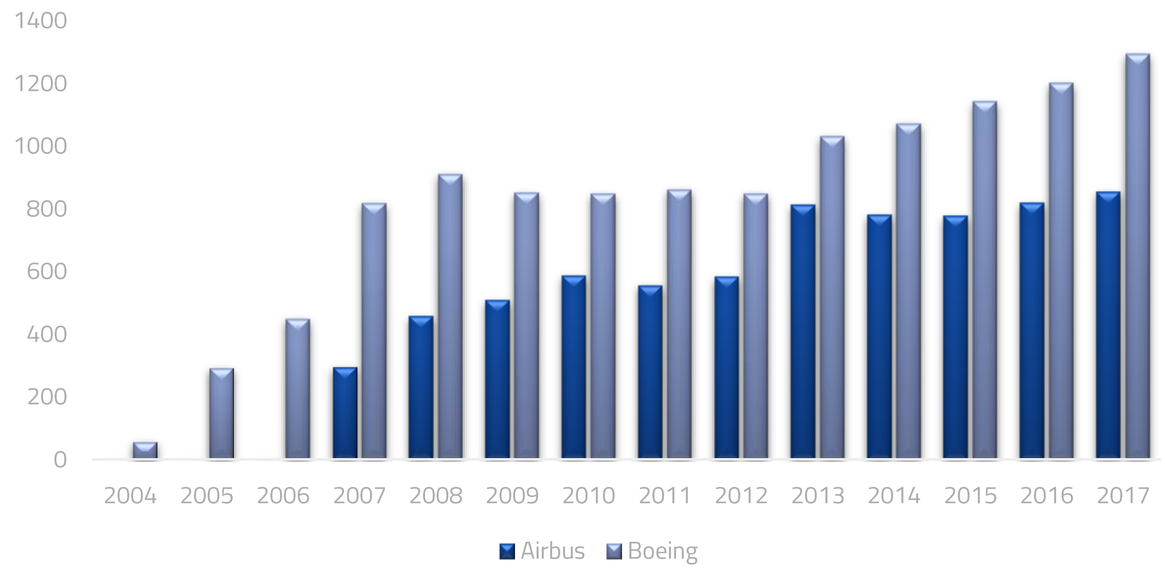

Figure 9.61 – A350 vs. B787 orders, cumulative by year
Source: Wikipedia web page

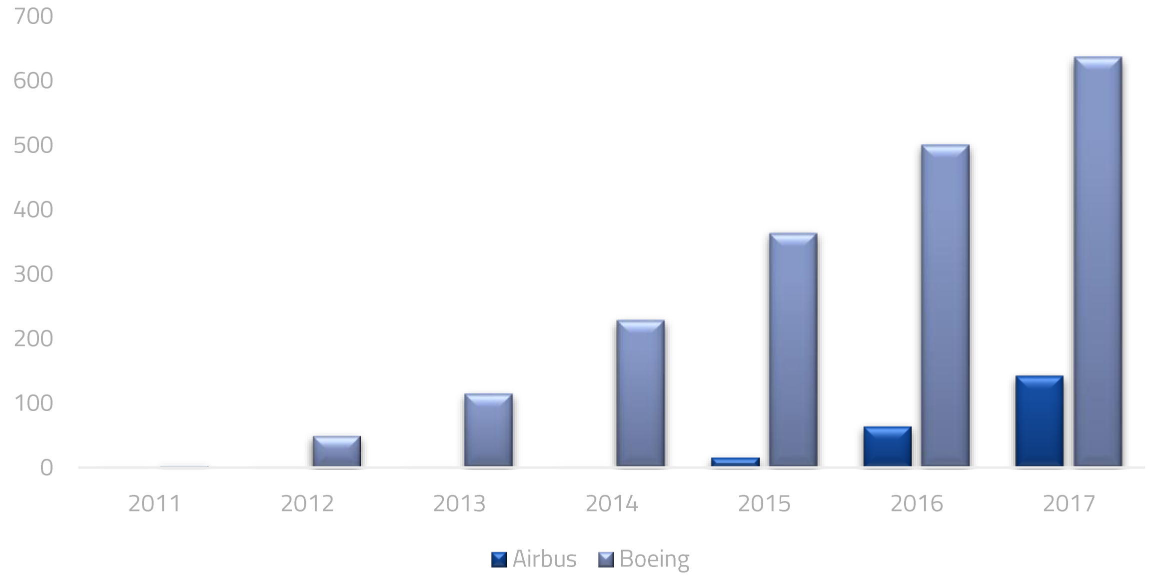

Figure 9.62 – A350 vs. B787 deliveries, cumulative by year
Source: Wikipedia web page

As can be seen from the previous images, the B787 has a clear advantage against the A350 concerning orders and deliveries due to the late response of Airbus to the Boeing challenge. However, it is important to note that there is an important gap in release dates since the A350 was released in 2015 while the B787 was released in 2007.

A380 vs. B747

The Airbus A380 is a double-deck, wide-body, four-engine jet airliner manufactured by Airbus. It is the world's largest passenger airliner with a capacity to accommodate 525 to 853 passengers and with a range of 8500nm. The A380 competes with the Boeing 747, the next largest airliner. Depending on the model, the B747 can accommodate 416 passengers to 660 passengers and has a range of 7260nm.

