

FROM HYBRID TO HYDROGEN: DEVELOPMENT AND OPTIMIZATION OF AIR TAXI LAYOUT SCHEMES AND PROPULSION SYSTEMS FOR URBAN MOBILITY APPLICATIONS

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ABSTRACT

The rapid expansion of urban air mobility (UAM) is transforming the market of short-distance transportation, offering a sustainable alternative to ground-based transit systems. The first part of this paper analyzes various propulsion system layouts and aircraft configurations that have been proposed for air taxis, emphasizing their applicability in both passenger and cargo transport. A comprehensive review of existing eVTOL (electric vertical take-off and landing) designs is conducted, highlighting the advantages and limitations of hybrid-electric and hydrogen-based propulsion systems. The study explores the integration of new aerodynamic schemes, such as tiltrotors and flying wings, with advanced energy management strategies to enhance efficiency and flight range. Next, in the second part of this paper, a hydrogen-powered vertical take-off and landing (HydVTOL) aircraft concept, named XFlight, is proposed, in two transport options. The first has a hydrogen-electric power plant inside the body, while the second option has it outside the body. The XFlight design aims to offer greater flight range, higher cruise speeds, enhanced system redundancy, and zero harmful emissions, making it a more efficient and environmentally friendly alternative to current VTOL and eVTOL solutions. The findings underscore the potential of hydrogen propulsion in shaping the next generation of UAM vehicles, offering a pathway to greater autonomy, cost-effectiveness, and scalability in urban transportation networks.

Keywords

urban air mobility, air taxi, hybrid propulsion, hydrogen-powered aircraft, electric motor.

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Received 22.12.2024 • Revised 21.01.2025 • Accepted 18.02.2025

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INTRODUCTION

The rapid growth of megacities and continuing urbanization are pushing land transportation systems to their limits, necessitating new mobility solutions [1]. Transitioning urban mobility to airspace brings opportunities to create a faster, cleaner, more efficient transportation system. However, the successful adoption of urban air mobility (UAM) will depend on multiple factors of an economic, social, and regulatory nature [2]. Active discussion currently focuses on issues of aircraft safety, public acceptance, sustainability, and environmental impact, as well as legal regulation, scalability, flexibility, and functionality [3].

A primary application of new UAM capabilities lies in passenger and cargo transportation within urban environments, using a variety of vehicles, from small drones to passenger aircraft [4] [5]. In practice, all such vehicles rely on electrically powered vertical takeoff and landing (eVTOL) capabilities, powered by a variety of propulsion systems (PS), from hybrid systems to all-electric designs. However, selecting the optimal powertrain layout for UAM remains a challenge, as efficient energy management across the flight cycle is difficult.

Current research unfortunately indicates only minor improvements in fuel efficiency for hybrid-electric designs, as compared to conventional propulsion system designs. Furthermore, these marginal gains are contingent on future changes in onboard energy density, which can also be obtained by using hydrogen technology. Achieving significant improvements will require integrating onboard energy management with the design methodology of the aircraft. Therefore, the design and layout diagrams of existing and prospective UAM aircraft need to be studied in order to rationally integrate onboard subsystems for reducing the flight cycle cost [6].

THE AIM AND OBJECTIVES OF RESEARCH

The purpose of this study is to define a new design and layout scheme for a hydrogen-powered vehicle capable of performing various UAM functions.

The main objectives are as follows:

- to review the UAM aircraft market and analyzing the key characteristics of air taxis, including their vehicle configurations, design principles, and layout schemes;
- to propose a rational aerodynamic scheme for a prospective hydrogen-powered air taxi, designed for performing UAM functions in both passengers and transport applications.

LITERATURE REVIEW AND PROBLEM STATEMENT

Air taxis are emerging as a transportation solution for single individuals or small groups of passengers seeking to avoid urban congestion by utilizing airspace for everyday commutes [7]. By adopting the electric vertical takeoff and landing (eVTOL) concept, air taxis will be able to operate from skyports retrofitted on the roofs of buildings, offering significant advantages for integration into existing urban infrastructure.

Previous studies [8, 9] have extensively analyzed air taxi designs and configurations in the existing literature. Global research efforts have yielded eVTOL air taxi configurations that can primarily be classified into three basic categories (Fig. 1).

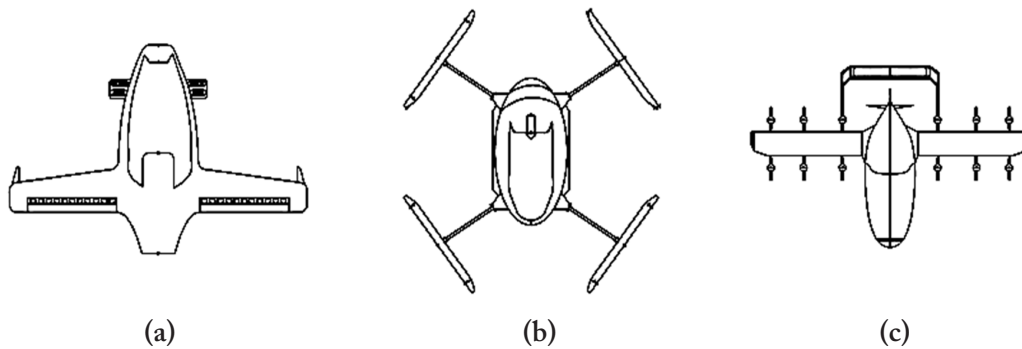


Fig. 1. The three primary eVTOL air taxi design configurations: (a) Vectored Thrust, (b) Lift+Cruise, (c) Wingless Multicopter [7].

The range of characteristics for air taxi configurations can be illustrated as follows, based on a selection of projects reported in previous studies (Tab. 1):

Table 1. Key air taxi design characteristics.

Characteristic	Vectored Thrust		Lift+Cruise		Wingless
	Tilt rotor	Tilt wing	Fixed horizontal	Fixed vertical	Wingless
Example of air taxi	<i>Bell Nexus</i>	<i>Air bus Vahana</i>	<i>Kitty Hawk Cora</i>	<i>Cartercopter</i>	<i>EHang 216</i>
Speed, km/h	288	230	180	282	100
Flying Range, km	241	100	98.8	256	35
Seating Capacity	4	2	2	4	2
Battery Density, kwh	50	40	63	300	110
Cruise Altitude, ft.	250	1,000	3,000	10,000	10,000

As previous studies have shown, each of these designs has its own distinctive strengths and weaknesses in terms of range, speed, passenger capacity, and environmental impact criteria. An optimized air taxi configuration must balance these factors while reducing operating costs across flight cycles.

NASA has proposed a set of conceptual designs for UAM aircraft that can be used for further research [10]; these concepts illustrate the diversity of eVTOL architectures currently under investigation and their suitability for different UAM missions (Fig. 2).

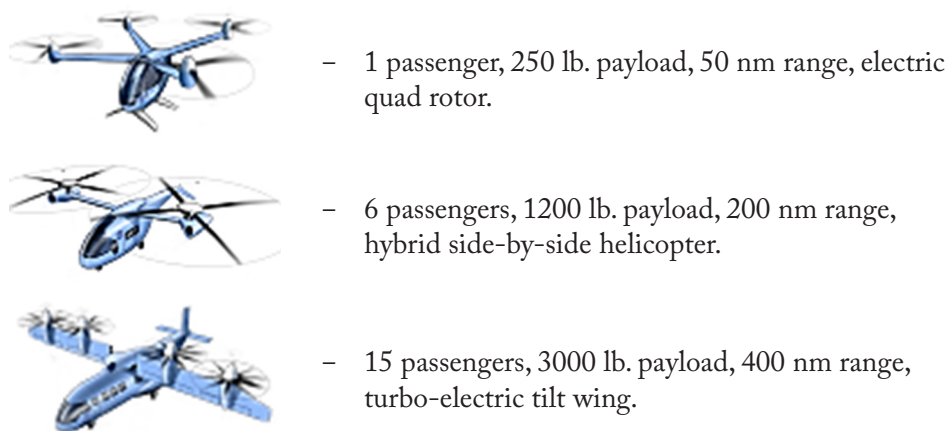


Fig. 2. Concepts of aircraft developed by NASA for UAM [10].

