URBAN AIR MOBILITY

A RESEARCH PROGRAMME OF THE FUTURE SKY JOINT RESEACH INITIATIVE

VERSION – JULY 2020

SUMMARY

Future Sky Urban Air Mobility (FS UAM) is the framework programme promoted by the Association of European Research Establishments in Aeronautics (EREA) targeting the topic of unmanned and autonomous aircraft systems with regard to new ways of mobility for urban and inter-urban passenger and cargo transportation. It is part of Future Sky, an ambitious EREA initiative intending to address the main issues challenging the EU leading position on aviation.

The enormous technological progress of the last decade in terms of miniaturization and digitization has paved the way to explore completely new and innovative areas of application. In particular, the topic of unmanned and autonomous aircraft systems has been experiencing a real hype for some time now with regard to new challenges in all areas of social life. The objectives of the FS UAM theme range from automated cargo transport to medical emergency services and piloted and autonomous passenger transportation.

FS UAM is an interdisciplinary programme. With unprecedented complexity, it combines the achievements of decades of experience in aviation with the seemingly unlimited possibilities of digitization and connectivity. On the one hand, these synergies result in new technology concepts and, on the other hand, in major challenges in terms of implementation, environment, legislation and safety. Aspects such as social acceptance, regulatory and standards frameworks, mobility planning and business models, safe and secure vehicles are key factors for the success of UAM as a long-term means of urban mobility.

In a nutshell, Future Sky Urban Air Mobility is expected to accompany the revolution of the known mobility modes in the urban as well as the regional environment. For research this new modality sets the challenge of adopting a holistic view beyond the boundaries of current aviation. Specific goals are on-demand mobility in both high density and rural or remote areas, regional seamless mobility, as well as unmanned cargo and autonomous passenger transportation to reduce ground traffic and to enable fast motion of goods and persons.

LEGACY

Unmanned and Passenger Piloted or Autonomous Aircraft Systems (UAM aircraft) are becoming increasingly important. Technological advances are currently enabling a new market for unmanned and autonomous systems regarding airborne transportation platforms for the use in urban as well as remote areas. There is an emerging trend regarding the development of UAM, which is primarily conducted by start-ups or commercial operators, including aircraft OEMs, resulting in a significantly increased rate of innovation compared to development cycles hitherto existing in the aviation industry.

The European Flightpath 2050 (FP 2050) contains the prognosis that, globally, by the middle of the 21st century, air cargo operations will increasingly be carried out by unmanned cargo. Further applications for UAM aircraft systems are foreseen in supplying poorly connected areas with urgent supplies, such as medicines or disaster relief equipment, as well as in agricultural applications (smart farming). UAM aircraft are also considered as a solution for fast, low-emission passenger transport in urban areas or between cities and for an extensive exchange of manufacturing components between industrial sites.

The use of UAM aircraft at a commercial level and joint operation in airspace with passengers poses new challenges for researchers, manufacturers, operators and legislators alike. In addition to the purely technical aspects, the integration of UAM aircraft into the airspace also gives rise to complex legal and procedural issues that must be investigated and redefined or regulated. In view of the complexity of the challenge, a compartmentalized approach to dealing with individual components that make up the entire system (craft separately from air traffic, separately from legal regulation) is no longer sufficient. Hence, they need to be considered, tested, validated and certified conjointly.

In this process, the topic of Urban Air Mobility raises new scientific questions addressing areas such as safety, airspace and Unmanned Aircraft System Traffic Management (UTM / U-space), performance-based operations, swarm exploration, flight termination, landing systems, detect & avoid, interference-resistant navigation systems, security and cybersecurity and many more. Since neither of these issues can be understood and solved by manufacturers or users nor by legislators alone, collaboration and support from the research community is of increasing significance in terms of forming a link for both technical and regulatory issues.

CHALLENGES

UAM approach faces a broad variety of challenges. A whole set of new technological standards and certification rules have to be developed in order to provide a solid basis for safe, innovative and sustainable aerial solutions. Developments in research, technology, manufacturing, operations and community outreach are of key importance.

The competitive mobility concepts in this theme cover UAM aircraft system approaches for cargo and passengers transport, including emergency services. Critical areas and technologies include: Safety, Security, Autonomy, Societal Acceptance, Integration, Regulations and Standards, Simulation, and Testing.

SAFE AUTONOMOUS FLIGHT

Safety as the highest good of aviation is based on the endless regulations and standards regarding certification and processes, which have established aviation as the safest means of transport. At the same time, the new UAM aircraft technology boasts of the great incentive that any application can be designed as completely autonomous in the future. For the UAM sector, the latter means the very complex process of successively increasing the degree of automation. At the same time, the difficult question is raised as to whether and, if so,

to what extent the previously known rules and safety regulations can (and must) apply to UAM as a new aviation branch. However, the long-term objective of urban mobility based on autonomous airborne solutions can only be successfully implemented if the safety of such systems can be adequately maintained at the same time.

