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# AAM Report

ASIA-PACIFIC REGION

1H 2022


Features

EVTOL OEM OVERVIEW
CHINA COUNTRY PROFILE
INSIGHT FROM SMG CONSULTING
EVTOL BATTERIES

Interviews

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AMPAIRE
GREPOW RECHARGEABLE BATTERY
牧羽航空 MUYU AERO
PANTUO
VERTAX
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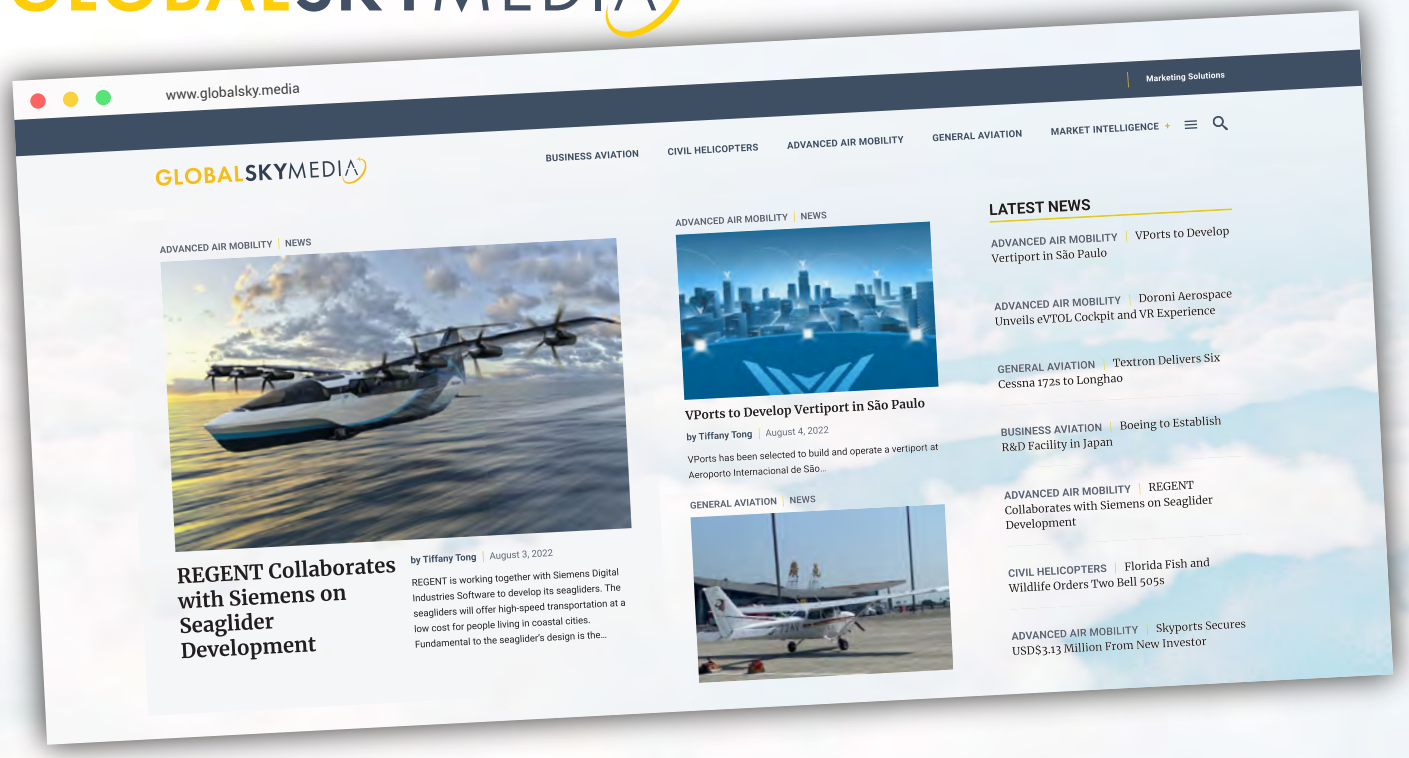


