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IFAR – The International Forum for Aviation Research

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1. Introduction

The future challenges of air transport motivated the leading worldwide aviation research institutions to found IFAR - the International Forum for Aviation Research which aims at discussing the global aeronautical challenges and the set-up of a Framework outlining worldwide research. Climate change is currently the most relevant topic and was the motivation to set up IFAR. However, IFAR also addresses other topics relevant for a global air transport system (e.g. noise, security, safety, efficient operations). IFAR connects and represents worldwide aviation research and provides a common voice for their members in the international dialogue. IFAR interacts with the society, global politics and industry and takes up the challenges identified by them.

The idea of IFAR was born at the Berlin Summit 2008 where key leaders of 12 international aeronautical research organisations met to address the question of future Air Transport in the context of climate change. In this regard, the participants agreed that any research and strategy contributing to new solutions will have to reconcile the increasing need for international mobility in a globalized work-sharing economy with the challenge of simultaneously developing new solutions to balance the climate effects of the accompanying world-wide air traffic growth. At the second Berlin Summit in 2010 16 international aeronautical research organisations met and eventually set up IFAR (IFAR, 2008).

The main objective of IFAR is connecting global research establishments and setting up a Framework agreed upon by research institutions worldwide. Within this document promising technologies will be identified which contribute to an improved Air Transport System. IFAR as research representative focuses on the identification of new technologies up to the development of Technology Readiness Level (TRL) level 6. The IFAR members agreed at the first IFAR Summit 2010 to focus in 2010/2011 on the topics related to climate change and to present potential solutions for an ecologically and economically efficient air transport system. Within the next years this Framework is going to be extended by taking the other topics noise, safety, security and efficient operations into account (Szodruch et al., 2011a).

This paper deals with the objectives, state-of-the art and future planning of IFAR. It highlights first ideas for improved technologies in the area Aeronautical Communications which is the main topic of this book. Aeronautical Communications is one relevant topic considered in IFAR which plans to contribute to an improved air transport system on a

worldwide level. A communications network is to be created which meets the requirements of the aviation industry of the future. Here, the data streams must, above all, flow reliably between the aircraft and the ground, and this must take place both in remote regions over the oceans and the poles as well as in crowded conurbations. Supplementary information means that such a new communications network can sustainably improve safety standards in aviation and also reduce environmental impact through optimised flight paths for example. Within Section 6 the IFAR future aeronautical communications aspects will be spotlighted.

2. IFAR history

The Forth Assessment Report of the International Panel on Climate Change (IPCC) has stirred an intensive public debate on future aeronautical research challenges and policies. By an initiative of the German Aerospace Center (DLR) a Summit was held in 2008 in Berlin as a response. 12 key international leaders in aeronautical research met to address the question of the Air Transport of the Future in the context of climate change. In this regard, the conference participants agreed that any research and strategy contributing to new solutions will have to reconcile the increasing need for international mobility in a globalized, work-sharing economy with the challenge of simultaneously developing new solutions to balance the climate effects of the accompanying world-wide growth in air traffic. The IPCC report identifies aviation to contribute 2–3 percent of today's total global anthropogenic CO₂ emissions. This prompted the International Air Transport Association (IATA) to set the long term challenge of Zero Emission Aviation by 2050 and emphasised the importance of addressing these challenges on a global level. Using the IPCC report and the latest research results on climate change as a basis, the Berlin Summit participants acknowledged the need for new solutions addressing both mid-term as well as long-term perspectives. Some solutions, such as the enhanced efficiency of aircraft and air traffic management systems have already resulted in major technological advancements and increased operational capabilities. Nonetheless, as air transport faces increasing demands, these topics remain to be core areas of aeronautical research. Accordingly, international research establishments are key actors, particularly in approaching the long-term and, thus, pre-industrial questions of research and development. The participants of the Berlin Summit welcomed this first event as a unique international forum to enhance discussion of the strategic challenges in aeronautical research. They agreed to establish an international platform for a dialogue to coincide with International Air Shows and with meetings all over the world.

At the Berlin Summit in 2010 key leaders of 16 international aeronautical research organisations met the second time and gave this forum the name IFAR which stands for International Forum for Aviation Research. The attendees continued the discussion on the topics related to climate change and agreed to develop a common Research Framework which represents the Aviation Research worldwide. The kind of organisation is under discussion and will be defined in the short future.

The outcome of the IFAR summit was summarised by the participants with in a declaration which is published at the IFAR website www.ifar.aero.

3. IFAR objectives

The objectives for IFAR were discussed at the last IFAR Summit in 2010 and the outcome was published within a declaration. These results are at this time first ideas which will be finalised in the short future. This section gives a summary of this declaration.

IFAR is a forum which represents the aviation research organisations worldwide. The specifics of the organisation (e.g. alliance) are currently under discussion and will be defined in the near future. Fig. 1 illustrates the interaction of IFAR with the society, global political influence organisations and industry. IFAR takes up the challenges identified by them and develops as reaction research strategies.

