GUIDE TO URBAN AIR MOBILITY

INTRODUCTION

Global manufacturers and suppliers continue to invest billions in electric cars, and the concept of mass electric vecicle (EV) adoption seems to be quickly morphing from far-off notion into an imminent reality. As quickly as electric cars have become part of our lives, another seemingly futuristic idea is gaining momentum.

We may be on the cusp of another electrification revolution – the electric urban aircraft.

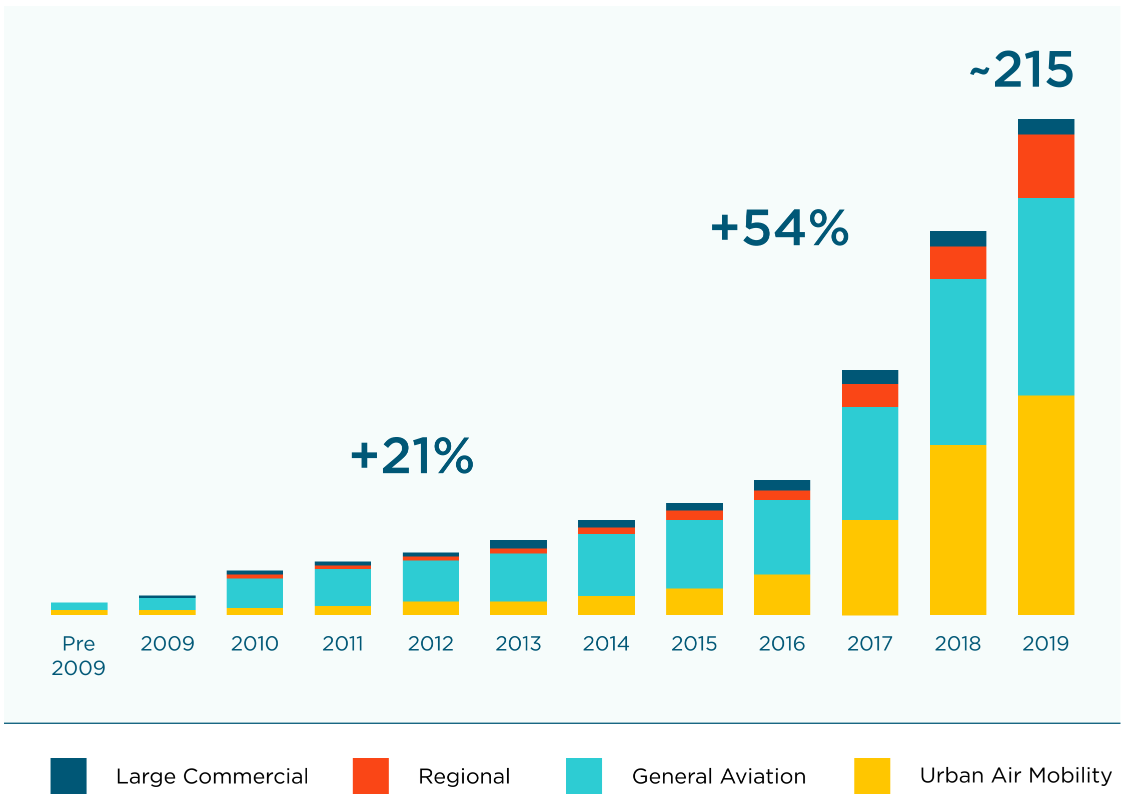
Urban air mobility (UAM) is a point of convergence for automotive and aviation organizations. This presents opportunities for collaboration between the industries, with air taxis being of particular interest. Intended to transport a few customers at a time, avoid congested streets over short distances, and reduce pollution, this category of aircraft is often envisioned as an electric vertical take-off and landing (eVTOL) vehicle. Startups and established OEMs alike have begun moving past ideation and into the development stage for these next-generation aircrafts.

Challenges to Realizing Urban Air Mobility

With great promise also comes myriad technological, logistical, and regulatory hurdles. UAM operators have technical and financial challenges to consider in order to ensure business viability. Regulators and government agencies need to ensure safety and environmental benchmarks are met while controlling airspace. And consumers must actually adopt it. If consumers don't feel safe, they won't fly, so a positive public perception of quiet, efficient, and safe UAV industry is key to the adoption of this novel mode of transportation.

This guide takes a focused look at the most pressing of these challenges and highlights the exciting technology that may make urban air mobility possible sooner than you might think.

KNOWN ELECTRICALLY PROPELLED AIRCRAFT DEVELOPMENTS*



*Only including developments with first flights after 2010; excluding unmanned electrical vehicles and rcreational developments. Source Roland Berger / Electric Aircraft Database

Thompson, Robert. (2020) “The number of electrically propelled aircraft developments grew by ~30% in 2019”. Roland Berger. 15 January 2020. https://www.rolandberger.com/en/Point-of-View/Electric-propulsion-is-finally-on-the-map.html. Roland Berger GmbH. Accessed 16 May 2020.

RANGE AND PAYLOAD

Meeting range and payload targets is critical to viable UAM business. The aircraft must be capable of covering the range of interest to passengers and must deliver desired passenger-miles per recharge. In order to move people effectively, urban eVTOLs must be able to carry the weight of its battery, propulsion system, and its cargo far enough to meet passenger's travel needs.

Concept Design

Detailed Design

System Integration

Model-based System Engineering

There are typically hundreds of mission requirements in the design of an aircraft. Each are technically complex in their own right, and some even conflict with each other. Below is a partial list of these mission requirements

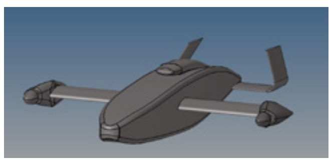
- Range
- Payload
- Distance to recharge
- Time to recharge
- Passenger-miles between recharges
- Safety
- Redundancy
- Noise
- Max speed
- Minimum hovering capability
- Size
- Weight
- Cruise speed

A methodical Model Based Systems Engineering (MBSE) approach enables OEMs to find trade-offs among conflicting requirements to determine system specifications for the aircraft.

