A Roadmap for Urban Air Services

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Abstract

The development of urban air services (UAS) for passenger and cargo transport have strongly been pushed in recent years. Within this research we develop a roadmap for UAS, that incorporates significant building blocks for the successful operation of urban air mobility (UAM) and urban air delivery (UAD) services. We consider elements such as vehicle development, technology, certification, drone navigation systems, vertiports, multimodality, eco-system and CONOPS. This allows to derive relationships between the different building blocks as well as requirements for the successful development. We define three phases, namely 1) demonstrator flights, 2) first commercial services and 3) regular operation, and discuss the anticipated development timelines for each of the building blocks using these phases.

1 Introduction

Urban air services (UAS) have generated a lot of interest in recent years. Technological advancements open up new chances for the application of vertical take-off and landing vehicles for cargo and passenger transport in urban settlements [1].Vehicle manufacturers are pushing technological advancements and first businesses are aiming to develop an entire eco-system around urban air mobility (UAM) and urban air delivery (UAD), including vertiport infrastructure and UTM (unmanned air traffic management). Industry efforts are accompanied by research activities that support the innovative sector in finding safe and sustainable ways to introduce this novel transport mode. Yet, it is still a long road to commercial UAM and UAD services.

This research aims to lay out a roadmap for possible futures of UAM, including passenger and freight transport. Developed within the H2020-funded project DELOREAN, this roadmap outlines trajectories for diverse topics. These include regulation and certification, vehicles and technology, UTM (Unmanned Aircraft System Traffic Management) and GNSS (global navigation satellite system), ground infrastructure, multimodal integration, market structure and eco-system or public acceptance. Furthermore, these findings are summarised in CONOPS (concept of operations) for passenger and cargo applications.

We define three development phases that allow us to set up a development timeline for the various topics:

1. demonstrator flights: trial operation, limited in time with a project based organization
2. first commercial services: selected use cases, areas and times of operation; not widely used
3. regular operation: large scale roll out in multiple areas; multiple use cases; large part of population has access

For passenger applications they specifically relate to: (1) piloted UAM - trials and early adopters, (2) piloted UAM - regular operations and (3) autonomous UAM - regular operations.

Uncertainties in the field of UAM for passenger and cargo applications make it difficult to predict exact timelines, yet we do so, aiming to give an impression of possible development pathways for UAM. Describing prerequisites to allow for a transition from one development phase to the next shows the interrelation between the different topics.

We use the roadmapping approach to assess the disruptive area of UAS. Since the late 1970s roadmapping has received increasing attention [2]. Technological advancements have increased the need for consistent objectives and strategies with regard to technology management and roadmapping is a structured, yet flexible approach to do so [3].

The literature on roadmapping can be distinguished into two streams, one tackling product developments, the other rather considering entire technology branches [4]. Product roadmaps rather take a company perspective, relating products, technologies and business opportunities, while technology roadmaps take a broader, multi-organizational perspective to also understand the effects on stakeholder groups [5]. Roadmaps often use visualization as means of communication, to simplify the core messages [6]. While often roadmap visualisations are simple and straight forward, their developments is a complex process that requires a sound understanding of relationships [5].

As the roadmap follows from a multiannual European project the different partners' expertise together with relevant literature was used to identify relevant building blocks and development timelines. We acknowledge that the choice of roadmap elements might be biased by the project focus and the different partners' background

2 The urban air services roadmap

We have developed a roadmap for the introduction of UAS, especially focussing on passenger (UAM) and cargo (UAD) applications. The roadmap encompasses nine building blocks (Figure 1):

1. Regulation and certification
2. Vehicle and technology
3. Advanced drone intelligent navigation system
4. Ground infrastructure
5. Integration with other modes of transport
6. Market structure & ecosystem
7. Acceptance & adoption
8. Use-cases & CONOPS for passenger applications
9. Use-cases & CONOPS for cargo applications

Amongst which the first seven are prerequisites for the introduction of UAD and UAM services and can hence be seen as preconditions for the successful implementation of CONOPS for UAM and UAD.