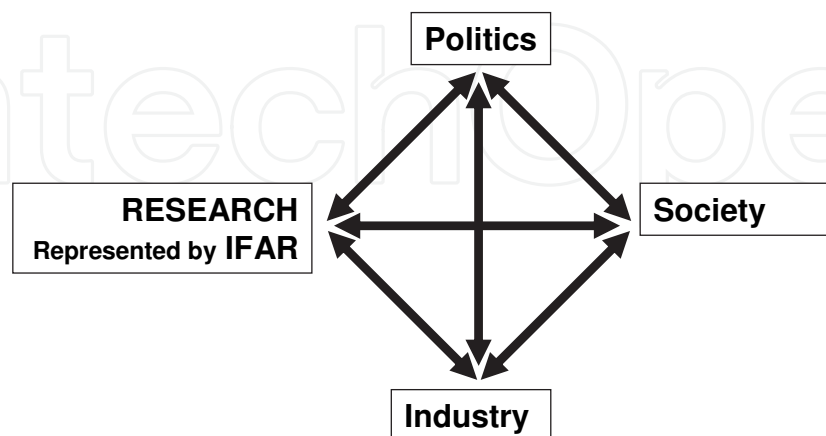


Fig. 1. Interaction of IFAR to politics, public and industry.

The main IFAR aims are

- to take up the environmental challenges for air transport industry as identified by the global community
- to present potential solutions for an ecologically and economically efficient air transport system
- to connect worldwide aviation research institutions
- to provide a common voice for the IFAR organisations in the international dialogue
- to focus IFAR's initiatives on the technologies to address climate change, impact of weather and natural phenomena, noise and local emissions, efficient operations, security and safety
- to concentrate at the beginning of IFAR's initiatives on climate change
- to develop an IFAR Framework considering other international aviation road maps and research initiatives.

IFAR is considering for the development of the IFAR Framework the following technological and other aviation topics which are of global nature:

- | | |
|--|---|
| <ul style="list-style-type: none"> • Technological topics <ul style="list-style-type: none"> • Climate change • Alternative fuels • Noise • Security • Safety and • Efficient operations | <ul style="list-style-type: none"> • Other topics <ul style="list-style-type: none"> • Education • Quality • Crisis management • Networking • Capacity |
|--|---|

Concerning the development of the Framework the participants agreed to the plan illustrated in Fig. 2. The partners started on the topic climate change which is mostly discussed in public and will continue in the next years with the other topics as noise, security, safety and efficient operations. IFAR will disseminate its work and progress to the public regularly at www.ifar.aero.

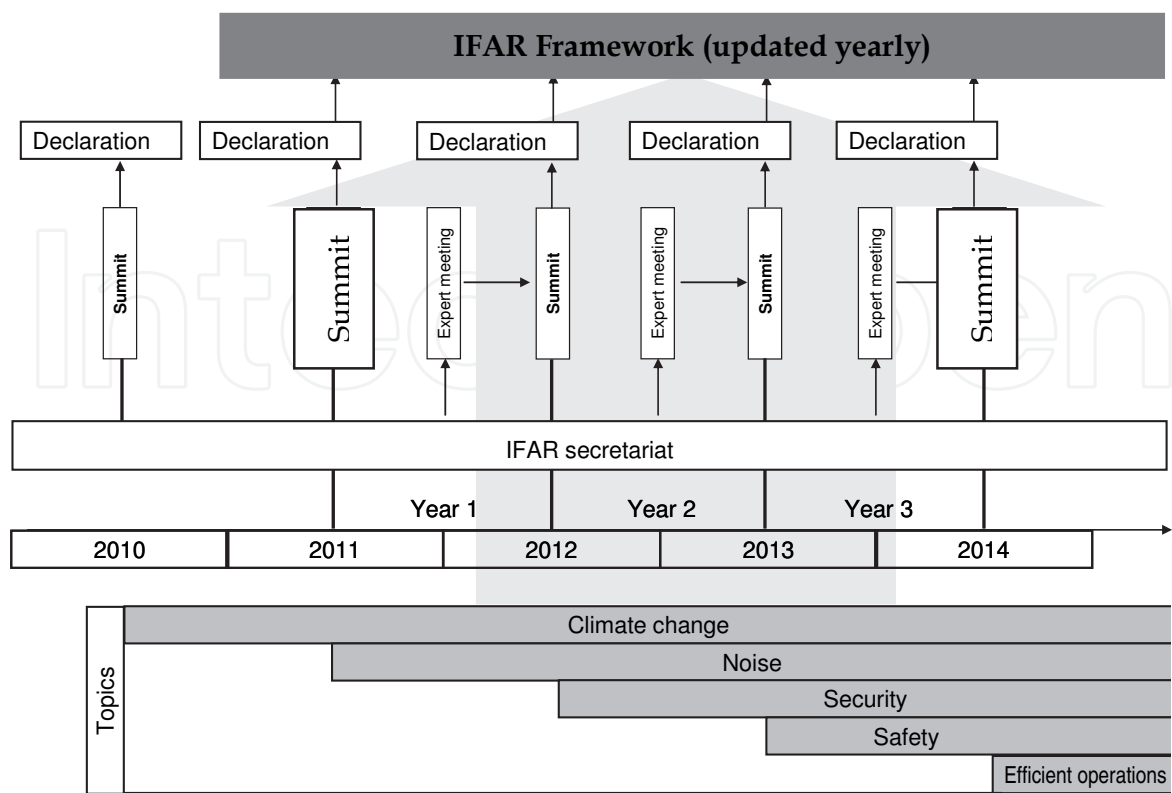


Fig. 2. IFAR meetings related to topics.

4. Aviation research - state of the art

4.1 History

Over the past 100 years aviation has transformed the society dramatically. Looking back at the last 50 years the aviation passed a spectacular development. The International Energy Agency (IEA) developed the graph in Fig. 3 which shows for that time the improvement of the energy intensity (fuel burn per passenger kilometre) for selected aircraft. This figure illustrates that the technology in engine, airframe and other measures has helped to reduce the aircraft fuel burn per passenger kilometre by more than 70%. This is already an excellent success. However, a significant growth of the Air Traffic System (cf. next section) is expected in the next years. Due to the negative impact on the climate and the decreasing availability of fuel resources there is still a high demand for a further improvement of the energy intensity. It is the responsibility of the aviation research to develop the corresponding new technologies as well as looking into alternative fuels.