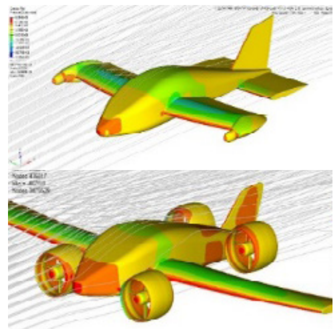
MBSE entails designing a vehicle for given mission requirements. A partial list of mission requirements includes range, payload, distance to recharge, time to recharge, passenger-miles between recharges, safety, redundancy, noise, max speed, minimum hovering capability, size, weight, cruise speed, and so on. A UAM vehicle may be required to satisfy hundreds of mission requirements. A methodical MBSE approach enables design engineers to find trade-offs among those mission requirements to determine system specifications for the aircraft.

US Naval Air Warfare Center: Navigating the Complexities of a System of Connected Systems

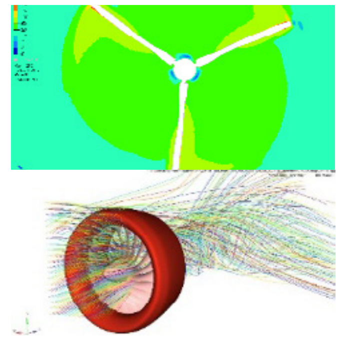
Let's investigate an example of application of MBSE to evaluate different types of drone propulsion systems and determine which propulsion best meets the mission requirements. This exercise was performed in support of US Naval Air Warfare Center's System Engineering Transformation (SET) Initiative. The goal here was to select the right propulsion system from two alternatives using an MBSE model. While this is a simple proof-of-concept model to demonstrate MBSE, real-life models would have many additional design variables. Variables would include the number and locations of rotors, the dimensions of all aerodynamic surfaces such as wings, flaps and rudder, the number, size and location of batteries, the number of motors in a rotor, and size of a propeller.



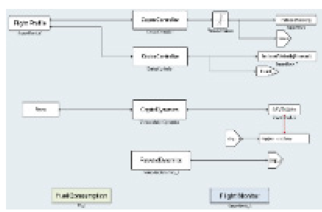
Initial Concept



Wing CFD analyses with tiltrotor (top) and ducted fan(bottom)



CFD analysis of tiltrotor (top) and ducted fan (bottom)



2D dynamic model in Altair Activate™ of the aircraft as a system – includes input form an array of CFD analyses of 2

Result of Vehicle System Optimization using Altair Active™, Altair Compose™ and Altair HyperStudy™

Vehicle systems specifications is the starting point for physical design of the vehicle. The first step of this design process would involve building a 1-D system model for optimizing the vehicle performance. This 1-D model would include mathematical models of each system in the vehicle. These models are parameterized, and the model is optimized for desired performance by varying those parameters. This optimized vehicle model provides specifications for designing each vehicle system.

Minimize Overall Vehicle Weight

Planes with minimized weights that also meet the criteria of strength, safety and noise would help meet the primary requirements of all the stakeholders. Lightweight planes would enable operators to increase the payload. Lower weight also helps reduce the size of the e-propulsion powerplant, which, in turn, leads to lower operating cost and quieter operation. It can be further leveraged to reduce the battery size, which would help reduce time to recharge.

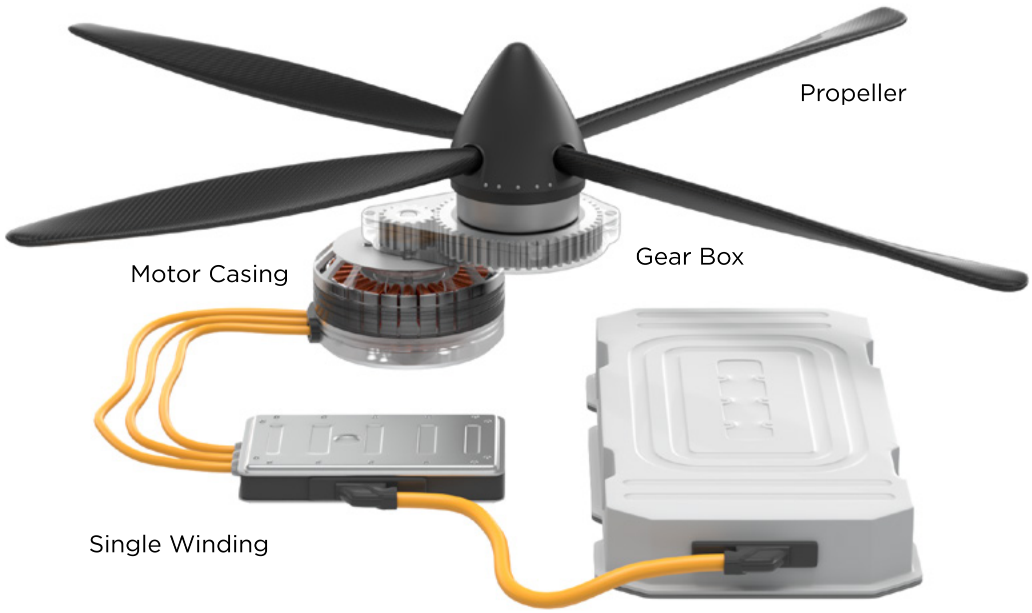
Structural optimization methods have long been used in the aerospace industry for designing light weight structures that meet structural performance requirements. Topology optimization is a key technology used in the process of structural optimization, developed to optimize structures considering design parameters like expected loads, available design space, materials, and cost. Embedded early in the design process, it enables the creation of designs with minimal mass and maximal stiffness.

This drone, developed by Maeer's Maharashtra Institute of Technology in Pune India, is a great example of topology optimization applied to reduce vehicle weight.

See the Customer Story

Design Efficient E-propulsion Systems

An efficient e-propulsion system is key to meeting mission requirements in a UAM vehicle. This system consists of five primary subsystems: Battery, Inverter, Motor, Gearbox and Propeller/Fan. The e-propulsion system can be optimized using MBSE processes similar to that of the vehicle system optimization. This leads to specifications for each subsystem, which can be addressed using multiphysics simulations and optimization.



Improve Battery Life and Charge Time

Battery power density, energy density, safety and charging time are the biggest hurdles in the UAM industry achieving its promised potential. Current lithium-ion battery technology simply has not yet reached the performance required to fuel practical urban air transportation. Vertical takeoff requires massive amounts of electrical power, which strain current Li-ion batteries to the point that they have little power left for the remaining flight and landing. Enough power must be reserved to complete the scheduled flight, plus additional reserves in case of rerouting or emergency scenarios.

Batteries must also be designed for fire-avoidance under impact or thermal runaway scenarios. These safety requirements are achieved using advanced simulations such as impact and coupled thermal and CFD simulations. Structural optimization would play a key role here in designing light-weight battery structures while meeting safety requirements.

