Operational Concepts for Urban Air Mobility deployment in the next decades

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Abstract. Urban Air Mobility development and deployment into future cities is gaining increasing and relevant interest in the last years, as a new mobility form suitable to meet the future greener, scalable and efficient mobility targets needed to solve the issues today's big cities are facing in terms of traffic congestion as well as related environmental consequences. In this framework, the ASSURED UAM (Acceptance, Safety and Sustainability Recommendations for Efficient Deployment of UAM) project has been funded by H2020 and is ongoing, with the main objective of providing cities with knowledge concerning deployment of UAM services and definition of necessary standards and recommendations assuring common acceptance, safety and sustainability within integrated metropolitan transport system for three time horizons (2025, 2030 and 2035). In the project, dedicated activities have been carried out to develop operational concepts for Urban Air Mobility (UAM) deployment in the next decades. The main results from these activities are presented in this paper, which namely includes the main project outcomes in terms of: the identification of the most relevant and promising technologies that can enable the UAM implementation over the next decades, taking into account the current technological trends and perspectives; the outline of the regulatory framework in which the UAM will be shaped in the next decades; the definition of the most relevant aspects and constraints affecting the UAM deployment from the point of view of integration of such new mobility form in the cities infrastructures; the outline of the foreseen UAM concept of operations and definition of the most relevant use case that are expected to be implemented in the cities over the three time horizons considered in the project, i.e. 2025, 2030 and 2035.

1. Introduction

ASSURED-UAM (Acceptance, Safety and Sustainability Recommendations for Efficient Deployment of UAM) project started in January 2021 and is developing of set of solutions which will assure UAM integration both with ATM and city organization (i.e. transport system) without compromising UAM acceptability, safety nor sustainability. Main objectives of the project are to describe the future in terms of probable UAM segment development and to assure broad and comprehensive organizational and policy definition support for authorities, policy makers and urban industry organizations. This

paper is a further contribution in the framework already defined by previous works that are accompanying the ASSURED UAM project evolution since its start in the year 2021. The project aimed to contribute addressing the challenge of enabling Urban Air Mobility (UAM) into European cities over the next decades, with particular focus on the medium-term time horizon up to 2035. The reference papers that described up to date the project evolution are in particular the works from [1] to [6] indicated in the references, whereas the full collection of the project reported outcomes is publicly available through the deliverables indicated in the references from [7] to [10]. It is worth noticing, finally, that the ASSURED UAM project works in close cooperation, with efficient cross-fertilization in particular with reference to the UAM integration into overall multimodal transport network related aspects, with the X-TEAM D2D (Extended ATM for Door-to-Door travel) project, as addressed in the reference papers from [11] to [17].

The main focus of this paper is on the summary description of the outcomes from the project activities that have been carried out to develop operational concepts for UAM deployment in the next decades. In section 2, first, an outline is provided of the project outcomes about the identification of the most relevant and promising technologies that can enable the UAM implementation over the next decades, taking into account the current technological trends and perspectives. In section 3, then, the outline of the regulatory framework in which the UAM will be shaped in the next decades is provided. Section 4 summarizes the most relevant aspects and constraints affecting the UAM deployment from the point of view of integration of such new mobility form in the cities' infrastructures. Section 5, finally, provides an outline of the foreseen UAM concept of operations and of the most relevant use case that are expected to be implemented in the cities over the three time horizons considered in the project, i.e. 2025, 2030 and 2035.

2. Technology readiness

UAM deployment is motivated by the presence of some relevant drivers (as summarized in Figure 1 [7]): the increase on urbanization that is detected all around the world since at least the half of the 20th century; the constant increase in traffic jams on the roads of all the most populated cities; the increased air pollution, due for instance in the cities to commuter trips due and from workplace by using personal cars or public transport on the surface; the increase in CO2 emissions, which is for the most part related to road transport. The presence of such important drivers and the continuously increasing sensibility of population to health and environment improvement themes, led to the idea of implementing electric-based transport in urban areas leveraging the 3rd dimension, i.e. the vertical mobility.