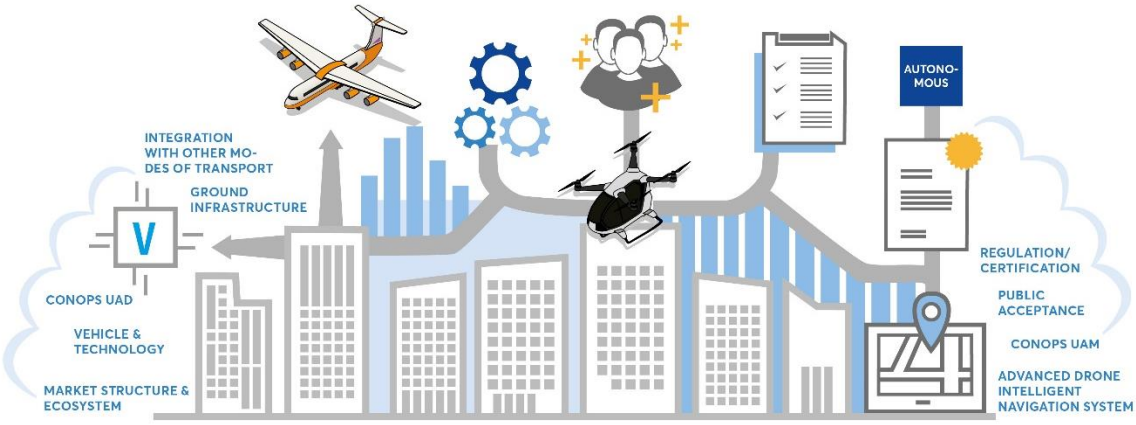

Figure 1: The roadmap building blocks

The roadmap hereby aims to highlight the relevance of the different building blocks, the opportunities and hurdles as well as the linkages between the various elements. Trying to derive a development timeline, we determine the expected points in time when a transition to the next development phase will take place.

The nine identified building blocks are assumed to be necessary prerequisites for the successful introduction of UAS. While some are closely linked, others are can rather independently be advanced and can hence independently enter into the next development phase. For this reason, the building blocks will also be independently described in the following sections. Yet, for the general operation and overarching success of UAS (basically CONOPS UAM /UAD) different essential building blocks need to be in place to reach the next development phase as shown in Figure 2.