Three dominant eVTOL concepts have emerged, each suited to different operational needs, such as intracity and intercity mobility [10]:

- Tilt-Thrust: utilizing tilt wings or rotors for takeoff and cruise;
- Lift + Cruise: uses independent propulsion systems for takeoff and for forward flight;
- Multicopter: a wingless aircraft with multiple fixed rotors for take-off and cruising, controlled by tilting the glider.

Compared to conventional helicopters, with one main rotor and petrol engine, eVTOL aircraft are expected to be much quieter, more reliable, safer, and cheaper. Table 2 summarizes the main types of UAVs and their propulsion systems for flights at various ranges in urban environments [10].

A recent study [11] summarized current technologies and challenges facing the eVTOL flying vehicle market for urban UAM applications. It reviewed existing electric drone systems for both passenger transport and cargo delivery, classifying eVTOL projects based on their design, specifications and performance parameters. However, it did not analyze the benefits of battery vs. hydrogen technology, or provide a comprehensive assessment of the design schemes and their functionality.

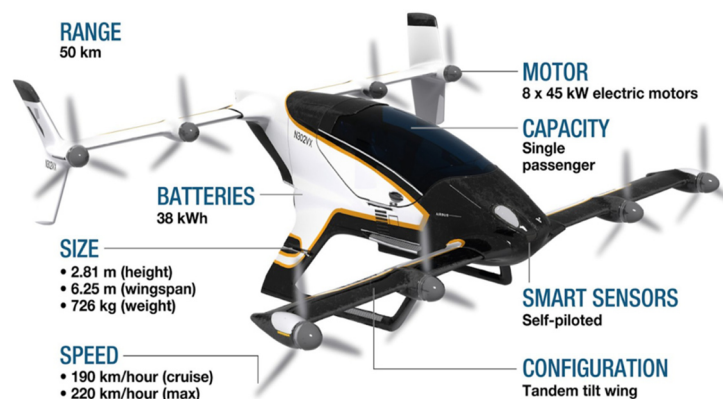
Table 2. UAV application concepts.

Number of passengers	50 nm trips per full charge/refuel	Market	Type	Propulsion
1	1 × 50 nm	Air Taxi	Multicopter	Battery
2	2 × 50 nm	Commuter Scheduled	Side-by-side (no tilt)	Parallel Hybrid
4	4 × 50 nm	Mass Transit	(Multi-)Tilt Wing	Turboelectric
6	8 × 50 nm	Air Line	(Multi-)Tilt Rotor	Turboshaft
15			Lift + Cruise	Hydrogen fuel cell
30			Vectored Thrust Compound	

To determine the most viable aerodynamic configuration and operational range for future UAM aircraft, a detailed review and analysis of existing and prospective air taxi designs is required. A key challenge remains in optimizing propulsion systems – particularly the integration of hydrogen-based solutions – to enhance performance while minimizing costs. This study aims to address these gaps by evaluating the feasibility of hydrogen-powered eVTOL designs for urban air mobility applications.

MAIN MOBILE VEHICLE PROJECTS

In 2016, Airbus launched the Vahana project (Fig. 3), as one of its first projects in Silicon Valley [12]. Vahana is quite close to realizing a convertible electric Airbus vehicle. Equipped with 8 electric motors with propellers, the aircraft is already performing flight tests in the United States. The aircraft is designed for single-passenger transport, operating on a predetermined flight path with slight deviations to avoid collisions with other aircraft. It is expected to achieve a range of 60–100 km, a maximum altitude of 1,500 m, and a cruise speed of 170 km/h.

**Fig. 3.** Vahana project [12].

Airbus has also developed the CityAirbus (Figure 4), a four-seat eVTOL designed for high-frequency urban transport, particularly for airport and railway station connections in areas with congested road networks. CityAirbus features four ducted propellers, enhancing safety and reducing noise emissions. With a cruise speed of approximately 120 km/h, the aircraft is designed to offer high-speed, cost-effective, and environmentally friendly urban transportation.

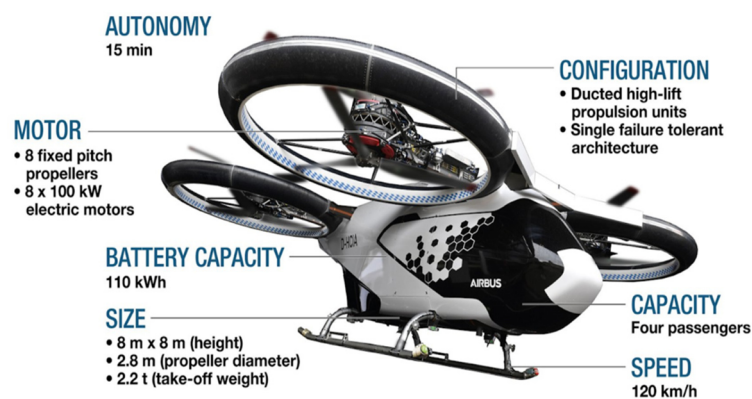


Fig. 4. CityAirbus project [12].

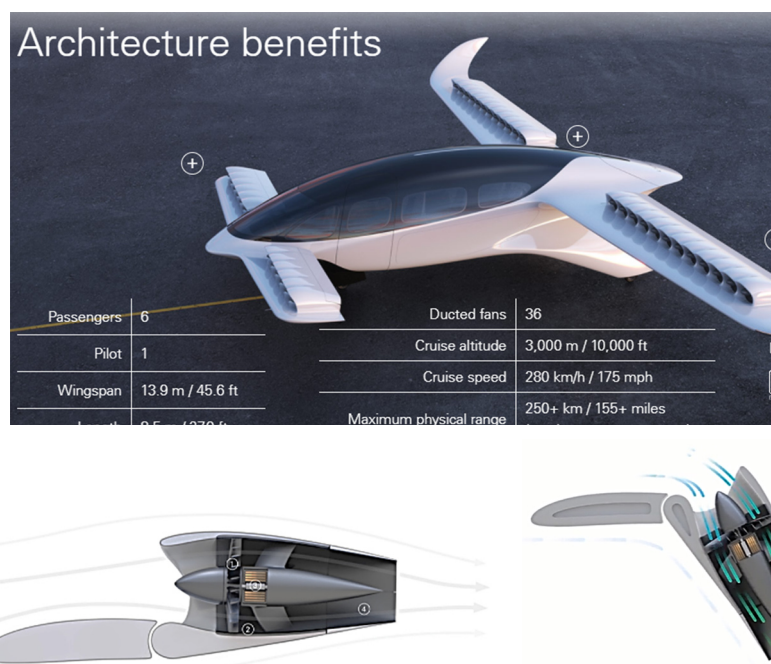


Fig. 5. Model of the 6-passenger serial Lilium Jet [13].

Since 2015, the German company Lilium has been developing patented eVTOL jet technology [13]. Through an iterative design process, four generations of prototypes have been built and tested, including a five-seat technology demonstrator. In 2018,

Lilium applied for type certification with both EASA and the FAA for the larger Lilium Jet, and work has started on a 7-seat aircraft that provides an environmentally friendly and affordable mode of high-speed travel. Fig. 5 shows the aircraft production model, which is scheduled for commercial operation after 2024.