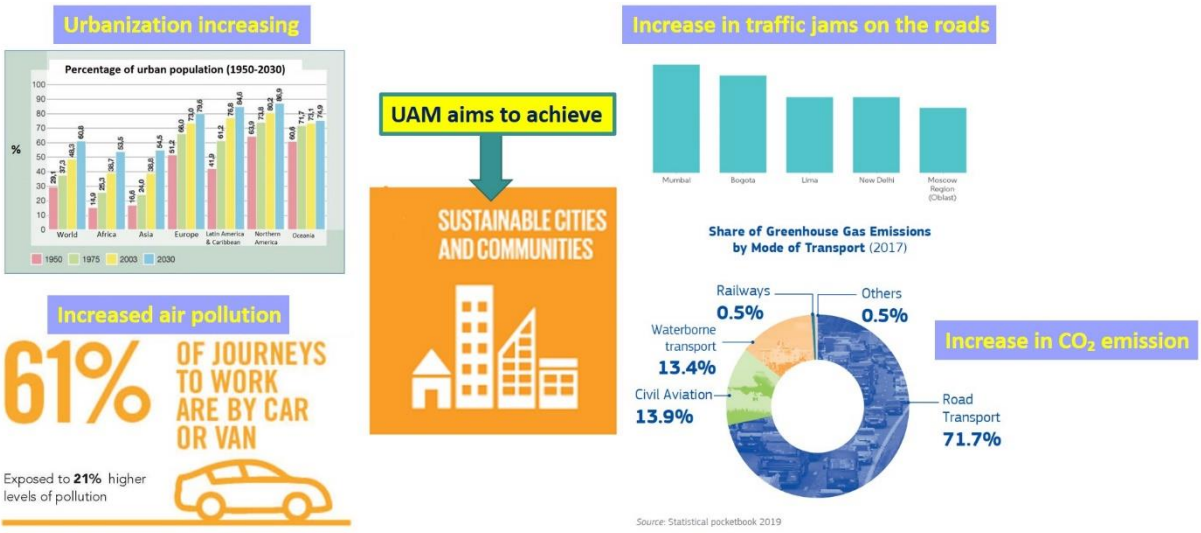

Figure 1. UAM implementation drivers [7]

It is clear that such new transport means first of all needs to be supported by proper technologies, therefore in the ASSURED UAM project an assessment has been performed of the existing and perspective technologies that can support UAM. Overall, the enabling UAM technologies reached a good level of maturity, due to the possible exploitation of technologies already considered in the domain of Unmanned Aerial Systems (UAS) and Remotely Piloted Aircraft Systems (RPAS), but not enough to allow their immediate insertion in the market.
Aeronautical technologies for UAM based transport applications are mainly constituted by existing and perspective Short Take-Off and Landing (STOL), Vertical Take-Off and Landing (VTOL), Personal Air Transport System (PATS) vehicles as well as cargo drones. Such vehicles need to be powered with low or zero emission propulsion systems, so that the most relevant powertrain technologies are the electric engines fed by batteries (for which the future availability, envisaged by 2030, of high-density batteries technology will be fundamental) or by fuel cells. Hybrid-electric propulsion using the conventional petrol for the thermal energy provision, on the other hand, appears to be strongly limited by the existing and perspective pollution constraints that will limit or prevent its use by 2035. Electric VTOLs (eVTOLs) are expected to be the more suitable choice.
In terms of vehicle configuration, then, currently many companies are experimenting three main concepts: multirotor systems, decoupled propulsion, tilt-rotor. The noise associated with the adopted configuration is expected to be an important factor, because eVTOLs are requested to be 15 decibels (dB) less noisy than existing light helicopters, which is about 70 dB at 500 feet versus 85 dB for a typical helicopter. Their required payload, if considered for application as air taxis, will be between 100 kg, for 1 pax, to 960 kg, for 9 pax plus baggage. Their expected safety level, then, will be required to be at least as safe as general aviation aircraft. In terms of business model, then, eVTOLs will be expected to be managed by service providers, which will purchase fleets of eVTOLs allowing to minimize per-vehicle costs, and will likely not be sold to private customers.
The UAM deployment, furthermore, requires the availability of different infrastructures, such as vertiports, U-space services and high bandwidth Information and Communication Technologies. The vertiports (as indicated in Figure 2) are expected to start by 2025 to support trial flights, as done by Skyports and Volocopter, and then increase in number and operations in the next years, up to 2030, leading to their operations in 2035. The U-space services, then, according to their expected deployment phases, will start to be available as U1 and initial U2 services by 2025, transitioning then to full U2 and U3 services by 2030 and final U4 services in place by 2035 (as indicated in Figure 2 [7]).