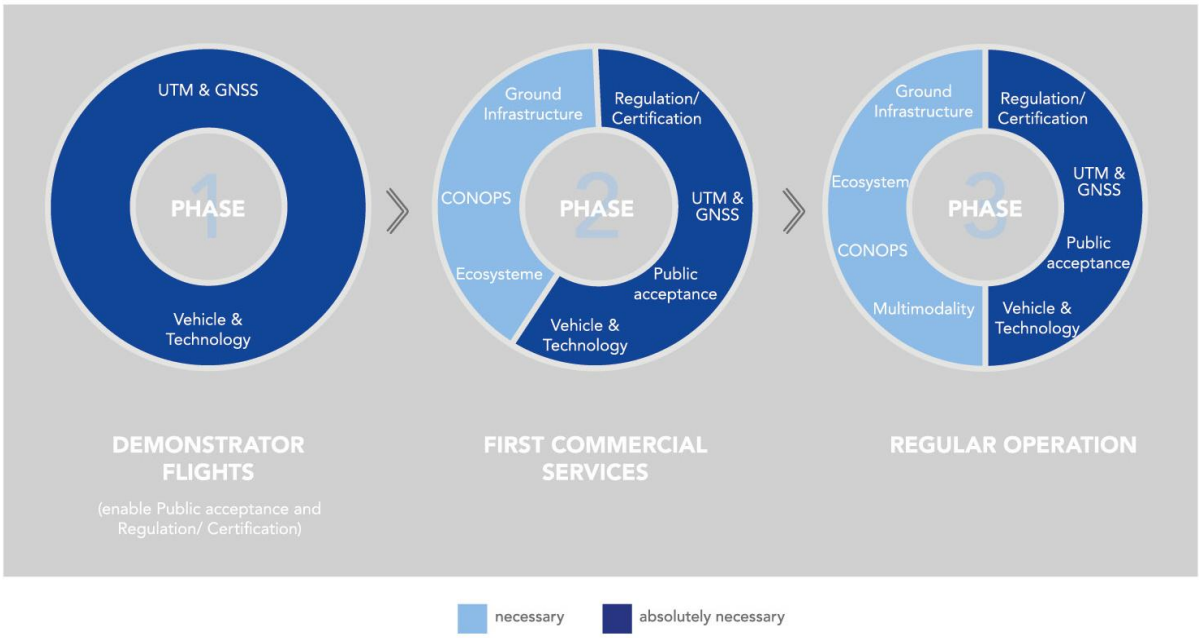

Figure 2: Prerequisites for the three development phases

UAS demonstrator flights are expected to only require the respective development to also be reached for advanced drone intelligent navigation systems as well as for vehicle and technology management. With regard to the other elements of the roadmap, either specific regulations are sufficient or their development is not essential.

When taking up first commercial services more building blocks are required to be in place. First proposals for use-cases and CONOPS need to be in place; additionally a small UAS ecosystem as well as first ground infrastructure are necessary. Even more urgent are respective regulation and certification, advanced drone navigation systems, public acceptance and technology as well as vehicles to be appropriately developed.

When going even one development step further to regular operations, we see that still regulation and certification, advanced drone navigation systems, public acceptance, vehicles and technology are absolutely necessary building blocks that have to have reached the respective development phase to enable large-scale UAS operations. Also the necessary requirements have mainly stayed the same, yet an additional point, namely multimodality, has appeared, which is necessary to enable seamless access to and egress from the vertiports.

This shows that taking up first demonstrator flights requires significant technological development levels, yet the remaining building blocks do not need to be in place. In contrast especially for commercial services to be successful all building blocks are relevant and need to be well developed. Therefore, we describe the different roadmap elements in more detail in the following. Figure 3 gives an overview over the different roadmap elements and the development timeline for each of the building blocks.