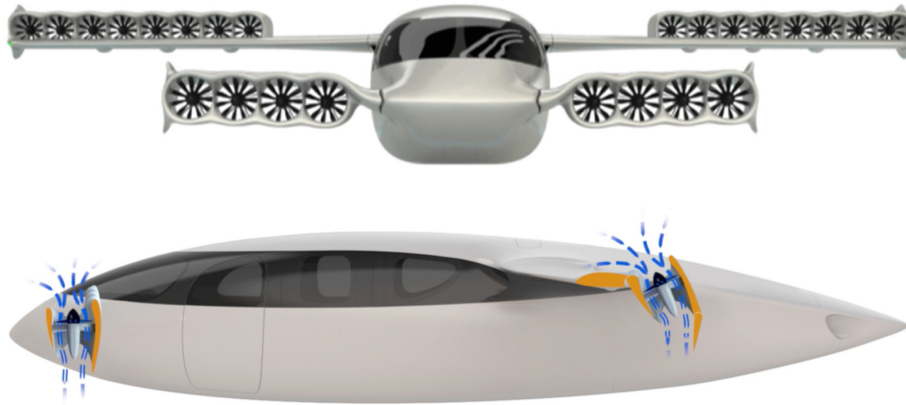


Fig. 6. The SiriusJet model with variable thrust vector [14].

SIRIUS AVIATION AG is developing an advanced aircraft with both eVTOL and high-speed horizontal flight capability [14]. This hybrid approach allows the aircraft to comfortably take off and land like a helicopter, and to fly as fast and energy-efficient as an airplane (Fig. 6).

The SiriusJet features deflected vectored thrust: a propulsion system that allows the jet to operate with low noise emissions. It has 24 ducted fans, 16 located along the wings, 8 mounted in the canard (Fig. 7), each powered by a separate electric motor.

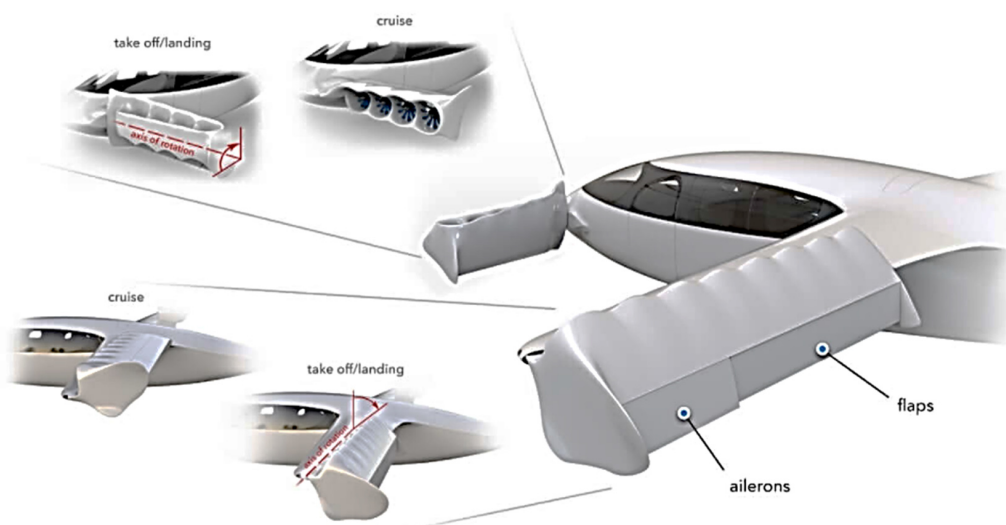


Fig. 7. The SiriusJet propulsion system [14].

The SiriusJet is being developed by a team of more than 300 engineers. The key specification of the SIRIUS 6-seater aircraft are as follows:

- flight distance: 240 km (full load);
- cruise speed: 310 km (at 10,000 ft);
- noise level: < 60 dB (lower noise than for an open propeller – the sound footprint is 100 times quieter than a helicopter's);
- passenger capacity: 1 pilot and 5 passenger seats; 1100 liters, 1.1 m³ (or ca. 39 ft³);
- cargo capacity: 1 pilot, 5100 litres, 5.1 m³ (180 ft³), max payload – 500 kg.

The cost-efficiency for a 100 km journey \$80 per passenger for the SIRIUS JET compared to \$400 per passenger for a helicopter. A trip from Zurich to Geneva, for instance, will take 45 min by a SIRIUS JET flight, but 3 hours by car, train or conventional aircraft.

In 2021, the Chinese company Pantuo Pantala showed a version of its air taxi called Concept H [15]. The aircraft features a streamlined fuselage, a large rear wing with upward-bent wingtips, and multiple rows of small electric motors along the wing (Figure 8). A distinctive feature of Concept H is its tilting wing system, which enables vertical takeoff and landing. This is achieved through 22 propellers, which have a much larger diameter than existing counterparts. The aircraft uses a standard cabin for 5 passengers. The declared flight range will be about 250 kilometers, and the maximum speed of the aircraft may reach over 300 km/h.



Fig. 8. The Pantuo Pantala Concept H project [15].

In 2019, Bell introduced an air taxi model for Uber [16]. The 5-seat NEXUS (Fig. 9) will be able to fly at speeds of up to 241 km/h. As a convertible aircraft, it will be able to carry passengers and cargo up to 450 kg. The Bell Nexus 4EX has four engines based on an electric or hybrid-electric platform, and is designed urban and suburban transport. The newly unveiled Bell Nexus 6HX, in turn, expands the scope of air mobility options.

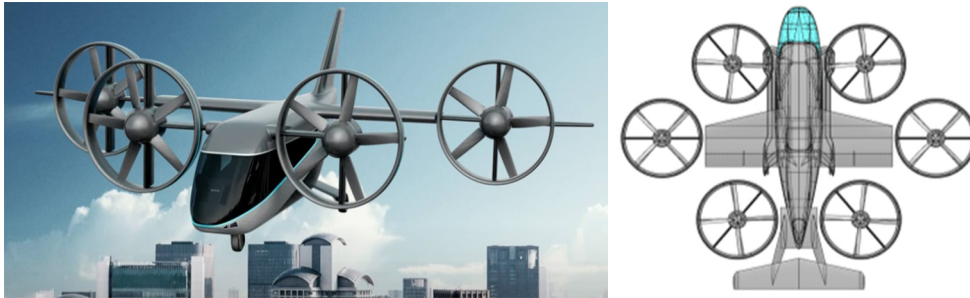


Fig. 9. The Bell Nexus 4EX and Bell Nexus 6HX air taxi projects [16].

The Cora project – by the American startup Kitty Hawk, founded in 2015 – became the first government-approved air taxi (Fig. 10) when in October 2017, New Zealand permitted test flights throughout the country [17]. The Cora air taxi is a fully electric aircraft with a maximum speed of 180 km/h, a flight range of 100 km, and an operational altitude of 150 to 900 meters. Designed as an unmanned aircraft, it is remotely controlled from the ground and is intended to be integrated into a mobile app-based taxi service.

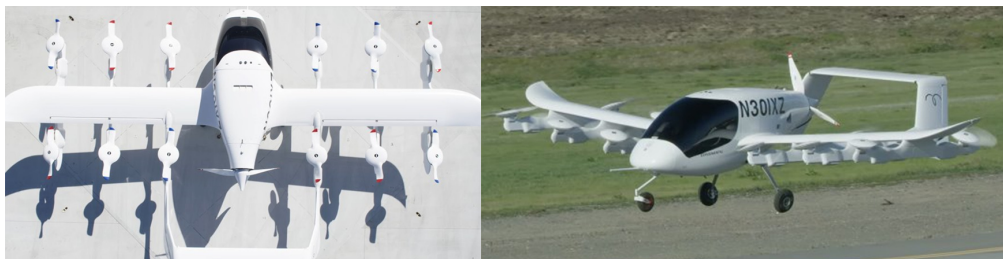


Fig. 10. The Kitty Hawk Cora project [18].

