WHITEPAPER ON FUTURE SKY

A EUROPEAN JOINT RESEARCH INITIATIVE FOR GREEN AND SEAMLESS AIR TRANSPORT

Prepared by Future Sky Board, June 2019

CONTENTS

SUMMARY

Future Sky (FS) is a Joint Research Initiative of the Association of European Research Establishments in Aeronautics (EREA) devoted to preparing key technologies and capabilities for a green and seamless air transport in Europe. Within Future Sky EREA promotes joining forces with the European industry and universities to design a new air transport system allowing environmentally friendly, smooth and efficient air vehicles and associated mobility.

Green and seamless air transport is to be thought as a key element for the most far-reaching goals of Flightpath 2050. Striving for a substantial increase in performance, safety, competitiveness, and acceptance, *Future Sky* aims at promoting maximum air mobility while making the highest demands on technologies as well as vehicle, system and operation design.

The overall Future Sky program is subdivided into six topics, each of them called "*Future Sky Theme*" and focusing on different aspects or challenges on track to the future air transport system:

- *Future Sky Theme* 1: SAFETY – The population of a Future Sky will be denser and definitely more diverse than it is today. For this, new safety rules, regulations, measures, and standards have to be developed and validated together with the development of technologies aiming at high level of safety.
- *Future Sky Theme* 2: QUIET AIR TRANSPORT – Reducing the noise impact of aviation is more critical than ever for the public acceptance of air transport system, both because health issues are now acknowledged to be at stake and because new challenges are emerging (Urban Air Mobility, Supersonic aircraft). The issue must be addressed thoroughly with experts in social sciences and urban planning beyond core researches on reducing noise at source through noise reduction technologies and low-noise vehicle designs
- *Future Sky Theme* 3: ENERGY – Aside from quietening air transport, greening is the second major challenge for future vehicles and power plants. Green and seamless air transport will require new propulsive concepts and technologies as well as new energy sources (drop-in or non-drop-in fuels, electrification) as an alternative to fossil energy sources.
- *Future Sky Theme* 4: URBAN AIR MOBILITY: This emerging new mode of transportation will provide on-demand mobility in high density as well as remote areas, regional seamless mobility, and efficient and environmental friendly manned and unmanned passenger and cargo transportation as set out by *Flightpath 2050*. This new FS Theme can be seen as a contribution to the reduction of road traffic congestion.
- *Future Sky Theme* 5: SECURITY FOR AVIATION: Nowadays, the security is a crucial international and societal challenge which faces a growth of the diversity security threats and the development of autonomous systems which increases dramatically the complexity of the threat management. Studies need to be carried out to determine the best measures for protection and the most appropriate reactions to develop appropriate, efficient and consistent solutions against the present and future aviation threats.
- *Future Sky Theme 6:* CIRCULAR AVIATION: The increasing environmental awareness within the European society is challenging the aviation sector to intensify its efforts towards a greener, cleaner and more sustainable aviation, by reducing its environmental impact in terms on consumption, waste and emissions connected to all aviation activities and operations. The principles of circularity, or circular economy, shall provide a framework to re-evaluate the complete, cradle-to-cradle, life cycle of each aspect of aviation, enabling the transition to circular aviation.

Future Sky seeks to rally the available but so far scattered capabilities to tackle the major longer-term challenges of Flightpath 2050. For this reason main feature of this program will be the coordination, as far as possible, of research establishments' efforts in the field of aviation research in Europe. EREA

believes institutional cooperation of European research establishments is the best guarantee to ensure medium and long term technology development beyond the scope of top-down approach in SESAR and Clean Sky JUs.

In *Future Sky* national research establishments develop and pursue roadmaps covering at least a period of seven years addressing the complete air transport system and tackling research gaps not fully covered by the national institutional research programs. To fill these gaps subsequent *Future Sky themes* are intended to grow into multidisciplinary clusters of excellence for research and innovation in Europe. Thereby *Future Sky* makes a substantial contribution to achieving the medium and long term goals of *Flightpath 2050* and helps preparing the Framework Programs to come.

INTRODUCTION

In 2011 the High Level Group representing leaders of European aviation society issued Europe's Vision for Aviation – a document known as ***Flightpath 2050*** – in response to "*Europe […] entering a new age where it faces many challenges such as globalisation, a financial system in need of reform, climate change and an increasing scarcity of resources.*" Combined efforts of all stakeholders are clearly necessary to master these challenges, especially by fostering research and innovation in order to maintain Europe's capacities and competitiveness of the European air transport system (ATS).

Based on *Flightpath 2050* the Advisory Council for Aviation Research and Innovation in Europe (*ACARE*) agreed *Strategic Research and Innovation Agenda (SRIA)* for coming decades providing a common roadmap to achieve the ambitious goals. The *ACARE SRIA* envisages attractive and efficient research instruments to be established, which ensure continuity between research on promising breakthrough concepts, their validation by focused R&D actions and finally their demonstration in an integrated environment. In recent and current European Framework Programs this was realized by using the concept of levels of funding opportunities, addressing the various technology readiness levels (TRL) and covering the full research and innovation chain. Furthermore, *Flightpath 2050* and the *ACARE SRIA* propose the establishment of multidisciplinary clusters of excellence for research and innovation, to achieve common technology goals. They ensure that the appropriate organizations are tackling activities at the appropriate level in the innovation chain. For demonstration activities on system level the well-known Joint Technology Initiative (JTI) concept has been proven to be successful. Today, the joint European efforts are reflected in Joint Undertakings (JU) such as recent and current Clean Sky and SESAR which support knowledge creation and innovation processes focusing the next generation of products and European ATS. The success of European aviation has proven the need for the continuation of such a phased approach. However, on a European level the funding focus is on demonstrator programs and not so very much on activities related to the **longer-term goals of *Flightpath 2050*** and the *SRIA*.

For cooperative, mid- to long-term research a similar concerted "all hands on deck" approach is crucial to strengthen Europe's leading position. As the European industry is leading the system demonstration activities in Clean Sky and SESAR, the European research establishments should be spearheading collaborative, mid- and long-term research by the most effective utilization of collective powers, i.e. knowledge and capabilities available in Europe.