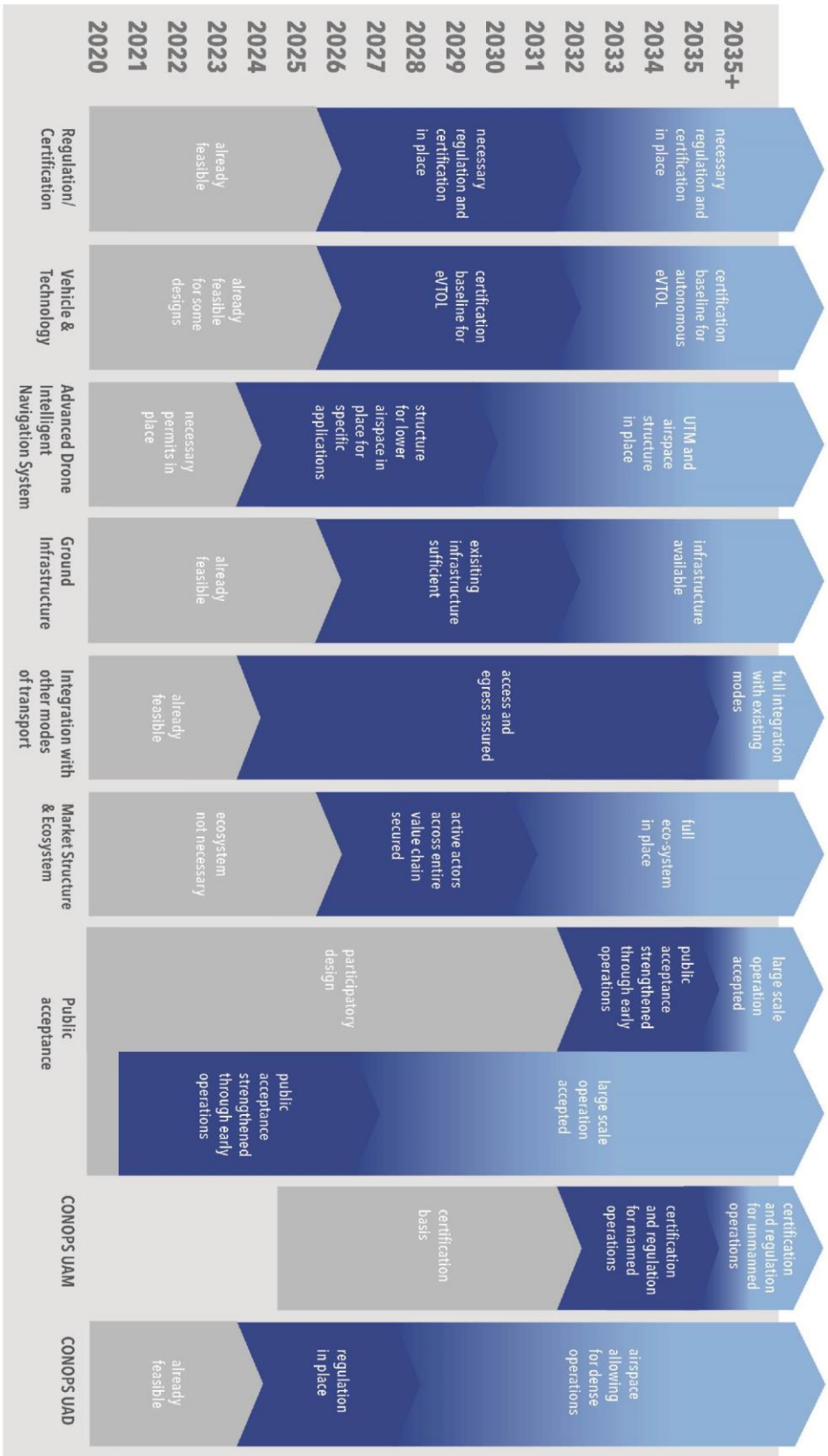

Figure 3: UAS Roadmap

a. Regulation and certification

Regulation and certification are required to enable commercial operation of UAS and will shape the CONOPS and application cases. Regulatory bodies around the globe as the FAA in the US and EASA in the EU need to define clear certification baselines to enable also next steps in vehicle development.

Yet, it is not only vehicle certification that is needed also regulatory standards for the general operation, the organisation of airspace, etc. need to be clarified. This requires policy makers and regulatory bodies to work hand in hand in enabling UAS.

Taking a regulation and certification a development timeline has been defined. Demonstrator flights in controlled scenarios (Phase 1) are already feasible today and hence do not require any further development. In order to take up first commercial services (Phase 2) necessary regulation and certification needs to be in place. For the European context we expect this is not going to happen before 2026 as the respective regulatory framework (SC-eVTOL) is expected to be available by then. EASA's regulation on unmanned UAM operation is a requirement for the transition to Phase 3, to enable large scale operations. This standard is not expected to be in place before 2032.

b. Vehicle and technology

Closely related to the above described area is the field of vehicle and technology. While battery improvements, enhancements in distributed electric propulsion and other technological advancements clearly enable UAS already today (at least for certain use cases). On the contrary the vehicle development strongly relies on vehicle certification standards. This is the case for two reasons, the first being that without a standard in place, even a perfectly functioning vehicle cannot be operated. Secondly, without clear certification standards vehicle development is a high risk as year-long development of a vehicle configuration could in the end be worthless if the configuration is not covered by the certification standard. Therefore, regulators and manufacturers are working hand in hand to ensure efficient and sensible regulatory standards.

Yet, for this reason, analogous to the above described development timeline, demonstrator flights in a controlled setting are already possible today. The transition from Phase 1 to Phase 2 for vehicle and technology is expected to take place in 2026, and the enhancement to Phase 3 is expected for 2032.

c. Advanced drone intelligent navigation system

The organisation of the lower airspace and the development of corridors for drones to operate are key requirements for the successful operation of UAS. The design and development of such advanced intelligent navigation system therefore has to be advanced. Through the use of sensors to detect their surrounding and through the use of GPS signals will add to the safety of UAM and UAD services.

Once again demonstrator flights (Phase 1) are already possible today if the necessary permits are in place. Starting from 2024 first commercial services (Phase 2) might be enabled by the establishment of suitable structures for the lower airspace for specific applications. By 2030 UTM and an appropriate airspace structure are expected to be in place and enable a transition to Phase 3. The main hurdle for entry into Phase 3 is the legislation for and the development of a globally applicable structure for the lower airspace.

d. Ground infrastructure

Transport drones and amongst them especially UAM vehicles require dedicated take-off and landing infrastructure, so-called vertiports. While compared to e.g. rail or subway infrastructure this is a rather small investment, this still requires operators and investors to be active and building permits to be in place.