Resilience to weather hazards has to be included both at the conceptual level as well as in the development process of vehicles and systems.

A link to FS Safety programme must be ensured even if specific solutions and technologies to UAM will be developed within FS UAM.

INTEGRATING AUTONOMOUS AIRCRAFT INTO AIRSPACE

The future usage and thus also the economic success of UAM aircraft systems of all kinds—be they micro-platforms or certified passenger transport systems—will depend to a decisive degree on the regulatory framework for this new airborne mobility. This mainly concerns the implementation of concepts regarding the use and regulation of the lower, uncontrolled airspace and the interaction with piloted or autonomous passenger vehicles. The long-term objective must also be to provide air traffic management with a seamless transition between UTM and ATM, i.e. between uncontrolled and controlled airspace, and in particular to provide cross-border solutions on a European level.

The integration of UAM aircraft into airspace will therefore be one of the major challenges and will require intensive efforts in terms of coordination and interaction with existing structures, processes, and entities.

RESEARCH INFRASTRUCTURES FOR UAM SIMULATION AND TESTING

While research has in the past been limited to test a manageable number of autonomous vehicles, the rapid growth of UAM will also require exponential increases in system testing to enable whole-system technology development, validation and qualification. As a result, in particular with regard to the validation of safety-critical systems, there is a need for new test methods and infrastructures, which do not yet exist or do not comply with new requirements. In order to close the existing gap in the national and European testing landscape and enable efficient and reliable verification and validation, there is a need to establish test facilities that combine the necessary skills and expertise, which will allow the entities involved in the development of UAM to work in an interdisciplinary manner.

Another challenge will be to ensure that the installation of new test centres is coordinated at European level from the outset and their integration into the network of existing test facilities. A close conceptual merger of sustainable Research Infrastructures (RI) or Technology Infrastructures (TI) must also be ensured.

ALIGNING URBAN AIR MOBILITY WITH ENVIRONMENTAL IMPACT

In times of an increasing discussion about emission limits and quantities and the associated question of environmental compatibility and sustainability, the aviation sector has to deal with existential fundamental considerations. Although the topic of clean mobility also addresses all other transport sectors, aviation in particular is faced with major challenges in responding to the new perspectives and demands including UAM concept.

The issue of sustainability will have a significant impact on UAM deployment, and in particular due to the urban air traffic and to immediate proximity to people. This concerns the development of alternative and novel propulsion systems, reduction of noise and pollutant emissions. Hybrid/electric propulsion is the focus of Future Sky Energy theme while noise is the focus of Future Sky Quiet Air Transport within the EREA Future Sky

Programme. Here global environmental impacts of creating a totally new mobility will bring up topics such as life cycle assessments and low emissions by using electric propulsion systems. Thus, important interfaces have to be ensured between the FS UAM theme and other FS Programme themes.

Anyhow, very specific developments in the hybrid/electric propulsion area related to UAM aircraft will be developed within the FS UAM theme.

SOCIETAL ACCEPTANCE

The socio-economic impact is of crucial importance for the future deployment of urban mobility concepts. The introduction of UAM applications will be accompanied by significant changes of the cityscape and will therefore be at the forefront of public attention.

Society's perception will be decisive for the development of unmanned and autonomous aviation and its prospects of success. The overcoming of scepticism and rejection due to fears and insufficient knowledge must therefore be an important focus of FS UAM theme.

Societal acceptance is linked to perception of safety, awareness of effective reduction of (pollutant and noise) emissions, and awareness of a positive economic impact on mobility costs, increase of accessibility to transport means. The ruling factors here are safety, noise and reluctance to absence of a pilot on board the aircraft.

SECURITY

The constantly increasing connectivity in everyday life is reflected to the same extent in aviation. Although this opens up a multitude of new possibilities and applications, it is true in both positive and negative respects. The higher the level of automation of UAM, the higher the sensitivity of those systems to interferences by unauthorized persons.

Artificial Intelligence (AI) approaches regarding the simulation of criminal intrusion attempts as well as the defence of the UAM systems is a key factor for the real deployment of the of UAM concept under blurred or variable boundary conditions. In order to validate the UAM systems typical attack scenarios should be simulated involving electronic flight control systems; the aim is to achieve a resilient UAM system able to withstand external violation attempts. To date, however, it has not been possible to set up AI approaches for security-sensitive aviation applications, amongst other due to the lack of necessary advancements in the field of AI research as well as of suitable detection capabilities.

On this security topic a strong link must be ensured with the developments within the FS Security theme focusing on Security for Aviation; anyhow specific developments for UAM will be developed in the FS UAM theme.

