Dedicated to innovation in aerospace

NLR-TP-2018-233 | May 2019

Urban air mobility

Current state of affairs

CUSTOMER: NLR

NLR – Netherlands Aerospace Centre

Netherlands Aerospace Centre

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EXECUTIVE SUMMARY

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Urban air mobility

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Figure 1: Render of Volocopter 2X (Volocopter, 2019)

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Problem area

Urban Air Mobility promises a revolution in urban transportation. For the first time ever, cities will be able to use the third dimension for their mobility needs. The traditional aviation industry and high-tech newcomers alike are making huge investments to make this still unproven technology a reality. As the societal impact, both good and bad, is still uncertain, local and national governments need to develop a framework that set the conditions for safe innovation in their region.

Description of work

This review puts the exciting (and sometimes frightening) developments of this new form of mobility into perspective. What is UAM exactly? What drives the people, businesses and governments to pursue this topic? If UAM were to be here, how would it look like? And how is all this linked to drone developments? And finally, what is keeping us from enjoying our flying vehicles?

Results and conclusions

The technical possibilities of UAM have a positive outlook, although troubles remain regarding battery technology and the certification of autonomy. The business soundness is yet uncertain. Especially so in Europe; other regions might be more suited for UAM market entry. Wherever UAM does become a reality, the capacity demand will rise to unprecedented numbers requiring an entirely new type of traffic management: UTM (US) and U-space (EU). Without the two, UAM will not succeed. Even if UAM is not in our immediate future it will be a valuable testbed for other services that make our society better.

Applicability

This document provides an overview of the current state of affairs surrounding UAM. Although by no means complete it links the main goals and drivers to current developments in UAM and adjacent fields such as unmanned systems (UAS) and unmanned traffic management (UTM). This connection helps to better understand the humdrum and as to why the sky is not yet filled with flying cars.

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Contents

Abbreviations

ACRONYM	DESCRIPTION
(e)VTOL	(electrically powered) Vertical Take-Off and Landing
ATM	Air Traffic Management
CO_2	Carbon dioxide
CONOPS	Concept of Operations
DEP	Distributed Electrical Propulsion
DNW	German-Dutch Wind Tunnels
drone	Generic, popular term for UAS
EASA	European Aviation Safety Agency
ELOS	Equivalent Level of Safety
EUSCG	European UAS Standards Coordination Group
FAA	Federal Aviation Authority
ICAO	International Civil Aviation Organisation
IenW	The Ministry of Infrastructure and Water Management
ILT	*Inspectie Leefomgeving en Transport*, Dutch national safety authority
LVNL	ATC The Netherlands (*Luchtverkeersleiding Nederland*)
MAAS	Mobility As A Service
MTOW	Maximum Take-Off Weight
NASA	National Aeronautics and Space Administration
NLR	Netherlands Aerospace Centre
NRTC	NLR RPAS Test Centre
PPP	Public Private Partnership
ROC	RPAS Operator Certificate
RPAS	Remotely Piloted Aircraft System
SESAR	Single European Skies ATM Research
SESAR JU	SESAR Joint Undertaking
TCL	Technology Capability Levels (NASA)
UA	Unmanned Aircraft
UAM	Urban Air Mobility
UAS	Unmanned Aircraft Systems
UAV	Unmanned Air Vehicle
UTM	Unmanned Traffic Management
VUTURA	Validation of U-space Tests in Urban and Regional Areas

1 Introduction

1.1 Context

Urban Air Mobility (UAM) promises a revolution in urban transportation. For the first time ever, cities will be able to use the third dimension for their mobility needs. The traditional aviation industry and high-tech newcomers alike are making huge investments to make this still unproven technology a reality. As the societal impact, both good and bad, is still uncertain, local and national governments need to develop a framework that set the conditions for safe innovation in their region.

To aid both industry and governments in this challenge, the 4-year NLR UAM programme investigates the opportunities and difficulties towards market introduction. In year 1 we scope the topic and investigate the concept of operation, concepts for certification and develop a VR-simulation of a representative UAM mission. Years 2 to 4 aim to further investigate the societal impact of UAM, test new concepts and move the operational certification forward.

This document provides an overview of the current state of affairs surrounding UAM. Although by no means complete it links the main goals and drivers to current developments in UAM and adjacent fields such as unmanned aerial systems (UAS) and unmanned traffic management (UTM[1]). This connection helps to better understand the humdrum and as to why the sky is not yet filled with flying cars.

1.2 Contact information

For questions or remarks you are invited to contact the NLR project manager Rui Roosien via ‘rui.roosien@nlr.nl‘.

[1] In the European Union, UTM is better known as U-space.

2 What is UAM?

UAM stands for Urban Air Mobility and is the name for a new branch of aviation. Although the term is now frequently used by industry and policy makers, it is less frequently defined. The liberal approach to the use of the term 'UAM' sometimes causes confusion. The National Aeronautics and Space Administration (NASA) defines UAM as "*a safe and efficient system for air passenger and cargo transportation within an urban area, inclusive of small package delivery and other urban Unmanned Aerial Systems (UAS) services, which supports a mix of on-board/ground-piloted and increasingly autonomous operations*" (NASA, 2017). In short: transporting people or goods in an urban environment by air. The popularity the term skyrocketed after 2015 when the first UAM concepts were introduced (see Figure 1).

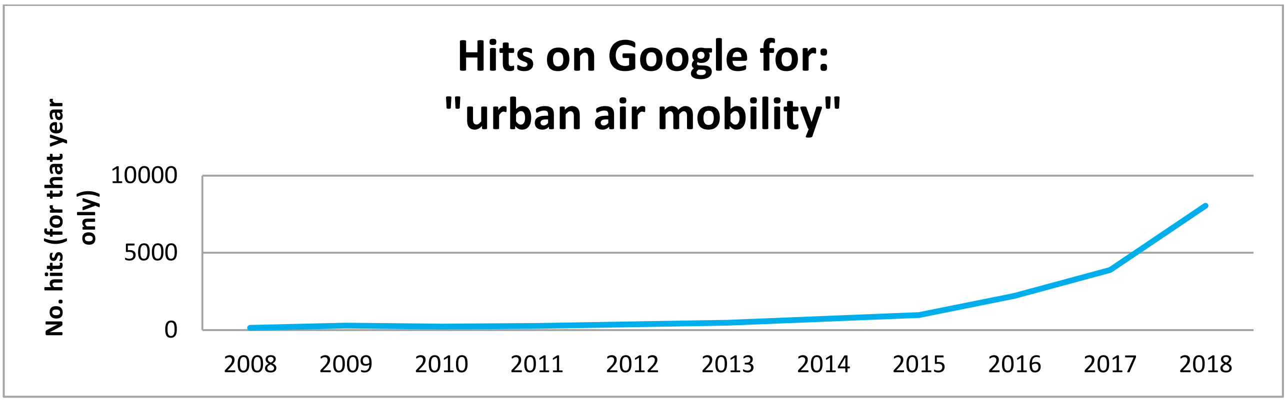

Figure 2: Looking back at the popularity of term "urban air mobility" in the last 10 years

The mission of UAM is the transport of passengers and cargo by air over relatively short distances (typically less than 100 km). The mission occurs in an urban environment either in cities or in between cities. The flight path is at relatively low altitude (~150 – 500 m) above people and/or property. This poses additional challenges compared to rural operations far away from people or property. In this document we look at missions where the payload can be categorised as critical, meaning that loss of the payload by itself can be considered a catastrophic event. Drone delivery of small packages is in this sense not critical and is therefore excluded from further assessment in this document. The mission is performed using an air vehicle. While this could include conventional aircraft or rotorcraft, these are usually not implied. Most UAM concepts use electrically powered Vertical Take-Off and Landing (eVTOL) vehicles of some configuration. The vehicles are sometimes popularly referred to as air taxis, passenger drones or just 'flying cars'. UAM supports 'increasingly autonomous operations', yet monitoring and control of the vehicle can be handled by a human pilot on board the aircraft, a human pilot at a remote location, automation on board the vehicle or a centralised automated system on the ground. The term UAM does not specify the level of autonomy!

Figure 3: From left to right - City Airbus (Airbus, 2019), Ehang 184 (Ehang, 2019), Pal-V Liberty (Pal-V, 2019)

3 Goals and drivers

The traditional aviation industry and high-tech newcomers are making huge investments to make UAM operations in the urban airspace a reality. The government authorities that are responsible for the safety and attractiveness of their regions face their own set of challenges. This section describes the motivation for UAM from different perspectives and explains the sudden rise of interest.

3.1 Societal drivers

Climate change, urbanisation, a growing population all pose societal challenges for governments to solve. UAM can link to these challenges via three key societal drivers: mobility, urban space and environment. A link with one or several drivers helps industry to gain political support and public acceptance.

3.1.1 Mobility

Mobility knows two (apparently contradicting) problems: congestion in the urban areas and a dissolving network in the country side. According to the United Nations, by 2050 almost 70% of the global population will live in urban areas[2] (United Nations, 2018), see table 1. For the ‘High-income countries’[3] this figure is already at more than 80% and will rise to almost 90%. Even more telling is the prediction that the number of ‘mega-cities’[4] will rise from 31 today to 41 in 2030 with 90% of the growth happening in Africa and Asia, see table 2.

