eZELOS
Twin-Hybrid

New Generation of a Light Helicopter/eVTOL for the AAM Advanced Air Mobility Market

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Initial Position

For the future AAM Advanced Market and UAM Urban Advanced Market, almost exclusively battery-powered eVTOLs are being offered as **air taxis** today.

They have been advertised with the slogan "Zero Emission" to attract investors, which has worked well for the first projects. However, weaknesses are slowly emerging in electric flight.

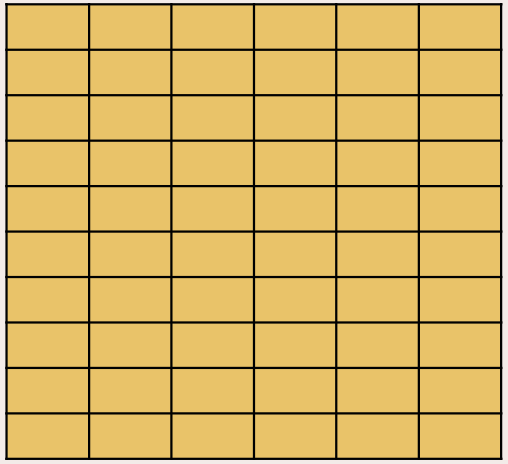
Most developers no longer write "Zero Emission," but only **"Zero Emission Flight“**. In many places, electricity is still not produced greenly, but through, for example, coal-fired power plants. Additionally, eVTOLs require large and heavy batteries for a relatively short flight, and lithium extraction requires energy. Lithium is not inexhaustible, and **65% of lithium** reserves are controlled by China. The eVTOL batteries have low cycles and a short lifespan. **Batteries** for eVTOLs are not only heavy but also expensive, which will drive operating costs up. Batteries for eVTOLs cannot be compared to batteries for electric cars. The battery industry invests in the development of car batteries because it is a multi-billion-dollar business, whereas eVTOLs are still a small market. The super battery does not exist today, nor will it tomorrow.

eVTOL developers have focused on futuristic design, **new propulsion systems** such as tilt wings, tilt rotors, or multi-copter concepts, and pure battery power. Cars, on the other hand, have remained practically unchanged, and most of them are still gasoline-powered. Going from 0 to 100 takes courage, and we are grateful for pioneers, but it is a long way until such projects prove themselves or receive certification. The greatest advantage of flying purely electrically with "Zero Emission" is also the greatest disadvantage. It is not because of the electric motors; they are already small wonders that immediately unleash full power (torque), make no noise, produce no CO_2, consist of few parts, and require practically no maintenance. But they require electricity...

Energy Density of Batteries

Many companies that produce eVTOLs are saying that they can not only replace some air journeys with a greener alternative but that their main competition is in fact cars. From a green standpoint, these claims don't fully stand up to examination.

https://eandt.theiet.org/content/articles/2023/03/how-the-evtol-industry-overpromised-on-green/



Energy content 1 kg kerosene

Energy content 1 kg high-performance battery

Product Comparison with Market Leaders

General Characteristics	Joby #	Archer #	Vertical Aero #	Jaunt #	Volocopter	eZELOS
Passenger Carry Capacity	Pilot + 4	Pilotless +4	Pilot + 4	Pilot +4	Pilotless + 1	Pilot + 2 or 3 Pax
Range	241 km	80 km	161 km	193 km	35 km	**500km**
Cruise Speed	321 km/hr	241 km/hr	241 km/hr	273 km/hr	96 km/hr	280 km/hr
Endurance	1hr 17 mins	38 mins	42 mins	120 mins	27 mins	**3hrs**
Path to Certification	Uncertain*	Uncertain*	Uncertain*	14 CFR Part 27	14 CFR Part 21	14 CFR Part 27
Empty Weight	1814 kg	2719 kg	1870 kg	1632 kg	290 kg	1042kg
MTOW	2177 kg	3175 kg	2380 kg	2721 kg	450 kg	1644 kg
Payload Capacity	363 kg	456 kg	510 kg	1089 kg	160 kg	**600 kg**
Product Cost (Unit)	$3M	$5M	$4M	$2M	$0.6 M	**$0.650 M**
Pre-Valuation	$250M	$100M	$89M	$100M	$170M	**$60M**
Current Valuation	$3.32B	$1.02B	$1.68B	Waiting for IPO	$1.87B	

