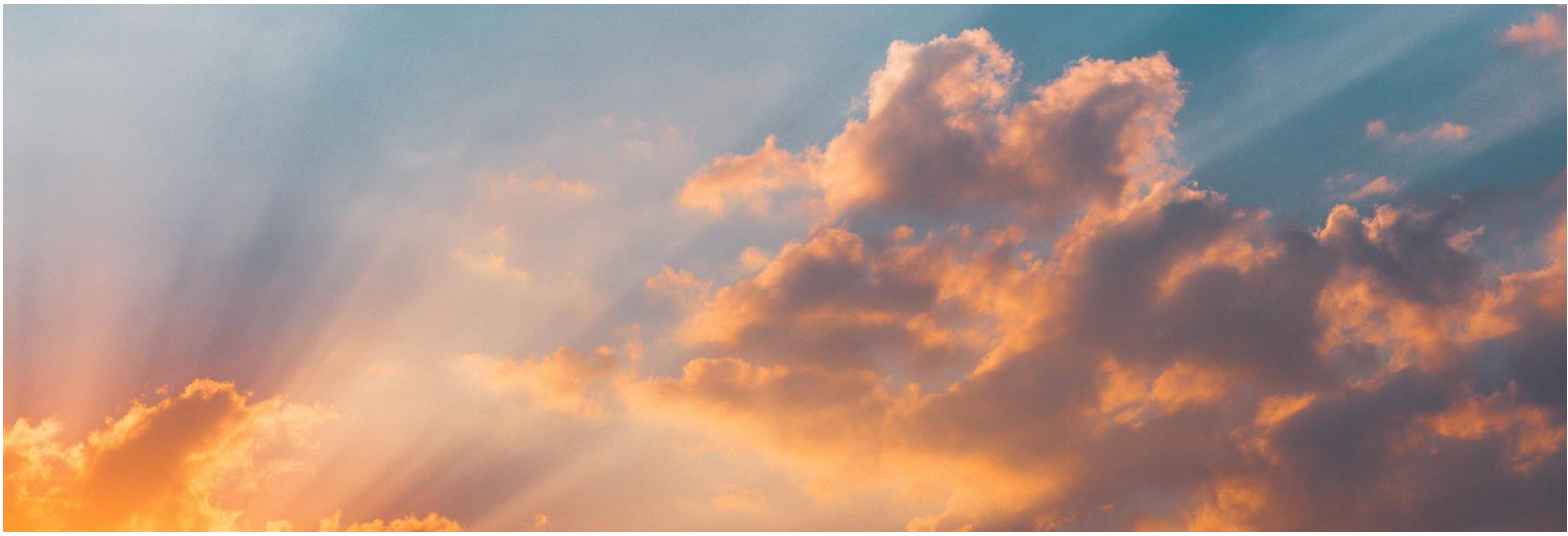

Zero Emission Future Urban Air Transport - who has the lead?

To achieve ‘Zero Emission Future Urban Air Transport’, rather than considering just the ‘air vehicle’ in isolation as the means to achieve this result, it is important to recognise that the means of transport is just one element of what could be defined as a highly complex system of interdependent parts. All elements of the system will need consideration, if collectively the objective of zero emission urban air transport is to be truly delivered.

By way of introduction a zero emission urban air transport system will need a vehicle and propulsion system that’s designed to carry passengers and or cargo. The power source and recharging of that power source must not emit greenhouse gases. A flight control system that controls the aircraft. Avionics that manage the flight controls, navigation, vehicle management, collision avoidance and safety protocols. Other software that allows scale, interoperability and profitability. An infrastructure for the vehicles to operate to and from. An air traffic management system for unmanned vehicles in low level airspace. A regulatory system that protects the public from harm and facilitates the developing market.

Prior to addressing what might be expected from such a system that will deliver ‘Zero Emission Urban Air Transport’, we firstly give thought to what might be defined as a Complex System given the component parts above.