Table 1: Annual percentage of population residing in Urban Areas (United Nations, 2018)

Location	2015	2020	2025	2030	2035	2040	2045	2050
World	53.9	56.2	58.3	60.4	62.5	64.5	66.4	68.4
High-income countries	80.9	81.9	82.8	83.9	85.0	86.2	87.3	88.4

All these people travel and most of it is done by car. In 2014, 83.4 % of all vehicle kilometres for passenger transport were done by car and this figure is steady (EUROSTAT, 2017). Unsurprisingly this leads to congestion: in 2014, Americans have spent an average of 42 hours per year in traffic jams. This amounts to a total cost of 6.9 billion hours, 11.7 billion litres of fuel and M$160 (TTI, 2015). Most likely, UAM will not be the ‘Holy Grail’ to solve congestion problems, but it can provide a relief for the most congested routes or act as a feeder to make public transport a more popular transportation mode (Porsche Consulting, 2018). Ultimately UAM aims to deliver services at a price point comparable or below that of a taxi, however initially the pricing will be a lot steeper (Holden & Goel, 2017).

[2] However, the definition of an ‘urban area’ is not fixed, but is defined per country. E.g. any community in Norway with more than 200 inhabitants is considered an urban area, whereas in the United States 50,000 inhabitants are the threshold for an urbanised area (United Nations, n.d.).
[3] A country with an annual gross national income per capita over $12,056 (World Bank Country and Lending Groups, 2018).
[4] Cities with more than 10 million inhabitants.

Table 2: Top-10 largest cities (United Nations, 2018)

2015	2025	2035
1. Tokyo (37M)	1. Tokyo (37M)	1. Delhi (43M)
2. Delhi (26M)	2. Delhi (35M)	2. Tokyo (36M)
3. Shanghai (23M)	3. Shanghai (30M)	3. Shanghai (34M)
4. Mexico City (21M)	4. Dhaka (25M)*	4. Dhaka (31)
5. São Paulo (21M)	5. Cairo (23M)	5. Cairo (29M)
6. Bombay (19M)	6. São Paulo (23M)	6. Bombay (27M)
7. Osaka (19M)	7. Mexico City (23M)	7. Kinshasa (27M)*
8. Cairo (19M)	8. Beijing (23M)	8. Mexico City (25M)
9. New York-Newark (19M)	9. Bombay (22M)	9. Beijing (25M)
10. Beijing (18M)	10. New York-Newark (19M)	10. São Paulo (24M)

* = new entrant

In sparsely populated areas on the other hand, mobility is constrained by a lack of facilities. This is further exaggerated due to the aforementioned increase of people leaving the countryside for the city. At the same time, existing solutions such as railways are expensive to maintain and build: above ground metro lines can cost M$15-30 per kilometre (Flyvbjerg, Bruzelius, & Wee, 2008). As UAM relies less on ground infrastructure and can provide more flexible routing it is potentially well suited for regions where the (sustained) demand is too low for a fixed transportation network. However, this use case is often not associated with **urban** air mobility.

3.1.2 Urban space

A lot of space in cities is used for transportation. This includes the roads themselves, but also parking facilities on the streets and in garages. Mobility as a service (MAAS) is a concept in which people no longer own their own vehicles, but either share vehicles or use a transportation service provider. The idea is that shared mobility requires fewer vehicles to meet a mobility demand compared to private ownership, thus freeing up space currently used for parking (Royal HaskoningDHV, 2018). UAM can alleviate pressure from the existing transportation system and make public transport and MAAS more accessible.

3.1.3 Environment

Although aircraft traffic numbers have been rising without exception since a short hiatus after the September-11 attacks in 2001 and after the start of the financial crisis in 2008 (Figure 5), environmental awareness is rising as well. Climate change is now a widely recognised issue. With the Paris agreements in 2015, government leaders have committed to take measures to keep the global temperature rise below 2°C compared to 'pre-industrial levels'. Actual reduction targets are not forced upon member states; instead each member state develops their own 'Intended Nationally Determined Contribution'. This may or not be legally binding; also time horizons differ per country. Every five years, all member states should report progress and pledge new goals (European Commission, N.D.). Although commercial aviation is exempt from this agreement, both industry and governments are looking for ways to curb carbon emissions from aviation through technical innovation and operational restrictions. The 'Flightpath 2050' strategic document of the European Commission aims for a 75% reduction in CO_2, a 90% reduction in NO_X, and a 65% reduction in perceived noise per aircraft (European Commission, 2011, p. 11). Another emission related topic is the health impact of (ultra) fine particle emissions by (predominantly) road and air transportation. Although little is known about the long-term effects now, it could very well be a future bottleneck (WHO, 2018). Contrary to most road vehicles and commercial airliners, most UAM-vehicles are electrically powered and could thus contribute to a reduction of vehicle carbon emissions and particle emissions.

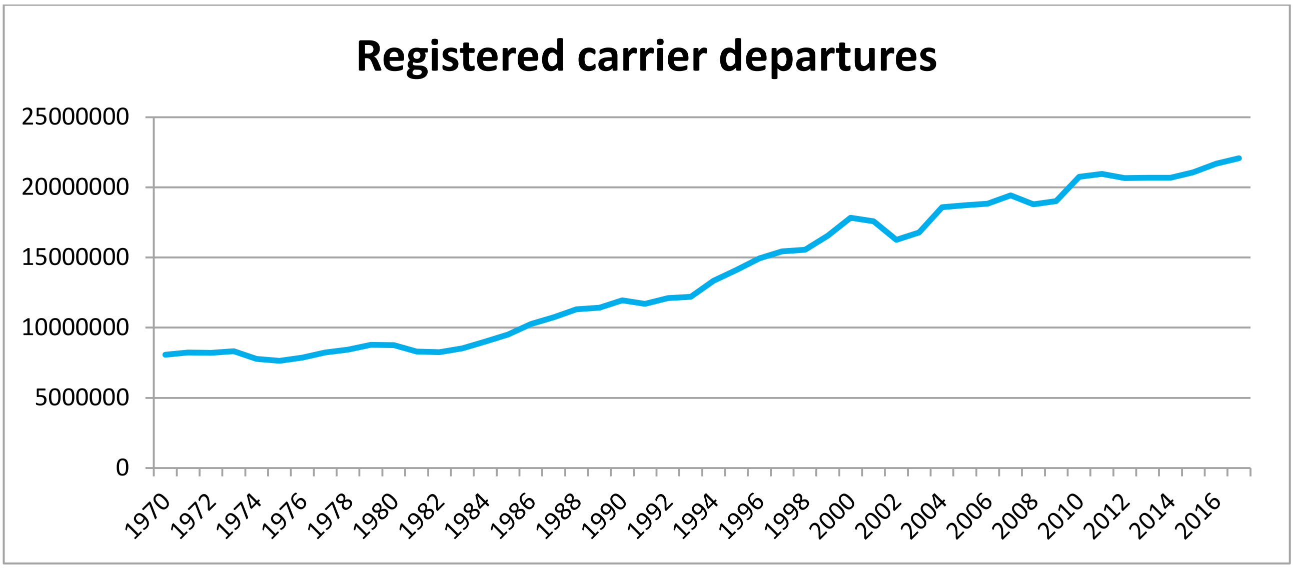

Figure 4: No. annual departures for the 'high income' countries (The World Bank, 2018)

Another environmental factor that haunts the aviation sector is aircraft noise. Even though the noise footprint for most Europeans has steadily decreased[5] (Boucsein, Christiaanse, Kasioumi, & Salewski, 2017), the number of complaints is growing. Airport developments in Germany, France, The Netherlands, and the United Kingdom provide token examples of the resistance to aircraft noise. The electric UAM-vehicles could reduce the need for conventional short-haul (<500 km) flights and thus reduce the noise footprint near airports. However, in urban areas where there currently is no air traffic, noise levels could very well increase. To mitigate this issue manufacturers aim to develop electric VTOL vehicles that are up to 4 times quieter than a conventional helicopter resulting in 62-65 dB_A at 300 feet (Porsche Consulting, 2018; Holden & Goel, 2017). The noise issue is further detailed in section 6.3.

3.2 Business opportunities

Business opportunities include unprecedented traffic numbers and new entrants to the aviation market. These are critical for industry to create a sustainable business model.

3.2.1 The numbers game

UAM will open up the urban airspace to commercial use in unprecedented numbers. Whereas currently helicopter operations are limited, i.e. in São Paulo there can only be six helicopters in the sky simultaneously (Monnet, 2018) and in most other cities this number is even lower, UAM could cause a shift towards air mobility. If just 5% of the Paris population were to use UAM once a week, you would easily reach more than a thousand movements per hour (Balakrishnan, 2018). Porsche Consultancy estimates the global market for UAM to reach $32 billion and 15,000 passenger drones by 2035 (shown as 'Passenger' in figure 5). 45% of this market will be based in the Asia-Pacific region, 30% in the America's, and 25% in Europe and the rest of the world (Porsche Consulting, 2018).