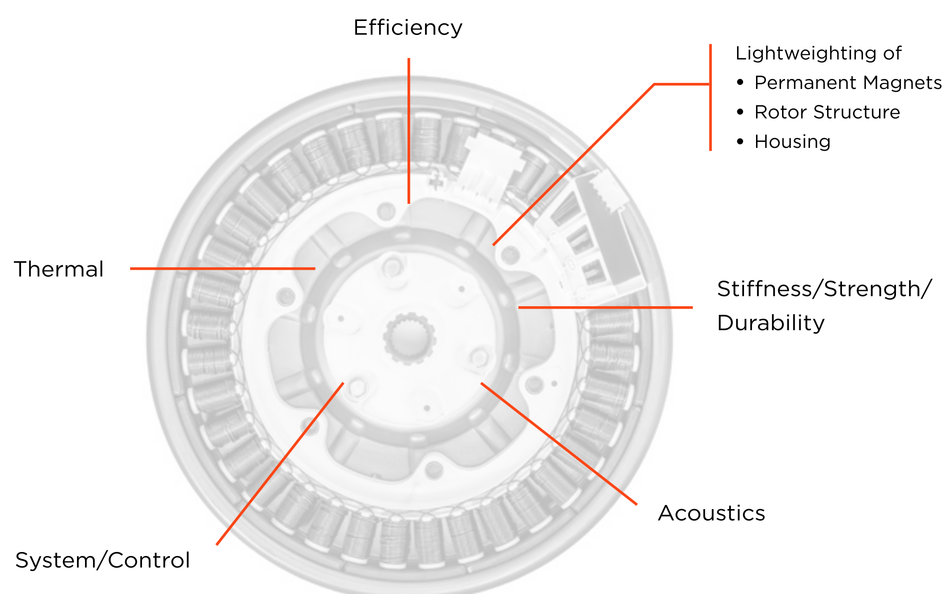
Automotive leaders like Hyundai and Toyota are investing in the aircraft space, so cross-industry collaboration could be a key to unlocking future battery innovations.

e-Motor Design

In order to extend the range of electric aircraft, the best place to start is the motor. Understanding how design decisions influence the thermal, mechanical and electromagnetic attributes of motor performance is critical to optimizing the efficiency of an e-propulsion system.

In the automotive domain, many organizations including the advanced drivetrain development team at Porsche AG, have the challenge of improving the total design balance in e-propulsion motors. This development challenge is answered with a multiphysics approach. The classical motor efficiency/power design problem is coupled with other physics to account for thermal effects, structural boundary conditions and vibrations. Simultaneously, detailed motor rotor stresses, motor vibrations and motor temperature are analyzed to drive design. The design process accounts for both individual motor design points (e.g. max torque) and evaluation across standardized duty cycles using reduced order models based on data provided by high-fidelity models from expert analyst physics simulation and optimization tools.

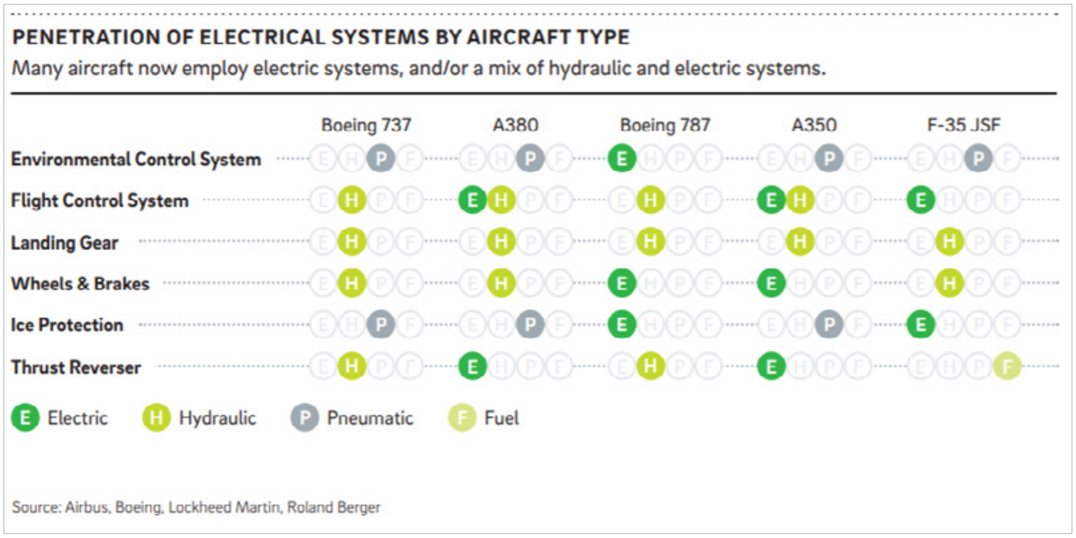
Read the Porsche AG technical paper



Multiphysics Design Loop

Power Electronics and Controls

Whether for ground or air transportation, it is important to consider power electronics and controls when refining the design of a motor through simulation and optimization. Idealized sinusoidal inputs are appropriate for developing concepts but modeling the pulse width modulation (PWM) of modern power electronics is important to the later stages of development. This type of inverter model combined with a representation of the current and speed controller will produce harmonic content in the inputs. The degradation of the inputs from ideal to realistic will reveal losses and torque ripple in the machine. In turn, the losses effect motor efficiency and the thermal behavior. Torque ripple is a cause of speed variation and NVH problems. Combining the high-fidelity model of the motor with a circuit simulation and the control algorithms is essential to achieving optimal system performance.