“Complex systems[1] are chiefly concerned with the behaviours and properties of systems. A system, broadly defined, is a set of entities that, through their interactions, relationships, or dependencies, form a unified whole. It is always defined in terms of its boundary, which determines the entities that are or are not part of the system. Entities lying outside the system then become part of the system's environment.”

After 40 years as a military and civil fixed wing and rotary wing pilot, I can list the set of entities, the interactions required and their dependencies. In my view, the system is complex as it meets the criteria that the system behaviour as a whole cannot be inferred from its properties / component parts. What can be inferred, however, are the attributes of how the system is expected to behave, which can be identified as:

1. Safety – no harm to any person or property working with or using the system or the environment around it.

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[1] https://en.wikipedia.org/wiki/Complex_system

2. Reliability – the system works as expected from the perspective of all stakeholders, the Government (integrated policy), the regulator (oversight), the investor(s), the owner / operator, the support service providers and the service users.
3. Resilience – the system can absorb and recover from external inputs such as weather events, technical grounding events, regulation changes and the inevitable "black swan". A black swan event was first described for the finance sector but applies to any sector. It is an unpredictable occurrence that has severe consequences.

In fact, we will have multiple systems, each with different entities, that will change the behaviour of the system which in turn will require different risk mitigations from stakeholders to make the system safe, reliable and resilient. As an example, urban air transport is likely to be all electric or hydrogen powered whereas international air travel will likely use conventional jet power fuelled with a sustainable but nevertheless hydrocarbon-based fuel.

So, what discrete and independent technology will be required for these complex systems to be safe, reliable and resilient, as well as "Zero Emission"? These can be described as follows:

1. The air vehicle itself, this includes all the components and source of power.
2. The software that controls the air vehicle and all the vehicle components and systems.
3. The software or artificial intelligence that controls the airspace that the air vehicle is in so that there are no collisions, the flow of air vehicles is managed, and priority can be controlled.
4. The systems that provide support, flow of people and baggage, "refuelling" in the context of hydrocarbon, hydrogen or electricity, technical support, flight check-in and security.

Success will require a lot of new, and in many cases, integrated technology. As I write this article, I can find dozens of different urban air mobility vehicles at various stages of design, test and certification. I am sure individually they will work, but where is the system that allows them to work together and in the live environment? Individual vehicles certified as safe, reliable and for sale are not going to be of much use in what will evolve to be a complex system without the system being designed as well.

As the basis for this is technology, we need to look at how technology maturity is measured. If we understand what system technology is necessary for (safety, reliability and resilience) then we can assess the maturity of that technology through Technology Readiness Level (TRL) and take a view on the overall system maturity.

The National Aeronautics and Space Administration (NASA) invented TRLs in the 1970's for use on space programs. Without going through the full evolution, The International Organization for Standardization (ISO) adopted the TRL scale with the publication of the ISO 16290:2013 standard. I acknowledge this TRL is designed for space programs, but it is also acknowledged that in a broad sense the TRL framework can be applied outside of the space environment.

In my view, the single biggest risk currently unmitigated, and on the trajectory of being realised, is the siloed development of what has to be an integrated system. This is evidenced by the application of TRL on what is going to be necessary. There is no single 'guiding mind' as to the perceived wisdom of what this system will look like, which gives rise to a lack of integration by design.

The air vehicle (including all the components and source of power)

In my opinion, this is at TRL 8 – there are vehicles available that are "flight qualified". They have been certified for flight with passengers, however, the technology is not flight proven in actual operations. Context is everything, I do not mean that passengers have not been carried, I mean the vehicles are not operating in an integrated environment with other airspace users carrying passengers and cargo for a fee.

It is easy to assume that the software is at TRL 8 along with the vehicle, however, I do not believe this to be the case. In my view, the software is at TRL 6 as it demonstrates the critical functions in a relevant environment. My questions related to an effective system are:

a. How does the software avoid a collision with any other type of air vehicle, especially those without transponding devices?
b. How does the software fail safe? There will be component failures, fires, loss of signal to name a few, as there is no pilot in control, only software, how does the system allow for failing in a safe manner?
c. How is the security of the system maintained against unlawful interference?