4.2 Outlook into the future

4.2.1 General CO₂ forecast

IEA published in 2010 the Energy Technology Perspectives - Scenarios and strategies to 2050. This report (ETP, 2010) analyses and compares various scenarios. It does not aim to forecast what will happen, but rather to demonstrate the many opportunities to create a more secure and sustainable energy future. A comparison of different scenarios demonstrates that low-carbon technologies can deliver a dramatically different future. However, it is mandatory not only to stimulate the evolutionary development of new

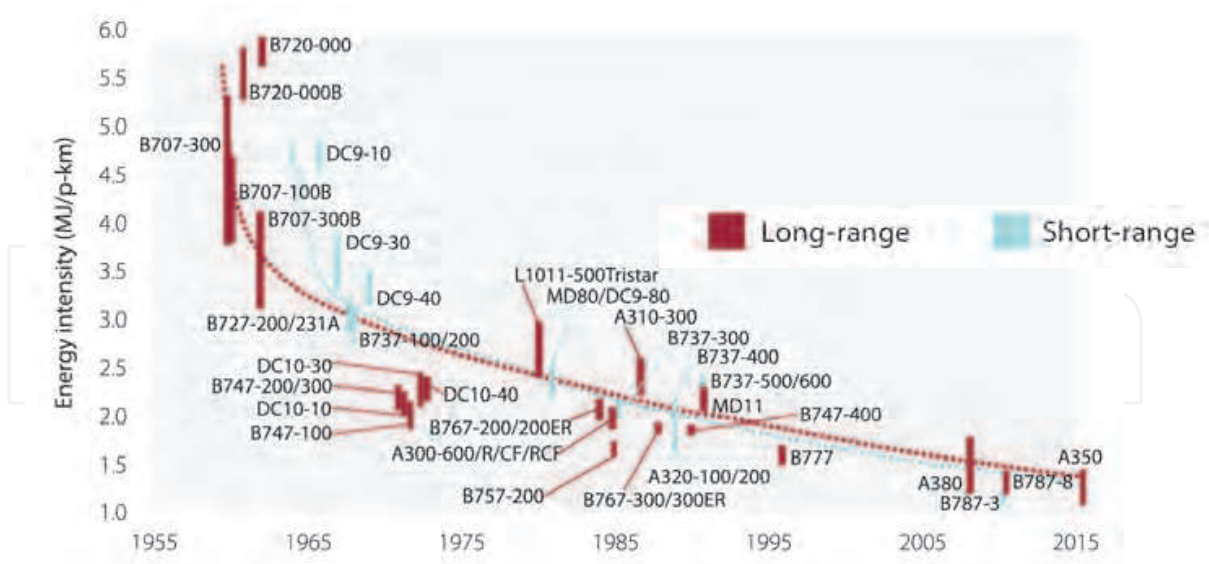


Fig. 3. Energy intensity of aircraft. The range of points for each aircraft reflects varying configurations; connected dots show estimated trends for short and long-range aircraft. (Source: IEA).

application oriented technologies but also to invest in revolutionary ideas and motivate creativity and fundamental research. Thus, simply increasing funding will not be sufficient to deliver the necessary low-carbon technologies. Current government RD&D programmes and policies need to be improved by adopting best practices in design and implementation. This includes:

- the design of strategic programmes to fit national policy priorities and resource availability;
- the rigorous evaluation of results and adjusting support if needed;
- and strengthening the linkages between government and industry, and between the basic science and applied energy research communities to accelerate innovation

Current energy and CO₂ trends run directly counter to the repeated warnings sent by the United Nations Intergovernmental Panel on Climate Change (IPCC), which concludes that reductions of at least 50% in global CO₂ emissions compared to 2000 levels will need to be achieved by 2050 to limit the long-term global average temperature rise to between 2.0°C and 2.4°C. Recent studies suggest that climate change is occurring even faster than previously expected and that even the “50% by 2050” goal may be inadequate to prevent dangerous climate change (cf. Fig. 4 and Fig. 5).

Temperature increase (°C)	All GHGs (ppm CO ₂ -eq.)	CO ₂ (ppm CO ₂)	CO ₂ emissions 2050 (% of 2000 emissions)
2.0-2.4	445-490	350-400	-85 to -50
2.4-2.8	490-535	400-440	-60 to -30
2.8-3.2	535-590	440-485	-30 to +5
3.2-4.0	590-710	485-570	+10 to +60
4.0-4.9	710-885	570-660	+25 to +85
4.9-6.1	885-1 130	660-790	+90 to +140

ppm: parts per million.

Fig. 4. Relationship between CO₂ emissions and climate change (ETP, 2010).