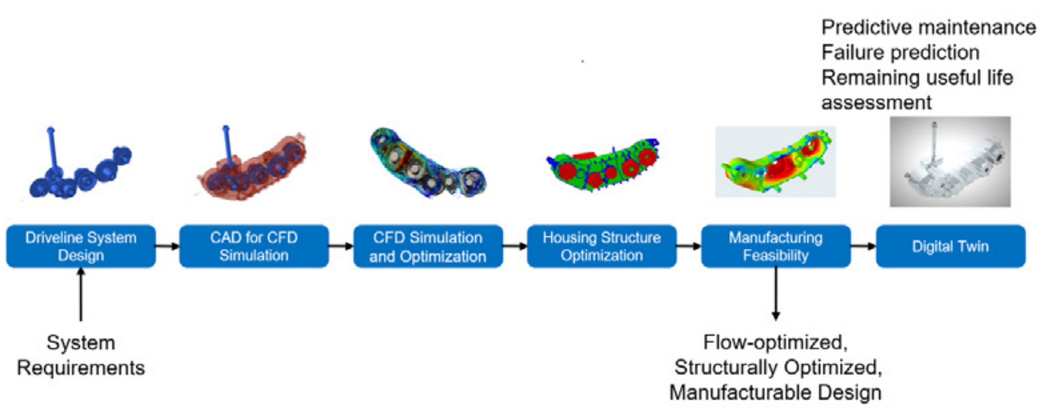


Thompson, Robert. (2017) "New Developments in Aircraft Electrical Propulsion". Roland Berger. 10 October 2017. https://www.rolandberger.com/en/Publications/New-developments-in-aircraft-electrical-propulsion.html. Roland Berger GmbH. Accessed 16 May 2020.

Gearbox Design

Design of aircraft gearboxes are one of the longest lead time items in aircraft design. It must meet stringent requirements of efficiency, thermal management, noise, safety and weight. Gearbox design challenges have been typically addressed using heuristic approaches, combining physical experiments and tests. This approach contributes to longer lead time and higher costs due to requirements for physical prototyping and multiple redesign iterations.

Recent advances in simulation technology, especially in gearbox oil flow simulation, has helped minimize physical tests needed to design gearboxes. The example below provides a simulation and optimization-based design workflow demonstrated on an aircraft engine accessories gearbox.

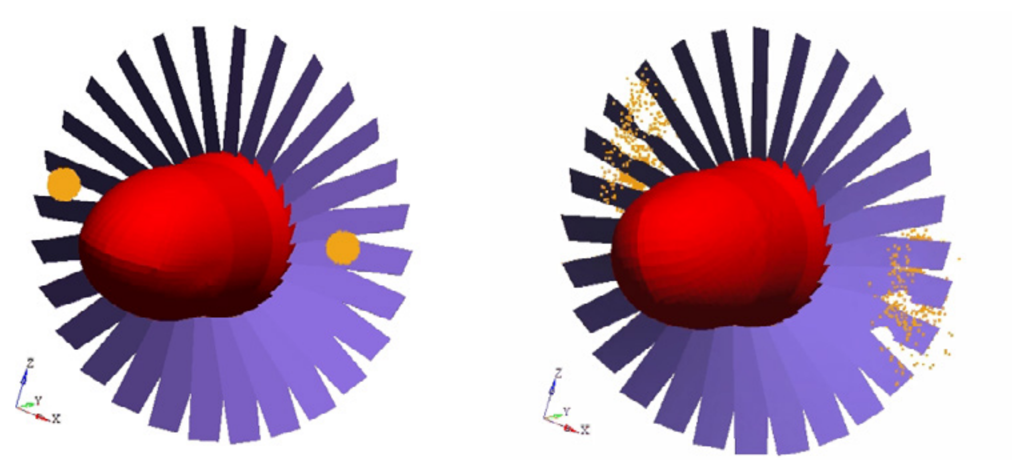


Propellers

The rotors/propellers of an eVTOL are a critical component providing both thrust and lift. Composite design techniques applied to the rotor blades of helicopters enable these parts to deliver the required strength-to-weight ratio, while exhibiting excellent characteristics for damage tolerance and fatigue life.

The use of simulation in the design process enables engineers to take advantage of laminate composite anisotropy to match the required load cases and the required stiffness. Analysis techniques inform design decisions by proposing optimal ply shapes, optimal number of plies, and the optimal ply stacking sequence. Modeling enables timely studies of static, modal, frequency response and dynamic performance of the rotor to be performed during the development process.

Rotor blades must meet safety requirements such as bird-strike and hail impact. The blades and aircraft fuselage must also be designed to ensure that aircraft fuselage is not compromised in a blade-out scenario.



PUBLIC ACCEPTANCE

Earning the public trust is pivotal for the realization of urban air mobility. Nearly a third of American adults still report a fear of flying, despite air travel being significantly safer than cars, statistically. Additionally, the introduction of noise pollution and air traffic leave many decisions to consider before making this new mode of transportation a reality.

Noise

If you've heard a helicopter, you know that they produce a tremendous amount of noise. In order to operate regularly in densely populated areas, the eVTOL of the future will need to be designed to minimize noise generated by the propellers and even tune the pitch of the sound they produce to meet an acceptable threshold for passengers, people near takeoff sites and under flight paths, animals, and the native and built environment around these routes.

e-propulsion systems are significantly quieter than the equivalent turbine engine. Hence, industry is investing heavily in e-propulsion for aircrafts.

We can simulate the radiated noise from rotors and the vibroacoustic effects on the surrounding environment using statistical energy analysis. This insight allows designers to predict how much sound is produced by an eVTOL and even how the sound is perceived both outside and inside the aircraft cabin.

Environmental Impact

Replacing fossil fuel transportation methods with battery-electric vehicles offer massive emission reduction possibilities. The reduction of the transportation industry's carbon footprint alone is instilling massive excitement among governmental agencies, environmental advocacy groups, and members of the transportation industry.

There are factors, however, that could negatively affect the environment that require further study. With increased air traffic, migratory patterns of local bird populations could be affected. Noise could also have adverse consequences on plant and animal populations in and around flight paths. Additionally, more work is needed to improve recycling and disposal practices for old battery packs.

SAFETY

In the end, it all comes back to safety. If the public at large is to confidently adopt eVTOL flight as a regular mode of commuter transportation, these vehicles need to meet regulatory standards including fail-safe design, but also win over the court of public opinion. Only a combination of advanced technology and systems in collaboration with seamless coordinated networks of trained professionals and infrastructure can ensure that these vehicles reach the skies. Through extensive virtual and physical testing, and with rigorous governmental, local, and industry oversight, I feel confident that I will have the opportunity to ride an urban air taxi in my lifetime.

> "We absolutely recognize that if we don't get that right, then the whole thing falls flat. Cost, noise, safety, privacy: There's excitement, but there's also apprehension around the unknown. That's understandable. As a new industry, we have plenty of work to do."

Oliver Walker-Jones, Head of Communications, Lilium

Poulton, Jeff. (2019) "Startups are pioneering a new industry that's looking to take short-distance travel to the skies". Roland Berger. 16 July 2019. https://www.rolandberger.com/en/Point-of-View/Looking-at-the-future-of-urban-air-mobility.html. Roland Berger GmbH. Accessed 16 May 2020.