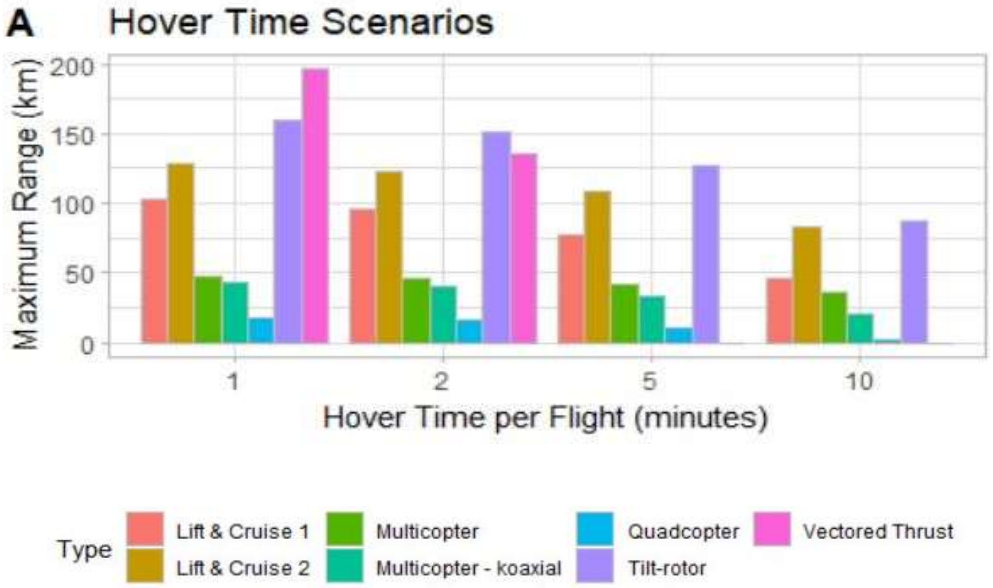
* FAA ruling on May 9th, 2022, stated that winged eVTOLs cannot get certification under Light Airplanes category (part 23)

None of these Aircraft OEMs have ever manufactured a product which has completed certification and is in production today

eVTOLs' Potential Performance

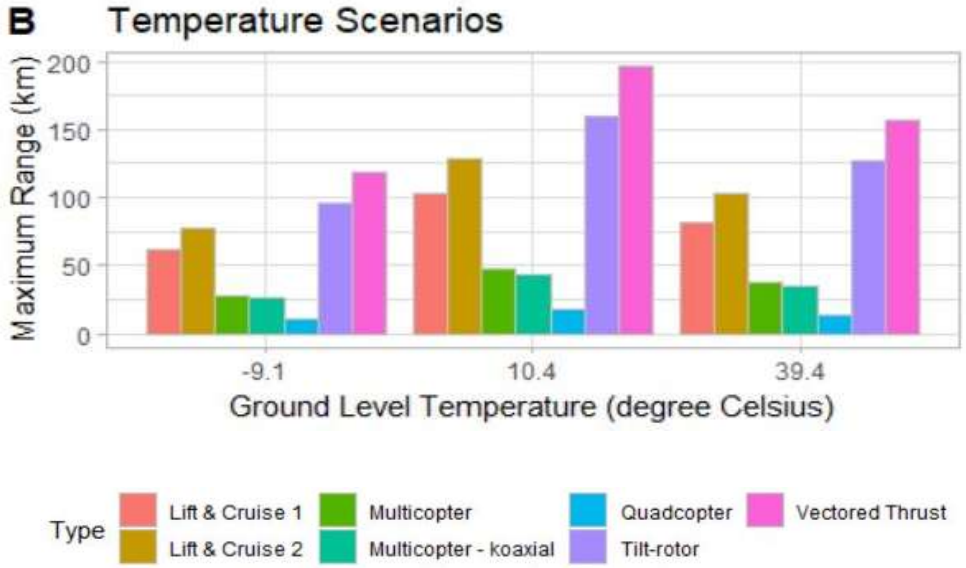
An interesting Paper by Sesar Innovation Days analyses the eVTOLs potential performance based on a specific operational scenario simulated:

Hover time scenarios per flight minute show on average, the range is reduced by just under **10%** during a two-minute hover phase. With a 5 min hover phase, the range is reduced by up to **30%** depending on the eVTOL type. The higher the hover time the lower the range, because the energy consumption during the hover phase is considerably higher than during the cruise phase