The members of EREA are concerned about the lack of attention paid to mid- to long-term research and the lack of European support for coordination between national institutional programs. Therefore, EREA takes the initiative to propose a common view on the **next but one generation of the ATS in Europe** to promote coordinated action in fundamental and applied research in Europe along the lines of *Flightpath 2050* and the *SRIA*.

Future Sky is intended to draw a picture that unites all relevant *Flightpath 2050* goals, i.e. to remind ourselves of the *Flightpath 2050* vision for an ATS of the year 2050 and its effects on the next but one

generation of the European ATS. By doing so *Future Sky* will have a major share in preparing the scientific basis for the European air transport system beyond 2025-2030, thereby preparing ATS research and innovation beyond Horizon 2020 and Horizon Europe and contributing to a research and innovation friendly environment for Europe.

VISION OF A FUTURE SKY

In a nutshell *Future Sky* envisages an **efficient, safe and environmentally friendly ATS** in line with society expectations. The *Future Sky* Initiative is devoted to preparing key technologies and capabilities for a cutting-edge green and seamless air transport in Europe by 2050. Such ATS complies with all goals set by *Flightpath 2050*, contributing to the objectives maintaining European global leadership and serving Society's needs while contributing to the achievements of COP21 goals and the 2030 Agenda for Sustainable Development subscribed by Governments and civil society.

Flightpath 2050 is based on the vision that by 2050 a huge diversity of air vehicles including disruptive mobility concepts and remotely piloted aircraft systems (RPAS) with all sorts of configurations and missions will operate in air transport network that is able to cater for much greater traffic densities, than it is the case today. The air transport capacity meets the expanding demand in the air and at airports through high utilisation levels, highly efficient operations, optimal routing and all-weather capabilities enabled by ultra-quiet aircraft. In this sense green and seamless air transport is a condensed form of the most far-reaching goals of *Flightpath 2050* as it is a synonym for maximum mobility with the highest demands on technologies as well as vehicle and system design.

Substantial change in capabilities of the future ATS calls for fundamental review of operation routines in terms of punctuality, information provision and possibility of handling different types of air vehicles simultaneously. The vision and requirements are defined in *Flightpath 2050*, but substantial research has to be performed and knowledge has to be collected to meet the up-coming challenges in time.

TOGETHER EXCELLING IN RESEARCH FOR AVIATION

In European aeronautics research, the gap between fundamental research at TRL 1 to 2, mostly pursued by universities, and industrial development at TRL of 5 and higher is bridged by national research establishments. It is their task to verify and integrate solutions and ideas, to advance them from the level of fundamental knowledge-oriented research to the level of applied product-oriented development, from the basics to prototyping and demonstration.

The interaction and teaming of universities, research establishments, and industry is effective at the national level. However, globalisation elevated most of the former national companies to a European level, especially in the aviation sector with its long supply chains and international assembly lines. Following this trend, research organizations initiated some successful bi- or even multinational collaborations such as DNW (the integration of the Dutch and German wind tunnels), ETW (a European wind tunnel founded by four nations), AT-ONE (ATM alliance between DLR and NLR) and the Joint Helicopter program of DLR and ONERA. However, there may still be a demand for a truly pan-European program dedicated to research establishments.

EREA, the association of European Research Establishments in Aeronautics, proposes *Future Sky* as a Joint Research Initiative in which development and integration of aviation technologies with a focus on the next but one generation of ATS shall be taken to the European level without creating new European funding instruments. EREA strongly believes coordinated institutional cooperation of European Research Establishments is the best guarantee for continuous technology development

beyond the scope of the programs like SESAR and Clean Sky. In addition, looking further ahead the attempt is made to target the complete ATS along the lines of a full life cycle engineering approach, partnering universities and industry and thereby contributing to the full Research and Innovation chain.

***Future Sky* will strengthen the outstanding European aviation network among industry, universities, and research establishments**. Universities will be invited to participate mainly on the lower TRLs, while the involvement of industry is vital to build bridges to the demonstrator programs. With such an approach, the *Future Sky* JRI works fully complementary to the industry-led approach, implemented in Clean Sky 2 JU, and prepares the ground for the future ATS as outlined in *Flightpath 2050*.

JOINT RESEARCH INITIATIVE FUTURE SKY

GENERAL APPROACH

The *Future Sky* Initiative consists in multidisciplinary programs – so-called ***Future Sky Themes*** – where major innovation areas of future ATS will be investigated (EREA internal organisation in Fig. 1). As described previously, the main features of the ATS that *Future Sky* wishes to promote are its resilience and environment-friendliness (green & seamless). Each cluster will investigate aspects affecting the desired features, derive technical solutions, verify concepts, validate technologies, suggest regulation or standardization rules and evaluate the overall impact. The overall *Future Sky* program is subdivided into six themes focusing on different aspects or challenges on track to the future Air Transport System: Safety, Quiet, Energy, Urban Air Mobility, Security and Circular Aviation.