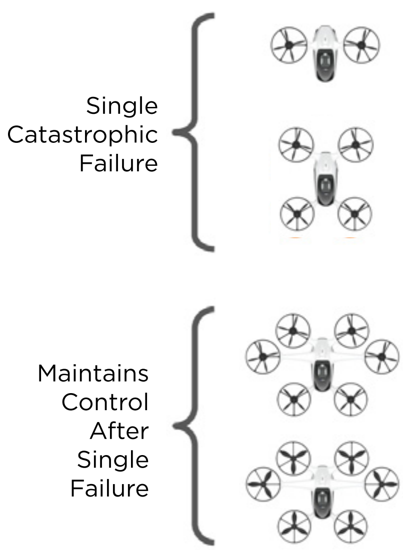
SAFETY AND REGULATION

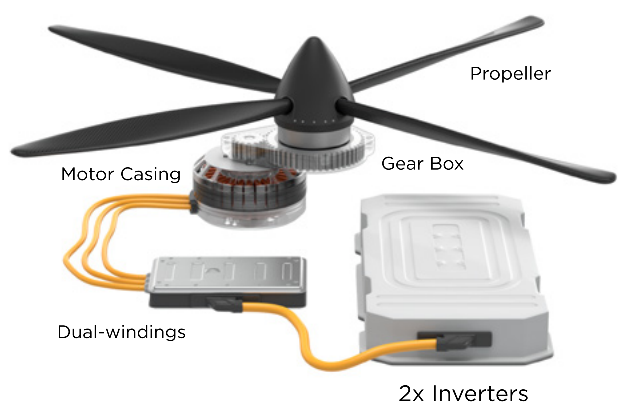
Fail-safe Design

Safety is the number-one priority of aerospace engineers, so the design of an eVTOL's motor and rotor systems must incorporate redundancy to avoid a single failure turning catastrophic. At the motor level, designers are exploring duel-windings and duel-inverter systems so the propeller system can still function if an individual component fails during operation. Further redundancy can be introduced at the rotor level, where the addition and strategic placement of more rotors allows an aircraft to maintain airworthiness even if one of the rotors suffers a failure event.

Designers are also exploring the incorporation of rotor-powered aircraft with winged designs. Although still using helicopter-like vertical takeoff and landing techniques, winged aircraft are less noisy in operation and can glide in total failure scenarios, making them safer to fly and easier to certify.

Additional motor components and rotor systems does introduce additional design complexity. To accurately model and understand the behavior of these complex multi-motor systems, system modeling and motor control technology help engineers simulate mechanical product aspects with electrical aspects (in 0D, 1D, and 3D) and leverage automatic code-generation for embedded systems.