The first prototype of the Volocopter VC200 air taxi passed flight tests in 2016 [18]. A new model, the Volocopter 2X, was subsequently built based on the prototype. The VoloCity electric air taxi (Fig. 11) is the first of its class to be designed and developed to meet EASA's stringent aviation safety standards. However, the VoloCity is just one important part of a wider urban air mobility ecosystem concept stretching from flight booking to landing, including VoloPort vertiports, the VoloIQ operating system, and the VoloDrone for heavy lifting.

The new eVTOL VoloConnect aircraft (Fig. 12), in turn, is designed to operate as an extension of VoloCity's urban air taxi services, in this case connecting city and the suburbs. The aircraft operates with two drag fans, as well as six electric motors and main propellers. It is designed to efficiently transport up to 4 passengers on 100 km routes with a maximum speed of 250 km/h and a travel speed of 180 km/h [19].



Fig. 11. The VoloCity project [19].



Fig. 12. The VoloConnect project [19].

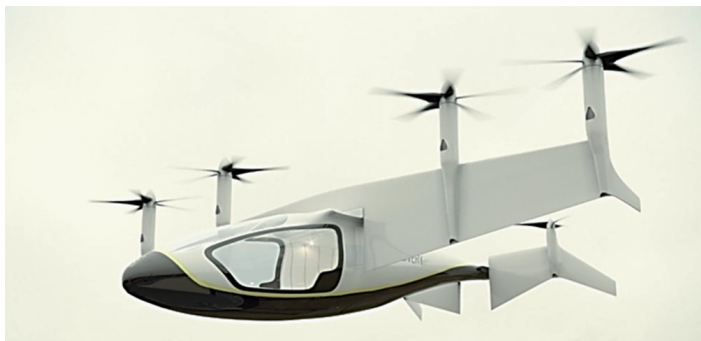


Fig. 13. The Rolls-Royce project [20].

In 2018, BMW's British subsidiary company Rolls-Royce introduced the concept of an aircraft with 6 electric motors powered by a gas turbine generator [20]. The aircraft design is based on a high-wing airframe with rotary-wing and tail fins (Fig. 13). There are two electric motors on the wing consoles and two more in the tail section. During takeoff and landing, all propellers are parallel to the ground. During flight, they rotate 90 degrees, the wing engines shut down, and only the two

tail engines continue working. The Rolls-Royce M250 turbine engine significantly increases the flight range up to 800 km, with a maximum speed of 250 km/h.

The Russian startup McFly.Aero [21] introduced the Bartini air taxi model in 2017 (Fig. 14). This four-passenger multicopter is designed to operate at a cruise speed of 300 km/h, with a flight range of up to 550 km (including 150 km solely on battery power). The aircraft has a flight duration of up to two hours, though its battery is optimized for 30 minutes of operation. It can operate at an altitude of up to 3,500 meters. Another McFly.Aero project, the Heparid multicopter, was presented in 2017 (Figure 15). This unmanned air taxi operates on a distributed architecture without a centralized control system. It has an estimated flight speed of 150 km/h, a range of 75 km, and a maximum flight altitude of 1,000 meters, with a flight duration of 30 minutes.

The Bartini project is equipped with four engines, which tilt to a vertical position during acceleration, allowing the aircraft to achieve higher speeds while optimizing battery power usage. The Heparid project is currently funded through venture capital. To further the development of urban air mobility, McFly.Aero has announced plans to establish research laboratories for testing urban route prototypes and integrating air taxi operations within the existing regulatory framework.



Fig. 14. The Bartini project [23].



Fig. 15. The Heparid project [24].

The Vy 400 air taxi project by Transcend Air was introduced in 2018 [23]. Designed as a tilt-wing VTOL aircraft (Figure 16), the Vy 400 is optimized for efficient city-to-city transportation [24]. It features tiltable wings with struts and is powered by a 1,300 kW Pratt & Whitney Canada PT6-67F turboshaft engine. Additionally, the aircraft incorporates a common push propeller and a 30 kW electric motor with a tail-mounted push propeller [25]. The airframe integrates geofencing technology and advanced sensors for obstacle avoidance. It has a maximum flight speed of 650 km/h, a range of up to 725 km, and a payload capacity of 1,000 kg. For enhanced safety, the aircraft is equipped with a parachute system for controlled emergency landings. It is designed to accommodate one pilot and five passengers.

In addition to the Vy 400, Transcend Air has developed the Vy 400R, a high-performance single-passenger aircraft (Figure 17). This model combines the speed and comfort of a jet with the maneuverability and flexibility of a helicopter. Utilizing VTOL technology, the Vy 400R features a tilt-wing, fly-by-wire design and is powered by a 2,500 hp GE Aviation CT7-8 turboshaft engine. It has a maximum flight speed of 660 km/h and a range of 550 miles.



Fig. 16. The Vy 400 air taxi project [26].



Fig. 17. The Vy 400R air taxi project [26].

Transcend Air plans to establish a short-haul air service between 46 cities, with an average ticket price of approximately \$280 per trip. The estimated cost per aircraft is \$3.5 million; certification was expected after 2023 but there are still no results.

The Vy 400 is part of a long lineage of vertically flying prototype aircraft, including the 900-kg piloted Elytron Converticopter. The power system (PS) is driven by a Pratt & Whitney Canada PT6A-67F engine, delivering 1,700 hp, supplemented by a Yasa 750 electric motor producing 40 hp [26].

In 2017, Vertical Aerospace introduced the VA-X1 eVTOL project [27]. In partnership with Honeywell, the company developed its second prototype, the VS-X2, which successfully completed its first flight. Vertical Aerospace's Urban Air Mobility (UAM) aircraft integrates Rolls-Royce's advanced electric propulsion technology. The aircraft features an all-electric propulsion system architecture, including a power distribution system and a monitoring system. The propulsion system is designed with lifting and push-pull electric power systems (PS) of up to 100 kW [27]. The VA-X4 project (Figure 18) was launched in 2020 to support regional connectivity and short-distance urban missions. The aircraft is designed to accommodate up to five people (1 pilot and 4 passengers). Commercial flights are preparing to begin after 2024. Production of the aircraft will take place in Great Britain.



Fig. 18. The VA-X4 aircraft design [28].

In 2016, the Chinese company EHang unveiled the first prototype of its EHang passenger drone. Since then, an improved EHang AAV has been developed, which has flown more than a thousand flights with passengers on board [28]. The technological concept of the EHang AAV is based on three basic principles: comprehensive safety, an autonomous pilot, and cluster control from an intelligent control center (Figure 19). This autonomous passenger aircraft is a low-altitude, short- to medium-range transport solution [29]. The aircraft weighs about 270 kg, has a maximum payload of 220 kg, a maximum range payload of 35 km, and flight speed of 130 km/h. It uses 16 electric motors. During tests, the drone lifted vertically up to a height of 300 meters, took off with a maximum load of 230 kg, made a flight along the set route of 35 km and reached speeds of 130 km/h. Additionally, test flights were performed at night and under varying weather conditions, e.g. in a fog

and heavy wind. Autonomous flight technology rules out the possibility of failure or malfunction due to man-made errors. The EHang AAV uses 4G/5G communications as a high-speed wireless transmission channel for trouble-free communication with the command and control center, which enables remote control of the aircraft and real-time flight data transmission.

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German company Fraundorfer Aeronautics is developing the six-seat TENSOR 600X air taxi with an electric motor [30]. The aircraft takes the form of an autogyro (Fig. 20). It uses a free-spinning main rotor and a push propeller in the tail section. The usage of gyroplanes as air taxis will reduce fuel consumption compared to other proposed concepts, as well as noise levels. The maximum speed of the air taxi will be around 213 km/h, with takeoff distance of 90 m and range up to 600 km. For easy operation, the aircraft will have 600 landing spots in Germany, providing traffic independence during rush hours and connection to remote locations in the suburbs [31].



Fig. 19. The EHang 216 airtaxi project [29].