In the following graphs, it can be seen a comparison between A380 and B747 orders (Figure 9.64) and deliveries (Figure 9.65), cumulative by year:

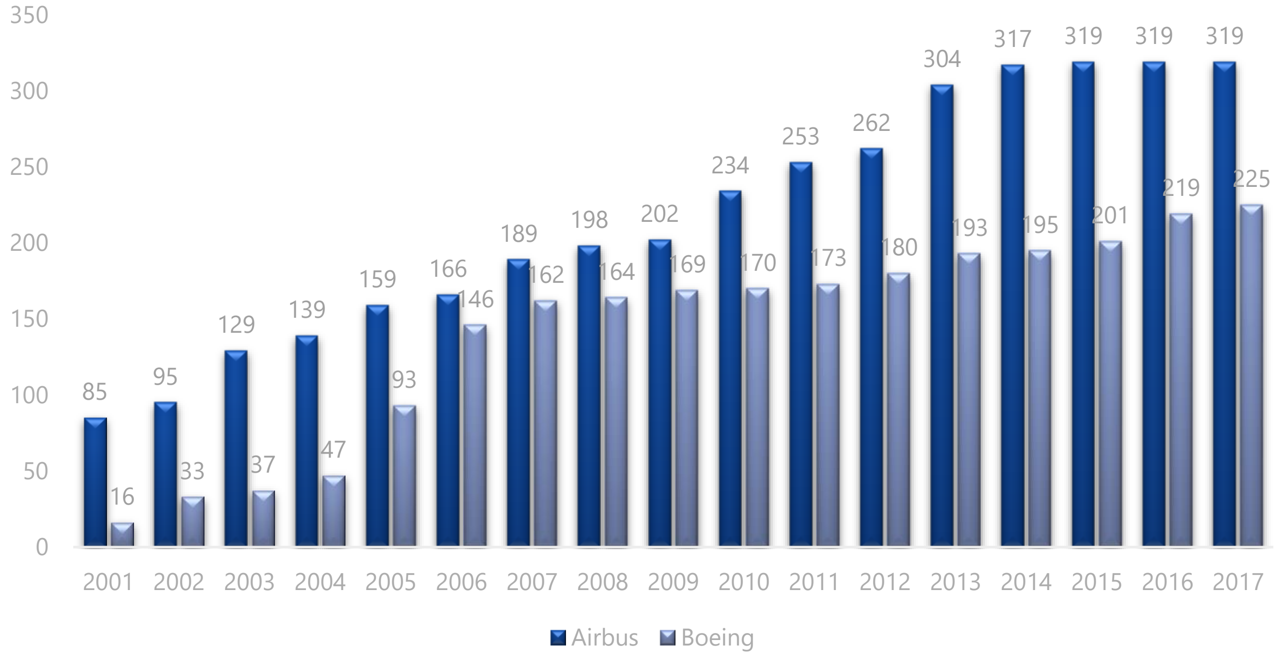

Figure 9.63 – A380 and B747 orders, cumulative by year
Source: Wikipedia web page

The previous image shows that in recent years the A380 has led the number of orders against the B747. However, it is important to note that the B747 was released in 1968, many years before the A380, accumulating in total 1568 orders.