[5] Despite an increase in traffic movements

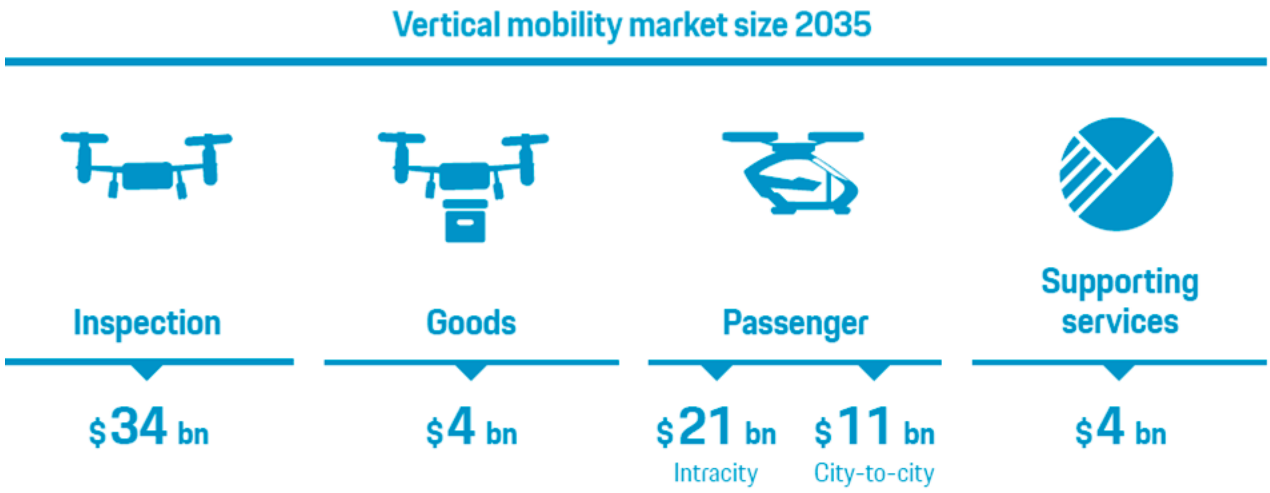

Figure 5: Market size of the vertical mobility market (Porsche Consulting, 2018, p. 19)

The shift towards systems for Urban Air Mobility with no pilot on board is expected to occur earliest 2035, representing a lag of at least 10 years from after the launch of fully autonomous self-driving vehicles anticipated for 2025 (SJU, European Drones Outlook Study, 2016). Public acceptance for automatic flying is likely to be impacted by advancements in these other sectors and technologies, in combination with advancements in unmanned cargo and military aircraft. The safe integration of these drones with other traffic will also place an additional burden on ground control.

Approximately 15,000 eVTOL units are estimated in 2035 on the basis of the market starting in 2025 (Porsche Consulting, 2018), see Figure 6. Most of these will fall into the 'certified' category under the EASA framework given their size, altitude and complexity (see §4.2.1). A summary of this projection is shown in Figure 7.

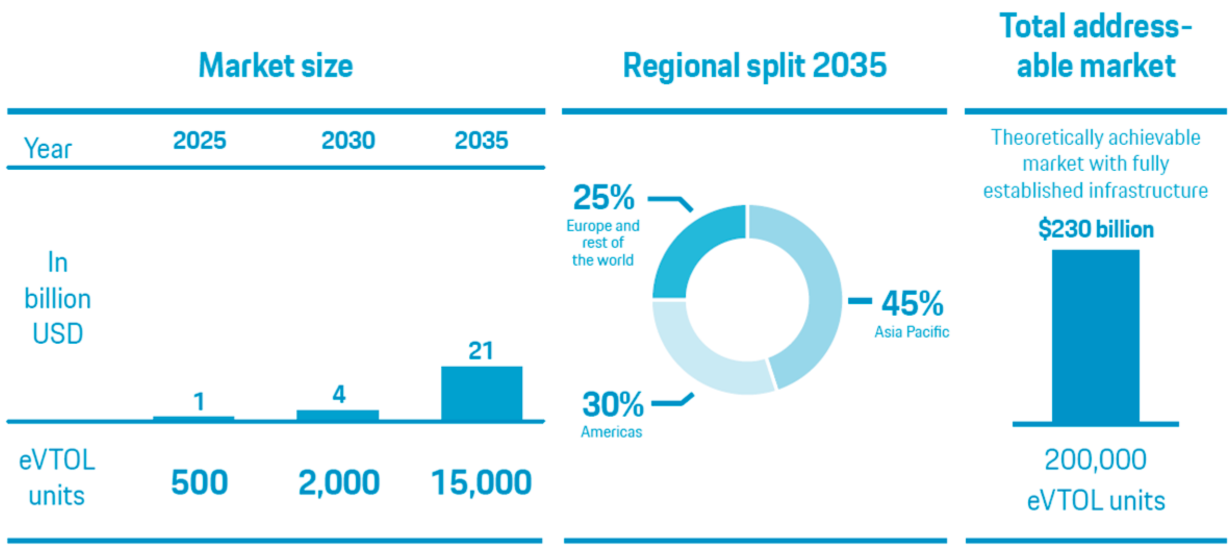

Figure 6: Summary of demand outlook in eVTOL vehicles (Porsche Consulting, 2018, p. 20)

This provides new opportunities for manufacturers from the traditional aircraft industry, but also new players such as VTOL start-ups, IT companies, and companies from the automotive industry. The potential market also provides new opportunities for fleet operators such as aircraft leasing companies, (executive) jet operators, ride sharing companies, and rental car companies (Deloitte, 2018). Each entrant can bring unique capabilities to the table (see Table 3).

Table 3: Possible entrants to the UAM market

Entrant	Examples	Advantages
Aircraft OEM	Airbus, Boeing	Experience with design and production to aerospace standards
VTOL start-ups	Ehang, Volocopter	Energy, innovative workforce, ability to raise capital
IT companies	Apple, Google	Financial reserves, innovative workforce, software knowledge
Automotive OEM	Audi, Daimler	Experience with (design for) mass production
Aircraft leasing companies	AerCap, GECAS	Experience with owning and financing large fleets
Jet operators	NetJets, XOJET, Stratos Jet Charters	Wealthy client base, experience with operating aircraft fleets and on-demand aviation
Ride sharing companies	Uber	Large user base, experience with on-demand transport and user experience
Rental car companies	Avis, Hertz	User base, experience with customer relations, fleet operations, payments

3.3 Why now?

The premise of urban air mobility is not new, yet UAM developments have only accelerated since 2014-2015. Investments in technology of over $1 billion lead to advances in batteries (lithium-polymer) and computer controllers for electric motors. Moreover, the lessons learned from drone technology allowed for the development of vehicles that were less expensive and more efficient than helicopters. The resulting range, while short, is acceptable for urban operations. A vehicle that is build-up out of simple components and software is more economical to operate and since it no longer runs a hydrocarbon combustion engine it is more environmentally friendly and quieter. In addition, regulators introduced new regulations that are performance-based (output driven) instead of prescriptive (input driven). This eases the introduction of vehicles that do not fit an existing, tried and tested, configuration (Wright, 2018; Hirschberg, 2018).

These advances come into an era of concerns of the general public for the health and climate impact of mobility and increasingly stringent regulations on emissions at a global level (the Paris Agreement) (see section 3.1 for more on the societal drivers behind UAM). All drivers that can help make UAM a reality today.

4 Related developments

Manned and unmanned aviation used to be two separate worlds within the aviation domain. But as the levels of automation of manned aviation increase, the size of unmanned vehicles increases, and unmanned aviation enters manned airspace, this distinction blurs. The two worlds now share similar challenges and confuse those who are lost in terms as 'autonomous aircraft', 'UAS', 'RPAS' and 'passenger drones'.

The International Civil Aviation Organisation (ICAO) is clear on the definition: any aircraft without a pilot on board is an Unmanned Aircraft System (UAS). When an UAS is flown by a remote pilot it is called a Remotely Piloted Aircraft System (RPAS) or model aircraft if flown for recreational use. UAS that do not allow for pilot intervention to fulfil their mission are called autonomous aircraft. See Table 4 for an overview. Other terms exist as well (Table 5).

Table 4: ICAO's UAS terminology (ICAO, N.D.)

Name	Description
Unmanned Aircraft System (UAS)	All aircraft flown without a pilot on board. Includes RPAS, autonomous aircraft and model aircraft.
Remotely Piloted Aircraft System (RPAS)	Aircraft flown by a human pilot from a remote location
Autonomous aircraft	Aircraft that does not permit intervention of a human pilot to fulfil their intended flight
Model aircraft	RPAS distinguished by their recreational use

Table 5: Other UAS terminology

Name	Description
Unmanned Air Vehicle (UAV)	Term now defunct, meaning identical to UAS
Drone	Generic, popular term for UAS. Term used by SESAR in U-Space. Used to have a strong military connotation

Wherever UAM becomes a reality, the urban airspace will face an unprecedented capacity demand of hundreds to thousands of movements per hour. The current ATM ecosystem is simply not equipped to handle these numbers, nor is it expected to be in the near future. Therefore, UAM will rely on a new type of traffic management for drones that is already in the making: UTM and U-space. UTM and U-space will not only empower UAM, but all kinds of airborne services such as drone delivery, inspection and surveillance. Thus to put UAM into context (and avoid confusion) we have to look at ongoing UTM and U-Space activities. Most of these activities are focussing on the safe integration of unmanned vehicles in the Air Traffic Management (ATM) system and the emergence of UAS operations at Very Low Level (<500ft) including urban environments. This chapter looks at the activities in The Netherlands, Europe, USA and the rest of the world.