> "There is, in my view, little point in having a safe, reliable and resilient vehicle to sit in if the environment it operates in is not safe"

Outside the vehicle

Outside the vehicle the system will need:

a. Infrastructure where the vehicle lands and departs, management of the flow of people and cargo, security, maintenance and additional required services provided.
b. Dynamic airspace access through geofencing.
c. Oversight of the flow, an urban form of air traffic control, but not control in today's sense of the word. Oversight is more akin to today's slot system. With small passenger numbers revenue will come from a high volume of flights.
d. Sense and avoid technology.
e. Vehicle interoperability technology.

The TRL of systems outside the vehicle is much lower, descriptions such as TRL 3 – "proof of concept", or TRL 4 – "verification in a laboratory environment" would be more realistic. Yet for the system to work in a safe, reliable and resilient manner, technology outside the vehicle needs to be at TRL 8 "flight qualified" or in layman's terms – available and working. The basis for this assessment is my knowledge of what would be required and research on who is developing what and where.

The systems that provide support

The saying "if you build it they will come" is true. But this will not assist with the creating of a safe, reliable and resilient service. It will create the conditions for firefighting on one side and commercial opportunity on the other side. This is today's airline model. The provision of services to an airline is not core business to the airline and whilst some have the scale to provide their own services by and large this is not the case. This drives a race to the bottom in practically all aspects of support and you get what you pay for. As a very experienced airline captain I can tell you that the sense of relief when the wheels come up as you zoom skywards is palpable.

The nub of this is that the TRL of the vehicles is way ahead of the other essential system components. This will lead to bespoke services where the volume of potential customers leads to infrastructure, airspace and operational solutions approved by the regulating authority with a ring fence built around the operation. This in turn will become the proving ground and "external laboratory" for technology development. What could possibly go wrong? Flight Global recently reported that Airbus Helicopters intends to be the "voice of reason" in the emerging market for electric vertical take-off and landing (eVTOL) aircraft, arguing that the industry is making too many unrealistic promises about service entry" – I could not agree more.

The answer to my question, “who has the lead”, is no one. Even the two world leading regulating authorities, The European Aviation Safety Agency (EASA) and the Federal Aviation Authority (FAA), are getting out of alignment. This has occurred before to the commercial advantage of FAA approved machines. EASA is consistently setting higher design standards in areas such as energy storage, crash resistance, thrust unit failures and blade fragmentation / failure than the FAA. In essence, EASA certified machines will be safer to fly in and FAA certified machines will perform better.

There is, in my view, little point in having a safe, reliable and resilient vehicle to sit in if the environment it operates in is not safe, does not allow for reliable day to day operations, and has very little resilience when poor weather or black swans come over the horizon. A black swan reflects an extreme rarity which cannot be predicted. What can be predicted is that they will occur and there will be more of them in the first years of live operations.

Conclusion

I do not believe this new sector of aviation is heading for disaster. Ultimately, all problems and difficulties will be resolved, the system in time will be made to work. So why do I believe those involved today are making the introduction and development of this market difficult? The answer lies in the machines – they look really good, innovative, clever, shiny, new, exciting, special and any other superlative adjectives. Investors want to be part of the action, engineers want to build them, business people and the public alike want to sit in them. However, terms like “geofencing”, “sense and avoid”, “vehicle interoperability”, “concept of operations”, “risk and safety management”, simply do not generate the same adjectives, but the system itself will not work in the way the public will expect without them.

Having articulated the problem I would like to add my emergent thoughts on some of the steps that can be taken to drive integration and develop the necessary operating environment.

- Cargo operations first this will drive forward the ‘whole system’ technology without harm to people.
- Accelerate system technologies to align with vehicle technologies.
- Europe needs an equivalent to NASA’s Advanced Air Mobility mission that will provide substantial benefit to U.S. industry and the public with this emerging market.
- Address the imbalance in investment – more needs to go into the technology outside the vehicle.

I expect to see disputes over this in the future as expectation and safe, reliable and resilient delivery are mismatched.

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