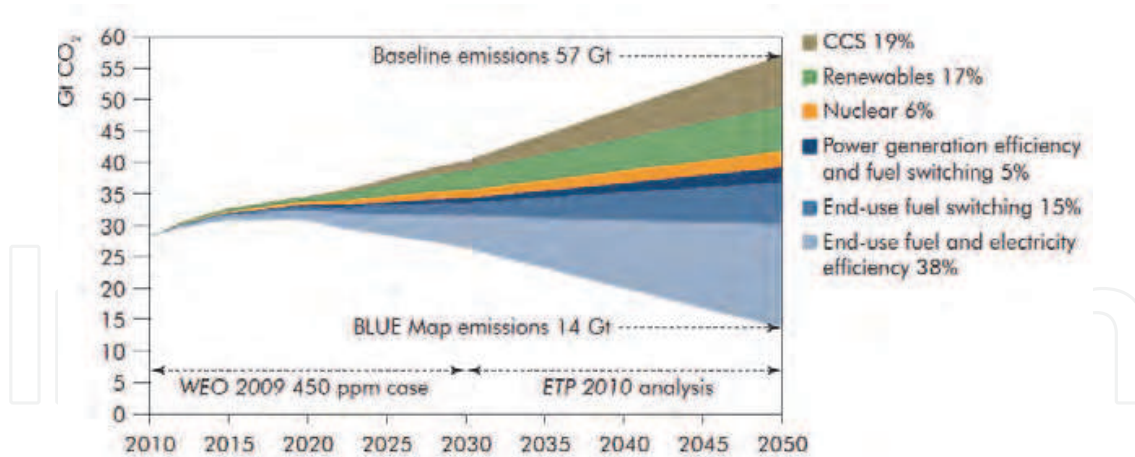


Fig. 5. Contribution of different technologies to CO₂ emissions (ETP, 2010).

4.2.2 Aviation

The current aviation's contribution to global CO₂ emissions is estimated at 2% and its contribution to total greenhouse gas emissions is approximately 3%, since other exhaust gases and contrails emitted during flight also contribute to the greenhouse effect. The aviation industry contributes approximately 8% to the world gross domestic product, and aviation growth is projected to be 5 to 6% per year (IATA (2009)). By 2050, the IPCC forecasts aviation's share of global carbon emissions will grow to 3% and its contribution to total greenhouse gas emissions is estimated to 5%.

According to (ETP, 2010) air travel is expected to be the fastest growing transport mode in the future as it has tended to grow even faster than incomes during normal economic cycles. Air passenger-kilometres increase by a factor of four between 2005 and 2050 in the Baseline scenario (no actions e.g. due to improved technologies, cf. Fig. 5) , or even by a factor of five in a High Baseline scenario. In the same period, aviation benefits from steady efficiency improvements in successive generations of aircraft. The technical potential to reduce the energy intensity of new aircraft has been estimated in a range between 25% and 50% by 2050. This is equivalent to an improvement of about 0.5% to 1% per year on average. Additionally, airlines show an improvement roughly by 2% in 10 years.

Fig. 6 and Fig. 7 depict the long-term growth of aviation, measured by revenue passenger kilometres and CO₂ emissions under different scenarios (Szodruch et al., 2011b):

- Scenario 1 represents the ATS up to 2050 with aircraft technology that is currently available. Improvements in fuel efficiency are therefore limited to the replacement of legacy aircraft currently operated with state-of-the-art technology.
- In scenario 2, a 50% reduction in specific fuel consumption (ACARE objective) is achieved by a combination of aircraft entering service after 2020, operational measures and improvements in air traffic management.
- Scenario 3 depicts a situation where CO₂ emissions are stabilised after 2030, without constraining aviation growth. This scenario requires considerable technological efforts in excess of the objectives, to achieve a stabilisation of emissions. In addition to operational improvements of the air transport system, the fuel efficiency of new aircraft types entering service after 2020 is required to increase by about 60% compared to the technology level of 2000.

The forecast of passenger traffic is based on the predictions of Airbus, and Boeing, which publish forecasts for up to 20 years, the International Civil Aviation Organisation's

(ICAO)(2007) Outlook for 2025, and the results of CONSAVE 2050; a study that quantified long-term scenarios to 2050 (Berghof et al., 2005).

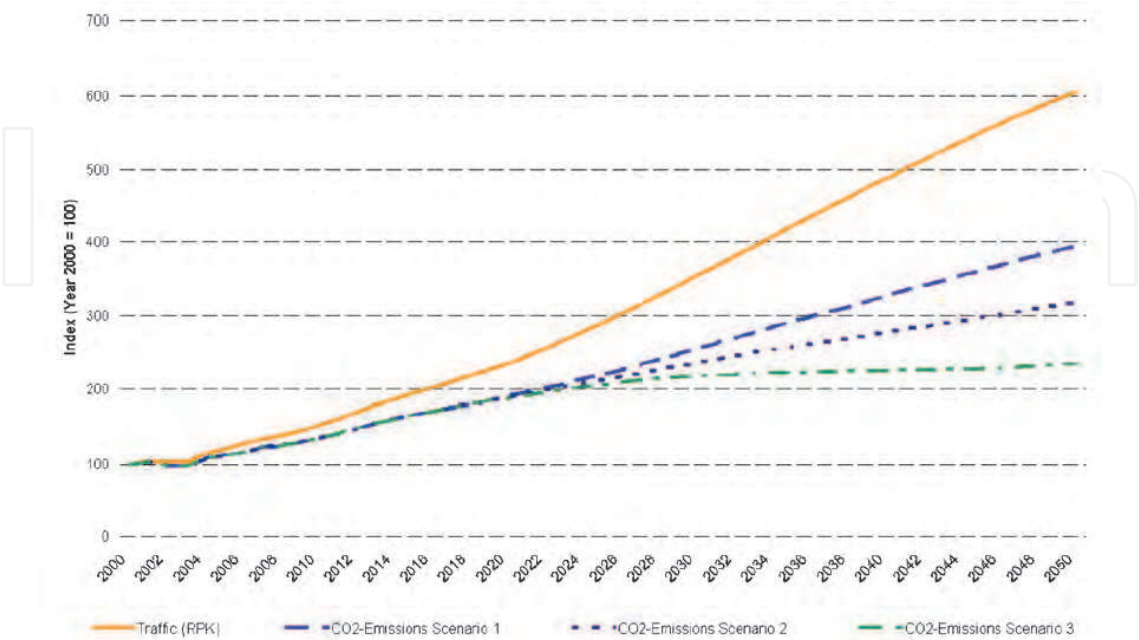


Fig. 6. Development of passenger traffic and CO₂ emissions 2000-2050.