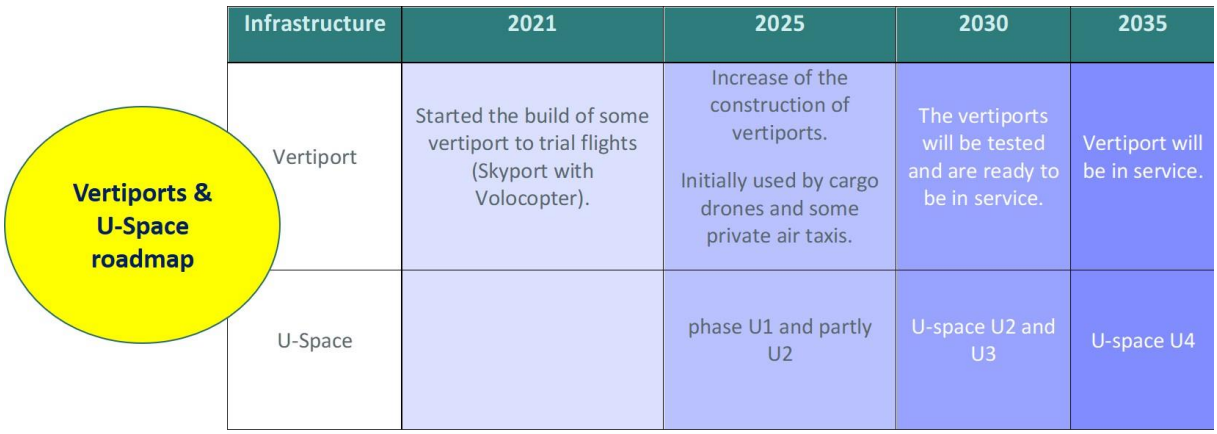

Figure 2. Vertiports and U-space expected evolution [7]

ICT, finally, is expected to follow an incremental deployment path that will progress gradually by 2035 (when only a few of the features indicated in the following will be available) towards its final 2050 vision, where full digitalisation and automation in all modes of transport will be supported by

adequate performance of IT systems and communication infrastructure (6G and beyond), allowing efficient disruption management thanks to the possibility to quickly adapt to dynamically changing operational environment.
The ASSURED UAM technology readiness studies overall results are reported in [7].

3. Regulatory framework

In addition to the analysis of technologies availability and evolutionary trends that can enable UAM implementation, as outlined in the precious section, ASSURED UAM also addressed the analysis regulatory framework in which the UAM will be shaped in the next decades. Indeed, the transport of people or goods enabling door-to-door (D2D) or near-D2D travel within or to densely populated urban areas with manned and unmanned aircraft of different configurations is already regulated and the most relevant aspect is the existing distinction between UAM operations transporting humans and/or dangerous goods and those which are not. The first targets at ensuring occupant and other airspace users' safety, while the latter targets at ensuring safety to (uninvolved) persons and property on the ground, and to other airspace users. Operations in the "certified" category are regulated through a vast diversity of regulations and standards all addressing specific parts of the operation (like the aircraft, the ground station, vertiport, operational aspects, etc), often with the need to demonstrate a defined minimum level of safety. The "specific" category, instead, is regulated in an operational centric manner (as depicted in Figure 3 [8]), meaning that only one flight authorisation is required which addresses all aspects in one (like the aircraft, the ground station, vertiport, operational aspects, etc). These build on risk assessments which are pre-defined or done by the applicant and assessed by the competent authority. Those are mostly assessed subjectively as a minimum level of safety is not provided.