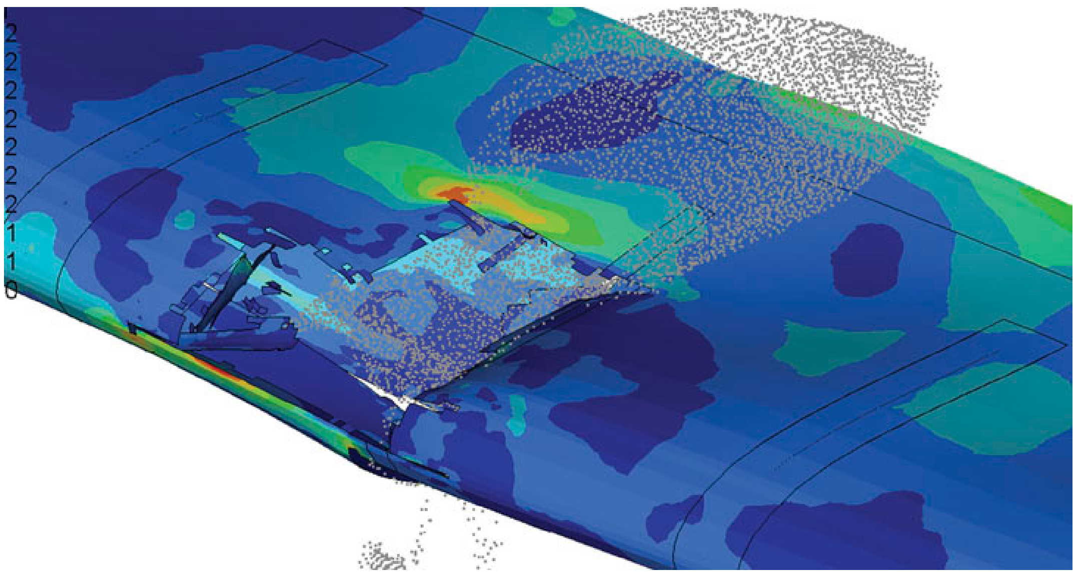


Impact

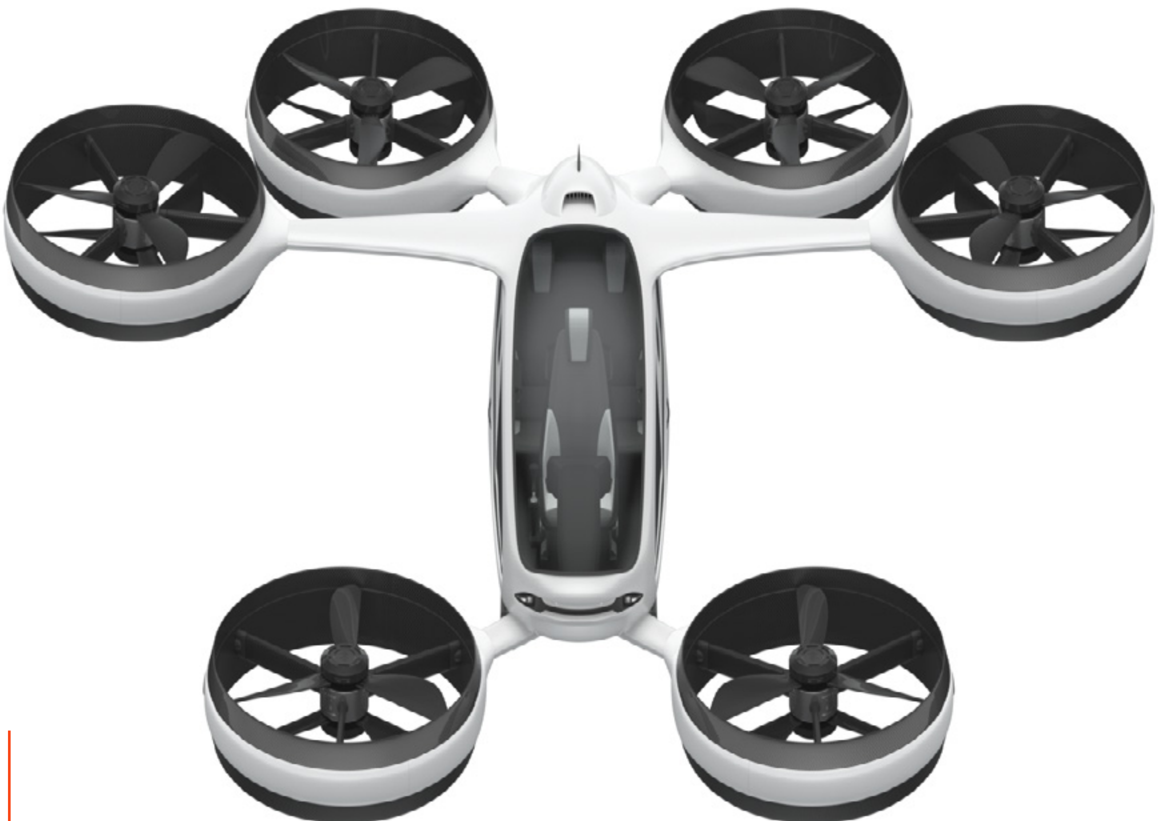
The structures and advanced materials used in eVTOLs need to not only stand up to the rigors of normal use but withstand unexpected impact, collision, and shock events as well. Hail, lightning, bird strike and other factors need to be virtually tested to ensure the aircraft is safe even under extreme conditions.

Because of the immense cost and logistical challenges of physical prototyping in the aerospace industry, simulation software is used to model the nonlinear structural behavior of metal and composite materials in impact scenarios. Altair technology has even helped NASA develop wireless sensors to detect lightning strike damage to composite aircraft, a technology that could be useful to urban air mobility vehicles as well.

The aircraft structure must be designed to operate after sustaining a certain level of damage. Such fail-safe structures can be designed using topology optimization as described earlier.



Simulation of bird strike on composite aircraft wing



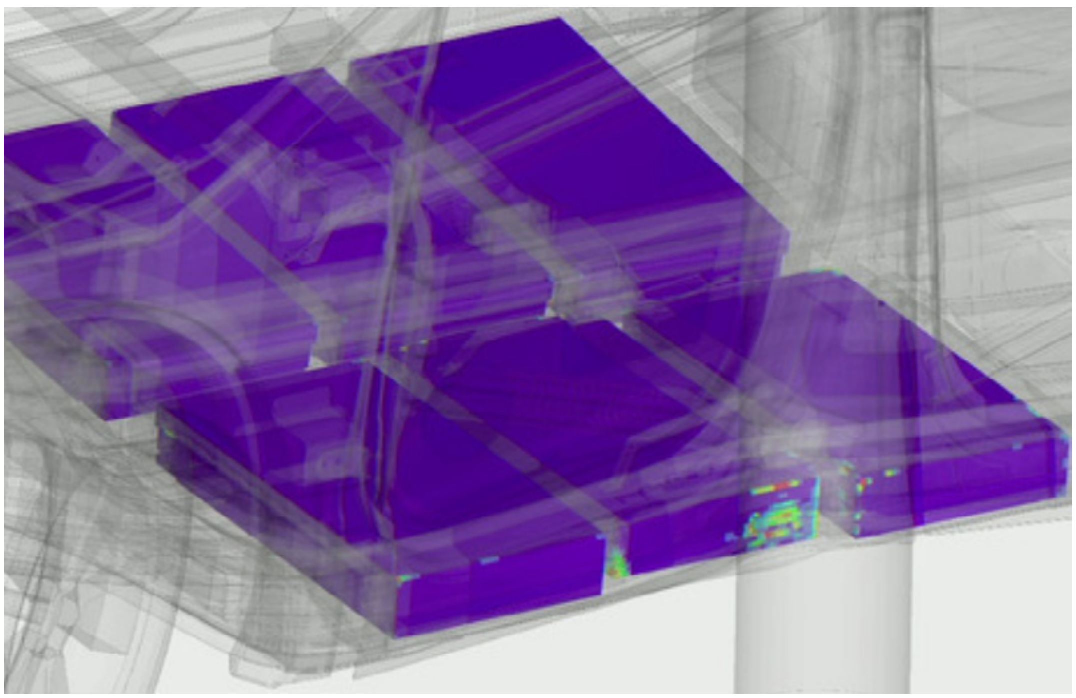
"People are starting to envision a multimodal transportation system, where urban air mobility will be an integral part. Adding another dimension to avoid road traffic will let you choose the best mode of transportation to get from point A to point B significantly faster."

Dhiren Marjadi, Altair VP of Global Aerospace Business

Battery Safety

Thermal runaway occurs when the rate of heat generated within a battery pack exceeds the rate the heat can be expelled. This phenomenon can lead to battery fire, which is obviously extremely important to prevent in the design of eVTOLs. The complex chemical, thermal, and structural properties of thermal runaway can be simulated in order to predict overheating scenarios and design systems that mitigate the risks.

Completing these safety simulations accurately overnight is critical to being first to market. Modeling battery impact with traditional FEA methods is computationally expensive and can't support this timing. The Altair Battery Designer project is an investment in validated safety simulation modeling that includes batteries and modules for crash events, impacts, shocks, and penetrations. This initiative will develop a software tool derived from directed research and multiphysics optimization. Altair Battery Designer initiative will consider the mechanical, electrical, electrochemical and thermal physics of the battery cell, module, and pack under exceptional mechanical loads to predict safety risks and prevent short circuits, thermal runaway, and combustion.



Read the white paper on predicting and preventing EV battery fire

Logistics

Combination of UAM aircrafts and drones require a solution for system of connected systems. We will not be able to depend on air-traffic controllers to guide the flight paths of each aircraft. Data analytics, radio frequency simulation, terrain mapping and machine learning will be key for the complex coordination of urban air travel. Internet of Things and digital twin technologies also offer exciting possibilities for predictive maintenance, telling operators when to service aircraft to maximize useful life and reduce failure risks.