URBAN AIR MOBILITY – ACTION LINES

UAM CLASS AIRCRAFT TECHNOLOGY ADVANCEMENT

The development of platform concepts for UAM in terms of feasibility studies and technological solutions will be essential to be compliant to the aim of safe, economic and environmentally friendly systems. Subsequently in the process of platform technology advancement, topics such as aerodynamics, noise emissions, propulsion, energy management, controls, mass and structure optimisation, regulations and standards will be the basis for conceiving innovative aircraft configurations and systems for UAM.

SRIA *"Action area 3.2 – Develop air vehicles of the future: revolutionary steps"* marks already the importance and innovation character of this area. Contrary to many assumptions, the development of UAM aircraft differs fundamentally from that of manned large aircraft. The technological advancement of UAM aircraft systems therefore plays a key role within this theme and will surely cover the following aspects:

- Development of novel technological solutions in research areas relevant for UAM. This mainly affects aerodynamics, electric / hybrid propulsion systems, sustainable alternative and efficient energy sources, highly agile flight controls, design of high-performance lightweight structures, safety rules and new standards.
- Technology Integration and Demonstration: The integration of novel technologies for UAM aircraft needs a dedicated effort; furthermore, demonstrators are needed for both platforms and systems.

AUTOMATION AND AUTONOMY

One major milestone of the implementation of UAM will be the gradual increase of automation of the systems in order to step towards full autonomy in the long run. With regard to this complex automation process, as prerequisite for the successful introduction and positioning of UAM, the following aspects need to be considered:

- A validation of the system and its sub-systems is essential after every single increase of the degree of automation. Such system validation also includes the adaption of appropriate existing components and platforms as well as the optimisation of new developments.
- Infrastructures, e.g. wind tunnels, high performance computing facilities, simulation centres, or flight test centres, will be necessary for the upcoming development and automation tasks within the UAM community as well as regarding the challenges of this Future Sky theme. These infrastructures will either be existing ones that can be directly used, or existing facilities that have to be modernised and/or adapted to UAM, or even new facilities to be constructed. Such test centres will thus serve as a cornerstone for the further development of UAM technologies and thereby play a pioneering part in the enhancement of Europe's scientific and economic leading role in the field of UAM.
- Due to the progress of digitalization, the improved knowledge in fluid mechanics, as well as the use of virtual environments and artificial intelligence, it will be possible to carry out a large part of all necessary system tests by simulation in the future. Hence, the research expertise and capabilities of the EREA partners in this field will be essential.
- As the majority of UAM systems will be of much smaller size than conventional (commercial and civil) aircraft, the use of scaled demonstrators for testing will significantly increase due to small and therefore more efficient scaling ratios. This applies to both the area of *Cargo Transport/ Unmanned Cargo Operations* and the one of *Piloted or Autonomous Passenger Transport/ Personal Air Vehicles*.

As unmanned aircraft systems become increasingly automated, they also become increasingly sensitive to interference by unauthorized people. Hence, in terms of security typical attack scenarios have be adapted to electronic flight control systems and systems can be qualified. Artificial Intelligence approaches promise a significant extension to the uses of unmanned and autonomous aviation systems with fuzzy or variable boundary conditions. Here again the link to relevant activities as well as the Future Sky Security Theme is essential regarding information and knowledge transfer.

The members of EREA, having skills and facilities in the field of aviation and having a broad experience in collaborative research and supporting European aviation stakeholders for decades, can contribute efficiently to build such a joint technology demonstration environment for the benefit of the European UAM community.

AIRSPACE INTEGRATION – UNMANNED AND AUTONOMOUS TRAFFIC MANAGEMENT

Air traffic management serves to ensure the safe and efficient movement of aircraft during all phases of their operation and subsumes all functions and services of air space management and air traffic services. A future airspace management system for unmanned, autonomous and airspace users will need to address a variety of constraints to ensure a safe and, at the same time, efficient integration of new airspace users. These airspace users can take a variety of forms and, in addition to VFR traffic, include other users such as personal air vehicles, cargo UAS, parachutists, weather balloons or priority air traffic such as emergency service helicopters. Research here needs to focus on a systematic analysis of the relevant U-space services to establish efficient and safe airspace and traffic management and their development and evaluation.

An essential research aspect of the integration of UAM aircraft into controlled airspace is, on the one hand, the ability of UAM aircraft to follow pre-set procedures. On the other hand securely and effectively interacting and communicating with air traffic control provides another important aspect of research.