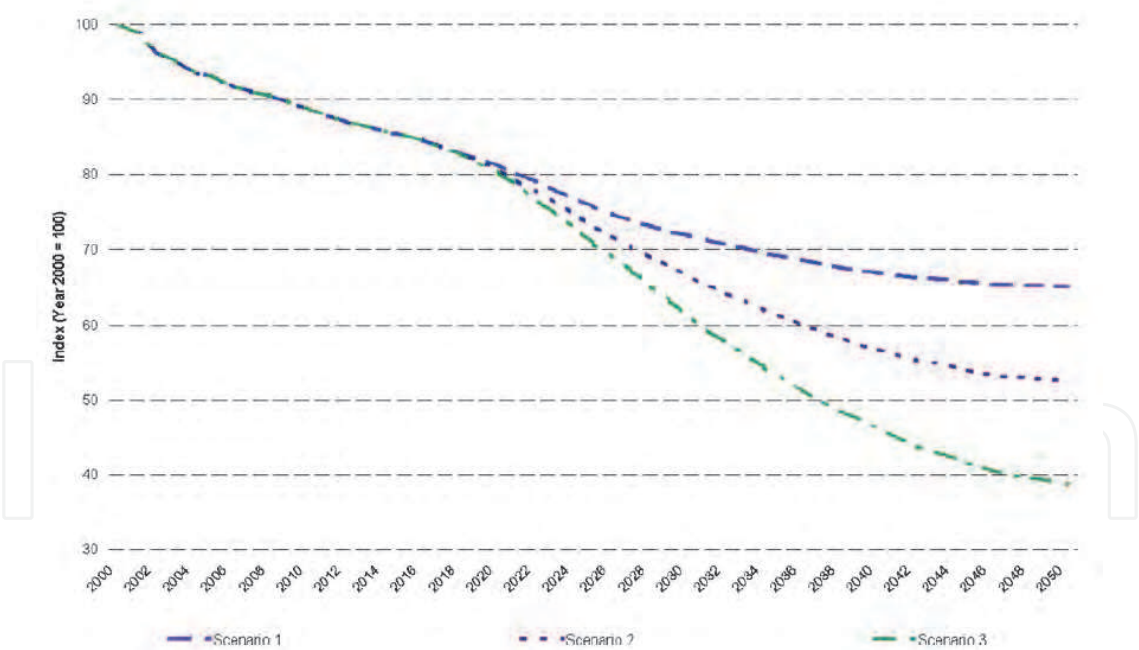


Fig. 7. Development of fleet-wide specific consumption 2000-2050.

5. IFAR Framework

5.1 IFAR approach

The IFAR approach consists of 3 steps illustrated in Fig. 8. Step 1 builds the IFAR vision 2050 which is mainly influenced by society, stakeholders and political demands (e.g. the

need for new technologies reducing influence on the climate). Step 2 considers new and visionary break through technologies which are expected to fulfil the goals in Step 1 and to improve the Air Transport System (ATS) in Step 3. Technologies considered in this regard are not only software or hardware but also improved operations or other innovative ideas. IFAR - as research representative - concentrates on technologies until TRL 6. Further development, qualification and product integration can only be done by industry. The search for new technologies does not necessarily need to be conducted within the aviation sector. They can also be transferred from other industrial sectors as automotive, space, energy, etc. Alternative fuels, which might play an important role in the future ATS can for instance be developed in the energy sector. On the other hand the new technologies developed in aviation may also be transferred to other industrial fields. Aeronautics is for instance working on the automation of the manufacturing process for future aircraft structures made of composites. This technology may be partly transferred to other sectors different from aviation. Step 3 is the future Air Transport System improved by the new technologies from Step 2. The expected impact of single technologies or combinations of them on the ATS is also part of Step 2. The new ATS has to take the influence of numerous regulations into account.

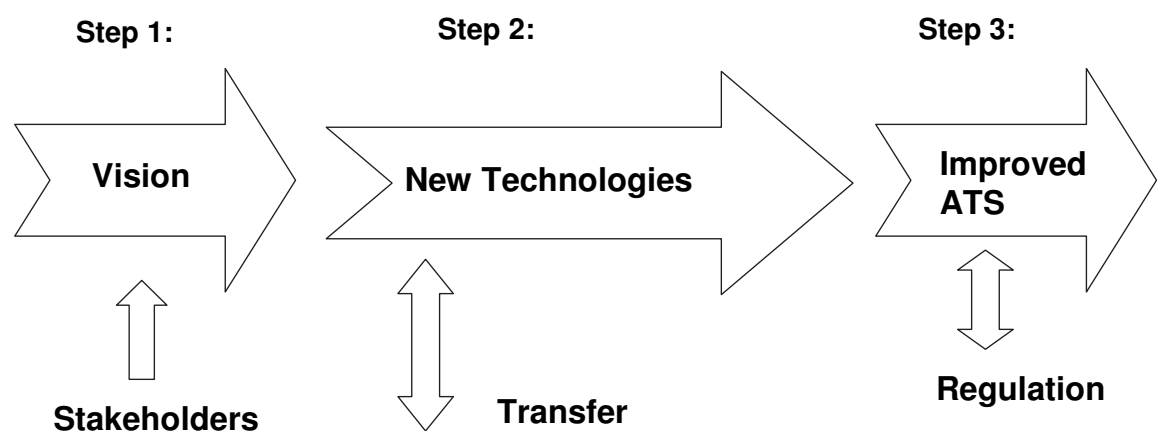


Fig. 8. IFAR approach.