Additionally, further technological advancements and testing are needed before autonomous passenger aircraft becomes a possibility. The introduction of many more human-operated aircraft will require many more trained pilots than currently exist in the workforce. Pilot shortages will necessitate an acceleration in training and certification of pilots and specialized eVTOL maintenance professionals.

"Air taxis are definitely the next phase of mobility. Urban centers across the globe are struggling to come to terms with the rising vehicle numbers and the resulting congestion, especially during peak traffic hours.

When air taxis become widely commercialized, they will definitely ease the traffic burden on city roads. They will usher in a nimble form of intracity travel, transporting people on the shortest possible route between two locations."

Joe Praveen Vijayakumar, Senior Industry Analyst at Frost & Sullivan

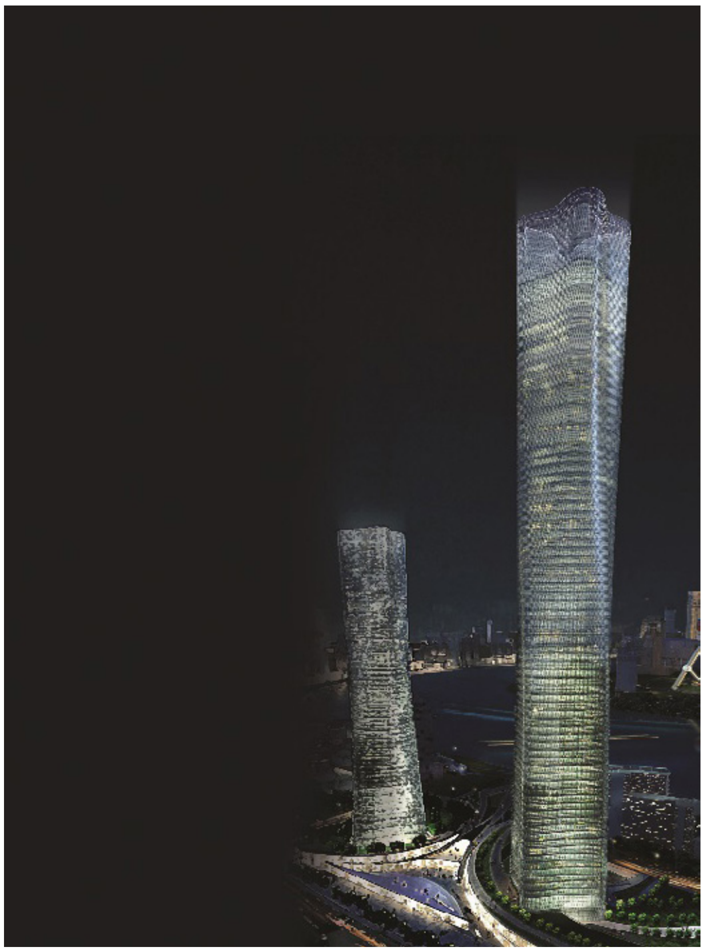
Hornyak, Tim. (2020) "The flying taxi market may be ready for takeoff, changing the travel experience forever". CNBC. 07 March 2020. https://www.cnbc.com/2020/03/06/the-flying-taxi-market-is-ready-to-change-worldwide-travel.html. CNBC LLC. Accessed 16 May 2020.

Infrastructure

Although air travel removes many of the infrastructure hurdles of ground transportation like road construction and maintenance, there are still many considerations to plan for. Cities will need to build a network of vertiports for eVTOL take-off and landing that enable fast charging and seamless passenger onboarding and offboarding.

The electrical power requirements of charging stations could cause additional strain on electrical grids if not properly managed. Tools like Altair Flux™ can be used to aid in the design and analysis of energy generation, transmission and distribution equipment.

In addition to user experience, vertiports will be required to meet stringent structural safety requirements that would include potential bad landings. Structural optimization technology described earlier in this document equally applies to architectural structures such as vertiports.



FROM THE DESK OF DHIREN MARJADI, ALTAIR VP OF GLOBAL AEROSPACE BUSINESS

"Dr. Dhiren Marjadi has more than 40 years of experience in the field of simulation-driven design and engineering. His early career focused on structural optimization, helping steer product strategy for renowned analysis software Altair OptiStructTM. Marjadi is now responsible for developing and implementing strategy for growth in Altair's business in the aerospace industry globally."

Why is urban air mobility and specifically electric vertical take-off and landing aircraft generating such excitement? What benefits could this new mode of transportation mode have for urban commuters?
Marjadi: In many cities, traffic congestion can add hours to people's travel time. Public transportation systems may also be limited in terms of where they go and may be inefficient for longer journeys outside the central downtown area. People always want to travel faster from home to work, work to home or anywhere else, and with the rise of on-demand mobility concepts like Uber and Lyft, people are seeing the convenience and financial benefits of mobility-as-a-service, which circumvents many of the costs and maintenance considerations of vehicle ownership.

I think whenever people can spend less time in transit, that is exciting to them. People are starting to envision a multimodal transportation system, where urban air mobility will be an integral part. Adding another dimension to avoid road traffic will let you choose the best mode of transportation to get from point A to point B significantly faster.

There are many new mobility initiatives outside of UAM, from automotive transportation-as-a-service models to autonomous cars, to high speed train concepts like the Hyperloop. Do you see UAM supplanting other new mobility concepts, or do you envision, as you said, more of a multimodal transportation future?
Marjadi: Rather than one catch-all solution, I believe mobility will be augmented by multiple transportation options. If you want to go from your home somewhere, you may first ride an electric scooter to a nearby vertiport and take a flight, or you may call an Uber to a train station depending on your location and destination. It could be any combination that will help you get from point A to point B faster, and air transportation will fill an important dimension that existing options struggle with.

For example, if I want to go from my home in Massachusetts to Washington DC, I have a couple options. By car, it's about a nine to ten-hour drive, but parking costs and ample public transportation in DC make having a car while I'm there unnecessary.

The fastest and most convenient way to DC for me is by commercial airline, but the one hour drive during Boston rush hour could easily turn into two hours or more and put me at risk of missing my flight. With UAM, I could call a ride-share car service from my home to take me to the closest vertiport in my town, then take an urban air mobility flight to the airport in just a few minutes.

COVID-19 has some reconsidering the ride-sharing model. Do you see this perception as a temporary or permanent shift, and how do you see it impacting the future of UAM?

