2019 IFAR White Paper on Urban Air Mobility

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Content

Introduction

This White Paper summarizes the discussions of the IFAR Members at 2018 IFAR Summit regarding the topic of the Urban Air Mobility (UAM). The members identified an eminent research demand regarding UAM in three topics:

- Safety standards of vehicles and operations
- Emitted noise during operations
- Social acceptance through customers as well as the affected population (public confidence) on the ground during operations

These three research pillars are crucial for an accelerated market diffusion of this new and promising field of UAM and should therefore be a focus of possible multilateral research cooperation within the IFAR community.

The paper is fully endorsed by:

- Aerospace Technology Institute, ATI, United Kingdom;
- Czech Aerospace Research Centre, VZLU, Czech Republic;
- Central Aerohydrodynamic Institute, TsAGI, Russia;
- Chinese Aeronautical Establishment, CAE, China;
- CSIR-National Aerospace Laboratories, CSIR-NAL, India;
- French Aerospace Lab, ONERA, France;
- German Aerospace Centre, DLR, Germany;
- Italian Aerospace Research Centre, CIRA, Italy;
- Japan Aerospace Exploration Agency, JAXA, Japan;
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- Polish Institute of Aviation, ILOT, Poland;
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- Von Karman Institute for Fluid Dynamics, VKI, Belgium.

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1. Business Models

Recent discussions on the future development of cities count on the 3rd dimension when it comes to handle increasing mobility and ever growing cities. Advances in technologies and the worsening of the traffic situation stimulate phantasies about future urban life. Hobby drones are already sold around the world and now the question is what we can expect if these drones are eventually able to transport people and goods on a safe, reliable and cost-efficient basis. This medium- and long-term market offers a number of potential business ideas and models.

The discussions on possible business models are based on the assumption that in general the related technology is matured, that there are no major show-stoppers, and that required technologies can be developed in sufficient time and the corresponding budget can be raised. Furthermore we considered not only passenger transport but also sending cargo and other urgent items by air services. Additionally not only intra-urban mobility is assumed but also inter-city traffic is part of the discussion.

The development of UAM is an evolutionary process which is starting from more or less existing infrastructures. Therefore it is assumed that the very initial introduction of especially PAX services is more likely between cities (or the remote airport and the city center) rather than transport within the city. The kind of transport initially introduced seems to be very much dependent on the city, its location, the specific area, the city's traffic infrastructure and the general environment. The service model---in contrast to the ownership model---is the prime target for the majority of potential business opportunities for urban air mobility. And safety and environmental issues are assumed to be solved and accepted by the public.

The following list of possible business models follows without further details of the respective positive business case, missing technologies or general chances for success. The listing is neither setting any priorities, nor considering difficulties of introduction or operation. The various business models are grouped in order to present a clearer overview of the wide spread opportunities in this new market of air transport:

1.1. Cargo / Freight Services

- Low-cost intra-city parcel delivery service
- Premium transport of high priced goods /express freight
- Off-shore freight services
- Luggage service to / from airport

1.2. PAX Services

- Recreational PAX drones or sight-seeing drones with the advantage of more easily achieving public acceptance of the new technology (especially pilot-less operation)

- Regular PAX services intra-city (Uber-like service)
- As the ground traffic will not really be reduced by one or two person drones a „Flying-Bus“ (4 to 8 PAX) is to be designed, build and operated
- Premium services for special (VIP) customers – condition based pricing
- Many unexpected events (weather, ATM, etc) can disrupt services so that alternative modes of transport have to be provided for the customer (multi-modal service provider)
- PAX transport to hotels
- Opportunity to build hotels or other venues outside cities (lower cost) and transport PAX into cities as required
- PAX transport from rural areas into the city
- Inter-city transport

1.3. Infrastructure Services

- Engineering, building and operation of appropriate places for take-off and landing – Vertiports.
- Energy service provider (batteries etc) for drones
- All services which relate to MRO (maintenance, repair, overhaul)
- Provide training services for all personnel involved (pilots, ground crew, safety, etc)
- Combine drone parking services with MRO
- Design, build and market personal delivery pads for drone service (internet-deliveries)
- Recycling services