The IFAR Framework is currently under development. It is planned to be a summary or harmonisation of available strategic documents provided by the IFAR partners. Two documents are public (from European Research Establishments in Aeronautics (EREA) which represents Europe (EREA, 2010) and from NASA (NASA, 2010) and other input is expected to be provided from IFAR discussions and further documentations by the partners. Strategic Road Maps of organisations outside IFAR will also be considered. Fig. 9 summarizes the public documents which contribute to the IFAR Framework, namely from the International Air Transport Association (IATA) (IATA, 2009), the International Energy Agency (IEA) (ETP, 2010), Advisory Council for Aeronautics Research in Europe (ACARE) (ACARE, 2010) or the Flightpath 2050 (Flightpath 2050, 2011).

Step 1: IFAR vision

Step 1 of the IFAR approach represents the IFAR vision which is influenced by stakeholders and by political demands. IFAR aims to develop an own target point in the vision for each single technological topic as climate change, noise, security, safety and efficient operations.

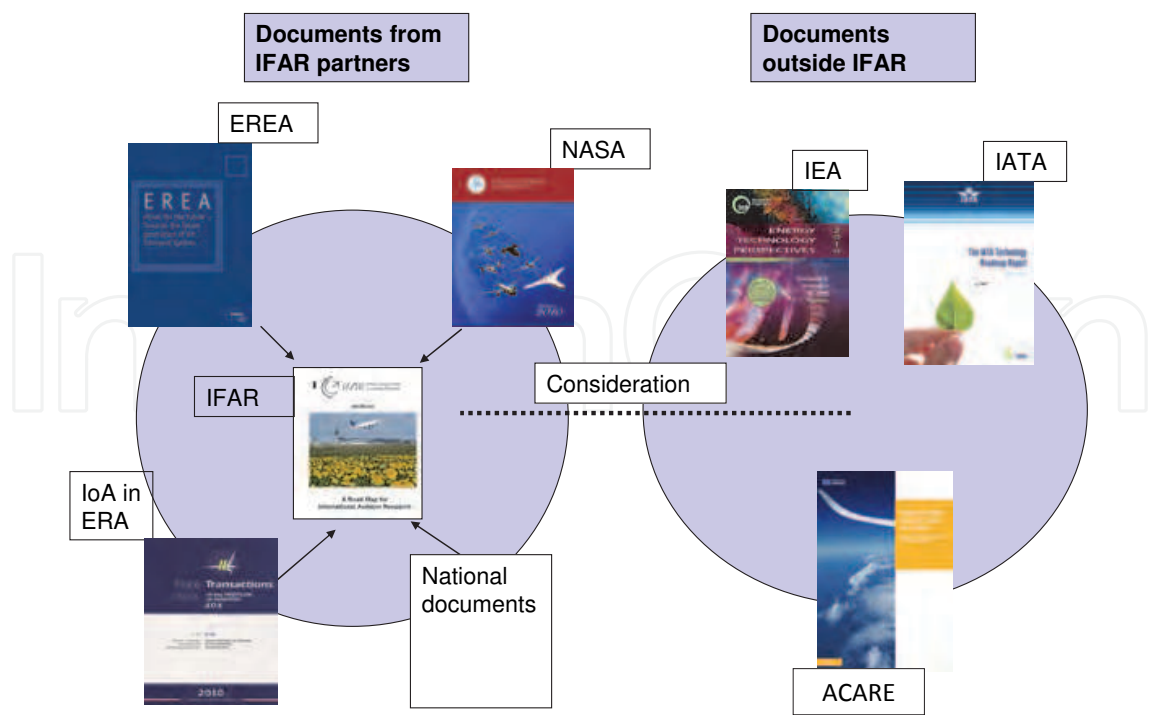


Fig. 9. Documents from IFAR partners and organisations outside IFAR.

For climate change there exist already for instance the following visions 2050 of IATA or IEA:

- IATA vision: 50% Reduction in net CO2 emissions over 2005 levels
- IEA vision for Aeronautics: ATS is operating with new energy sources by 30%.

IFAR is currently developing its own vision. For the topic climate change the already available visions from IATA or IEA will be taken into account, but the IFAR vision will be extended by the consideration of the total Air Transport System as well as the impact on the global temperature increase. Air transport impacts the climate directly for instance by contrails, soot, CO2, NOx and other emissions. All this leads to an increase of the global temperature. However, there are operational technologies (e.g. flying in different altitudes or routes) which have influence on the global temperature but not CO2. Thus, the inclusion of the global temperature as an additional metric is reasonable and will allow a better evaluation of the impact of such technologies on the climate.