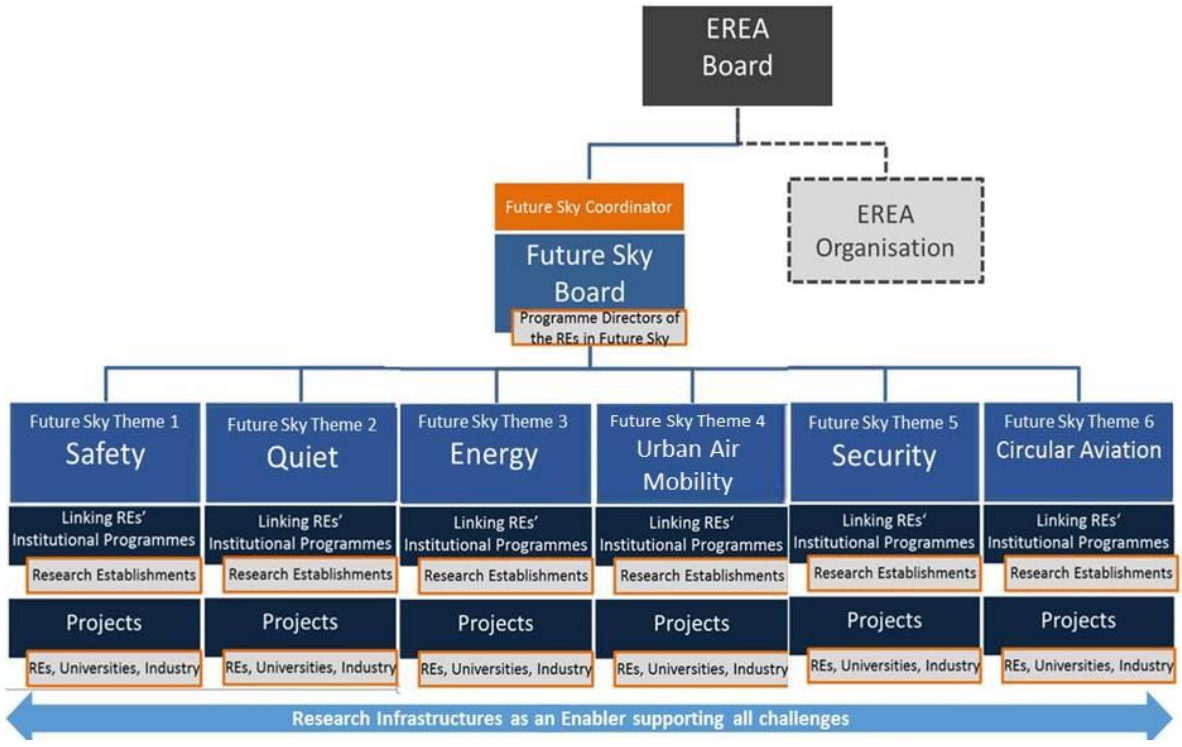

Fig. 1: EREA Internal organisation for the Future Sky Program.

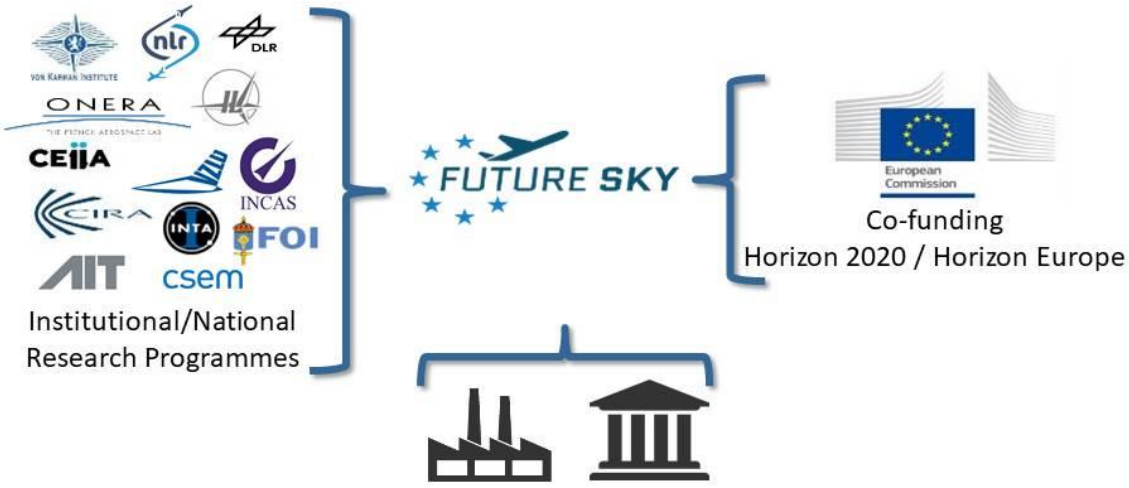

Fig. 2: Future Sky as coordinating entity for mid- to long-term aviation research in Europe.

Part of each *Future Sky Theme* is dedicated to **linking research establishment institutional programs**. Information regarding currently ongoing institutionally funded projects in each appropriate field of activity, funding modalities and further administrative information will be gathered and analysed to identify duplications or gaps. The purpose of this step is to create a periodically updated information basis for participating partners and for the European Commission. Having such an overview, European aviation research community will gain the overview over the current status of ongoing work and optimal partners for intended cooperation. Additionally to that national decision-makers will acquire the possibility to align research programs, projects and funding schemes along existing or barely investigated topics or to initiate promising cooperation. For each particular *Future Sky Theme* a **roadmap** (summarised below) is defined by research establishments covering most relevant fields of work. It will be executed under the responsibility of EREA and its individual members as part of the co-funded *Future Sky Theme*.

Academia and industry interested and committed to the long term objectives of the *Future Sky* projects are invited in dedicated workshops to express their interest in teaming up with EREA for collaboration in the projects defined under each *Future Sky Theme*. This collaboration should lead to results that would not have been achieved with national efforts only. Intermediate results gained in *Future Sky* on lower TRL should complement aviation related top-down actions. Globally, the *Future Sky* program is aiming at technologies and solutions beyond the scope of currently running Joint Technology Initiatives Clean Sky 2 and SESAR 2020 (Fig. 3), thus increasing global air mobility by preparing new technologies, concepts and operation. Substantial and coordinated involvement of research establishments makes this challenging goal possible.

Future Sky focuses on research towards mid- to long-term goals of *Flightpath 2050*. One major feature of the *Future Sky* program is involvement of national research establishments gathered in EREA and linking their institutional research programs. Joining forces by linking research efforts at European level will magnify scope and impact of the results impossible to achieve through individual national efforts. In order to fulfil this goal, **EREA is committed to involve third parties in the research activities of *Future Sky*, so that a proper knowledge and technology transfer between basic researches into industrial application can be ensured**. *Future Sky* does not intend the creation of new European funding instruments, but appreciates to make use of existing ones.