1.4. Medical, Search and Rescue Services

- Medical drones for transport of blood, medication, tissue samples, organs, etc.
- Fast transport of defibrillator to accident locations
- Disaster relief by transport of urgently needed material, inspection, etc.
- Rescue services in case of car breakdown
- Rescue services from ships

1.5. Supportive Businesses

- Cyber security provider for the entire operation
- Design, build and operate „Anti-drones“
- Provide advertisement services to inform the customer during all phases of transport (exploring routes, calling air-taxi, flying, paying etc.)
- In order to make air taxis look attractive special design is offered (external, interior)
- Service Apps which track potential customers and offer near and easy air transport
- All services around insurance of drones

1.6. Inspection and Monitoring Services

- Various kind of inspection tasks like forest fires, pipelines and other infrastructures
- Border control and surveillance,
- Monitoring and control of city traffic
- Various police applications

2. Social Acceptance of Urban Air Mobility

Safety is the top priority factor for the social acceptance of UAM solutions. While users already trust in technology and are excited to use it, proving safety is especially critical for non-users which have to be convinced regarding the novel mode of transportation.

Social acceptance derives mainly from the following aspects:

Safety: The technology has to be safe. One safety failure may build social resistance delaying technology introduction by a decade or so.

Noise: Most of citizens will not agree to increase current levels of noise in the cities. Actually current trends calls for noise pollution reduction. UAM technology has to address this challenge by introduction of low-noise-emission solutions.

Airspace management: Air Traffic Management (ATM) is a big topic calling to answer questions how to manage significant number of objects in third dimension in space layer close to citizens' heads. Will people accept autonomous vehicles or is a pilot still required.

Weather: Management system has to guaranty safe operation also in bad weather conditions.

Data security: The system management may require significant amount of data to perform properly – technology providers have to ensure users that their personal data is secure.

Security – terror attacks: The UAM technology potentially might be utilized to organize terror attacks. Society has to feel that the system is secured from bad-intentions interception.

Value for money / Cost of the service / Accessibility: People won't accept a technology impacting significantly the city which will not be accessible for most of the society. The economical factor plays critical role – the cost of the journey has to be tolerable for a regular citizen.

"It has to make sense": UAM should not be an ideology – it should be means of people everyday life improvement.

Perception / Emotion: Traditionally, some people are attached to own a personal vehicle. Moving towards autonomous system may create their resistance.

Side picture / City appearance / Aesthetics: A swarm of flying objects occluding the sky in the city might be considered by some as anaesthetic or disturbing.

Environmental impact: Society will not accept a new technology which will have adverse impact on the environment.

Modality: UAM has an integral part of multimodal means of transport.

Other identified factors: Passenger comfort, health of the society, age of potential users, trust in technology.

Facing these obstacles will be a key aspect of the success of UAM applications. Hence, potential solutions have to be presented, which e.g. can be grouped in three main areas as follows:

2.1. Safety/security

- Most of the participants agreed that the community should aim at high safety levels – potentially the same as currently existing in civil aviation.
- The vehicles should start operation in the uninhabited areas and with cargo to lower down the risk of people injuries during potential early failures.
- During the discussion the opinions varied if the system should start with manned or unmanned air vehicles. One argued that autonomous system is safer as it eliminates human factor while others claimed that manned vehicle feels safer.
- Research is needed on how to certify aerial vehicles. Community should find all possible safety threats and come up with a comprehensive certification procedure. Modelling and simulation should be applied to create robustness.
- The UAM community should educate people about the safety level.
- The system may start in a small pilot city to prove safety and robustness.
- Community should highlight examples showing that UAM is safe.
- Promotion actions – e.g. free travels.
- The access to the vehicles should be controlled to increase security levels.

2.2. Noise

- Design for low noise. The low-noise criterions should be one of the critical factors during the air vehicle design process. Front edge design tools and technologies should be included.
- If the low-noise technology is not mature yet – a research should be done to develop new knowledge.
- Identify the target acceptable level of noise and frequency. Some medical or social surveys should be performed in order to define the noise and frequency levels which will be accepted by the citizens. Some knowledge can be leveraged form other industries. Most participants argued that existing city noise levels should not be exceeded.
- Test air vehicles in real environment and ask society for impressions.
- Create tools to factor the noise.