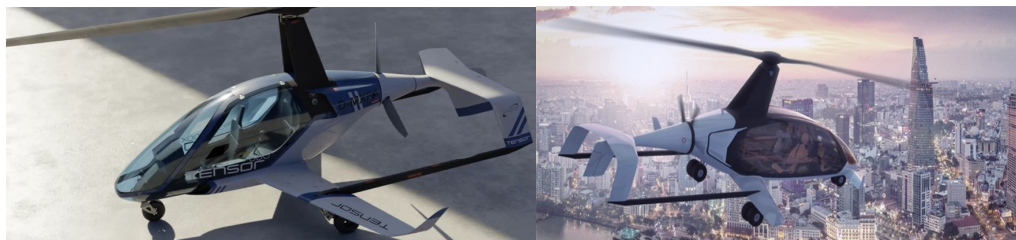


Fig. 20. The TENSOR 600X project [30].

The Volante Vision Concept, in turn is Aston Martin's exploration into personal air mobility [32]. Produced in partnership with Cranfield Aerospace Solutions, Cranfield University, and Rolls-Royce, this concept aircraft with vertical take-off

and landing capabilities demonstrates Aston Martin's forward-looking design ingenuity (Fig. 21). Air travel will be a crucial part of the future of transportation and the Volante Vision Concept describes Aston Martin's influence in mobility innovation. With room for three adults, the concept is a near-future study that previews a flying autonomous hybrid-electric vehicle for urban and inter-city air travel, providing fast, efficient and congestion-free travel. The Volante Vision Concept will take full advantage of the latest advances in aerospace, electrification, and autonomous technologies, coupled with Aston Martin's signature design. In the developers' estimation, such fan positioning will provide increased wing lift due to a significant airflow acceleration on its upper surface. In addition, the separate fans control will allow better control of the aircraft in the air.

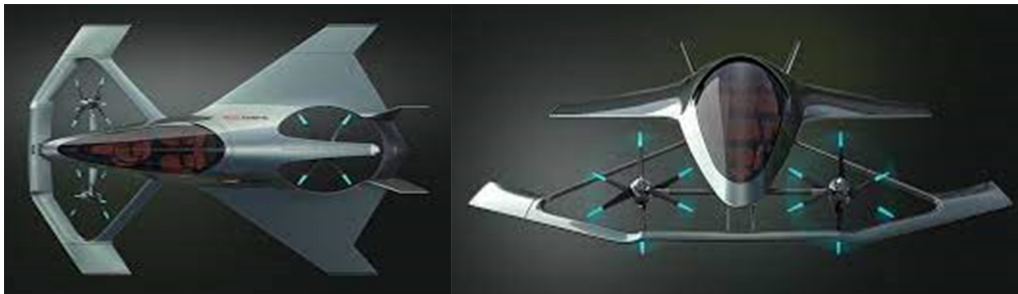


Fig. 21. The Volante Vision Concept [32].

In 2017, the French company Onera presented a model of the electric plane AMPERE [33], featuring a classic airplane layout with a high-positioned wing and a T-shaped tail. The upper plane of the wing has 32 small electric fans on its front edge (Fig. 22). The AMPERE is a distributed electric propulsion regional aircraft demonstrator for transporting up to 6 people over 500 km in 2 hours. One of the challenges is to achieve optimal propulsion performance while generating as little drag as possible. Distributed electric propulsion entails a rethinking of aircraft design to obtain both aerodynamic and flight control benefits. The primary objective of the AMPERE project is to bring distributed electric propulsion technology to maturity. Onera is exploring innovative solutions for providing validated and integrable technologies to industry. The hybrid energy source, using fuel cells (in partnership with the Atomic Energy and Alternative Energy Commission (CEA)), is supplied with pressurized hydrogen at 700 bar, while lithium-ion batteries provide transient power during aircraft maneuvers.

In 2019, the American company Alaka'i Technologies unveiled the Skai project [34]: a hydrogen-powered air taxi that is one of the most advanced hydrogen-powered air taxi technologies (Fig. 23). Designed as a highly efficient and simplified air mobility system, Skai aims to provide on-demand transportation with minimal complexity, allowing passengers to travel seamlessly from point A to virtually anywhere. The aircraft operates using hydrogen fuel cells, which generate electricity

to power all onboard systems and six quiet electric outrunner motors [34]. It has a flight duration of up to four hours, a payload capacity of up to 1,000 lb, and a top speed of 115 mph. It can accommodate up to five passengers, and its hydrogen fuel cells allow for refueling in less than 10 minutes [35]. These fuel cells generate electricity to power all onboard systems, including the six quiet electric outrunner motors.



Fig. 22. The AMPERE project [33].

Skai's propulsion system consists of six pairs of brushless electric motors, eliminating the need for a gearbox or tail-rotor connection. This redundant design enhances reliability, ensuring that the aircraft can tolerate the failure of one rotor and continue its flight. Even in the event of two rotor failures, the aircraft remains capable of performing a safe landing. To further improve safety, Skai's three primary systems – rotors, fuel cells, and flight computers – are triple redundant, reducing the likelihood of catastrophic failure. Additionally, as a final fail-safe measure, the aircraft is equipped with an airframe-mounted parachute to ensure a controlled descent in the event of an emergency.



Fig. 23. Skai air taxi project [34].

Uber and Hyundai unveiled an eVTOL airplane with an electric motor [36]. The aircraft will carry up to 4 passengers, reach speed up to 290 km/h, climb to heights of 300-600 meters and be capable to fly 100 km on a single battery charge. The two companies will develop ground infrastructure jointly, and they hope to launch the first commercial project soon.

In 2019, the Israeli company EVIATION unveiled its all-electric Alice passenger plane [37] – a small 11-seat plane (2 crew members and 9 passengers) with a maximum

takeoff weight of 6350 kg (Fig. 24). Alice is one of the largest electric planes in the world [38]. The aircraft is built of composite materials and has an electric remote control system. It is equipped with three electric motors, with 350 hp (260 kW) each, from Siemens, although the the Magni250s engines MagniX, with the power of 375 hp (280 kW), can also be used. With lithium-ion batteries, the aircraft can cover 1046 km at 482 km/h.



Fig. 24. Alice airplane design [39].

The American company Terrafugia (since 2017 owned by the Chinese concern Geely) presented a full-size prototype of a proposed electric aero taxi TF-2A. The developers are now preparing for aircraft flight tests [39]. With a maximum takeoff weight of 1.2 tons, the aircraft is capable of carrying passengers and cargo weighing up to 200 kilograms over a distance of up to 100 kilometers. The TF-2A will be able to fly at speeds of up to 180 km/h at altitudes up to 3,000 m.

A Joby Aviation air taxi project, with 6 electric engines, has been under development since 2020, with the main investor being Toyota [40]. The aircraft is designed with a high redundancy level to maximize reliability and features a high level of comfort and safety (Fig. 25). It is 100 times quieter than conventional aircraft, has speeds of 200 mph, a range of more than 150 miles on a single battery charge, and zero carbon emissions. More than 1,000 test flights have been performed. The company planned for the first large-scale production to begin in late 2021, with the aircraft to be certified in 2023 and commercial operations to begin in 2024. However, these plans have not yet been implemented.



Fig. 25. The Joby Aviation aircraft design [40].

A new air taxi project has been launched by e.SAT (Germany), under the name Silent Air Taxi [41], being developed by about 50 engineers from RWTH Aachen Technical University, with components for its fuselage being developed at the Fraunhofer Institute [42]. The aircraft will be lifted into the air by engines produced

by MTU Aero Engines (Fig. 26). In development for over four years, its design incorporates technical solutions that have subsequently been patented. Silent Air Taxi will be able to carry 1 pilot and 4 passengers up to 1000 km at 300 km/h. It will require a distance of only 400 m for take-off. The most distinctive feature of the Silent Air Taxi design is the closed-circuit wing. This technical solution is rarely seen in aircraft construction, and it is not yet known whether the company will be able to achieve EASA certification after 2024.