Step 2: New technologies

IFAR aims to identify promising and breakthrough technologies which are expected to fulfil the IFAR vision defined in Step 1. IFAR considers here for instance technologies improving the performance of the aircraft, the airport, the air traffic management (ATM), flights with low environmental impact (different altitudes or routing) or the interaction of all technologies together. Other examples are alternative fuels to reduce the carbon foot print of the Air Traffic System and minimise the independent of oil. The technologies considered in IFAR cover the full range of the ATS (cf. Fig. 10). The technologies are usually developed by the aviation sector itself but they may also be transferred from or to other industrial sectors as automotive, space or energy. IFAR is currently developing a technology tree which will be one main part of the IFAR Framework. The technologies will be the input from available IFAR documents provided by the IFAR partners (cf. Fig. 9).

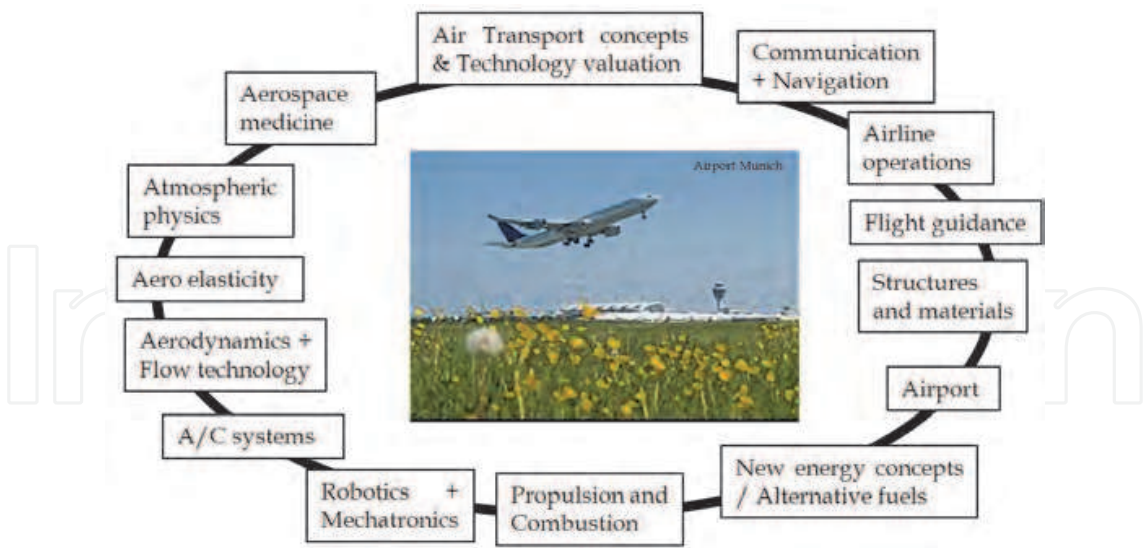


Fig. 10. Aviation topics considered in IFAR.

Step 3: Improved ATS

Step 3 of the IFAR approach represents the Future ATS. The improvement will be an outcome of the assessment of the new technologies discussed in Step 2. IFAR defines and agrees during expert meetings on the level of technology impact.

6. Communications aspects

Within the IFAR, communication and navigation are considered as an aviation topic. The technologies for the future communications infrastructure (FCI) are based on seamless networking and future data links. The concept of seamless networking describes the interoperability of all existing and future (digital) data links and service-oriented avionic architectures to allow a single infrastructure and information management system to deliver instantaneous data with high quality. To enable this concept, new data links with higher capacities, better flexibility, and increased coverage are needed. Fig. 11 shows a global aeronautical communication network.



Fig. 11. Integration of different data links into a global aeronautical communication network.

6.1 Existing visions for ATM by 2020

The Single European Sky ATM Research Programme (SESAR) aims at developing the new generation ATM system capable of ensuring the safe and smooth air transport worldwide over the next 30 years. SESAR's goal to 2020 is saving 8 to 14 minutes, 300 to 500 kg of fuel and 948 to 1575 kg of CO₂ per average flight (SESAR, 2009).

The Next Generation Air Transportation System (NextGen) developed and planned to be implemented by the US Federal Aviation Administration (FAA) will allow more aircraft to safely fly closer together on more direct routes, reducing delays and providing unprecedented benefits for the environment and the economy through reductions in carbon emissions, fuel consumption and noise. By 2018, NextGen will reduce total flight delays by about 21 percent. In the process, more than 1.4 billion gallons of fuel will be saved during this period, cutting carbon dioxide emissions by nearly 14 million tons (NextGen, 2009).

One major pillar in the SESAR and NextGen concepts is the FCI to support the new operational concepts that are being developed.

The ACARE Vision beyond 2020 (and towards 2050) states a noise reduction by innovative mission and trajectory planning due to a better ATM. Furthermore, improved ATM and operational efficiency contribute by 5-10% to the reduction of fuel burn and CO₂. Additionally, by an existing FCI, the overall fuel burn can be reduced by 5-10% due to better flight planning, speed management, direct routes, etc. (ACARE, 2010).

6.2 Visions by 2030

Until 2030 the overall vision by using new aeronautical communications technologies in a seamless networking concept is an improved traffic management. The resulting benefits which support the aforementioned visions for 2020 are: less fuel consumption, increase of traffic capacities, less delay in flight operations and better flight planning. Furthermore, instead of stand-alone equipment for each data link, an integrated approach for all communications technologies will reduce weight and power consumption during flights and will benefit in less fuel consumption.

A further goal is the combination of communications and navigation. The new communications systems might be further developed to include a navigation component. Thus, future communications systems could implement alternate positioning navigation and timing (APNT) and act as fallback solutions in the case of a GNSS failure. This will also facilitate smoother transition phases for new system generations due to a better usage of frequency capacities.