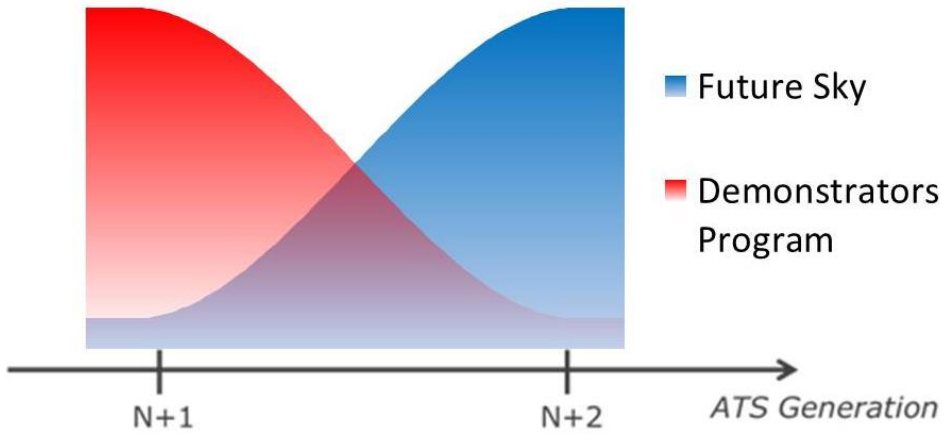

Fig. 3: Programmatic scope of Future Sky.

FUTURE SKY THEME 1: SAFETY

With up to 25 million commercial flights to be expected by 2050, the ability of the future ATS to deliver excellent safety performance, independent of any environmental hazards or disturbances, is not a given. While any spare capacity remaining in the ATS is taken up by the growing traffic load, thus removing to recover from disturbance, with a new demographic entering the industry both in the air and on the ground, and new business models, new vehicle technologies, and new entrants in the ATS, the goal of reducing the accident rate to less than 1 accident per 10 million flights presents a formidable challenge.

This topic thus calls for enhanced cooperation between research establishments, giving a clear commitment to link their nationally funded institutional programs and to work closely together with European Aviation Safety Agency (EASA) and EUROCONTROL in order to ensure the integration of research results at EU level. Joint activity will also involve oversight authorities, service providers (airport operators and airlines), universities and industry, and take into consideration the recommendations from *ACARE* (*SRIA*) and the OPTICS projects. The research in this *Future Sky Theme* will address the following topics to achieve a significant aggregated impact on the safety performance of the future ATS:

- Decreasing accident risk by developing new and more efficient safety interventions, both at the technology level, the operations level and the human operator level, specifically for the main accident categories Aircraft Upset/Loss of Control and Runway Excursion. Interventions shall include advanced flight envelope protection and improved protection against external hazards including adverse weather hazards (poor visibility, icing, lightning, wind & turbulence)
- Strengthening the capabilities in Europe to manage diverse risk by developing and applying advanced tools and techniques such as data analytics and dynamic risk modelling, to detect the emergence of new risks in the air transport system – such as mass diversion, to assess their potential impact and to investigate potential interventions;
- Strengthening vehicle resilience for impacts (birds, drones), and on-board hazards such a fire;
- Finding new ways to significantly strengthen the effectiveness and efficiency of Safety Management, including Integrated Risk Management, the development of organisational design guidelines and the development of new and effective and (cross-organisational) safety culture interventions;

- Enhancing the effectiveness of aviation sector specific Safety Oversight and performance-based regulation;
- Improving passenger and crew safety by adapting the development of cabin environment technologies and airframe technologies;
- Further enhancing the role of the Human Operator by developing more advanced methods & techniques for Human Performance Management and crew interaction in highly automated environments, and by strengthening European capabilities in the field of evidence based training, advanced flight simulation - including virtual flight simulation and blended learning;
- Developing methods to ensure the safety performance of new entrants in the air transport system such as personal aircraft and supersonic transports as well as new technologies such as Artificial Intelligence. This shall include new approaches & tools for certification such as digital twins and virtual certification;
- Improving maintenance safety across the full vehicle and ATS life cycle.

It is essential that the work is closely coordinated with rulemaking programs and industry development programs at the European level to ensure that the results of the research under this *Future Sky Theme* find their way into safety regulations, technology and development operations.

FUTURE SKY THEME 2: QUIET AIR TRANSPORT

In *Flightpath 2050* it is stated that the air transport will grow continuously reaching 25 million commercial flights by 2050. This is approximately 2.5 times today's traffic (2015). Due to limited air space and ground area this traffic volume cannot be sustained from the noise perspective by the current European ATM. In addition to that, continuous urbanization demands more sophisticated interaction of the overall air transport system (especially airports) with its neighbourhood. These two opposing trends make another goal defined by the *SRIA* comprehensible: reduction in noise emission by 65% as well as substantial reduction of further emissions. Even more stringent noise requirements recently appeared with the "*Environmental Noise Guidelines for the European Region*" released by the WHO on mid-2018, and airports authorities do not know yet how to cope with.

In addition, there is a complex scheme of intricate noise regulations applied throughout Europe (national, federal, local) but most of them are only based on averaged intensity-based metrics, disregarding aspects such as emergence, duration and repeatability and non-acoustical factors. Last, considering the above-mentioned trends, it is foreseeable that new quiet aerial vehicles have to be developed and existing regulations have to be further refined in order to cope with *Flightpath 2050* goals.

Future Sky Theme 2 will investigate the noise aspects of increased air transport and its impact on the environment. The aim of *Future Sky Theme* 2 "Quiet Air Transport" is to derive new approaches to aviation noise – addressing noise at source (aircraft), air transport scenarios and community noise. This *Future Sky Theme* will focus on quietening one purposely selected relevant air transport scenario. Links will be established with *Future Sky Theme* 4 (Urban Air Mobility) as well as with the top-down approach of Clean Sky and with SESAR.

To define its contours, the initiative will:

- Provide mixed fidelity prediction toolsets for targeted design of low impact concept aircraft and hi-fi methods for "virtual noise assessment";
- Develop fresh ideas for low noise technologies and for disruptive low-noise aircraft designs;
- Establish scientific process to derive aircraft source noise targets from relevant noise impact metrics, including human factors;

- Create a basis for new standards in noise impact assessment encompassing more comprehensive noise metrics and non-acoustical factors in the prospect of reducing annoyance and health impact;
- Address along with *Future Sky Theme* 4 the noise impact of new Urban Air Mobility both from a technology and from a regulatory standpoint;
- Contribute to the training of young scientists through their involvement in research on aviation noise;
- Disseminate results and support their implementation by end-users such as airlines and airports.