For demonstrator flights (Phase 1) no additional ground infrastructure is necessary and they are therefore already feasible today. For an entry into service, with first commercial services being offered (Phase 2), existing infrastructure (e.g. helipads) with some adaptations are largely still sufficient and should hence be possible by 2026. For a large scale operation infrastructure investments are required, a transition to Phase 3 is therefore not expected to take place before 2032.

e. Integration with other modes of transport

Inter- and multi-modality are key for the success of transport services not only for UAS but for mobility offers in general. Physical as well as digital integration are enablers for seamless mobility. For Phase 1 of UAS operation integration with other modes of transport has little relevance and therefore is already possible today. Phase 2 with first commercial services taking place is not expected to be possible before 2024. For this at least convenient access and egress has to be assured. Large scale UAS operation (Phase 3) in contrast requires full integration with existing transport modes. This can mean on a physical level such as enabling easy changes of transport modes at mobility hubs or the integration of e.g. booking platforms. These steps are not expected to be taken before 2035.

f. Market structure and ecosystem

For successful urban air services an entire UAS ecosystem is necessary. Players along the entire value chain from suppliers to service providers, digital platform providers, vehicle manufacturers, MRO companies, vertiport providers, air navigation service providers, communication service providers and insurance companies [1] are essential to efficiently operate UAM and UAD services.

Once again demonstrator flights (Phase 1) can already take place without an entire ecosystem in place. Yet, to take up commercial services the eco-system is essential. By 2026 actors across the entire value chain are expected to be active, enabling first commercial services (Phase 2). Only with a full eco-system in place a large scale roll out is feasible. This is not expected to be possible before 2031.

g. Acceptance and adoption

Public acceptance as well as user adoption are essential for the success of UAM and UAD services. Public acceptance on the one hand encompasses the broader public's and in particular non-users' perception of UAS. It is essential that the public has a positive basic attitude towards the novel transport service as otherwise policy makers will be reluctant to introduce these new service offers. On the other hand user adoption, so people's willingness to use the service is essential for economic success of the service. Especially public acceptance is often seen as key requirement for the success of UAS [7].

Phase 1 in large parts is already possible today as demonstrator flights do not require broad public support. In contrast they can even be used to build trust in the service and enable participatory design. The development timeline hereafter is not clear. Depending on the specific application cargo vs. passenger transport, the region of introduction Europe vs. Asia, and possible accidents that could happen during demonstrator flights the transition to Phase 2 has either already taken place or is not expected to be possible before 2032. Building upon these then possible first commercials services a transition to Phase 3 with full scale operation is not expected to take place before 2027 or even after 2035 respectively.

h. Use-cases and CONOPS for passenger applications

The use-cases and CONOPS for UAM and their development timeline strongly build upon the building blocks described above. Depending on the specific city and the target use customer segments use-case and CONOPS will differ. This building block incorporates all above mentioned requirements.

Entry into Phase 1 with piloted operation for first trials and early adopters is expected starting from 2025. From 2032 onwards, when certification and regulation for manned operations is in place Phase 2 with regular piloted operations is possible. Autonomous UAM operations is expected to only be possible after 2035.

i. Use-cases and CONOPS for cargo applications

Also the use-cases and CONOPS for cargo applications consider all relevant requirements and are hence a good summary of the above described. Yet, for cargo transport developments are expected earlier than for passenger transport. Phase 1 with trial operation is already possible today. The necessary requirements for first commercial services in certain regions is expected to be possible by 2024. The transition to Phase 3 with dense operation in cities is expected to take place by 2028.

3 Conclusion

This roadmap shows that the different building blocks of UAM and UAD operation are strongly interwoven. These linkages results in requirements and hurdles and some building blocks, such as regulation and certification, have to advance faster in order to allow for successful UAS development.

Figure 4 aims to visualize the different building blocks for successful UAS development and allows the reader to discover several necessities for UAM and UAD.

Figure 4: Storytelling-picture for urban air services

Acknowledgments

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For more information feel free to consult the project website under https://delorean.pildo.com

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