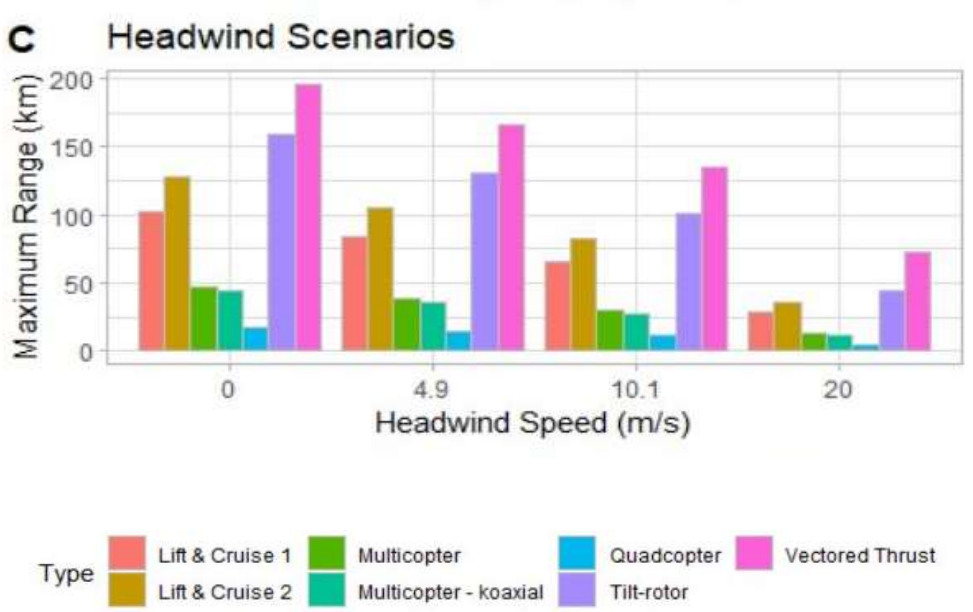
eVTOLs' Potential Performance

Optimal operating temperature of the electric battery ranges between 10°C and 30°C. At a temperature of around -9,1°C, the battery drops ca. 40%. The colder the outdoor temperature, the higher the loss of the battery's capacity. Similarly, at a high temperature of 39,4°C, the battery only has an average of 20% of its capacity left. This means that the temperature has a considerable influence on the total range.



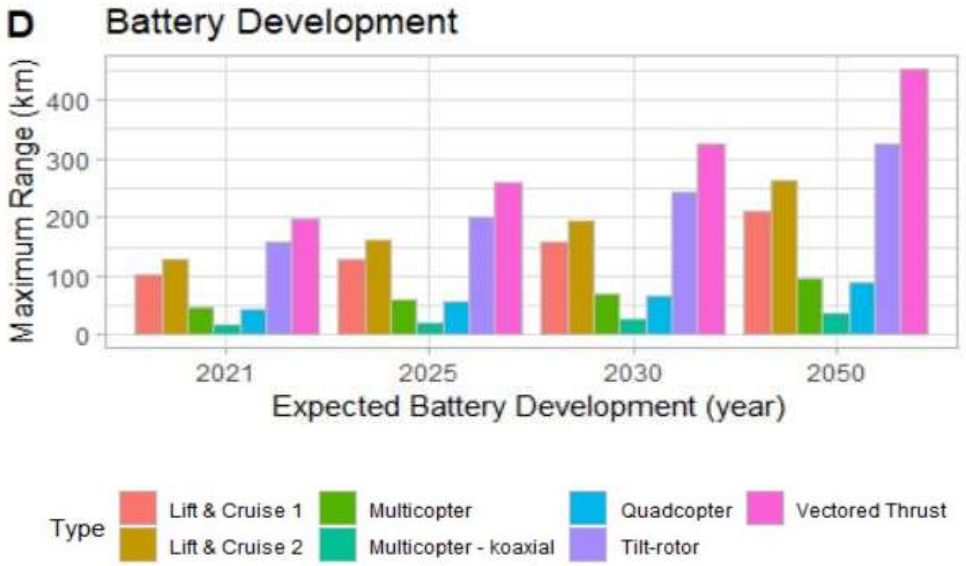
eVTOLs' Potential Performance

The range is reduced by 18% at a headwind speed of 4,9 m/s. On windy days (10,1 m/s), the range can be reduced by 22%. In worst-case conditions (20 m/s), the range can be reduced by up to 55%.