FUTURE SKY THEME 3: ENERGY

Flightpath 2050 sets ambitious goals relating to environment and energy supply in aviation. The ambition is to improve eco-friendliness of aerial vehicles and to cut CO_2 and NOx emission by 75 % and 90 % respectively while preserving European Competitiveness.

One first step for the European aviation community is to enlarge the adoption of alternative fuels which is a rather mature technology but needs the full deployment in daily business for the complete A/C fleet.

Substantial energy saving and pollution reduction are expected by the introduction of Hybrid-Electric Aircraft and by implementing in the Airports emission-free ground handling and taxiing.

Future Sky Theme 3 will deal with new propulsions systems and concepts, innovative aircraft architectures, and energy on board systems. The objective is to focus on medium and long term R&TD preparing the scientific and technical basis for the **European Air Transport System beyond 2035 aiming at zero CO_2 emissions.**

Within the *Future Sky Theme* 3 the following technologies will be considered:

- hybrid and electrical engines/propulsion systems;
- innovative energy sources (Batteries, Fuel cells);
- innovative configurations of air vehicles with breakthrough technologies (e.g. aerodynamics, aerostructures, flight mechanics);
- energy management and on board electric equipment;
- emission-free ground handling and taxiing in airports.

Furthermore, demonstration both on-ground and in-flight (subscale demonstrators) for hybrid propulsion and for fully electric propulsion will be addressed.

Finally, the adoption of the alternative fuels will be addressed considering different aspects both technological and operational. Some aspects related to alternative fuels with respect to economic and ecological impact, together with a general life cycle assessment for new hybrid electric technologies, will be performed in coordination with *Future Sky Theme* 6 dedicated to Circular Aviation.

Application of hybrid-electric technology will be relevant to the UAM and specific activities will have to be coordinated with *Future Sky Theme* 4.

FUTURE SKY THEME 4: URBAN AIR MOBILITY

Urban Air Mobility (UAM) is to improve the efficiency of transportation in urban as well as inter-urban areas while reducing the environmental impact. Taking into account the costs and the value of time saved by airborne solutions, UAM will offer attractive mobility on demand alternatives at an urban, suburban and inter-urban levels. The aim is to shift a part of medium and long distance single passenger car trips as well as short and medium distance cargo transports to small aircraft. In summary UAM sets out three main objectives: on-demand mobility in high density as well as remote areas, regional seamless mobility in terms of *Flightpath 2050* goals, and efficient and environmental friendly unmanned cargo and piloted/autonomous passenger transportation.

Innovative solutions for UAM will address vehicle and system integration concepts with regard to the development and implementation of safe, efficient, integrated and sustainable air mobility systems over large metropolitan areas.

UAM faces a broad variety of challenges. A whole set of new technological and regulatory standards have to be developed to provide a solid basis for innovative and sustainable aerial solutions. The competitive concepts in this theme cover manned and unmanned system approaches in the areas mobility services for people, emergency services and freight. Challenges will be faced in the categories Autonomy, Safety, Societal Acceptance, Integration, Regulations, Simulation, and Testing, respectively. The joint research initiative of *Future Sky* Urban Air Mobility will focus on the following topics:

- UAM Class Aircraft Technology Advancement: The development of platform concepts for UAM in terms of feasibility studies and technological solutions will be the first step following the aim of safe, economic and environmentally friendly systems. Subsequently, in the process of unmanned aircraft technology advancement, topics such as aerodynamics, propulsion, energy management, flight envelope protection, mass and structure optimisation will be the basis for the developments of innovative vehicle configurations and of systems.
- Autonomy: Automation and autonomy are key technologies for visionary aerial mobility solutions; thus, these topics will need large efforts and investments for systems and vehicle validation (i.a. adaption, optimisation), for infrastructures (wind tunnels, hybrid/electric propulsion testing and validation, high performance computing etc.), simulation, unmanned cargo and piloted/autonomous passenger transport business models. Furthermore, automation and autonomy are linked to the field of artificial intelligence and digitalization thus cross fertilisation is needed.
- Unmanned Aircraft System Traffic Management (UTM): The future usage and thus also the economic success of unmanned and autonomous aircraft systems will depend to a decisive degree on the regulatory framework for this new airborne mobility. The integration of UAM systems—also covering the field of UTM/U-space—will need to focus on system certification, regulations, societal acceptance, and testing.
- Strategies for Mobility: Overarching mobility concepts will pave the way for solutions beyond the state-of-the-art in terms of mobility systems and urban planning at large.
- Public Acceptance and Environment: The consideration of socio-economic effects is of crucial importance for the future of urban mobility concepts. In addition, it is above all noise and weather aspects that have to be addressed both for ensuring public acceptance and in the development process of innovative vehicles and systems.

Two sub-themes will be established in order to cover the aspects of aircraft technology advancement as well as of automation and airspace integration of autonomous systems in a comprehensive manner.

FUTURE SKY THEME 5: SECURITY FOR AVIATION

Since 2001 the way to envisage aviation security has deeply evolved because of terrorist attacks and the increase of emerging threats and vulnerabilities. Although many projects were focusing on detection and prevention, studies need to be carried out to determine the best measures for protection and the most appropriate reactions and to develop a joint simulation environment to evaluate the efficiency of security concepts or security systems. The performance assessment of security solutions and the definition of appropriate Key Performance Indicators (KPI) are today essential needs to build an aviation security policy taking into account the issues of the development of autonomous systems, which increases dramatically the complexity of the threat management.

The main goals are to identify the best solutions in a standardised way regarding their efficiency and trust for the protection and to improve the resilience of the whole aviation system and the passenger survivability. Furthermore the aviation community has to anticipate unknown future threats instead of reacting continuously in hindsight with new strict regulations.