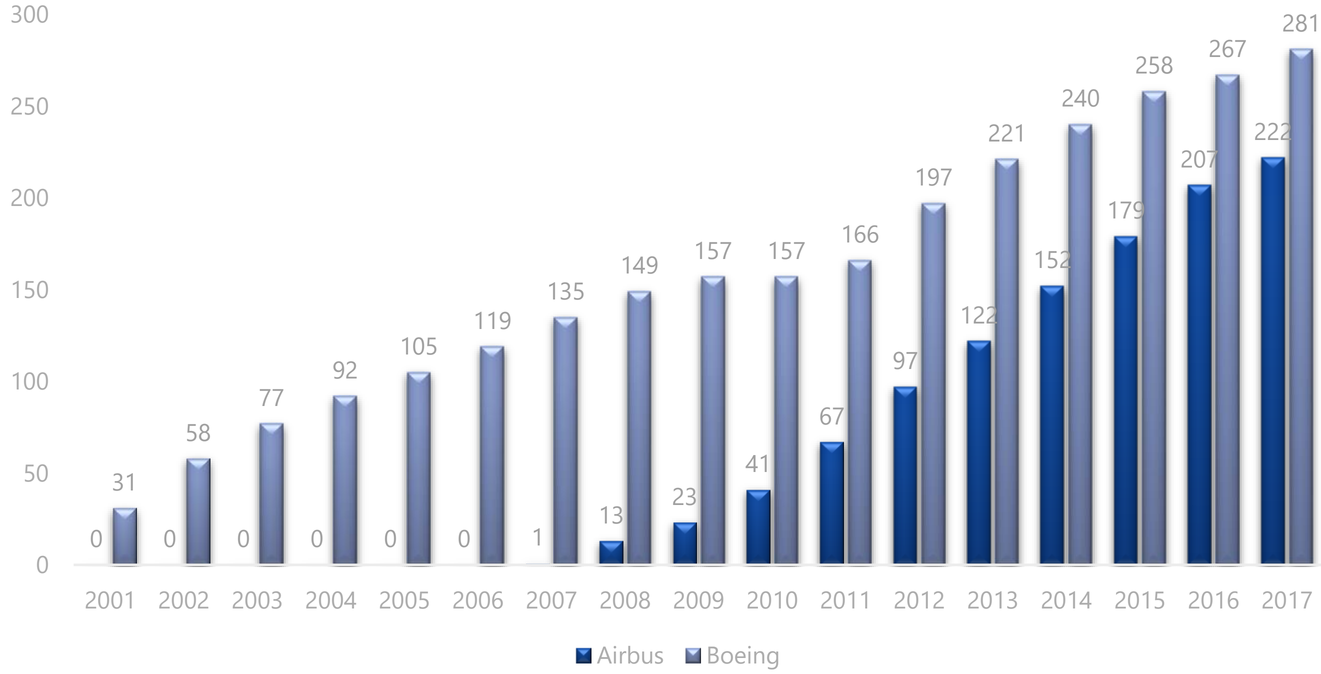

Figure 9.64 – A380 and B747 deliveries, cumulative by year
Source: Wikipedia web page

In terms of deliveries, it can be seen from the previous image that Boeing has had a clear lead in the number of deliveries in past years, accumulating in total 1543 deliveries. It is reasonable since the release date of the A380 is 2005, many years after the B747. The four-engined airliner may be a dying species: the B747 is surviving on orders from freighters and the A380 on orders from airlines in the Gulf. The long-haul market is being taken over by the B738/B777 and A350.

STORY OF AIRBUS A380 AND BOEING 747 COMPETITION

During the 1990s both companies, Airbus and Boeing researched the feasibility of a passenger aircraft larger than the Boeing 747, which was then the largest airliner in operation. Airbus subsequently launched a full-length double-deck aircraft, the A380, a decade later while Boeing decided the project would not be commercially viable and developed the third generation 747, Boeing 747-8, instead. The Airbus A380 and the Boeing 747-8 are therefore placed in direct competition on long-haul routes.

Both Airbus and Boeing published various comparative performance and operational characteristics of their aircraft to demonstrate the superiority of one aircraft over another. However, neither the presented data nor unclear methodology allows verification of the presented information.

In 2007 Singapore Airlines CEO Chew Choong Seng stated the A380 was performing better than both the airline and Airbus had anticipated, burning 20% less fuel per passenger than the airline's 747-400 fleet. Emirates' Tim Clark also claimed that the A380 is more fuel economic at Mach 0.86 than at 0.83. Independent analysis shows a fuel consumption per seat of 3.27 L/100 km for the A380 and 3.35 L/100 km for the B747-8I. A hypothetical re-engined A380neo would have achieved 2.82 to 2.65 L/100 km per seat depending on the options taken.

As of December 2015, Airbus had 319 orders for the passenger version of the A380 and didn't offer yet the A380-800 freighter. Production of the A380F has been suspended until the A380 production lines have settled with no firm availability date. Some A380 launch customers converted their A380F orders to the passenger version or switched to the 747-8F or 777F aircraft.

At Farnborough in July 2016, Airbus announced that in a "prudent, proactive step," starting in 2018 it expects to deliver 12 A380 aircraft per year, down from 27 deliveries in 2015.

In February 2019, Airbus announced the end of A380 production by 2021, after its main customer, Emirates, agreed to drop an order for 39 of the aircraft. Airbus will build 17 more A380s before closing the production line, taking the total number of expected deliveries of the aircraft type to 251. At that time, 747 backlog and production rates were sufficient to sustain production until late 2022.

In 31st of January 2020, Boeing had no outstanding unfulfilled orders for the 747-8I passenger version and 17 for the 747-8F freighter and Airbus had 11 A380s remaining to be delivered.

The Covid19 pandemic has a major impact on the A380 fleet. Almost half of the European A380s will be decommissioned at the end of COVID-19. Air France is withdrawing all its A380s.

The A380's retirements in Europe began before COVID-19. Lufthansa was the first to plan for retirements, announcing last year that it would withdraw six A380s in 2022. These six retirements were brought forward in April 2020. Lufthansa announced in May 2020 that it will withdraw one more A380, halving its original A380 fleet from 14 to September 2020.

The exits carry the European A380 fleet from 37 to 20, a decrease of 46%.

In May 2020 Emirates is seeking to cancel the last five of their final eight A380 deliveries but Airbus does not want to agree because the planes are already in assembly. Speculation is mounting that Emirates could permanently decommission up to 40% of their A380 fleet. This is the result of the President Sir Tim Clark statement from May 2020 that “the A380 is over” and that the airline would be 20-30 per cent smaller as a result of the coronavirus pandemic.

Emirates, the largest A380 operator by far, is exploring options to reduce its fleet of A380s, potentially more than 50 aircraft.