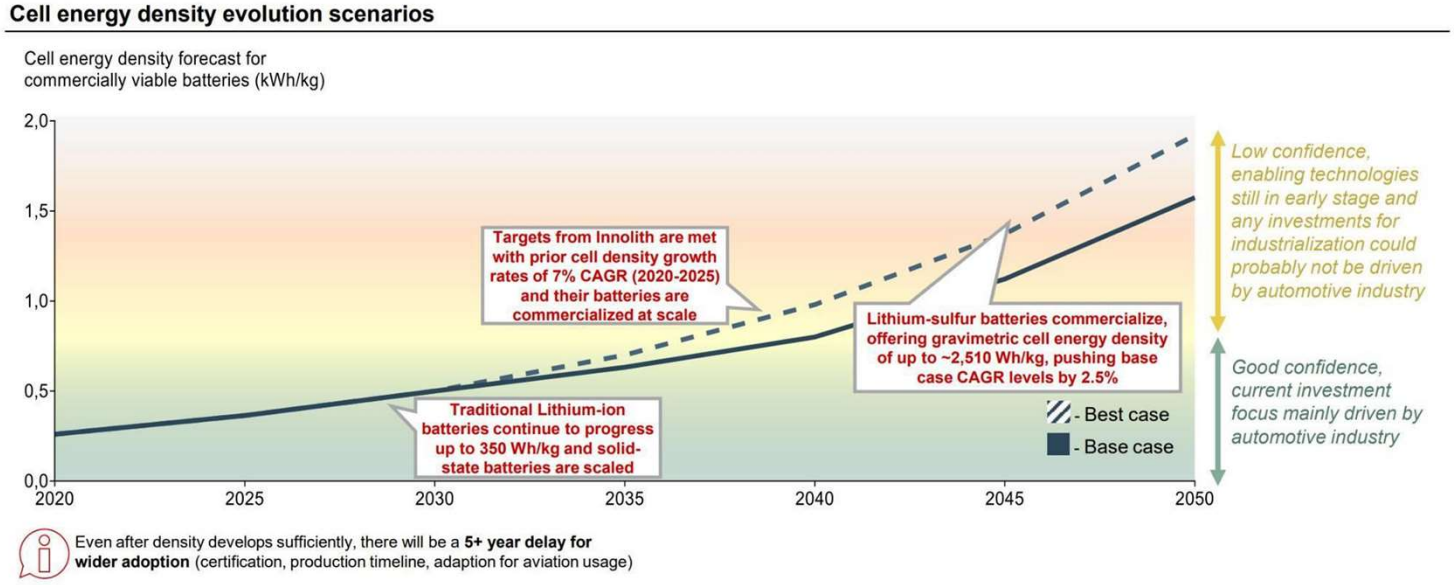
eVTOLs' Potential Performance

Based on the forecasted battery development, it is assumed that maximum range of eVTOLs will increase over time as the development in the field of battery technology continues. According to the current forecasts of Fraunhofer-Institut für System- und Innovationsforschung ISI, an increase in the range by an average of 48% in the next 10 years and by about 110% in the next 30 years can be expected.



Excerpt from an interview: VTOL INSIGHTS NEWS

Meanwhile, Pfammatter points out, “Batteries are the biggest weakness the eVTOL industry faces and why hybrid-powered systems are better. Pure electric aircraft are an ecological disaster because their power source is only good for three months tops before they get cooked and must be replaced. This could cost an eVTOL company with a small fleet of aircraft, a further USD 4 to 5 million a year. Then, while in use, the batteries need to be charged every 30 minutes, which can take over half an hour to achieve, where important passenger custom goes amiss. Short term, where is the profit when each aircraft could cost up to USD 8 million to construct? It will be the VTOLs like ours at Dufour and not the eVTOLs that will reply Pfammatter then points to the problem of battery power. “eVTOLs are limited by their batteries. The longer the aircraft has been flying, so the less power is available in an emergency. Here, helicopters are safer as they’re lighter and have more power.



Lithium Batteries

The density of lithium batteries is unlikely to increase significantly in the coming years for several reasons. First, the production of lithium is not easy and requires a lot of energy. Second, the recycling of lithium batteries is also not simple and requires energy. Third, lithium batteries that need to react quickly tend to lose energy rapidly and can only deliver full power for a short time before losing density and performance.

Lithium is a relatively rare element and extracting it from the ground requires significant energy inputs. Moreover, the process of refining and processing lithium for use in batteries is complex and energy-intensive. While research is ongoing to improve the efficiency of these processes, it is unlikely that significant breakthroughs will be achieved in the short term.

Lithium Batteries

In addition, while lithium batteries have high energy density compared to other battery types, they have limitations in terms of their ability to deliver power quickly. This is because the chemical reactions that occur within the battery during discharge and recharge are not instantaneous, and the speed at which they occur depends on the materials used in the battery. As a result, lithium batteries that need to deliver power quickly tend to lose energy quickly and cannot sustain peak performance for long periods. This can limit their usefulness in certain applications, such as electric vehicles or other high-performance devices.

The environmental impact of lithium mining and battery production is a topic of much debate and study. While lithium batteries are often touted as a more environmentally friendly alternative to fossil fuels, the production and disposal of these batteries can still have significant environmental impacts.