6.3 Visions by 2050 and beyond

During the Aerodays 2011 in Madrid, Spain the European Commission released Europe's new vision for aviation by 2050 (Flightpath 2050, 2011). This vision was created by a European High Level Group on Aviation and Aeronautics Research including all key stakeholders of European aviation. The Flightpath 2050 addresses several goals in respect of future communications strategies, for example:

- Travellers can use continuous, secure and robust high-speed communications for added-value applications.
- The transport system is capable of automatically and dynamically reconfiguring the journey within the network to meet the needs of the traveller if disruption occurs.
- An air traffic management system is in place that provides a range of services to handle at least 25 million flights a year of all types of vehicles, (fixed-wing, rotorcraft) and

systems (manned, unmanned, autonomous) that are integrated into and interoperable with the overall air transport system with 24-hour efficient operation of airports.

Besides the Flightpath 2050 there exist also visions of a one pilot cockpit respectively unmanned cockpit which is only feasible with the FCI fully implemented. The necessary ground assistance for a single pilot aircraft or an unmanned aircraft requires highly reliable data communications and high capacity data links which need to be implemented in the final FCI stage.

Furthermore, synergies between sky and sea could be envisioned. This would require a development of a holistic communications infrastructure between aviation and ocean freight / shipping. Since shipping and aviation are using very often the same routes or encounter communications problems in remote areas, this vision envisages a flexible interoperable network between aircraft and ships to enable communication everywhere. Therefore, aviation could support the efficiency of world's largest cargo segment, could also support the reduction of fuel usage (communication of better route planning information), and could support and get communication possibilities in remote areas.

6.4 Readiness level of communications technologies

First studies on seamless aeronautical networking were already done and a proof-of-concept was given, e.g., EU Research Project NEWSKY. A first prototype of such a concept is developed within the EU Research Project SANDRA (SANDRA, 2009). Additionally, an underlying technology of the seamless network is the concept of an aeronautical mobile ad hoc network (MANET). The aeronautical MANET is envisioned to be a large scale multi-hop wireless mesh network of commercial passenger aircrafts connected via long range highly directional air-to-air radio links (cf. Fig. 12)



Fig. 12. Example of aeronautical MANET (Medina et al., 2010).

The underlying seamless networking concept is only ready to fully operate by deployment of new data links with higher data rates and flexibilities. An already existing digital data link is VHF Digital Link Mode 2 (VDL2). A high data airport wide data link, namely AeroMACS (EUROCAE WG-82, 2009), is under investigation and also the L-Band Digital Aeronautical Communications System (L-DACS) (Action Plan 17, 2007). Iris, element 10 of the ESA ARTES programme, aims to develop a new air/ground satellite-based solution for the SESAR programme by providing digital data links to cockpit crews in continental and oceanic airspace (Iris, 2009). In addition to the air/ground capability, some of the mentioned data links or unknown future data link technologies could also support air-to-air (A2A), resp. point to point and/or broadcast communications. In the following Table 1 the TRL of these future communications technologies are listed depending on the envisioned decades. All the aforementioned visions of a fully interconnected world through virtual technologies in 2050 are only feasible by the development and deployment of a FCI based on seamless networking with all communications technologies.

Technology	TRL today	TRL in 2030	TRL in 2050
Seamless Aeronautical Network	3-6	9	9
Aeronautical MANET	2	6	9
VDL2	9	9	9
AeroMACS	5	9	9
L-DACS	4	9	9
Iris	3-4	9	9
A2A	2	6	9
Holistic Network (aviation/shipping)	1	2	6

Table 1. Readiness Level of future aeronautical communications technologies.

7. Conclusions

The International Forum for Aviation Research (IFAR) is a new initiative to connect and represent leading worldwide aerospace research organisations and to allow communication on all global research topics. Climate change is currently the most relevant topic and was the motivation to set up IFAR. However, IFAR also addresses further areas relevant for a future global air transport system (e.g. noise, security, safety, efficient operations). The idea of IFAR was born at the Berlin Summit 2008 where key leaders of 12 international aeronautical research organisations met to address the question of the Air Transport of the Future in the context of climate change. At the second Berlin Summit in 2010 16 international aeronautical research organisations met and eventually set up IFAR. IFAR aims to develop an International Aviation Framework specifically addressing the most important questions for a future global air transport system. In a first stage the Frame work will concentrate on topics related to climate change. Within the next years this Framework is going to be extended by taking the other relevant challenges like noise, safety, security and efficient operations into account. This paper deals with the objectives, state-of-the art and future planning of IFAR. It highlights also first ideas for improved technologies in the area Future Aeronautical Communications for the future. The results of the working groups, the discussions among the participants and the specific actions within the framework development will be regularly updated the IFAR website www.ifar.aero.

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Future Aeronautical Communications

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There are well-founded concerns that current air transportation systems will not be able to cope with their expected growth. Current processes, procedures and technologies in aeronautical communications do not provide the flexibility needed to meet the growing demands. Aeronautical communications is seen as a major bottleneck stressing capacity limits in air transportation. Ongoing research projects are developing the fundamental methods, concepts and technologies for future aeronautical communications that are required to enable higher capacities in air transportation. The aim of this book is to edit the ensemble of newest contributions and research results in the field of future aeronautical communications. The book gives the readers the opportunity to deepen and broaden their knowledge of this field. Today's and tomorrow's problems / methods in the field of aeronautical communications are treated: current trends are identified; IPv6 aeronautical network aspect are covered; challenges for the satellite component are illustrated; AeroMACS and LDACS as future data links are investigated and visions for aeronautical communications are formulated.

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