2.3. Perception

- Introduce the idea gradually. Start for public services (e.g. Ambulance). People will have time to get used to new mode of transportation. Acceptance will spread bottom-up.
- Communicate “why we do it”. Show benefits to the whole community.
- Educate people about the safety levels of technology. For social acceptance important is not how safe is the mode of transport but how society perceive the safety level.
- Lobby and educate in pop-culture.
- Do not introduce it as a luxurious toy, but rather as a solution for the whole society.
- Probably there is no universal solution to convince societies around the world. Understand local specifics and develop dedicated solutions for different cultures, generations etc.

On the basis of these areas and in order to apply the actions mentioned before, three main recommendations can be formulated:

1. **To identify and encourage authorities that will educate people and make them want to have UAM.**
2. **To generate comprehensive certification procedure and create robust system.**
3. **To identify acceptable sound level and frequency / annoyance level.**

3. UAM Orchestration – Arrangement, Coordination and Management of UAM Operations

The topic of UAM Orchestration is intended to generate ideas and solutions on the arrangement, coordination and management of UAM Operations. Therefore it is discussed by generating potential uses cases which form the basis for the remaining discussions on UAM Orchestration.

3.1. Use Cases

UAM Orchestration puts a focus on generating a diversity of use cases that would constitute potential UAM Operations. These uses cases form the basis to discuss challenges and solutions around the remaining aspects of this topic.

The use cases include:

- Goods transport
- Public services: ambulances, fire brigade, surveillance, blood transport, diplomatic documents delivery
- Taxi service (including ride sharing)
- Tourism
- Flying “Bus”
- Personal air vehicle: for a small minority
- Mobility of aging community
- Disaster relief
- Transport to hospital from remote areas
- Point-to-point intra-city
- Inter-city transport for distances beyond 50 km
- Feeder network to city trains

Due to the envisaged costs of UAM solutions, most experts share the view that the opportunity for Personal Air Vehicles is a niche with significantly lower volumes than other applications which would be enabled through ownership by large companies, financial houses or public service entities. Goods delivery presents an opportunity to de-risk and mature the technology as a first step. Challenges to be addressed to enable widespread adoption of UAM include:

- Transit and times to transit between transport modes for public commuting needs to present a saving in overall commuter time in comparison to current transport modes.
- Safety and certification of the platform is a key enabler for this transport mode.

- UAM requires successful integration of an Unmanned Traffic Management System into a classic Air Traffic Management System to enable safe air operations.
- Cost and affordability. There needs to be a fine balance between time and cost. Cost cannot be justified if time benefit is small especially after transit time is considered. However, there are use cases, without cheaper alternative road transport solutions, in which case cost is smaller barrier to adoption.
- Public acceptance is critical for long term success.

3.2. Infrastructure

A focused discussion on infrastructure yielded the following critical aspects for consideration:

Transit time: Transit time through proposed vertiports must present an overall saving in transit time of this transport mode in comparison with current transport modes. Management, safety and ease of commuter traffic through the proposed vertiports is a critical factor to be considered.

Energy: Practicalities of delivering requisite energy to charging stations need to be addressed. Handling of energy storage systems, time to make battery changes, time to discharge/recharge batteries as well as feasibility of achieving through life cycle environmentally friendly charging were also raised.

System and platform logistics: System diagnostics for timeous fault finding, maintenance of infrastructure and platforms and availability and turn-around time for delivery of spares were identified as issues to be considered.

Emergency services: Coordination with emergency services and enabling the work of emergency services in the event of failures was highlighted as an issue to be addressed.

3.3. Air Traffic and Air Space Management

There are various modes of travel including scheduled point to point operations, on-demand travel as well as free flight modes. These must all be considered in the development of ATM systems and procedures. There is a widely held view that a classic ATM will not suffice to integrate UAM operations. A fully automated ATM or platform is not feasible in the short to medium term.

Operations need to be augmented to enable safety. Air traffic management requires sharing ATM between UTM operators and government (or government appointed operators). A UTM must be expanded to include UAM operations. Real-time data transfer from the platform as well as information exchange between classic ATM and UTM operators is a key enabler to achieving the requisite safety of operations. Allocation of pre-determined corridors can be potential solutions to UAM operations.

Perfectly autonomous vehicles are unlikely in the short to medium term. Vehicles require augmentation (e.g. sensed breaking) to enhance safety of the platform in the short-medium term.