The *Future Sky Theme* 5 on Security for Aviation will investigate the following key elements:

- The development of a joint simulation environment and the associated tools and platforms to assess the performance of security concepts and solutions against present and future threats. This joint environment is the mean to develop a comprehensive aviation security knowledge and the appropriate management of the aviation security based on the performance of the entire security system. The main outcomes of the use of this environment, will be:
    - Definition and use of appropriate KPIs.
    - Analysis of complex and dynamic scenarios including attacks of multiple and coordinated threats against different and complementary security systems.
    - Development of dynamic risk assessment methodologies to reach valuable "Security for Aviation" conclusions.
    - Evaluation of vulnerability phases during the operational use of aviation systems.
    - Establishment of appropriate solutions in order to take into account the issues of the development of autonomous systems.
    - Ranking the potential security solutions by performance assessment.
- A good balance between the developments of the different strategic facilities: numerical tools, experimental tools and system tests. Models, simulations and several types of real tests are indispensable elements for the development of valuable solutions of protection and resilience. Furthermore the development of the models of the threats and the security systems based on generic models and components is essential in order to overcome limitations due to IPR and national classification issues.
- Although further investigation on threat detection, identification and prevention are needed, studies need to be carried out to determine the best measures for protection and the most appropriate reactions (prepare, respond, recover). Concerning the threat detection phase, the performance of the surveillance within the aviation system and the monitoring of potential threats, have to be evaluated taking into account ethical aspects.
- A long-term vision with far goals and disruptive approaches has to be encouraged by:
    - Specific Calls for cross-fertilization with other domains.
    - A Civilian Aviation Security Research Network. This aviation security community will learn about the efficiency of security solutions, will adapt the security measures to the threat evolutions, and will anticipate unknown future threats instead of reacting continuously in hindsight with new strict regulations.

In a practical way, EREA members suggest to launch the development of a joint simulation environment based on a shared platform and/or a network of connected platforms. The first steps for this environment building should be focused on the performance assessment in a standardised

way and KPI definition obtained with the analysis of a scenario involving several drones in the attack team against an airport in which are taken into account the air activity and a set of counter measures (including drones) dedicated to its protection.

FUTURE SKY THEME 6: CIRCULAR AVIATION

The vision of FlightPath 2050 describes how aviation will be actively engaged in "*protecting the environment and the energy supply*", providing "*sustainable [...] connectivity for passengers and freights*", and "*protecting the environment and enabling the use of sustainable energy and alternative energy sources*".

Insofar sustainability in aviation mainly referred to reducing polluting emissions from operations; therefore, the focus has been on high efficiency gas engines, lightweight solutions, alternative fuels and (hybrid-) electric solutions. Though useful, this approach only covers part of the lifecycle of an aircraft, and only a limited amount of the overall energy consumption and pollution emissions related to aviation. Recently, sustainability has also approached aspects related to production and manufacturing, both the traditional manufacturing process for old aircraft, and the recent, innovative processes and advanced materials for new aircraft designs. Although the design and manufacture of recyclable air vehicle is one of FlightPath 2050's goals, most aspects such as production, end-of-life solutions, maintenance and (most of) operations of aircraft and airports have been neglected in the life cycle analysis.

Circular economy principles focus on minimizing systematic leakages and negative externalities; such principles can enhance the already ongoing research activities and industrial implementations of more sustainable solutions in aviation, by expanding their current fields of application (from local to global) and by initiating new applications. Applying sustainable solutions only locally will never allow achieving the reduction in emissions desired to reduce the effects of the climate change. The overall aircraft lifecycle, from cradle to cradle, needs to be reassessed.

During the design phase, the cost of the entire lifecycle (cradle-to-cradle, including resourcing raw materials and disposal at end of life) shall be evaluated and design decisions based on this. Design solutions incorporating recycled materials and/or with focus on extended durability and ease to repair, disassemble, and reuse, shall be encouraged.

During the manufacturing process, the environmental impact is managed through a better control of used materials, reducing waste and energy consumption at manufacturing facilities and rationalizing the logistics (for example, favouring local production). First-time-right solutions are fully integrated in the workflow.

During operations, the full operational status can be maintained by integrating the information from the structural health monitoring system with the repair solutions designed synergistically with the aircraft itself. Refurbishment is favoured by modular design of structural components and interiors.

At the end of an aircraft lifecycle, the objective is to reuse and recycle up to 95% of aircraft parts, with particular focus on including composite materials used in aircraft manufacturing.

Under the umbrella of *Future Sky Theme* 6 on Circular Aviation, every research topic concerning aviation could be placed. A limited, and therefore by far not exhaustive, list of topics, which should be object of research, is:

- Design
  - Choice of materials;
  - Design to improve durability, structural integrity and ease to repair, to upgrade…;
  - Design for modularity;
  - Design for disassemble, in order to maximize the recovery of valuable materials and components.

- Production
  - Reduce scrap and waste by first-time-right approaches;
  - Improve efficient use of tooling / flexible manufacturing.
- Operation
  - Operational use of the aircraft (already part of programs like SESAR, not part of this FS theme);
  - Alternative propulsion like (hybrid-)electric (already part of Energy theme);
  - Alternative fuels (id.);
  - Maintenance, Repair and Overhaul (MRO).
- End-of-life
  - Recycling of materials;
  - Reuse of components and systems.
- Airports
  - Zero emission and zero waste airports;
  - Integration of airport infrastructures with community infrastructures.
- Airlines
  - No waste flights;
  - All electric ground operations.
- Policy and regulation
  - Encourage reuse and recycle projects
  - Taxes
- Business models
  - For airlines (for example, ownership versus lease or co-sharing of aircrafts);
  - For airports;
  - For manufacturers.

FUTURE SKY SET-UP

PARTICIPANTS & INVOLVEMENTS

Future Sky is initiated by the European Research Establishments in Aeronautics (EREA) – however, participation of universities and private companies is foreseen and highly appreciated.

EREA

EREA is a non-profit organization, which represents European national research organizations at the European level and has following goals:

- Promote and represent joint interests of national research organizations;
- Intensify the cooperation in the field of civil, military and space-related aeronautics research;
- Improve and intensify the cooperation with third parties in the field of aeronautics;
- Facilitate and integrate management of joint activities.