4.1 The Netherlands

On a national level the Dutch government accommodates UAS operations and innovations whenever possible, yet also has to protect the public interest (van Nieuwenhuizen Wijbenga, 2018). What is allowed is the result of an integral balance of interest between economic, social and safety factors that is continuously evolving. No less than four Ministries are actively involved in this dossier.
The following four applications are identified to have the most innovative potential:

1. Inspection and infrastructure
2. Smart Logistics
3. Safety and Security (including countermeasures)
4. Agricultural and nature

The government foresees four phases for professional drone operations towards 2030, as shown in Table 6.

Table 6: Evolution of professional, civil drone operations towards 2030 (van Nieuwenhuizen Wijbenga, 2018)

Development phase	Allowed operations
Phase 1 (current situation)	Drone operations limited to line of sight (LOS) operations away from people and buildings
Phase 2 (in pilot phase)	Line of sight operations in urban areas, beyond line of sight (BLOS) operations in rural areas (currently in pilot phase)
Phase 3	BLOS operations in urban areas
Phase 4	Complete integration of drones into the airspace, unmanned freight and passenger transport

Access and integration of drones into the airspace is addressed through participation in the European U-space program (see section 4.2.1). An example project, led by NLR, is the Validation of U-space Tests in Urban and Regional Areas (VUTURA) that aims to demonstrate U-Space services at U1 (foundation services) and U2 (initial services) levels in four different scenarios (rural, urban, B-VLOS and cross-border, including smart city operations).

The embedding of U-space is also included in the 'Herziening Luchtruim' of IenW that aims to completely redesign the Dutch airspace. ATC The Netherlands conducts an exploratory investigation into the technological implementations that are needed to accommodate drone operations in the airspace. NLR has been given the role of the overarching program management. NLR will make an active contribution to the dissemination of knowledge and the exposure of projects.

4.1.1 Test locations

Drone operations can currently only take place at specific locations or at a designated test location. At the moment, the Netherlands has six of these test locations, each with specific characteristics and possibilities.

These are:

- NLR RPAS Test Centre (NRTC) in Marknesse
- Space53 at Twente Airport
- Military air base Woensdrecht near Woensdrecht
- Military naval base De Nieuwe Haven in Den Helder.
- DronehubGAE at Eelde Airport
- Dronecenter Valkenburg (under supervision of the NRTC)

Specific regulations are under development to make testing and experimenting with drones at test sites easier for companies. The Cabinet's commitment is to let the regulations for test locations come into effect simultaneously with the entry into force of the European rules for the use of drones (see §4.2.1). This means that these regulations can be aligned as far as possible with upcoming EU legislation, which should ease the transitions phase.

4.1.2 Regulatory framework drones

The Netherlands distinguishes three categories of drone operators as shown in Table 7.

Table 7: Dutch categories of drone operators

Category	Restrictions	License
Recreational	Recreational use, vehicle less than 4 kg	Open
Professional (light)	Strict operational restrictions, vehicle less than 4 kg	ROC-light
Professional	Vehicles more than 4 kg	ROC

When the revision of the basic aviation safety regulation comes into force before the summer of 2018, the European Union will be responsible for all civilian drone regulations. For this, the European Aviation Safety Agency (EASA) developed a proposal for a new regulatory framework. The Netherlands will have to implement these regulations nationally. To this end, the ministries concerned will work closely with the (un-) manned aviation sector. Please refer to section 4.2.1 for a description of the new EASA framework.

Finally, the Dutch national aviation authority (ILT) has taken the initiative to set up an expert group of drones, consisting of representatives from trade associations, knowledge institutes and the government. The aim of the Expert Group is to discuss the development of frameworks and guidelines of the ILT for obtaining permits. With these frameworks and guidelines, companies can make their permit applications a lot simpler and faster, which allows the ILT to evaluate the permit more efficiently.

4.2 Europe

The drone market has started bringing significant benefits all over Europe and continuation of that growth is duly expected. Service providers such as Altitude Angel, Unifly, Airmap and DroneRadar already sprouted to capitalize on this growth. To further unlock this value, Europe is taking a series of immediate actions to both boost innovative capabilities and implement comprehensive regulation that creates a single drone market. The SESAR public private partnership (PPP) has been selected to coordinate drone airspace integration activities, while EASA will take the coordinating role in safety and regulation and the European UAS Standards Coordination Group (EUSCG) coordinates UAS-related standardisation.

4.2.1 SESAR

As the selected body to coordinate drone airspace integration activities, SESAR developed a vision to allow the efficient and safe operation of both manned and unmanned systems in a shared airspace (SJU, European ATM Master Plan: Roadmap for the safe integration of drones into all classes of airspace, 2018). This vision will be achieved through two complementary threads:

- An evolutionary thread, addressing the accommodation and integration of large certified remotely-piloted drones with manned aviation. (“RPAS”)
- An innovative thread, providing airspace access to large numbers of typically smaller drones, supported by automation and connectivity. (“U-space”)

Evolutionary thread: RPAS

The evolutionary thread expects large drones to be remotely piloted with an identified operator and fly under instrument flight rules (IFR) and (an equivalent to) visual flight rules (VFR). These RPAS will interact with ATM in the same way as manned aircraft, with special provisions designed to compensate for the fact that the pilot is not on board the aircraft. Given the expected traffic, the evolutionary thread is not feasible for UAM.

Innovative thread: U-space

For operations of smaller drones U-space has been defined. U-space makes use of a set of new services and specific procedures designed to support safe, efficient and secure access to airspace for large numbers of drones. These services rely on a high level of digitalisation and automation of functions, whether they are on board the drone itself, or are part of the ground-based environment. U-space provides an enabling framework to support routine drone operations, as well as a clear and effective interface to manned aviation, ATM/ANS service providers and authorities. U-space is therefore not to be considered as a defined volume of airspace, which is segregated and designated for the sole use of drones. U-space is capable of ensuring the smooth operation of drones in all operating environments, and in all types of airspace. It addresses the needs to support all types of missions and concerns all drone users (including military) and categories of drones. U-space will also facilitate complex future applications such as urban air mobility (SJU, U-space Blueprint, 2017).

The progressive deployment of U-space is linked to the increasing availability of blocks of services and enabling technologies. Over time, U-space services will evolve through four service blocks as the level of automation of the drone increases, and advanced forms of interaction with the environment are enabled. The four blocks of services are:

- U1 **U-space foundation services (2019+)** provide e-registration, e-identification and geo-fencing.
- U2 **U-space initial services (2022+)** support the management of drone operations, including flight planning, flight approval, tracking, airspace dynamic information, and procedural interfaces with air traffic control.
- U3 **U-space advanced services (2027+)** support more complex operations in dense areas and may include capacity management and assistance for conflict detection.
- **U4 U-space full services (2035+)**, particularly services offering integrated interfaces with manned aviation, support the full operational capability of U-space and will rely on very high level of automation.
-

4.2.2 EASA

On request by the European Commission, Member States and other stakeholders, European Aviation Safety Agency (EASA) developed a proposal for a new regulatory framework for all unmanned aircraft. The new framework should by flexible depending on the type of operation and be performance based, instead of compliance based.

This resulted in a general concept with three categories of UAS operations (‘open’, ‘specific’ and ‘certified’) each with different safety requirements, proportionate to the risk. ‘Certified’ drones should demonstrate equivalent levels of safety as manned aircraft and thus meet relevant government rules for flight and flight equipment. ‘Open’ drones are those that can be operated without prior authorisation by the competent authority provided certain operational limits and/or rules (i.e. within special use airspace). ‘Specific’ are all others that need prior approval based on risk assessment or complying with a standard scenario, or an operator holding a certificate with privileges.

A draft EU Opinion (EASA, 2018) has been approved by the European Parliament and is now in the process of be approved by national parliaments. It proposes draft regulation for UAS operations in the 'open' and 'specific' categories. All drones below 25 kg will be divided into classes based on their maximum take-off weight (MTOW). The risk of operations will determine whether they can operate in the 'open' or 'specific' category. Drones that have MTOW of 25kg or more, or that want to operate above 120m or want to operate Beyond Visual Line of Sight (BVLOS) automatically fall under the 'specific' category.

When mapping the categories in the EASA draft regulation to the current Dutch situation, the following picture is visible. The recreational pilots and the professional pilots with a limited license (ROC-light) fall under the category "open". The professional pilots with a full ROC fall under the category "specific".

Regulation for the 'certified' category is not expected before 2022-2023. These regulations will be far more stringent given the associated risk to both occupants and other 3rd party entities. UAM will most likely fall into the 'certified' category.

4.2.3 EUSCG

The bodies involved in the planning and development of drone-related standards have recently agreed collectively to establish the European UAS Standards Coordination Group (EUSCG). The EUSCG is a joint coordination and advisory group established to coordinate the UAS-related standardisation activities across Europe, essentially stemming from EU regulations and EASA rulemaking initiatives. The EUSCG provides a bridge between European activities in this domain and those at international level. The main task of the EUSCG is to develop, monitor and maintain an overarching European UAS standardisation rolling development plan, based on inputs from the EUSCG committee members, while addressing the needs identified in the European ATM Master Plan.

The EUSCG work ensures a better coordination and monitoring of the relevant activities affecting standardisation:

- rulemaking activities under EASA responsibility,
- update to the European ATM Master Plan by including UAS provisions,
- standardisation activities executed by the relevant standardisation bodies, including EUROCAE

The main deliverable of the EUSCG is the European UAS Standardisation Rolling Development Plan which will be progressively updated to reflect the current situation. It will also provide a method for the identification and discussion of overlaps and gaps, and as a basis for feedback to contributing organisations, to improve overall coordination of standards development.