4. Possible Powertrain & Energy Storage Technologies Based on the Current Developments

The field of possible powertrain and energy storage technologies was intended to generate ideas and solutions on the utilization of current technologies as well as a possible outlook on needed technologies in the near future. Technical solutions will be depending on the mission-type for the envisaged vehicle, the needed power demand as well as the infrastructure.

As the main mission type cannot be foreseen by now, three representative missions are defined:

1. Package delivery
2. Emergency medical services (EMS)
3. Passenger transport (PAX) services

Also, criteria are defined to assess potential powertrain and energy storage technologies. These are:

- Emitted and perceived noise
- Flight distance during the respective mission
- Maximum take-off mass (MTOM)
- Public acceptance, both passengers and ground affected public
- Reliability and maturity of the propulsion technology
- (Already established) certification procedures regarding airworthiness
- Environmental conditions during operation (VFR, temperature, etc.)
- Interface possibilities at the vehicle as well as on the ground infrastructure
- Maintenance aspects regarding each technology
- Charging / fueling time

The identified energy sources for UAM applications are:

- Batteries (Li-Ion, Li-S, Li-Po, …)
- Fuel cells (hydrogen or methane powered)
- Ultra- and supercapacitors
- Kerosene, Avgas, LPG, CNG, PtL
- Alternative fuels like design fuels and biofuels
- Solar power
- Cryogen power
- Compressed air

Regarding a possible propulsion system solution for UAM traffic, the following architectures and motors were taken into account:

- Electrical motors (incl. control and cables)
- Piston engines
- Turbine engines
- Compressed air motors
- Rocket engines
- Distributed electric fans
- Hybrid systems

IFAR sees hybrid systems as the most promising technology in terms of maturity and applicability in the near future. Sole electric solutions for vertical lift for PAX services need some more years till availability. But there will be a mid-term range availability of sole electrical solutions. Also, superconductivity is one important technology (to replace copper), but today it's not mature, together with the electronic power control system.

Although members conclude that convertible-like configurations present a high complexity grade, having a negative impact on cost and maintenance activities (as in order to allow UAM a fast market entry, technical solutions with lower complexity grade will be prioritized), two promising solutions for EMS and PAX services can be tiltwing or tiltrotor configurations, allowing vertical take-off and landing abilities. This would minimize the needed infrastructure (vertiports, helipads, etc.) but still increase the power efficiency of the overall vehicle design as those systems can fly in conventional aircraft modes during cruise. Here, hybrid systems like gas turbines plus electric power drives can play a tremendous role to achieve those ambitious goals. The question about which type of hybrid system (e.g. serial, parallel) will be the most promising and most appropriate in terms of UAM solutions needs to be discussed in the near future.

5. Novel Approaches for Certification and Regulation of Highly Automated Unmanned Systems

In order to generate ideas and solutions regarding possible certification and regulations procedures of unmanned systems operating in UAM scenarios, ten subtopics are presented as a framework for future discussions:

1. Development, organization approval
2. eVTOL certification and specification
3. Type certification
4. Production organization approval
5. Airworthiness certificate
6. Operation certification
7. Maintenance organization approval
8. Continuous airworthiness
9. Pilot license
10. Starting and landing infrastructure approval

Out of these subtopics a lack of safety and certification procedures for highly automated (autonomous) vehicles can be identified as these aircraft still possess a low maturity level. As these vehicles will probably operate in low altitudes in urban scenarios, it is mandatory that these systems will have a high level of automation and even a conditional based autonomy standard for onboard situation awareness. The needed technical and regulatory requirements are still in research both by private and public entities worldwide and must converge into a worldwide valid standard. The overall system reliability during operation is the main driver of this, but is still not addressed in a quantitatively value.

Main impact factors for the overall system reliability were identified as:

- Operating scenario space including operation costs
- Possible needed all-weather operation capability
- Design of the air traffic management and regulations for UAM operations in urban areas
- Certification of manufacturing processes
- Certification and proof of concepts for needed subsystems (e.g. Detect and Avoid) which are needed for highly automated and conditional based autonomy operations
- A manageable level of system complexity

IFAR sees its role as

- **the main driver for the development of certification procedures** – both for vehicles and ATM structures, and
- **the leading innovator for new subsystem technologies** – such as Detect and Avoid systems, safe and reliable communications links, and many more.