Fig. 26. The E.SAT aircraft project [41].



Fig. 27. Cassio 2 (VoltAero) project [43].

The French aviation start-up VoltAero has unveiled the final design of its nine-seat Cassio 2 hybrid aircraft (Fig. 27), which could become a “Tesla of the skies” within the next two years [43]. Equipped with VoltAero’s proprietary propulsion module – which combines electric motors and an internal combustion engine – the Cassio aircraft will have propulsive power ranging from 330 to 600 kilowatts, corresponding to versions of the aircraft with four, six, and 10-seats [44]. The Cassio 2 combines advanced aerodynamics with an electric hybrid PS, making it much quieter, more efficient, and more environmentally friendly than conventional aircraft in its class [44]. It is equipped with VoltAero’s proprietary propulsion module – which combines electric motors and an internal combustion.

In mid-sized Cassio version – which has six seats – the hybrid power module combines 300 kW of internal combustion engine power with three electric motors of 60 kW each, delivering a total power of 480 kW. These multiple sources of power ensure very safe modes of operation by utilizing one source of power (electrical or mechanical) – or both – depending on the usage scenario. In a typical flight, the

electrical motors would be used for nearly-silent takeoffs and landings, with the internal combustion engine serving as a range extender [44].

Otto Aviation has unveiled the technical specifications of its revolutionary Celera 500L bullet plane [45]. With a top cruise speed of 740 km/h and 8,334 km range, the Celera 500L can carry up to 6 passengers anywhere in the United States without a stop for refueling (Fig. 28). On one liter of fuel, the Celera 500L travels 7.6 to 10.6 km, compared with 0.85 to 1.27 km/liter (2-3 mph) for traditional aircraft. Operating costs will be no more than \$328 per hour, compared to \$2,100 for modern business jets. One of the aircraft's most distinctive features is its exceptionally high glide ratio of 22:1, which is more typical of gliders than conventional aircraft. This means that if the engine is turned off at an altitude of 10 km, the Celera 500L can glide more than 200 km, enhancing both safety and fuel economy.

The company Piirstrel has developed the NUUVA V300 autonomous cargo aircraft with a long flight time, economy, and payload [46]. The NUUVA V300 is an autonomous, high-capacity, long-range eVTOL UAV designed to provide logistics by air (Fig. 29). It is 10 times more economical to operate than modern helicopters, requires no runways, and provides increased safety and reliability through the certified Pipistrel electric motors. The NUUVA V300 is equipped with a hybrid-electric propulsion system using special take-off and cruising systems. It takes off and lands using 8 independent battery-powered Pipistrel E-811 electric motors, which are already EASA-certified.

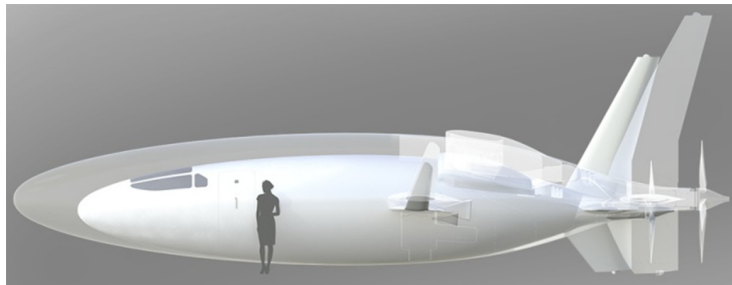


Fig. 28. Celera 500L project [45].

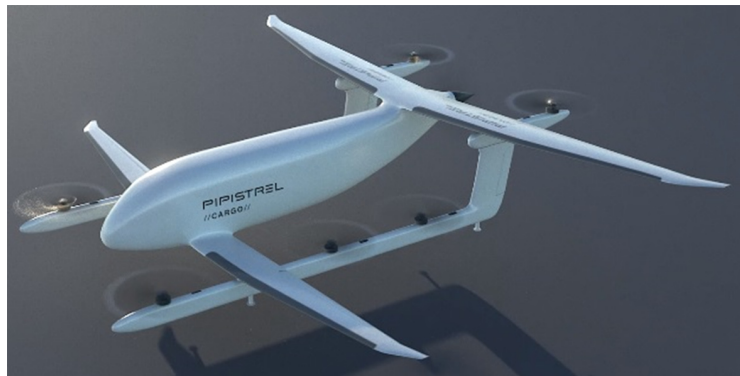


Fig. 28. Celera 500L project [45].

The above analysis of UAM market development suggests that the key players in this market include: Volocopter, Ehang, Aeromobil, Terrafugia, Lilium, Kitty Hawk, VRCO, Vertical, Aerospace, Airbus, Toyota, Pal-V, Bartini, Opener, Hoversurf, Audi, Porsche, Bell Aviation, Joby Aviation, NFT Inc, Vimana, and Workhorse Group. The forecast for aviation technology development through 2040 highlight several key trends and necessary advancements:

- The development of regional jet aircraft with fewer than 20 passengers is expected to be unfeasible, as they can be expected to be replaced by small electric aircraft in the next 10 years.
- The development of large-sized jets will likewise have no future, if the electrical component in the design and operation of their engines does not see significant advancements.
- New aircraft designs based on a new aerodynamic designs, such as a flying wing with electric or hybrid engines or a propeller-driven convertiplane design, need to be investigated.

The advantages of integrating new and known aircraft and hybrid propulsion systems need to be investigated, based on the calculation of their operating hybrid propulsion characteristics.

METHODS AND RESULTS OF RESEARCH

Currently, cargo and passengers are being transported to many locations around the world by helicopters, which are less efficient in cruising flight. As a result, ongoing research seeks more aerodynamically efficient aircraft designs to reduce operational costs while maintaining the vertical take-off and landing (VTOL) capability.

Existing VTOL aircraft primarily rely on traditional propulsion systems [47; 48], including turbojet (TJ) and turboprop (TP) engines. In these aircraft, the lifting force for vertical takeoff is created either directly by the thrust of the turbojet engines, ejectors, or fans (as seen in such aircraft as the Bell ATV, McDonnell Douglas AV-8B Harrier II, Rockwell XTV-12, Lockheed Martin F-35C Lightning II, Yak-141) or, alternatively, using an air propeller of the turboprop (as in the Bell V-22 Osprey, Convair XFY Pogo, Volante Vision Concept) [49; 50]. The engines of these VTOL vehicles are usually located in the fuselage or on the wing [51].

Vertical take-off and landing aircraft with electric propulsion systems (eVTOL), by contrast, rely on electric propulsion systems, with lifting force generated by propeller thrust [49] (as in the Voyager X2, CityHawk, and Soar). Existing VTOLs with turbine engines have disadvantages including the high cost of turbine engines, the presence of harmful emissions due to combustion products, and the significant danger posed to passengers by liquid fuel combustion products in the event of VTOL

accidents. In addition, another disadvantage of VTOL and eVTOL with a helicopter mode of cruising horizontal flight is low aerodynamic quality, which reduces the range and duration of the flight. The disadvantages of VTOL with a hybrid flight control system the (Volante Vision Concept) include the complexity of the hybrid control system, low flight speed and low aerodynamic quality of eVTOL in cruise flight modes, the presence of harmful emissions due to combustion products, and low VTOL reservation level.

To address these limitations, a hydrogen-powered vertical take-off and landing (HydVTOL) aircraft concept, named XFlight, is hereby proposed, in two transport options. The first option has a hydrogen-electric power plant inside the body (Fig. 30, 31), while the second option has it outside the body, in removable tanks (Fig. 32). The XFlight design aims to offer greater flight range, higher cruise speeds, enhanced system redundancy, and zero harmful emissions, making it a more efficient and environmentally friendly alternative to current VTOL and eVTOL solutions.