Lithium Batteries

The mining of lithium can result in habitat destruction, water pollution, and other environmental damage. In addition, the production of lithium batteries requires significant energy inputs and can result in greenhouse gas emissions and other pollution. However, some argue that the environmental impact of lithium mining and battery production is still lower than that of fossil fuels when the full lifecycle of the products is considered.

One key factor in the environmental impact of lithium batteries is their potential for recycling. While recycling lithium batteries can be challenging, it is possible to recover many of the valuable metals and materials used in the batteries, reducing the need for new mining and extraction. Overall, the environmental impact of lithium batteries is complex and depends on many factors, including the source of the lithium, the energy sources used in battery production, and the potential for recycling and reuse. As with any technology, it is important to carefully consider the environmental impacts of lithium batteries and to work to minimize these impacts wherever possible.

Air-Taxi eZELOS Twin-Hybrid compared with Purely Electric Air-Taxi

At UASystems SA, we believe that an error being made these days is undervaluing over 100 years of helicopter technology development - a design that is currently at its prime.

The advantages sought by new alternatives (tilt-rotor, tilt-wing, multi-copter, just to name a few) are offset by the difficulties (complex control systems and transition maneuvers, poor aerodynamic performance, and the list can continue).

Therefore, the helicopter remains the most successful means of vertical flight. New aircraft architectures must prove themselves over time and demonstrate the capability to fly in adverse, cold, and windy conditions, or in hot-and-high environments.

Now is the moment to electrify helicopters, and that is precisely what we do with eZELOS. Our unique twin-hybrid system safely compensates for battery limitations, including weight, reduced capability at low temperatures, and limited operational life.

Main Targets

1

Safety in the air

The presence of ICE has a two-fold purpose: to run the cruise stage of the flight in the most efficient way and to provide the necessary energy to charge the batteries used by the electrical engine in the take-off and landing phases.

The system is fully redundant in both directions, and a failure of one of the propulsion systems is compensated by the presence of the other, ensuring the continued safe operation of the aircraft.

2

Safety on the ground

Since the batteries are charged by the on-board ICE, there is no need to plug in the system when stationary.

This gives complete freedom of operation, providing the eZELOS with a unique capability: flying from everywhere to anywhere.

3

Environmentally friendly

eZELOS' twin-hybrid propulsion promises 50% fewer CO2 emissions and a reduced noise footprint, making it truly deserving of the "green" label.

4

Efficiency

With 60% lower operating costs than the same category legacy helicopter, it is a viable winning option for the developing AAM market. If air-taxi is your business, then eZELOS will help you earn money by staying in the air longer than any competitor.

eZELOS: The Twin-Hybrid Air Taxi with Longer Range and Versatile Drive Systems

Purely electric air taxis, as most are today, have a short range. eZELOS is unique with its twin-hybrid solution, which has **the largest range** and the longest flight time compared to the competition. The eZELOS also does not need a battery charging station, which is probably not available in all islands or locations, making us independent. eZELOS also has three different drive systems, and the pilot can choose between hybrid, purely electric, or only ICE motors, making eZELOS very safe. Furthermore, eZELOS has autorotation, which the competition does not have.

In terms of noise, eZELOS can match the competition. We land and take off electrically. In addition, the **noise** is also reduced by 8 blades and the absence of the tail rotor. The number of revolutions of the rotor is always the same, unlike in electric air taxis, which have several small electric motors that, with the adjustment of the motors (tilt rotors, multi-copters...), and the different speeds of the propellers, generate frequencies that are not necessarily pleasant.

eZELOS: The Twin-Hybrid Air Taxi with Longer Range and Versatile Drive Systems

We also believe that manufacturers of fully electric air taxis only meet the **specifications** (range and endurance) they communicate under the **best conditions** (temperature and wind). For example, if it is very cold or hot or there is a strong headwind, the range will be significantly reduced. It should also not be forgotten that the performance of batteries decreases over time. Some calculations/simulations can be found here.

In conclusion, the rotor mechanism that led to the development of the helicopter was invented by the Spaniard Juan de la Cierva in 1923, and this year marks its 100th anniversary. Today, it is known as the Autogiro, Gyrocopter, Autogyro, or Gyroplane. In aviation, proven technology is essential for safety, and it is better to choose **reliability over novelty**.

Advantages of the eZELOS

(Twin-Hybrid propulsion system)

The eZELOS twin-hybrid propulsion system produces 50% less CO2 and has 60% lower operating costs compared to light helicopters. eZELOS requires less power storage in modern, long-lasting batteries and thus protects valuable raw materials (sustainability). No downtime is required while charging the batteries and flight reserve time is maximized. . . unlike all-electric aircraft like eVTOLs.