4.3 United State of America

Since the number and type of UAS operations envisioned in the US far exceeds existing ATM capacity, the Federal Aviation Authority (FAA) acknowledged the need to develop a concept for unmanned traffic management (UTM). UTM was to be separate from, but collaborative with the existing ATM system, and to provide the means to support UAS operations in uncontrolled airspace where no air traffic separation services are provided.

4.3.1 NASA and UTM

Building on its legacy of work in air traffic management for manned aircraft, NASA leads the research of prototype technologies for a UTM system that could develop airspace integration requirements for safe and efficient low-altitude operations (NextGen, 2018). One of the attributes of the UTM system is that it should not require human operators to continuously monitor each vehicle. Instead, the system should provide human managers with data to make strategic decisions related to initiation, continuation, and termination of airspace operations. In its most mature form, the UTM system could be developed using autonomous characteristics that include the autonomous closure of operations due to inclement weather.

NASA envisions two types of possible UTM systems. The first type would be a ‘Portable UTM system’, which would move from between geographical areas and support operations such as precision agriculture and disaster relief. The second type of system would be a ‘Persistent UTM system’, which would support low-altitude operations and provide continuous coverage for a geographical area. Either system would require persistent communication, navigation, and surveillance coverage to track, ensure, and monitor conformance.

While NASA won’t have a direct hand in providing design input for UAM vehicles, it provides technical leadership in areas that require the UAM community to work together. The first step in this is that NASA called for and awarded a UAM market study to look at the market potential in order to better understand the issues and gauge the speed with which it may develop. The UAM market studies will help ensure that the most relevant and appropriate research agenda is developed and that the right path is chosen to create high impact industry partnerships (NASA).

Regarding UAM, NASA aims to (NASA ARMD, 2017):

- Create a strategic programme that aligns efforts on airspace integration, safety, autonomy, and UAS, and manufacturing and materials activities,
- advance American quality of life, economic opportunity, and standard of living through air mobility,
- provide benefits to smaller unmanned aerial systems as well as larger general aviation and commercial passenger aircraft.

Cooperation between Europe and the US is achieved through the Memorandum of Cooperation on civil aviation research and development, which includes a specific cooperation plan on UAS. In this framework, the SESAR JU, the FAA and NASA aim to deliver a joint vision for safe integration of drones in all classes of airspace, including U-space and UTM. This cooperation framework also allows an exchange of views concerning common operational and deployment challenges, including the standardisation and regulatory roadmaps.

4.4 Global

4.4.1 ICAO

In 2015, the Unmanned Aircraft Systems Advisory Group (UAS-AG) was established, to support the Secretariat in developing guidance materials and expedite the development of provisions to be used by States to regulate unmanned aircraft systems (UAS). With its industry and international partners, as well as the Member States, the group has been instrumental in providing support to the global aviation safety collaboration.

Furthermore, the Remotely Piloted Aircraft Systems Panel (RPASP) was established to coordinate and develop ICAO Standards and Recommended Practices (SARPs), Procedures and Guidance material for remotely piloted aircraft systems (RPAS), to facilitate a safe, secure and efficient integration of remotely piloted aircraft (RPA) into non-segregated airspace and aerodromes.

At a global level, Europe is deeply involved in ICAO work on RPAS integration and the definition of a common framework for UTM. The ICAO RPAS Panel has developed an RPAS CONOPS and work is ongoing to identify the required updates to SARPs to allow IFR RPAS integration. In addition to this, Europe also actively contributes to the ICAO UAS advisory group on UTM to ensure global harmonisation.

4.4.2 JARUS

JARUS, which stands for Joint Authorities for Rulemaking on Unmanned Systems, is a group of experts from the National Aviation Authorities (NAAs) and regional aviation safety organizations. Its purpose is to recommend a single set of technical, safety and operational requirements for the certification and safe integration of Unmanned Aircraft Systems (UAS) into airspace and at aerodromes (JARUS, 2017). Civil autonomous unmanned aircraft, which are not a part of the RPAS family, are not being considered by the international and national organisations that are working on integration into controlled airspace.

At present 52 countries, as well as the European Aviation Safety Agency (EASA) and EUROCONTROL, are contributing to the development of JARUS. Since 2015, the Stakeholder Consultation Body (SCB) representing all industry communities of interest has also been establish to provide support to all JARUS activities. Each State or Regional Organisation will need to decide how to use the harmonised provisions developed by JARUS. JARUS does not develop industry standards and will not draft ICAO SARPS or guidance material unless ICAO requests such assistance.

4.4.3 GUTM A

The Global UTM Association (GUTMA) is a non-profit consortium of worldwide Unmanned Aircraft Systems Traffic Management (UTM) stakeholders. Its purpose is to foster the safe, secure and efficient integration of drones in national airspace systems. GUTMA’s goal is to take an organized and systematic approach, and design UAS traffic management (UTM) systems to enable the safe, orderly, and expeditious flow of traffic.

The mission of GUTMA is to define a high-level architecture that is globally accepted by the industry and promoted to national aviation authorities as the basis of a standard UTM architecture (GUTMA, 2017). See Figure 9 for a breakdown of the architecture.

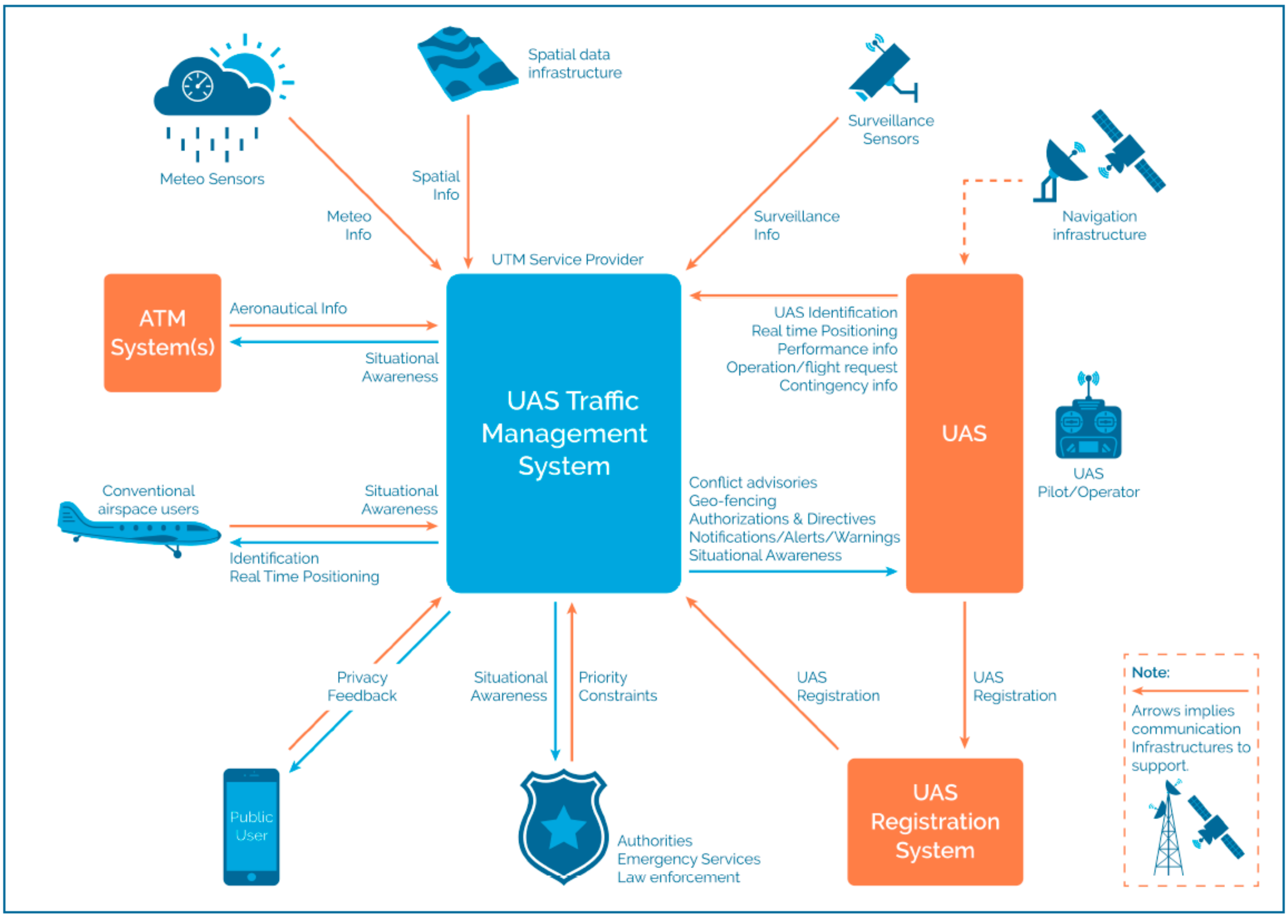

Figure 7: GUTMA's view on a UTM system

4.4.4 Others

Worldwide there are many other UAS/drone activities ongoing, Japan for instance is developing its own UTM system called J-UTM. They have an allocated budget of 125 M €. Denmark has made 25M € available for the development of the Odense test centre. The Spanish region of Galicia makes 24M € available for the next 2 years and 115M € to 2021 for a drone program called CIAR. Singapore is collaborating with Airbus in the development of Skyways, a new automated delivery drone service. And major tech companies (Google, Amazon and DHL) are all developing their own drone-based delivery technology.