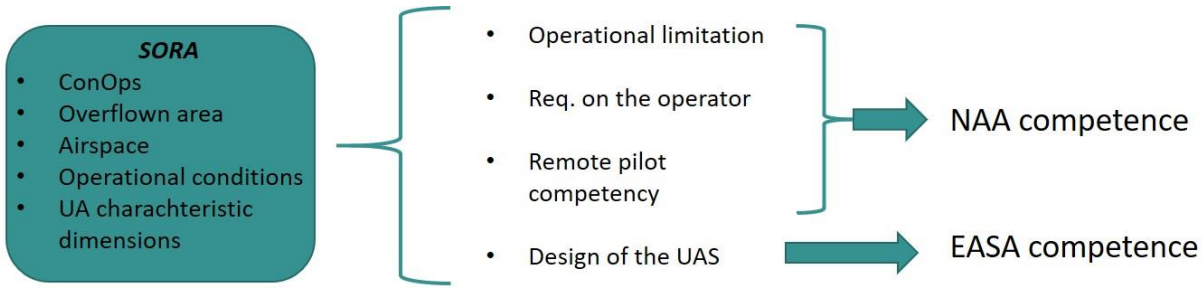

Figure 3. Operational authorisation for the "specific" category [8]

Regulations impact the industry in the sense that there is still not a market for UAM that would require the constant certification of urban aircraft and the technology is still advancing at a rapid and unpredictable pace. Momentum for the development of UAM solutions is rising due to the urgent necessity to alleviate the current transportation systems in the growing mega cities of the world. Companies and development teams for the urban aerial vehicles must look into the hazards and impacts of UAM transportation and, accordingly, develop their vehicles for a seamless certification and quick implementation of these solutions in urban space. The present ATM shall evolve, integrating the UAM innovative solutions, concepts, and traffic models by changing the existing rules, policies, and procedures. A need is recognized and requested to incorporate the role of the cities and regions as one of the competent authorities in the governance of the urban airspace.
The ASSURED UAM study about regulations identified a clear trend towards UAM technical and operational developments as well as further integration in city mobility concepts. A wide variety of standardisation development organisations address that the first introductions are expected between 2025 and 2035. However, from the point of view of the effective integration of UAS in the urban space, it is important that representatives of guideline development organizations, industry, agencies,

and other important players are involved in the development of standards covering a wide range of issues.
The ASSURED UAM technology readiness studies overall results are reported in [8].

4. Urban mobility integration

ASSURED UAM studies recognized that the UAM needs to be integrated in as much as possible seamless way with the surrounding urban transport environment, to allow its full exploitation and deployment. Together with changes in transport behaviour and lifestyles, advances in urban mobility technology are opening new pathways towards a decarbonised and sustainable urban transport system. The transition towards automated, connected, electrified and shared mobility for both people and goods (e.g. last-mile delivery via autonomous pony express and drones) is already on the way. Changes in urban mobility will affect cities' health, socio-economic conditions, land use, energy efficiency and use of renewables, requiring the appropriate policy framework, standards and planning. Cities are also soon expected to be challenged to integrate the emergent concept of "air mobility" in specific niches of markets and transport segments.

Integration of UAM with cities' networks and operational systems is still not in the agenda of most of the cities as it is demonstrated by the lack of regulation about it, availability of infrastructure dedicated to the emergent mean of transport or even by the lack of knowledge about what is the attitude of citizens and other key stakeholders about its deployment. Trying to establish how the integration might occur in the short-medium future is an exercise with a high level of uncertainty. Under the current framework, it is expectable that populational density will continue to increase in urban areas and people will still make systematic daily movements to assure the home to work trips. If this trend will continue along the time, then UAM will need to be integrated within cities' network in a wide system perspective:

- safety and security issues must be approached and solved prior to its deployment;
- public acceptance and relevant regulatory and organisational aspects of UAM systems must be predicted;
- operational and service' concepts allowing UAM traffic to be embedded in multi-modal urban transportation environment are essential requirements to complement the infrastructure adaptation, evolution and integration for efficient and seamless door-to-door mobility;
- the sustainability with regard to the overall environmental footprint should be guaranteed.