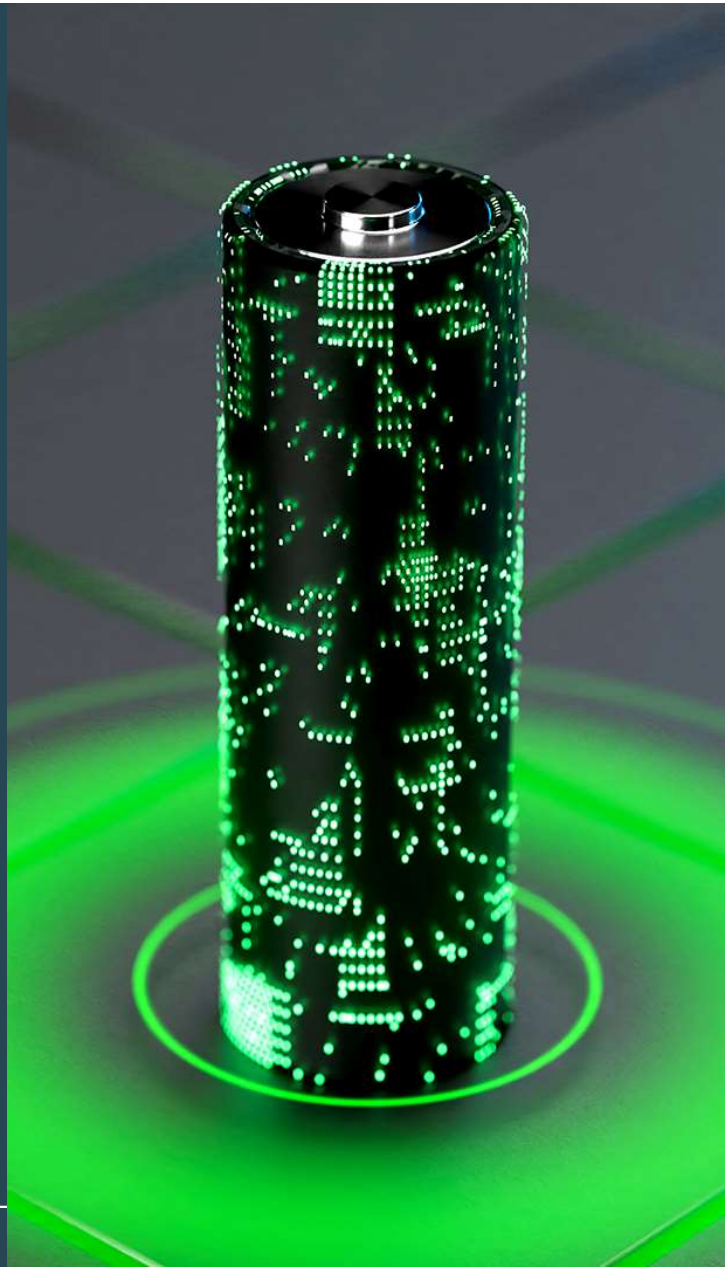
Our decision to equip eZELOS with a twin hybrid is driven by the current and mid-term projected state of pure electric propulsion technology. Batteries for eVTOL are expensive, heavy, have a limited lifespan, and low recharge cycle lifetime. If the temperatures are not ideal (ideal temperatures +10 degrees Celsius until +40 degrees Celsius), battery performance decreases rapidly. The relatively short lifespan of the batteries massively increases the operating costs and charging the batteries for at least 30 minutes after every flight greatly reduces operational revenue.

Headwinds also reduce the range/endurance of most non-aerodynamic eVTOLs. Conventional helicopters must have a flight reserve of at least 30/45 minutes (turbine/piston engine) after landing. This reserve becomes a sticking point for the certification bodies for eVTOL. 100 liters of fuel always represent 100 liters of fuel, but the performance of a battery decreases practically after every flight (the battery "tank volume"). After a while 100 liters become 90 (battery liters), then 80 (battery liters) ... like our experience with PCs and smartphones, battery performance is not a constant compared to gasoline. Solutions for the legal reserve, therefore, become a more complex matter, and having enough energy at the end of a flight in case of an unforeseen event is a challenge for developers.

Limitations of Battery-Powered eVTOLs

A helicopter almost always has full propulsion power available. If a critical incident occurs at the end of an eVTOL flight, depending on the configuration of the system, it cannot be guaranteed that the batteries will still be able to deliver sufficient power to respond. Strict regulations for the reserve of eVTOLs result in excess battery mass being carried along and those expensive batteries having to be replaced after a short period of operation in order to be able to maintain the reserve/performance to protect passengers, this triggers high operating costs and is unsustainable as the batteries contain valuable raw materials, which then need to be disposed of too early.