5 Vehicles

We are still the early days of UAM and eVTOL vehicles. As a result, there are no best practice solutions yet that dictate the vehicle configuration. The number of design options is large and highly mission dependent (Siegel, 2018).

5.1 Missions

As of now the full potential of UAM is still unclear. However, one can foresee a number of missions that are likely candidates for a UAM business model. These include personal (VIP-)transport, ‘intra-city’ transport, city-to-city transport and emergency vehicles (police, medical and fire brigade). An UAM-service should provide a timesaving including transfers of at least 20% compared to other modes of transport to become sufficiently attractive (Porsche Consulting, 2018).

The first operating model is personal transport where one or two persons will travel distances up to 80 kilometres from a selected number of helipads for business or leisure. The vehicles will be operated by an on-board pilot supported with advanced automation to reduce workload and training needs. Due to small production numbers and the need for a pilot this model will be for the high net-worth demographic only. The target demographic can be compared to that of the (on-demand) helicopter market. The advantages of this operating model are the technical feasibility since no full autonomy is required and the relatively low numbers so no mass production is required and the impact on traffic capacity is relatively low. Disadvantages are the small target demographic and the lack of a societal benefit of the service which hurts the likelihood of public acceptance.

The second operating model is an ‘intra-city’ operation where two to six passengers share a vehicle for a 20 to 50 km trip in an urban area, for instance for a trip from a ‘vertiport’[6] in the city centre to the nearby airport. First- and last-mile transport can be provided by public transport or taxi. The vehicle will be operated by an on-board pilot at first. To improve the business model, the on-board pilot will be replaced by a remote-pilot or an autonomous auto-pilot as soon as this can be developed and certified. This type of service is aimed at mega-cities with 10+ million residents. A network of approximately 5 vertiports in a single city could provide the minimum viable product for this service aiming primarily at business people (Balakrishnan, 2018). As the network expands and the costs come down to a level comparable to a taxi, the service will become accessible to most. In a research for Airbus, the Boston Consultancy Group indicated the airport transfer as the most ‘impactful’ business case (Airbus, N.D.). The difficulty with this operating model is the ratio revenue- / non-revenue seats. Depending on the size of the vehicle, the pilot seat takes up 15-25% of the potential revenue seats. Removing the pilot from the vehicle thus dramatically improves the business case. This can be achieved either by a remote pilot on the ground or with autonomous systems. The certification mechanism for autonomous operations is currently non-existent and the means of compliance are very difficult to create.

The third operating model is a ‘city-to-city’ operation. As battery technology improves, operations between cities and regions of up to 400 km become feasible. This can reduce travel time for a long-distance commute or allows for a wide range of “spontaneous, on-demand trips”. To operate in a city environment, an electric power train is desirable. However, this requires an energy storage capacity that is currently not available. Also, the long distance requires high

[6] Vertical take-off and landing facility for UAM vehicles

aerodynamic efficiency. The vehicles that provide this (dual phase or transition phase vehicles, see §5.2) are mechanically more complex and more difficult to certify.

The final business model includes emergency response vehicles for the different emergency services. eVTOL vehicles could potentially offer similar capabilities as existing helicopters but with increased flexibility, lower operator requirements (due to automation), lower operating cost (due to mechanical simplicity) and a lower noise footprint. Together with VIP services, this model is predicted to be the premier way to enter the UAM market. In comparison to VIP services, the requirements regarding (operational) cost are higher, but public acceptance is likely to be easier.

Other operating models include inspection and delivery of goods. Both models are outside the scope of this document.

5.2 Configurations

The vehicle of choice for UAM is the electric VTOL. Contrary to conventional these vehicles strongly differ in appearance. Three types can be identified that each suit different missions.

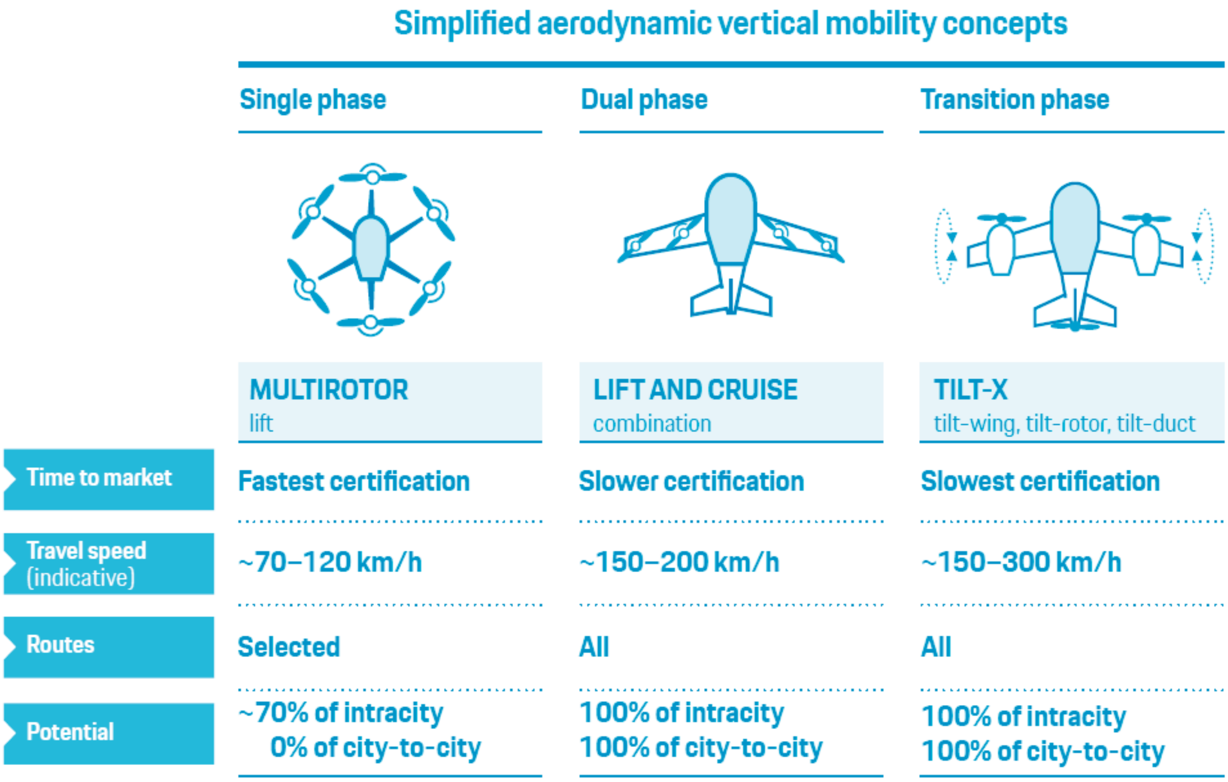

Figure 8: The three basic aerodynamic concepts for drones (Porsche Consulting, 2018, p. 9)

The following paragraphs provides examples of the before mentioned configurations. The examples are from the Electric VTOL News website (Vertical Flight Society, 2019) which has more than 100 aircraft catalogued in the most extensive directory of electric and hybrid-electric vertical take-off and landing aircraft in the world. The catalogue averages a rate of two new aircraft per week as more aircraft are unveiled and new actors join.

Multirotor

Figure 9: eHang 184 (Ehang, 2019)

Figure 10: Volocopter 2X (Volocopter, 2019)

Dual phase

Figure 11: Embraer DreamMaker (Embraer, 2019)

Figure 12: Kitty Hawk Cora (KittyHawk, 2019)

Tilt-X

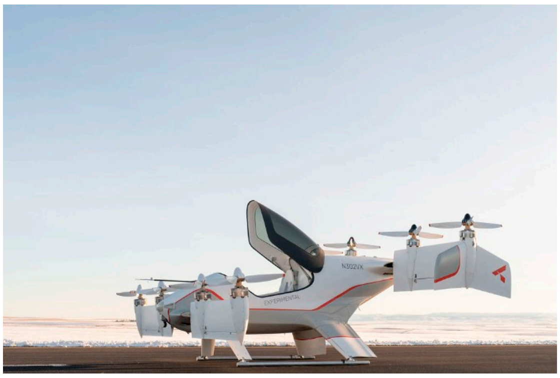

Figure 13: A^3 Vahana Alpha 2 (Airbus, 2019)

Figure 14: Bell Nexus (Bell, 2019)

5.3 Concepts

Together with the new vehicle configurations discussed in the previous paragraph, operational concepts are being developed to provide new ways of on-demand urban transportation. These concepts will not stand alone, but need to integrate into multimodal transportation options. This chapter provides insight into some of the major concepts envisioned.

5.3.1 UBER

With its Elevate project, ride sharing company Uber paves the road for UAM operations with eVTOL vehicles. The concept is detailed in “Fast-forwarding to a future of on demand vertical mobility” (Holden & Goel, 2017).

To the user, Uber promises to turn time wasted in traffic into valuable time spent on work or family. To the industry, Uber promises to connect operators with its 60 million users. Elevate identifies the main hurdles for the UAM market, provides a path to market introduction and describes the requirements for infrastructure, operation and user experience. The breadth of the concept is truly impressive.