At the moment following research establishments are contributing to EREA:

- AIT: Austrian Institute of Technology (Austria)
- CEiiA: Centro para a Excelência e Inovação na Indústria Automóvel (Portugal)
- CIRA: Centro Italiano Ricerche Aerospaziali (Italy)
- CSEM: Centre Suisse d'Electronique et Microtechnologie (Switzerland)
- DLR: Deutsches Zentrum für Luft- und Raumfahrt (Germany)
- FOI: Totalförsvarets FOrskningsInstitut (Sweden)

- ILOT: Instytut LOTnictwa (Poland)
- INCAS: Institutul National de Cercetari Aerospatiale ”Elie Carafoli” (Romania)
- INTA: Instituto Nacional de Técnica Aeroespacial (Spain)
- NLR: Nationaal Lucht- en Ruimtevaartlaboratorium (Netherlands)
- ONERA: Office National d’Études et de Recherches Aérospatiales (France)
- VZLU: Výzkumný a Zkušební Letecký Ústav (Chech Republic)
- Affiliate member: AFIT/ITWL: Air Force Institute of Technology (Poland)
- Strategic partner: VKI (Belgium)
- Strategic partner: TsAGI: Central Aerohydrodynamics Institute (Russia)

Future Sky is open to all full EREA members - they are indeed the backbone of the initiative. The necessary requirement for participation is the willingness to commit to the research schedules and to contribute with sufficient resources.

Future Sky will help bridging the gap between the fundamental research and knowledge available at universities on the one hand side and industrial R&D on the other hand. The main task of the research establishments within this concept is to identify how basic knowledge can be made available for product development, to derive and to implement a roadmap within each *Future Sky Theme*.

Beyond, *Future Sky* may also be instrumental for the EU to foster wider cooperation on upstream research on aviation, for instance through liaising with the *International Forum on Aviation Research* (IFAR) or by spearheading topical collaborations with countries of the Eastern Partnership.

Universities

It is essential for *Future Sky* to have close links with universities where basic knowledge is generated and young researchers are educated. In order to achieve improved visibility of the *Future Sky* among the academic community, organizations representing university and further higher education services are welcome to participate. The main tasks of academic partners will be to introduce perspective and non-validated ideas for further investigation. Additionally to that, ways of how to transfer latest research and development results into the education process will be addressed.

The European Aviation Science Network (EASN) composed of Universities is an official partner of EREA. It is therefore important to raise awareness of teachers and lecturers from Universities and Engineering schools and to be more attractive for young professionals. It is noteworthy that this kind of educational actions, once well-defined and duly introduced, may be also supported by the European Commission.

Industry

Industry as a provider of services and products is one of the major drivers of the technical evolution. In Future Sky industrial partners will identify market needs and test it for everyday use and system suitability. It is intended to integrate into the JRI not only aircraft or systems manufacturers, but also companies representing different aviation branches, e.g. airport operators or airlines as well as industry associations.

Governmental authorities

Future Sky will address several topics which relate to regulatory issues, for example in the field of aviation safety, which is not only a domain of national institutions and industry, but also of pan-European governmental bodies such as EASA and EUROCONTROL. The latter are welcome to contribute to the progress and results of *Future Sky* towards its alignment with European regulations.

European Commission

The European Commission will be closely involved into the preparation and operation of *Future Sky*. This will take place on two levels. A project officer representing the European Commission will be involved in management of each *Future Sky Theme* project ensuring proper reporting and reviewing.

Consortium as a Whole

Since *Future Sky* is open to participants with different goals and background, it needs an organisational structure that ensures comprehensive decision-making and transparent communication (Fig. 4).

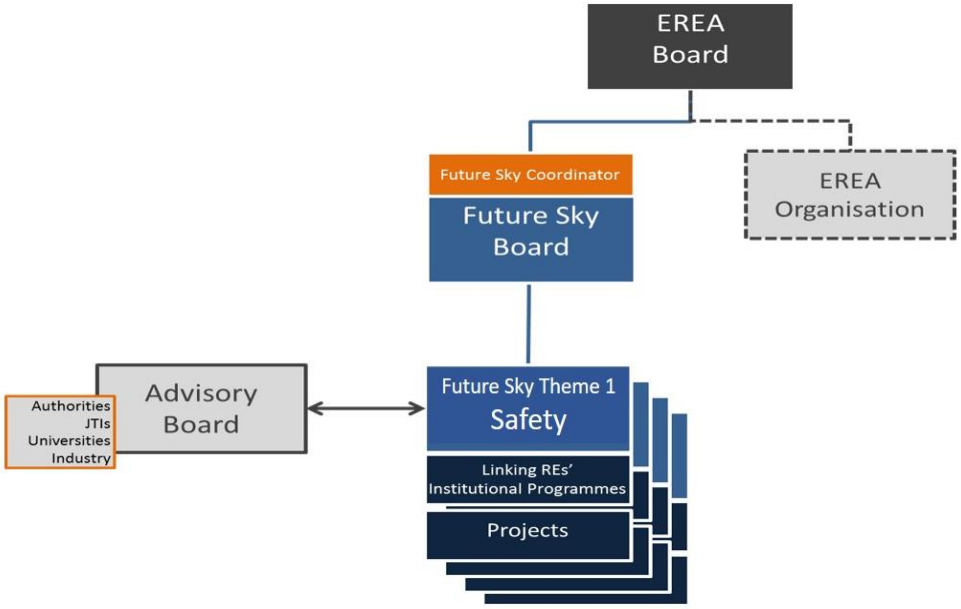

Fig. 4: Organizational structure of Future Sky.

EREA Board: consists in directors of EREA full members and has an initiating (sponsoring) function. The *EREA Board* appoints leaders to the *Future Sky Board* and to each *Future Sky Theme*.

The *Future Sky Board* consists in aeronautics program directors of those EREA members participating in *Future Sky* and it is chaired by the *Future Sky Coordinator*. This body prepares the programmatic outline, act as a steering group for *Future Sky* as a whole as well as for the *Future Sky Themes*. The *Future Sky Board* communicates with other stakeholders of the aviation research community. One major task of the *Future Sky Board* is to approve the linking of national institutional programs within each *Future Sky Theme* and to authorise the resulting research roadmap. The *Future Sky Board* meets upon request from the *Future Sky Coordinator*, at least twice a year. Relevant activities and progress within the *Future Sky* JRI are reported to the EREA Board on regular basis.