Marjadi: People travel by UAM is certainly being scaled back, but I see this as a temporary shift. My view, and I believe the industry's perception, is that as we advance global virus treatment and prevention strategies, the world will still move toward shared mobility models. The benefits in terms of the environmental footprint, personal time savings, easing of urban congestion, and cost to commuters remains extremely compelling. So, while public health remains paramount, I still see a bright future for UAM civilian transportation systems.

While travel by people has scaled back significantly across all sectors, at the same time, demand for the transportation of goods is going up. We are all ordering much more online and it's delivered directly to our home. Urban air mobility plays a significant role in that also.

The Amazon truck delivering packages to your house may soon be replaced by a fleet of drones, who pick up small packages and deliver to your doorstep. That is more energy efficient, quieter, more economical, and faster.

Another sector that is highly interested in eVTOL is the defense world. Because of its quiet nature, it's not easily detectable and could more covertly and efficiently transport goods and people to difficult-to-reach locations. The Department of Defense and defense companies worldwide are investing money in eVTOL vehicles for that reason.

You can even see it as great tool for disaster relief, getting supplies to a place that's been hit by a natural disaster. You can imagine a shipload of equipment could be taken to an area hit by a hurricane, then have food and medical supplies flown to locations inaccessible to ground vehicles. Even search and rescue missions could be dramatically better, replacing a few helicopters with a swarm of small drones that could cover an area within a few hours.

Why has electric propulsion been deemed the most likely method for powering urban air mobility?

Marjadi: Two primary reasons why companies are focused on electrical transportation systems are noise and environmental pollution. People do not want sound pollution in their neighborhood. If you want to put a vertiport next to my home, I don't want a helicopter with an internal combustion engine taking off and landing every 10 minutes. Helicopters have one to two rotors - they're very long rotor blades and they create a lot of noise.

Electrical propulsion is inherently quieter because of the quieter engine, but also the shift to a multi-rotor system. We call that distributed power. With more blades that are shorter in length, you can significantly reduce noise. We're talking about between 45 and 60 dB, which is roughly the level of noise you'd expect walking around in a city. It would blend into the sounds you hear in an urban environment.

People also don't want to have aircrafts creating a cloud of pollution around where they live. That's another reason why electric propulsion is almost a given for urban air mobility. Hydrogen fuel cells are a possibility, but there are issues around hydrogen storage. How are we going to store hydrogen in a crowded city? You don't want a huge tank of hydrogen or jet fuel on top of a building. The transportation and storage of hydrogen is going to be a big challenge.

What technical advances are needed in order to make electric-powered UAM a reality?
Marjadi: In the eVTOL world, the biggest challenge is creating a propulsion system that will deliver a higher number of passenger-miles between recharges. The current limitation is the power density and energy density of batteries. Those two numbers need to go up between four to 10 times in order to have a reasonable urban air mobility system. Battery research is first and the foremost.

We also need efficient and safe battery management. We need to make sure that there are no thermal runaways within the battery that could lead to fire. Safety will be paramount to ensuring the success of this business.

After that, efficiently using the battery power for efficient motor, gearbox, and propulsion system operation is the remaining challenge. I believe the technology already exists to achieve this but putting it all together is a complex undertaking. Model-based system engineering is the key to optimizing the hundreds of (sometimes competing) mission requirements that go into designing an aircraft.

It's been interesting to see how influential the automotive industry has been in the early investment and development of UAM. Can you comment about why automotive has been so eager to join the fray, and what unique expertise these companies bring to the business?
Marjadi: Since UAM vehicles are flying objects, the first initiatives were started by the aerospace industry. Aerospace companies have been working on this for nearly 10 years now in really a big way. The automotive companies, however, started getting in over the last three or four years. That's because Uber has changed the way the automotive world is working. The concept of owning a car is becoming somewhat outdated. People don't want to own a car anymore, especially in urban areas. It's becoming a pay-per-use economy for personal transportation.

Car companies see that urban air mobility is inevitable. It's going to come sooner or later, so they want to get a share of the revenue from this on-demand transportation. They see there is a whole lot of money out there. It's a completely new field - not really a car, but not a really a plane. It's something in between.

Both auto and aero industries have a lot to offer in this area, so they want to use their expertise to own a piece of the pie. That's why you see cross-industry partnerships forming to share knowledge and capitalize on this opportunity.

Adapting their methods to suit anticipated production volumes of the UAM vehicles will be a challenge for both aerospace and automotive industries. You might produce a few thousand planes over the lifetime of a model, whereas car companies are used to producing by the millions. UAM will fall somewhere in between in terms of the volume.

Aerospace companies must learn how to scale production and maintain efficiency, and the car companies have to learn how to make a lesser number of vehicles while still being profitable.

When considering mass adoption of UAM, the model of human air traffic controllers monitoring airspace doesn't seem scalable. How are regulators approaching safety challenges concerning airspace traffic?

Marjadi: Thanks to our commercial airline industry, the technology largely exists already. There is some autonomy that will have to come into the picture, which might seem scary at first, but when you fly today, your plane is flown almost 95% of the time in some sort of autonomous mode. Takeoff, landing, and taxiing are human controlled, but the rest of the journey is driven by artificial intelligence.

It's certainly not crazy to have trepidation about anything autonomous, especially with some highly publicized accidents in the early testing days of self-driving cars, but in many ways autonomous air travel has fewer safety hurdles and is very well controlled.

Unlike cars, you don't have to worry about pedestrians, or broken traffic lights, or obstructions like a fallen tree branch or an animal wandering into the road. If every UAM vehicle is given a predefined destination and a predefined path, called geo-fencing, that does not interfere with any obstacles or other flight paths and you build in tracking mechanisms, then all vehicles would communicate with each other when they are flying, especially while approaching close proximity. If they're all tied into a central control station with required levels of redundancies, then this can be a very, very safe environment to fly urban air mobility vehicles and drones.

Industry needs to get together and prepare that with the FAA, and I think that's the main challenge, but it's not something unsolvable. It will be a combined effort between manufacturers, localities and federal regulators, but they are all incentivized heavily to ensure the safest possible experience. The good part is that the technology and infrastructure already exist and will just need to be configured to deliver a solution.

Do you have any predictions about whether you'll personally take a UAM flight in your lifetime?

Marjadi: Actually, I think we all will be taking UAM flights within the next two to three years. Drones delivering packages are already happening in certain areas. You could say I'm optimistic, but programs are rolling out soon in Dallas, Los Angeles, Australia, Brazil… all over the world. I would imagine my first drone-delivered package will come to me within the next six months and I believe human transport is absolutely coming sooner that people think.

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