In UBER’s Elevate vision, the VTOL fleet will likely be supported in a city through a mixture of both ‘vertiports’ and ‘vertistops’. These ports are situated on top of familiar structures such as parking garages and high rise buildings. Vertiports would be large multi-landing locations that can accommodate up to a dozen vehicles and have various support facilities (i.e., rechargers, support personnel, etc.). Vertistops, on the other hand, would be single vehicle landing locations where no support facilities are provided, but where VTOLs can quickly drop off and pick up passengers without parking for an extended time.

Furthermore, UBER fully details the user experience. The customer will be able to use the UBER app to book different types of on-demand transportation: bike-sharing, VTOL or car. The app would feature clear time and price trade-offs between these modes. When arriving at the vertiport/-stop, the customer enters through a building that provides the security, screening, waiting area, and other functions. Along the trip the customer will be provided with real-time trip information including location and remaining time. When arriving at their destination customers will be dropped off at easy access points to automobile, public transport or pedestrian walkways to complete their trip.

UBER’s vision is tailored for operation between vertiports and vertistops. VTOLs could potentially take off and land at private residences; however UBER does not expect that VTOLs deployed on ridesharing networks will be owned by individuals, as they will be significantly more expensive and more complicated to operate than cars. Uber will leverage the developments of NASA UTM and utilize technologies as developed in the FAA’s NextGen program.

5.3.2 AIRBUS

As part of its vision for VTOL systems, Airbus is exploring a range of urban mobility solutions and supporting services.

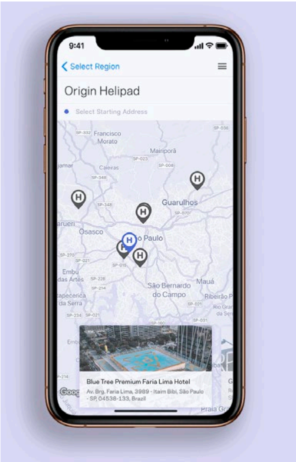

Figure 15: screen shot of VOOM mobile user interface (Airbus, 2018)

VOOM
Voom is an on-demand helicopter booking platform recently purchased by Airbus Helicopters. The service is available to commuters in São Paulo and Mexico City and makes Airbus the first globally operating UAM service provider. VOOM is a platform that connects the rider with trusted and licensed air taxi companies via a mobile website. Connecting ground transportation can also be booked via the Voom platform. Voom currently operates at a price that is up to 80 percent less than traditional helicopter services - competitive to taxi operations ($10/min with an average flight time of 9 min).

VOOM allows Airbus to test the market for UAM services even though the eVTOL vehicles are still in development.

Vehicles
Airbus is has multiple UAM vehicles in development designed for different use cases:

CityAirbus is a multi-passenger eVTOL that is designed to carry up to four passengers over congested megacities in a fast, affordable and environmentally friendly way. The multi-propeller platform will initially be operated by a pilot for certification and market entry purposes. In time, CityAirbus is intended to be fully autonomous and self-piloted, once regulations are in place. Similar to Voom, customers will be able to use an app to book a seat on a CityAirbus, proceed to the nearest helipad, and climb aboard to be whisked away to their destination.

Project Vahana is a single-passenger or cargo, all-electric, fully-autonomous, vertical-takeoff-and landing demonstrator for VIP or emergency services. It uses eight electric motors and a tilt-wing configuration to enable both hover and cross-city range on battery power alone. On 31 January 2018 Vahana successfully completed its first full-scale flight test, reaching a height of 5 meters (16 feet) before descending safely.

Supporting initiatives
Airbus thinks beyond the role of a vehicle OEM and aims to develop and promote the whole UAM ecosystems.
Two projects deserve emphasis:

Project Altiscope is a simulator that helps evaluate different ATM policy options and operational models for different types of flying vehicles to share airspace safely and efficiently. In addition, Altiscope writes whitepapers on topics such traffic volume, noise and third party risk. The library is open source to promote adoption by others.

Airbus is also the driving force behind the Smart Connected Cities: Urban Air Mobility programme of the European Innovation Platform (EIP). The UAM EIP aims to connect cities and regions with a mobility need with industry and investors to accelerate the development of UAM services. The goal is to demonstrate the value of these services instead of promoting the technology. Several regions already started initiatives to do so, including Euregio together with NLR.

5.3.3 VOLOCOPTER

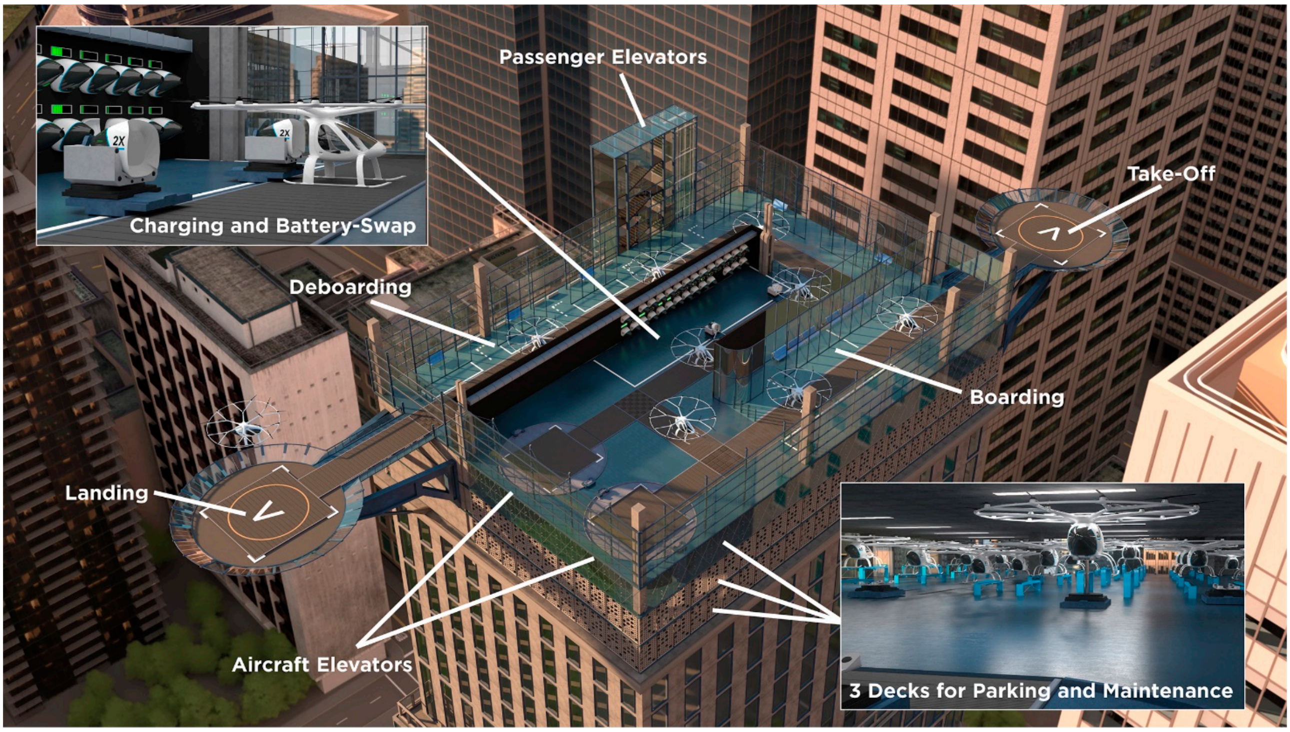

Figure 16: Impression of a Volo-Hub (Volocopter, 2019)

Volocopter's vision integrates air taxis into existing transportation systems as they believe that autonomous driving will not solve the traffic congestion problem. It utilizes a vehicle that is emission-free, electrically powered and that can take off and land vertically, offering a high degree of safety based on full redundancy in all critical systems. Volocopters are based on drone technology and scaled up to carry two people, initially for distances of up to 27 km.

The concept Volocopter envisions consists of Volo-Hubs and Volo-Ports. The Volo-Hubs resemble cable cart stations with Volocopters landing and taking off every 30 seconds for example. Once landed the Volocopter is moved inside the Volo-Hub. Passengers disembark the aircraft protected from wind and weather. Battery packs will be swapped automatically in a protected area by robots before moving on to the section, where passengers embark for take-off. Volo-Hubs are the key to substantially increase the capacity of any Volocopter system. Aside from protected deboarding and embarking, they offer sufficient space to park all Volocopters in operation and provide the infrastructure for charging and maintenance.

Volo-Ports expand the Volo-Hub system and offer direct access to a company, shopping mall, hotel or train station for example. They do not require any charging or parking infrastructure and subsequently will be less complex to build. Any Heliports can be used as a Volo-Port with minimal modification.

Volocopter expects any air taxi transport system to begin with a point to point connection and over time grow into a system of dozens of Volo-Hubs in a city. It will be on-demand, shared (i.o.w. not a privately owned) and autonomous. First commercial operation is slated for 2021!

6 Challenges

For Urban Air Mobility to become a reality many challenges need to be overcome. Though not complete, this chapter describes some of the major challenges. The source for this material comes from Uber's Elevate vision document (Holden & Goel, 2017) and from notes taken during the 2018 Future of Transportation World Conference in Cologne, Germany.