All these factors are essential to integrate UAM with ground mobility and are supported by the premise that the current habits of active population remain within the current trend. Under such premise, UAM will find its probable niche either in specific markets such as post-delivery, emergency deliveries or business trips. However, if the teleworking will significantly replace the face-to-face work, the current challenges of congestion in peak periods, lack of parking spaces, individual transport invading cities every morning are likely to considerably change. Under that uncertain framework, UAM will likely need to present technological developments that allow it to have a cost that is easily affordable by the population, so it can be considered as a mobility option integrated with the reminder ones. Alternatively, UAM will be constrained to delivery services and not to transport services.
The ASSURED UAM urban integration studies overall results are reported in [9].

5. UAM ConOps and most relevant Use Cases

Based on the consideration of the previous studies, as outlined in the above sections, in the ASSURED UAM project the definition of a Concept of Operations for the UAM integration into urban and peri-urban environment has been addressed. Such studies included the consideration of the UAM transport system most relevant key factors, such as: vehicles technologies, ground infrastructures and services, UAM baseline (2025), intermediate (2030) and target (2035) scenario, UAM needs and expectation, regulations and procedures, flight operations.

UAM based transport system needs include finding suitable locations for vertipads and vertiports, aiming for safety level similar/equal to commercial aircraft and achieving low noise level for better social acceptance. On the other hand, UAM based transport system expectations include improved emergency response time, reduction of traffic jams, reduction of local emissions, development of remote areas, and also creation of new job opportunities for people in a sustainable way.

Main considered UAM applications in the project are cargo and passengers transport and for both the defined ConOps defined the actors, roles, procedures and responsibilities. In terms of certification requirements, it is expected that UAM commercial passengers' transportation will remain a highly regulated market and it will be under the guidance of the Federal Aviation Administration (FAA) in the US and European Aviation Safety Agency (EASA) in the European Union, involving several certification requirements as summarized in the following Figure 4 [10].

The UAM implementation is required to solve cities congestion and pollution problems. In ASSURED UAM the involved municipalities emphasized their issues in this field, which become requirements for improvement for the future UAM deployment. GZM metropolis experiences that the lack of necessary services available locally generates a lot of long trips to the nearest centers, mainly by car. Porto has a crucial commercial and financial role that must be supported by a proper physical network to move flows of people and goods. In Bari, the overwhelming majority of daily trips involve the use of private cars, so that daily trips inside the city of Bari are more than 125000. This allocates high expectations for improvement to UAM.

The ASSURED UAM project, therefore, identified several possible UAM applications, such as: transport of goods, transport of people, air ambulance, emergency supply delivery, transport of organs, search and rescue in case of disaster recovery, infrastructures' inspection, precision agriculture, environmental monitoring, land and buildings monitoring. From this wide spectrum identified for UAM applications, the project selected the applications more related to general public utility and services, and focused on these as the most promising ones in terms of overall societal impact in everyday life and in terms or biggest expected positive impact on the overall urban mobility: the goods delivery and the transport of people. The ConOps, therefore, has been detailed considering 6 Use Cases (UCs), in incremental way according to the three baseline (2025), intermediate (2030) an target (2035) time horizons, as indicated in the following Figure 5 [10].