A hydrogen-electric power plant may include a small tank of hydrogen, a fuel cell (Fig. 33, a) or a battery (Fig. 33, b) to supply electricity to an electric motor.

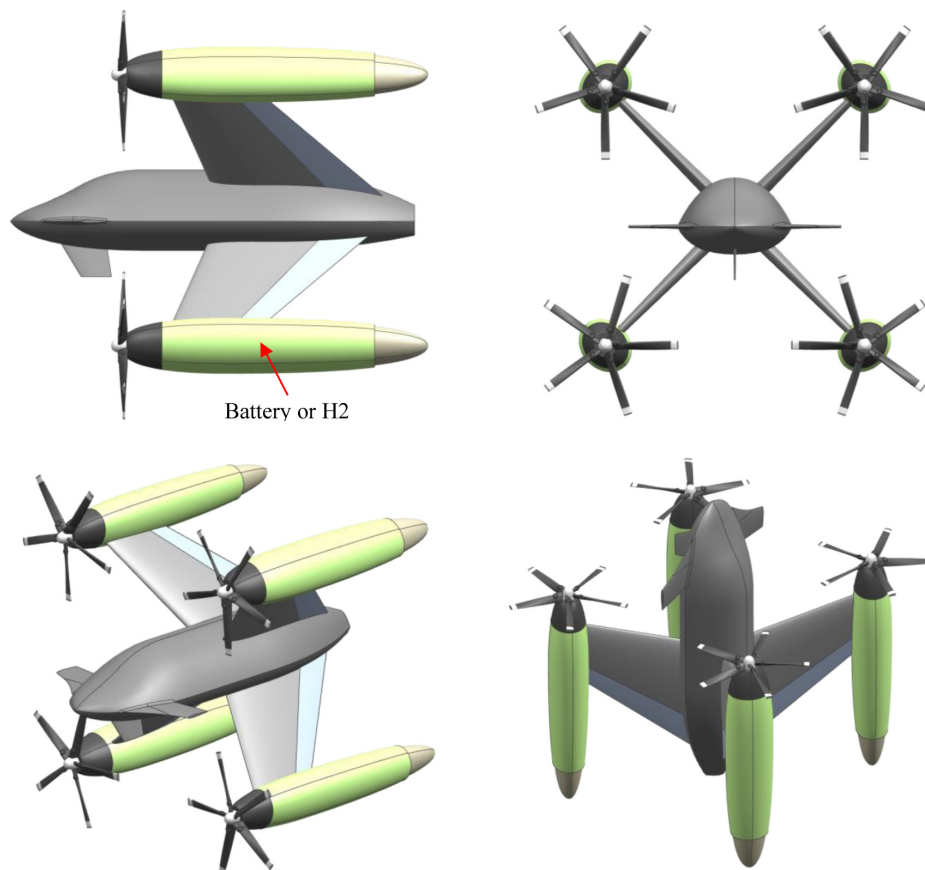


Fig. 30. Scheme of the airplane for transport (option 1).

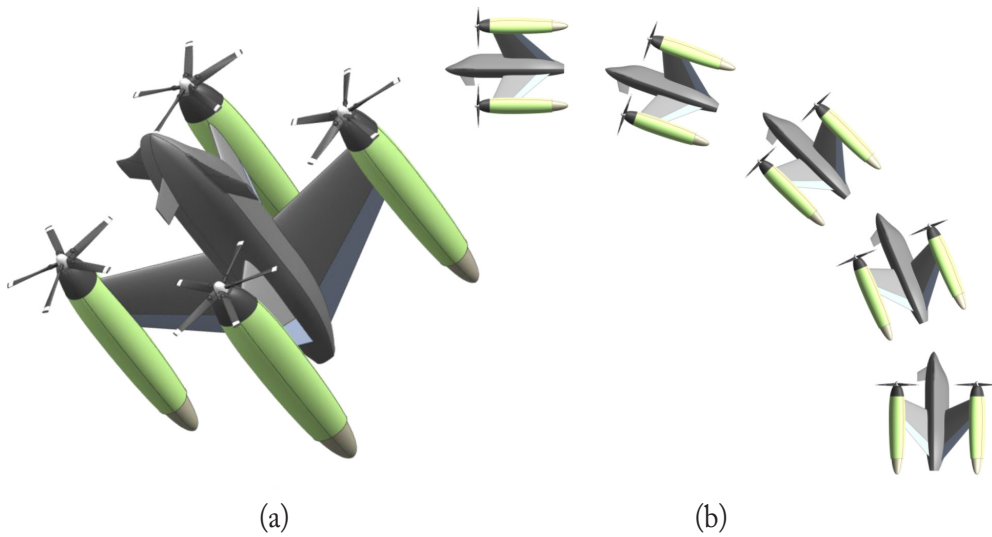


Fig. 31. Scheme of the airplane for transport option 1: the aircraft in transition position from vertical take-off to horizontal cruising flight (a) and process of changing from vertical flight to horizontal flight (b).

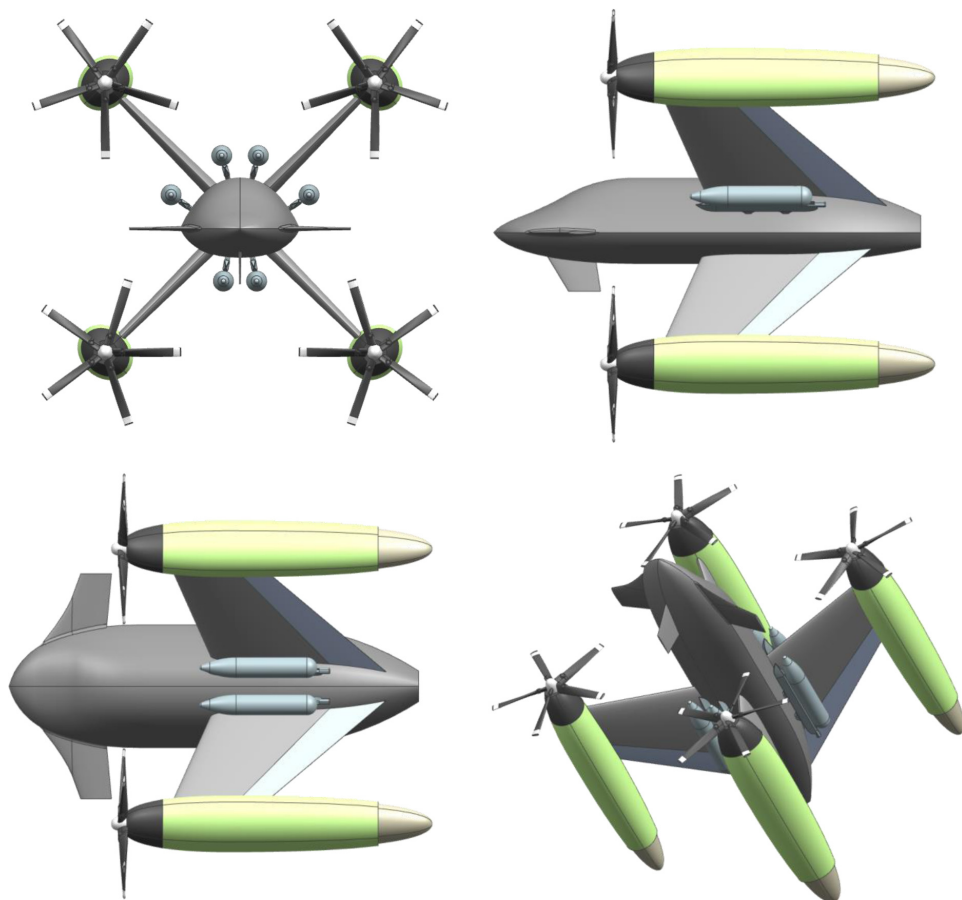
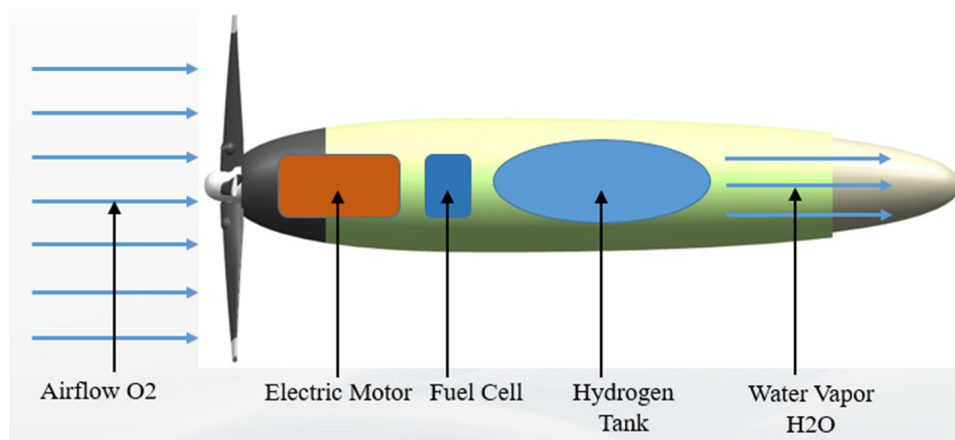
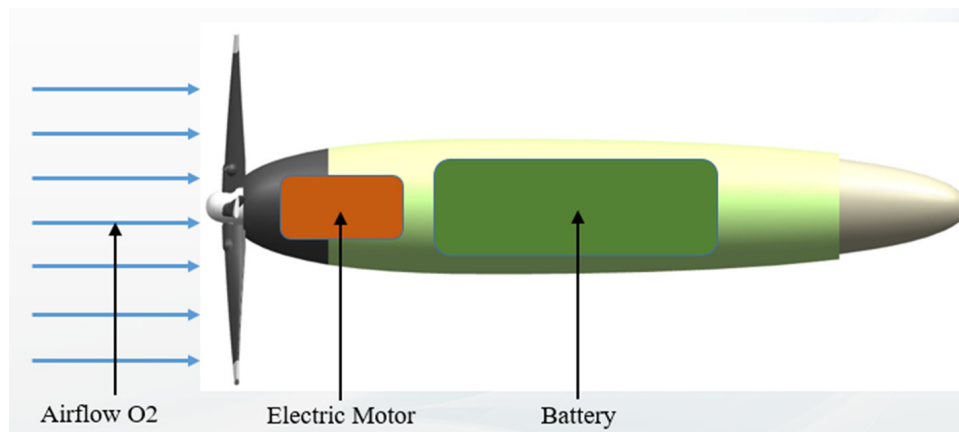