Advisory Boards bring together authorities, academia, industry and JUs to advise the *Future Sky Theme* consortia. Professional exchange on regular basis is intended to maintain information exchange and to avoid duplications of activities performed in Europe. Additionally, intermediate results both from *Future Sky* and from *Advisory Boards* participants should be exchanged on a regular basis.

Each *Future Sky Theme is* led by a *Future Sky Theme* Leader who coordinates the programmatic outline of the *Future Sky Theme* and who is supported by a *FS Theme core-team*, in order to manage the proposals phase and the project work afterwards. The *Future Sky Theme* Leaders coordinate the effort in the different *Future Sky Themse* in order to ensure each theme contributes to the overall goals of *Future Sky* and duplication of work is avoided.

Future Sky Joint Research Initiative is an undertaking which relies on the willingness of each participant to contribute to common goals with resources and information. It is expected that **universities** bring in and share their fundamental knowledge, experience and ideas regarding the future ATS. At the same time, the **industry** and associations are asked to share their long term visions and needs also concerning own interests and interests or goals of their customers. EREA members

contribute with their own research infrastructures and also develop the possibility to make it available to further project partners.

BUDGET & FUNDING MECHANISMS

The *Future Sky* research programme disposes of a budget consisting of the partners' contribution, usually in-kind. However, due to the pan-European societal impact of *Future Sky*, co-financing as a coordinated joint research activity under Horizon 2020 / Horizon Europe is required. It is intended that each *Future Sky Theme* will be financed by small as well as medium-size projects (L1- and L2-types), assuming about € 25 million required European funding per Theme, which will be matched by the participants according to the Horizon Europe funding mechanisms.

TIMELINE

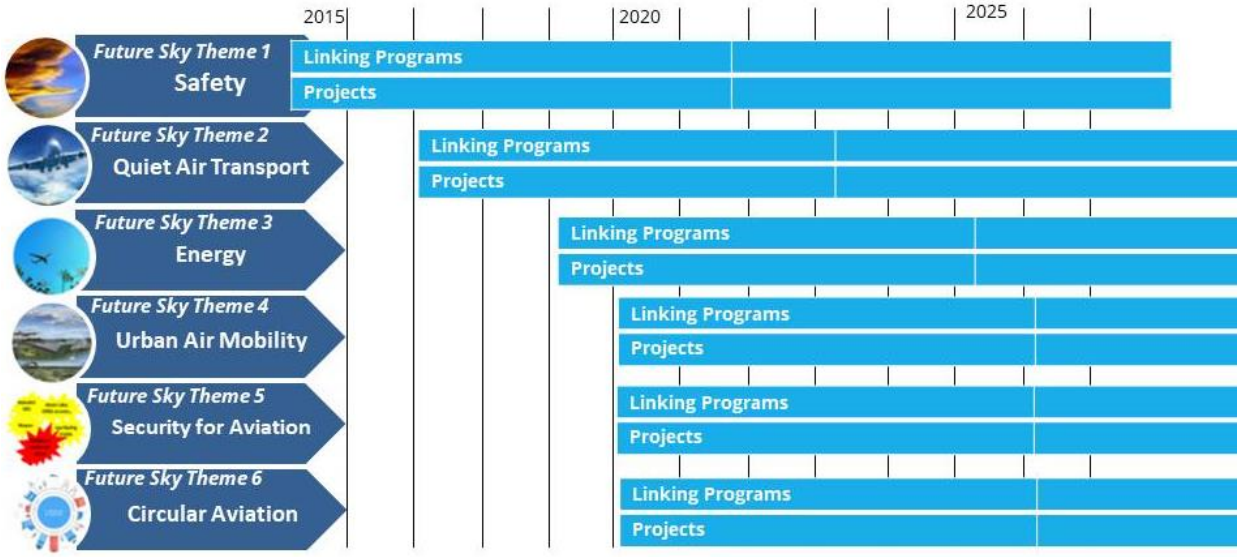

Fig. 5: Timeline of Future Sky.

OUTREACH & EXPECTED IMPACT

IMPACT

***Flightpath 2050* goals**: *Future Sky* substantially contributes to Europe's vision of a future air transport system coming true. Reaching two generations of ATS ahead, *Future Sky* paves the way for joint European demonstrator programs succeeding Clean Sky and SESAR. Furthermore, Future Sky provides a platform for an international outreach in pre-competitive fields of aviation and ATS research.

Coordination: *Future Sky* by its very nature strongly fosters cooperation and linking of the European research establishments. In doing so, *Future Sky* maps capacities and capabilities of the research establishment and publicises competencies and interests among universities, research establishment and industry strengthening the Europe-wide network in aviation research and development.

Knowledge: To prepare technologies for the future, knowledge and expertise are needed, including the relation of local (national) knowledge to European strategic knowledge. While the top-down approach in Clean Sky and SESAR supports the knowledge building process for products mainly at the OEM and SME side, *Future Sky* contributes to enhancing knowledge transfer, including the transfer to the next generations. Building a bridge between universities and industry on a European level, *Future Sky* contributes largely to the education of future aviation engineers and scientists, the core resource of Europe's future.

Competitiveness: The top-down approach in Clean Sky as well as SESAR adds to the competitiveness of the next generation of products and European ATM. *Future Sky* adds to the scientific and technology basis for future aviation business beyond this scope, for the next but one generation of products and ATS.

Attraction: Some 100 years ago, aeronautics fascinated the public because it was an adventure. Some 50 years ago, aviation fascinated because all-new products such as the B747 or the Concorde were perceived as the incarnation progress. At present, aviation seems to have become a business just like any other. However, there are still physical limits to be explored in the future; there are new challenges and possibilities, asking for new approaches in thinking and therefore for creative people. *Future Sky* addresses this field, and makes aviation fascinating again for the public. Even though this is an indirect goal, it is of high importance, not only within aviation.