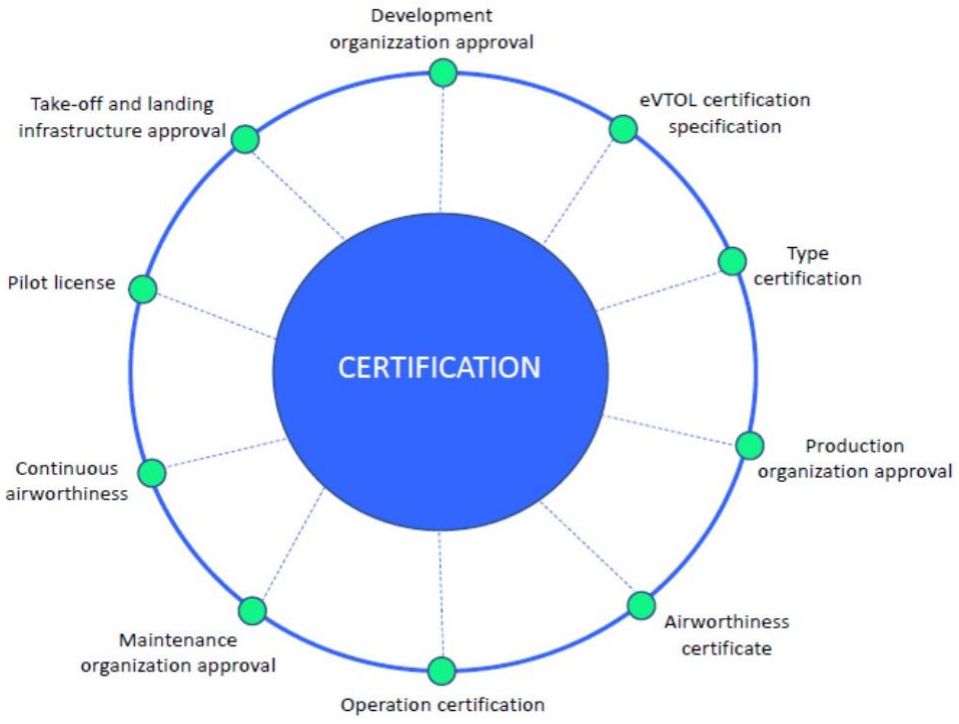

Figure 4. Certification requirements for UAM drones [10]

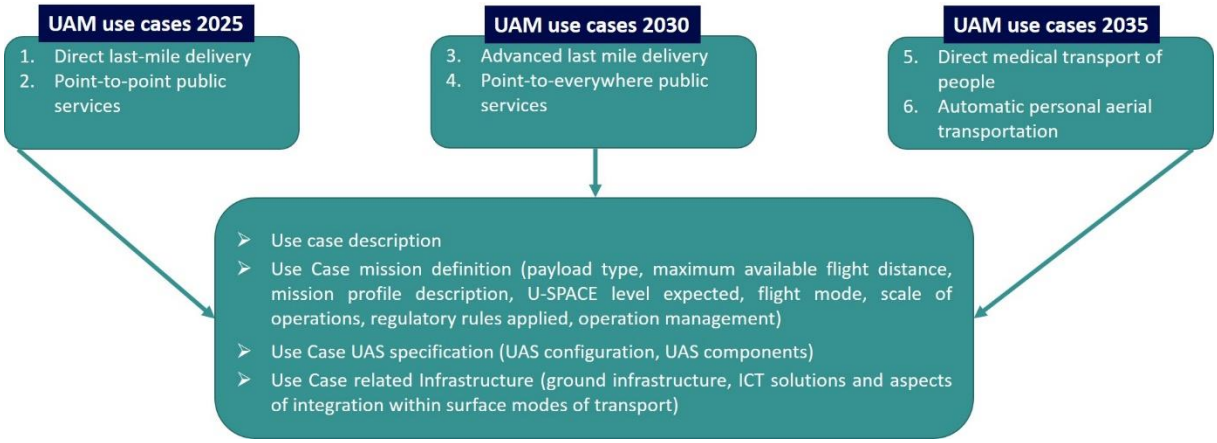

Figure 5. ASSURED UAM developed Use Cases up to 2035 time horizon [10]

Based on the project studies, the cargo applications are expected to be matured and routinely operated already by 2030, whereas for transport of people the 2035 time horizon can be considered the first step in experimental application, being instead the full maturity of this application expected by 2050, in compliance with the X-TEAM D2D studies [11]-[17].
The ASSURED UAM ConOps and Use Cases studies overall results are reported in [10].

6. Conclusions

The ASSURED UAM project designed a specific Concept of Operations for the integration of Urban Air Mobility (UAM) into urban and peri-urban mobility system, according to multiple time horizons (5, 10, and 15 years). The ConOps includes all the relevant aspects (as resulting from the dedicated studies carried out in the project) in terms of technology readiness, regulatory framework and urban mobility integration. Six incremental main use cases (UAM operational models), 2 for each considered time horizon (2025, 2030 and 2035), have been defined and integrated also aspects related to UAM integration into multimodal transport, in cooperation with and based on the outcomes of X-TEAM D2D project. The ASSURED UAM project studies are aimed to inform and support the strategical choices to be implemented by European cities in the next decades to allow efficient and successful implementation of UAM in the overall urban transport system and environment.

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