This type of recycling also requires energy again. Batteries for eVTOL cannot be compared to batteries for electric cars, cars batteries have different requirements based on their use. The batteries of some eVTOLs already reach their performance limits at the start of the operation to manage take-off.

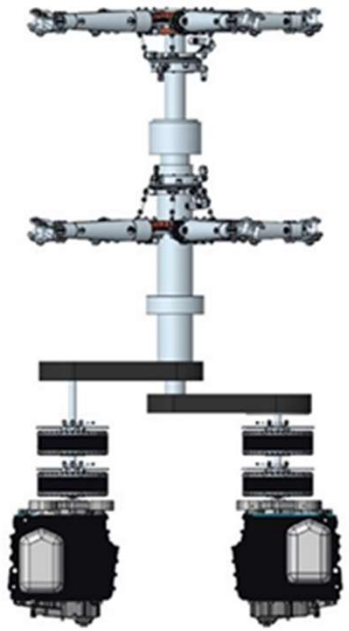


eZELOS Twin-Hybrid: Overcoming the Limitations of Battery-Powered eVTOLs

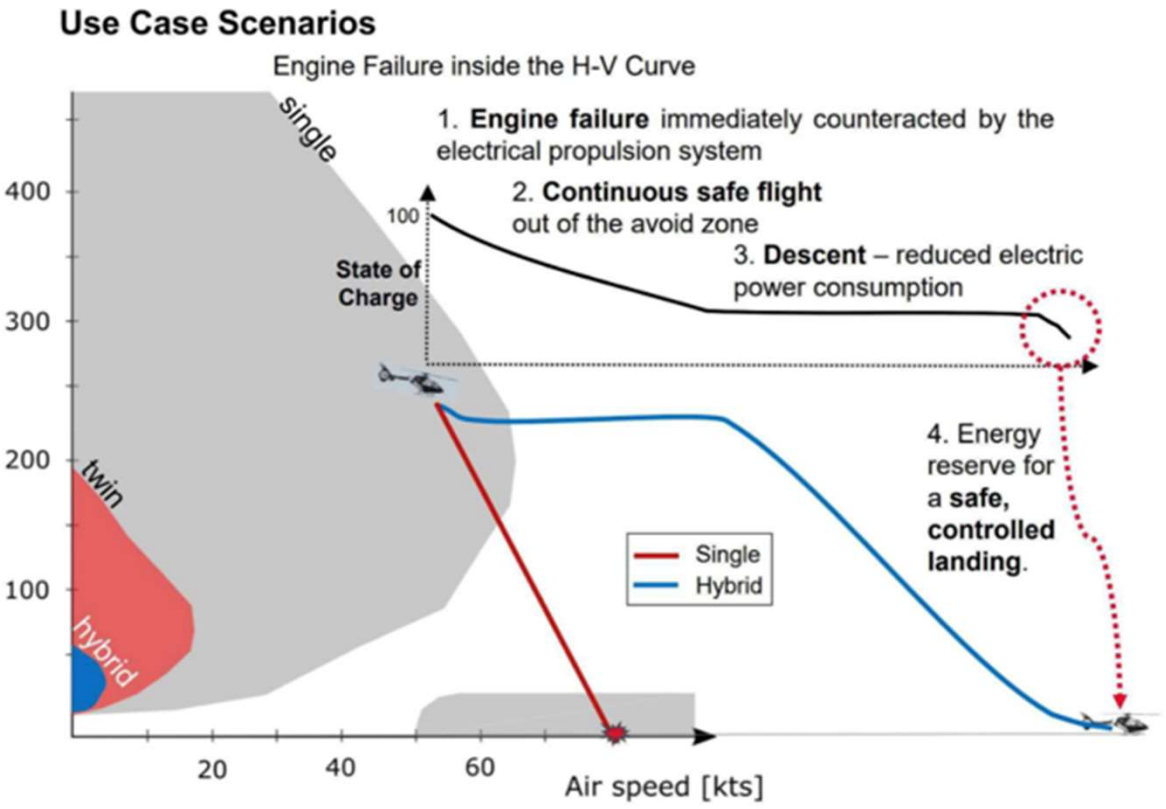
eZELOS already uses a safe, redundant, twin hybrid propulsion system to be immune to any possible propulsion system failures. The start is electric, so the required torque of the electric motors is immediately available for fast take-off, which saves a lot of time compared to today's engine warm-up requirements for conventional helicopters.