Fig. 32. Scheme of the airplane for transport (option 2).



(a)



(b)

Fig. 33. Hydrogen-electric power plant scheme.

Several options are being considered in preliminary studies.

The closest existing prototype to the proposed XFlight technical solution is the eVTOL Bell Autonomous Pod Transport (APT) [52, 53]. The Bell APT is a multicopter cargo aircraft with vertical take-off and landing. It has a biplane design based on a normal aerodynamic scheme, directional control rudders and stabilizers, and electric propulsion. The APT 70 takes off vertically and transitions into horizontal cruising flight, improving efficiency over conventional multicopter configurations.

However, the Bell APT has several limitations that impact its performance. The biplane wing configuration generates high aerodynamic drag, reducing the aircraft's overall aerodynamic efficiency in cruise flight. Additionally, its range is limited by the capacity of electric batteries, and the performance of its electric propulsion system is affected by environmental temperature and operating time. These constraints highlight the need for a more efficient and long-range VTOL alternative.

The XFlight project addresses these challenges by incorporating a “duck” aerodynamic configuration with an X-shaped wing and a hydrogen propulsion system. The engines are positioned in nacelles at the ends of the X-shaped wing, allowing for improved flight stability and safety. By placing hydrogen tanks away from the fuselage, the design reduces fire hazards, enhancing both flight safety and maintenance efficiency. Additionally, the rotation direction of the propellers is optimized to reduce the intensity of wingtip vortices, thereby minimizing inductive drag. This design enhancement increases the aircraft’s aerodynamic efficiency, leading to higher cruise speeds, extended range, and improved flight duration.

Compared to the Bell APT prototype, the XFlight aircraft achieves longer range and higher cruise speeds, all while producing zero harmful emissions. The operational workflow of XFlight consists of several key phases: The aircraft performs a vertical takeoff from the launch position (Figure 31, b). After gaining altitude, it transitions from vertical takeoff to horizontal cruise flight and then accelerates to cruise speed. The aircraft's high-speed cruise mode is achieved through a powerful hydrogen propulsion system and an X-shaped wing with moderate elongation, optimizing aerodynamic performance.

The cruise flight phase benefits from the “airplane-like” flight dynamics, offering higher aerodynamic efficiency compared to traditional helicopter-mode cruising. To further enhance efficiency, the propeller rotation direction is designed to reduce wingtip vortices, lowering inductive drag and improving overall aerodynamic performance. Additionally, high flight safety is ensured through a redundant control system and the strategic placement of hydrogen fuel tanks outside the fuselage, significantly reducing the risk of fire hazards.

By integrating hydrogen propulsion, optimized aerodynamics, and advanced safety measures, the XFlight project offers a highly efficient, long-range, and environmentally friendly VTOL solution. These innovations position XFlight as a next-generation urban air mobility (UAM) aircraft, capable of enhancing transport efficiency and operational reliability while minimizing environmental impact. Taken together, these innovations position XFlight as a next-generation urban air mobility (UAM) aircraft taking advantage of hydrogen power, capable of enhancing transport efficiency and operational reliability while minimizing environmental impact.

CONCLUSIONS

The first part of this study reviewed the UAM market and analyzed the main characteristics of air taxis, their configurations, designs, and layout schemes. This detailed assessment of existing air taxi research in the literature has highlighted unique features, application areas, and current aerodynamic design concepts. The review of existing propulsion systems and configurations revealed that while battery-electric eVTOL designs offer low emissions and reduced noise levels, they

remain limited by energy density constraints, resulting in shorter range and lower payload capacity. Hybrid-electric systems provide extended operational range but still rely on fossil fuels, limiting their environmental benefits. The analysis of aerodynamic layouts showed that tilt-rotor and lift+cruise configurations provide better efficiency in forward flight, whereas multicopter designs offer improved maneuverability and simplified control systems. These findings underscore the need for alternative propulsion solutions that improve efficiency without compromising sustainability, motivating the exploration of hydrogen-based propulsion in this study. Additionally, the review identified challenges related to weight, infrastructure requirements, and operational feasibility, all of which inform the design considerations for the proposed XFlight concept.

Next, building on the surveyed previous research and identified challenges, the second part of this study introduced the XFlight concept – a hydrogen-powered vertical take-off and landing (HydVTOL) aircraft. The XFlight design presents a rational aerodynamic configuration tailored for passenger and cargo transport within the urban air mobility (UAM) framework. By integrating a hydrogen propulsion system, the aircraft enhances sustainability, efficiency, and operational flexibility. The XFlight project merges the advantages of both airplane and helicopter transport principles, optimizing performance for both cargo and passenger applications. Its capability to operate unmanned in a combined flight mode – taking off like a helicopter and cruising like an aircraft – substantially reduces operating costs compared to conventional VTOL solutions designed for similar applications. Two transport options for the XFlight project were outlined: the first with a hydrogen-electric power plant inside the body, the second with hydrogen tanks outside the vehicle.

Further research is ongoing to refine the aerodynamic configuration of the XFlight design, focusing on different flight cycles, passenger capacities, and cargo load variations. Particular emphasis will be placed on evaluating the hybrid propulsion system's performance across multiple flight modes, ensuring optimal efficiency and scalability for future UAM operations.

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