6.1 Airspace integration

Urban airspace is already open for business. With ATC systems exactly as they are, a VTOL service could be launched and even scaled to possibly hundreds of vehicles. São Paulo already flies hundreds of helicopters per day. Under visual flight rules (VFR), pilots can fly independent of ATC and when necessary, they can fly under instrument flight rules (IFR) leveraging existing ATC systems. However, a successful, optimized on-demand urban VTOL operation will necessitate a significantly higher frequency and airspace density of vehicles operating over metropolitan areas simultaneously. In order to handle this exponential increase in complexity, new (possibly distributed) ATC systems will be needed. A multitude of challenges needs to be resolved, among others:

Table 8: Airspace integration challenges

Challenge	Research questions
Interaction with manned aviation	• What are the separation standards? • What are the rules of the air? • Who is responsible for separation?
Seamless integration with existing Air Traffic Management systems	• How to connect U-space / UTM systems to existing ATM systems? • Should an air traffic controller be informed/involved? • How to prevent unauthorised operations in restricted airspace?
Voiceless communication (datalink)	• Is there enough bandwidth?
Navigation for urban operations	• What accuracy, reliability and integrity is required? • How to prevent spoofing and jamming?
Surveillance	• Will there be coverage in shielded areas (i.e. between buildings)

Initiatives like the development of U-space (§4.2.1) and NASA's UTM (§4.3.1) are on their way to address these challenges, but they will play out over many years and their pace may ultimately bottleneck growth.

6.2 Certification and liability

Before any new vehicle can operate, tit will need to comply with regulations from aviation authorities charged with assuring aviation safety (FAA/EASA). These regulations enforce standards for vehicle design, production, pilot licensing, maintenance and operating requirements. While challenging (and slow), it is expected to be solved within a relatively short period of time (~5 years). This assumes however that there still is a human pilot available, at least as a fall-back solution. For some operations, a viable business case can only be made if the pilot is removed from the vehicle. To design and develop advanced autonomous systems is a major technical challenge. The major difficulty with autonomous systems lies with certification: the rules of compliance (standards) and means of compliance (proof) both need to be developed. Developments in the automotive industry on 'Artificial Intelligence' and 'Machine Learning' are promising, but still unproven. With autonomy comes the problem of allocation of responsibility. "Who is responsible when things go wrong?" Not an easy question, as we see in the automotive industry that in spite of improved safety, the liability costs for autonomous vehicles went up. While automotive liability laws may suffice for now, new liability laws need to be created otherwise things may figuratively come crashing down, even before it got off the ground.

Regulators need to step up otherwise the business model will fail. One step that can help to radically accelerate the development of new standards is the use of industry consensus standards rather than the government-set prescriptive standards. This implies that the community takes responsibility for developing the certification basis and then presents it for adoption by the regulator. This consensus-based approach has already been adopted in other fields by both the FAA and EASA. In the end aircraft manufacturers should be able to apply for an experimental airworthiness certificate for their aircraft before the type certification basis is defined, in order to gain experience and collect data to prove that operations are safe.

As an alternative to complying with a standard requirement directly, evidence can be presented that the level of safety is equivalent to that what is intended in the legislation. This approach fits those situations where the vehicle or operation does not comply with the assumptions behind the prescriptive regulation in place. One possible way to prove the safety of autonomous systems is to add autonomous systems to piloted operations. Thus, enabling large-scale data collection demonstrating with statistical significance that autonomous flight is at least as safe as piloted flight. This is a similar approach as occurring today with self-driving cars, beginning with semiautonomous operations assisted by safety drivers. This could circumvent a very lengthy standard specification process for autonomy, while providing the regulator with the statistical safety proof that is needed to move forward with confidence.

6.3 Public acceptance

Besides the occasional emergency response helicopter, the urban skies are free of traffic. UAM has the potential to dramatically change this. Despite the goal to develop quiet vehicles, there will be new traffic operating close to where people live and work. Experience with aircraft noise has shown again and again that new groups of people exposed will lead to a sharp increase of complaints. Therefore, the noise impact needs to be managed. Possibly akin to ICAO's balanced approach for manned aviation by developing the quietest vehicles, low noise procedures, smart urban planning and, if necessary, operational restrictions.

Similarly there is the issue of (actual and perceived) third party risk; the risk of damage to people or property inflicted by a UAM vehicle. Unproven technology, large traffic numbers and a vulnerable environment could spell disaster if not properly managed. Furthermore, accidents in the early phases of UAM could ruin the public trust in these vehicles. Therefore, new technologies need to radically out-perform conventional alternatives for it to be perceived safer. As Derrick Xiong, co-founder and chief marketing officer of EHang China stated:

> *"People are not afraid to die, but are afraid of new ways to die..."*

Then there is the issue of privacy. Since these services will rely on heavy data communication between vehicle, infrastructure and passenger, all these channels need to be secure. Third party privacy or 'How to handle flyovers or flybys of people and their property?' is also an issue. Privacy issues could lead to undesired airspace restrictions and minimum altitudes.

Public acceptance is not only a function of managing the factors of noise, third party risk, privacy and security, but also about perceived benefit. A new service that only benefits the rich and famous and disturbs the rest will be treated differently from a service that is accessible to most. Similarly, a service with a clear societal benefit (e.g. an emergency response helicopter) is viewed differently from a service without such a societal benefit (e.g. recreational aviation). Furthermore, culture plays an important role to public acceptance of new technology (Yeniyurt & Townsend, 2003). Therefore, it can be expected that some regions will be more open towards the introduction of UAM than others.

6.4 Battery technology

Besides operational, regulatory and societal challenges, there are also still technological challenges that need to be overcome. One of these is the use of batteries as the energy source. The specific energy (the amount of energy per unit weight) of batteries today is insufficient for long-range commutes with passengers or cargo. Compared to gasoline the specific energy of batteries is 40x (!) lower. Batteries also do not reduce in weight when used. Currently the state of the art in battery technology is the Lithium Polymers (LiPo) battery, but these can be unstable and decompose, leading to fires as was seen with the introduction of the B787. Research is ongoing on lithium-metal batteries but predominately for the automotive industry. Experts expect that the battery development for cars will stop when they reach 500-600km range, at that time aerospace will be on its own. Instead we should look at hybrids (Hydrogen fuel cells), which could potentially provide ranges up to 1600km, but for which the technology is still in its infancy, complex and therefore costly (Wright, 2018).

Another challenge with respect to batteries is the charge rate and longevity, which do not yet support the intense high frequency demand of ridesharing operations. Additional research into pulse chargers (capable of recharging in as little as 10 minutes) is already showing improved cycle life and maintaining improved maximum charge capacity over time. Achieving rapid charging for large battery packs is as important, if not more important than achieving high specific energy batteries.

6.5 Infrastructure

Finally, the development of sufficient landing pads and service stations pose an operational burden to deploying a VTOL fleet in cities. If VTOLs are going to achieve close to their full potential, infrastructure will need to be added and integrated with other modes of transportation to create multimodal network hubs. Likely candidates are high-rise buildings, parking lots, empty spaces near highways and existing public transport hubs. How these will be developed, funded and operated is yet unanswered.

7 Conclusion

Takeaway
Even if UAM is not in our direct future, it can still serve as a catalyst for other developments that can improve on the quality of life, economic opportunity, and standard of living.

Analysis of the current state of affairs with respect to Urban Air Mobility presents a generally positive outlook on the technical possibilities of this new class of air vehicles and operations. Technical inhibitors are expected to be overcome, although battery technology is still a weakness, especially for city-to-city operations. In terms of other technical inhibitors, airspace integration, operations in between high-rise buildings and certification of advanced autonomy are probably the most challenging. But there is more.

Judged by the current state of investment, the industry is hell-bent on making UAM feasible. Yet uncertainties remain about UAM's business soundness. How can the financial hurdles of certification be overcome and how can one compete with or complement existing modes of transport? One of the most important research questions directly related to the business case is how to take the expensive and revenue-sapping pilot out of the vehicle.

Furthermore, it is not only about industry and investors. Especially for urban operations the matter of public acceptance is most important. This is a function of the perceived benefit versus (fear of) annoyance and risk. The perceived benefits will highly depend on accessibility and social relevance of the service. As shown by the first casualties by self-driving cars, the public opinion is very sensitive to the safety performance of new technology. Thus the attitude towards annoyance and risk will be strongly formed by the results of the initial pilots. Services that serve a public cause (e.g. emergency response services) and show a clean safety record can help build acceptance for other services in the future. Finally, the degree to which societies are open to new technologies will differ among regions and cultures.

What about UAM in The Netherlands? Most service providers claim to bring helicopter-like passenger services to mega-cities with approximately 20 million inhabitants. This implies New Delhi before The Hague. However, even if UAM will not appear in the direct future of the Netherlands, UAM R&D can serve as a catalyst for the development of solutions for all sorts of urban air operations.

For example a dedicated traffic management system: U-space (in Europe) or UTM (in the US). Because, wherever UAM becomes a reality, the urban airspace will face unprecedented levels of capacity demand. The current ATM ecosystem is simply not equipped to handle these numbers, nor is it expected to be in the near future. As such UTM and U-space will not empower just UAM, but all kinds of airborne services such as drone delivery, inspection and surveillance.

If these services can provide a clear benefit in terms of mobility, use of space and sustainability, these are worth pursuing. Especially in a densely populated country such as the Netherlands, public acceptance is key. Research on noise, safety & third party risk and integration with existing infrastructure is required to determine and improve the public acceptance of urban air operations.

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