With eZELOS, the operating speed of the rotors is reached electrically and then the speed remains approximately constant during the entire flight, including landing. This protects the batteries and thus increases the battery life; Based on vendor experience, we expect +2z,000 charge/recharge cycles, far more than most competitors in the eVTOL market. Thanks to hybrid and direct drive, we can continue to meet the reserve required by the approval authorities.

Internal combustion engines are started in the air to reduce noise on the ground to a minimum. Another advantage of the eZELOS is that the combustion engines for the generator can also be used as a drive (direct drive), which ensures that the ICE can continue to fly in the event of any propulsion subsystem failure. This enormously improves safety and worst-case scenario there is the option of autorotation.



eZELOS Twin-Hybrid propulsion system



Lilium: Customcells ramps up production for air taxi super batteries - manager magazin

Customcells is working with the Californian company Ionblox on development. The partners rely on one high silicon content. According to Customcells, independent tests recently showed that the cells still delivered 88 percent of their original performance after 800 charging cycles. They had aimed for a value of 80 percent.

eZELOS Twin-Hybrid

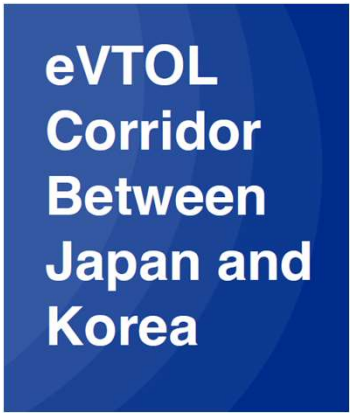
"800 cycles are not a lot for an air taxi. What do you do after the 800 cycles - change batteries or shorten the distance? What do the certification authorities say about non-linear energy sources? 100 liters of kerosene are always 100 liters of kerosene. Another good reason why we use a twin hybrid on our eZELOS is that much smaller batteries are needed, we can also fly through the direct drive of the ICE (Redundant Propulsion System) and still have a CO2 reduction of +/-50 %; A first step, and that with a constant range including reserve."

eZELOS – New Generation of a Light Helicopter/ eVTOL for the AAM Advanced Air Mobility Market

Most of the current eVTOL /Air-Taxi companies focus on UAM Urban Air Mobility like shuttle services to and from airports from urban centers.

Thanks to its hybrid drive system, eZELOS has a longer range than the purely electric eVTOLs of our competitors. Our main focus is on flights currently operated with classic helicopters, as there are no alternatives and new routes. The costs per person are becoming cheaper and more sustainable. In many cases, we can also massively reduce the travel time of ferry connections and passengers are not tied to fixed departure times. Connections to islands are popular routes, we can create needs with the eZELOS in many places. An interesting market is certainly also the tourism industry, where thanks to eZELOS there are no longer long journeys in cars or buses to interesting hotspots and the perspective of the country from the air is certainly a highlight that you will fondly remember later.

Some examples of many routes



eZELOS Specifications

General: (Air-Taxi, -Ambulance - Cargo manned/unmanned)

- Endurance up to 500+km (Depending on configuration)
- Cruise speed 280km/h / Max. Speed 320km/h
- Payload 550+kg

Propulsion System (Total power for take-off +500kW)

- 4 x Electrical engines
- 2 x EDF Electrical Ducted Fans
- 2 x Piston engines
- 8 x Blades (Coaxial 2 x 4)

eZELOS Specifications

Three Flight Modes in one System

- Full electrical flight mode
- Piston engines mode (Direct Drive)
- Hybrid mode

Comfort

- VIP comfort
- Electrical doors
- Air Conditioner
- Luggage compartment 2m x 30cm x 60cm

Conclusion/Summary

Here are several reasons why it makes sense to build hybrid-powered eVTOLs (electric Vertical Take-Off and Landing) rather than relying solely on batteries.

First, batteries are expensive, heavy, and have a limited lifespan. A hybrid motor allows the use of smaller batteries, which **reduces the need for lithium and lowers costs**. Lithium is a valuable resource, and its mining and processing can have negative impacts on the environment. The use of hybrid propulsion also enables eVTOLs to have longer flight times and more reserves, which increases safety.

Second, hybrid drives can make a significant contribution to reducing CO_2 emissions. **Reducing CO_2 emissions** by 50% is already a big step towards sustainability and climate protection. By combining electric and internal combustion engines, the advantages of electric motors, such as high performance and low maintenance, can be combined with the advantages of internal combustion engines, such as greater range and greater operational reliability.

After all, a pure electric start saves time because it does not have to be brought up to operating temperature.

Overall, the use of hybrid engines for eVTOLs offers a promising opportunity to combine the advantages of electric motors with those of internal combustion engines to create powerful, safe, and environmentally friendly engines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