Within SRIA's *Action area 3.4* the aspect of environmental performance in combination with UAS is being described as follows: *"Improvements to air operations and traffic management should deliver significant environmental benefits. The individual optimisation of each aircraft operation will reduce fuel usage (and hence CO2 emissions) and perceived noise. Every phase of a flight, and the flight as a whole, needs to be optimised for environmental efficiency in the new ATM context developed by SESAR. 4-D trajectory management should be standard. […] The increasing availability and use of remotely-piloted aircraft systems (RPAS) must be carefully managed in order not to create problems for the safe execution of ATM. However, their impact on the environmental well-being of the population is not very strong and could be mitigated predominantly through regulation rather than through research."*

In order to develop and validate such an integration concept, the applicability in particular of published take-off and landing procedures, interaction with air traffic control, operational and technical taxiing management requirements and possible procedures in the case of a data link interruption need to be tested.

Aiming at a successful integration of UAM aircraft, the main focus has to be on:

- Safety,
- System certification,
- Regulations and standards,
- Testing,
- Societal acceptance,
- Economic needs.

Due to the complexity and delicacy of the combination of these aspects, it is crucial to promote interdisciplinary research collaboration between heterogeneous, diverse areas of research as well as to promote the dialogue with government authorities and relevant stakeholders of the UAM community.

STRATEGIES FOR MOBILITY

Overarching mobility concepts will pioneer solutions beyond the state-of-the-art in terms of mobility systems and urban planning at large. The necessary installation of new research and technological infrastructures mentioned before shows the extent of the changes in the introduction of UAM applications.

The development and integration of new strategies for mobility should therefore pave the way for the long-term (re-)structuring of urban and regional aviation. At the same time, the synergies and coordination of European and national mobility concepts will be the winning approach to ensure the UAM effective adoption.

In addition to the major objectives in FP 2050, the Strategic Research and Innovation Agenda (SRIA) and the national aviation strategies of EU member states are to be taken into account to coordinate the R&TD roadmaps. In addition, the expertise of the EREA partners will be very relevant to shape and implement the EU R&TD roadmaps together with institutional R&TD programmes of each research entity within EREA.

ENVIRONMENT – SUSTAINABILITY AND SOCIETAL ACCEPTANCE

In terms of environmental sustainability it is essential to pursue the expected impact mentioned in the SRIA Action Area 3.3: *"The proposed actions will ensure the development of sustainable aeronautical products through increased recyclability and reuse at the end of service life to ensure better use of resources, materials and processes."* Hence, the development and production processes of UAM should be fundamentally aligned with these requirements. The focus will be especially on the research field of electric or other alternative propulsion specifically designed for UAM operations, reduction of noise and pollutant emissions. As mentioned before, the aspect of global life cycle assessment even going beyond recyclability as well as consequences on renewable energy demands have to be addressed.

In order to address social acceptance, it will be unavoidable to involve not only the standard aviation stakeholders but also research areas that deal with the physical as well as psychological effects and influences on the population. For example, the handling of pilotless systems as well as data protection represent essential factors of social acceptance and thus must be observed in all phases of UAS flights since describing a potential hazard.

At the same, emissions of light, noise and air pollutants play an important role as a major acceptance factor as well. While the latter two show the direct link to the Future Sky themes Quiet and Energy, the topic of data protection builds the bridge to Future Sky Security. These themes will provide essential data results for further investigation and adaption regarding UAM systems.

Other elements are awareness of a positive economic impact on mobility costs, and increase of accessibility to transport means. For these elements innovative business models will have to be developed and their positive impact to be properly disseminated not only within the aviation stakeholders but also towards users/consumers association and towards the general public.

ORGANISATIONAL REMARKS

For the targeted specific research projects, a close interaction with other EREA activities (e.g. TRIG considering existing and future UAS infrastructures such as test centres) will be essential for the relevant sub-themes and topics of Future Sky UAM.

TOWARD AN ENLARGED AUDIENCE

With regard to the above mentioned challenges and in light of the complex landscape from which they stem, the range of partners to be involved by EREA in the FS Urban Air Mobility is to be extended with the following stakeholders:

- EU Policy-makers,

- Academic and university research centres,
- The Aviation industry,
- The Security industry,
- European organisations (EASA, EUROCONTROL, JRC…),
- The European network Small and Medium Enterprises,
- The Airport network (ACI Europe),
- Public Private Partnerships or Joint Research Initiatives (EIP-SCC UAM, SESAR, Clean Sky…),
- Similar eligible entities from non-EU countries,
- Transportation agencies from rail and automotive sectors.

Through Urban Air Mobility, the EREA intends to articulate with relevant partners shared views endeavouring to pave the way for common projects. Further to the challenges introduced above, these projects may target the priorities detailed hereafter.

The framework in which these priorities should be addressed is H2020 in the short term but an important step will be to include this new mobility concept in Horizon Europe.

TRAINING AND EDUCATIONAL ACTIONS

The European Aviation Science Network (EASN) composed of Universities is an official partner of EREA. It is therefore important to start engaging a common approach on this topic in the prospect of raising 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.