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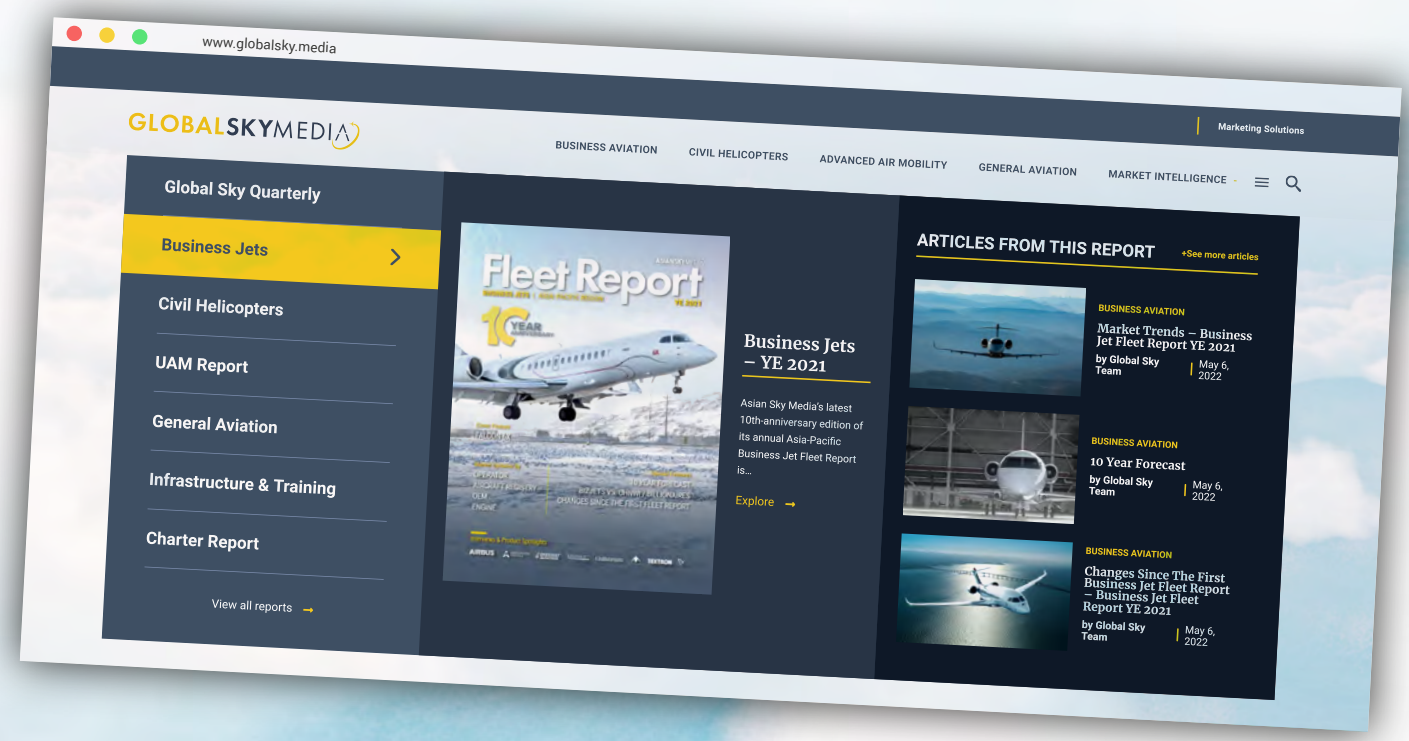

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**COVER IMAGE**
Volocopter
Volocity

# EDITOR'S NOTE

As a child, I'd often dream of different ways of making money. It wasn't a big dream – I just wanted to make a little bit of extra pocket money.

Eventually I decided that I'd make and sell jam. Whilst that might seem like a quintessentially British thing to do, there were definite advantages in it, not least the fact that I could outsource the production to my mother, who was terrified that I would have somehow set fire to the kitchen or ruin her precious AGA cooker.

However, being a child, I didn't have money to buy the things I needed to make the jam (and my mother didn't want to pay for them just in case she ended up with a kitchen full of unsold jam) so I needed people to pay for the jam upfront.

And that was the problem. Whilst people said that they would happily buy my jam, they weren't prepared to pay any money up front. Suffice to say my jam dreams were soon shattered, and to this day I cannot even look at a jar of jam without dreaming about what could have been.

If just one person had given me the money up front, or even part of the money, then I would have had the confidence to continue, and who knows, I could have been writing this to you today as the King of Jam.

Which is why United Airlines paying Archer, the eVTOL OEM, a pre-delivery payment is such a watershed moment in the AAM industry. We have seen orders, multi orders and mega orders, but until United put their money where their mouth is, nobody had put down a single cent for any AAM aircraft, at least not publicly.

Whilst USD$10 million might not seem like a lot of money, it pales into insignificance when compared to the billions of dollars already thrown at the industry, the fact that Archer received a pre-delivery payment has huge ramifications for the industry. And let's not forget that it is not a small startup that nobody has heard of before, it is United Airlines, one of the biggest airlines in the world.

It can be treated as validation of the industry, that people outside of OEMs building the aircraft and VCs funding them believe in the work that is being done. It is the first real sign that we will be getting somewhere, that all of the ideas, plans and prototypes are being validated and that the sector will soon be fully commercialized.

It also means that there has never been more of a need for a second edition of our AAM report.

So, the report you're reading now is the second edition. Much has changed – including the name. With the original report we stuck to the Urban Air Mobily (UAM) name as it was more familiar, but now as the market has matured further, the switch to Advanced Air Mobility (AAM) seems appropriate. The term is also used more frequently than UAM and has become more accurate as the sector grows outside of its original ambitions to solve urban mobility issues, and looks at connecting nearby city centers as well.

With the new name also came some decisions surrounding the terms used. This biggest one of these was whether we used crewed or manned. Following an internal discussion, we decided to use crewed, not only because it is the term that is used more commonly, but also because it is a technically more accurate term to describe if the aircraft is being piloted.

The AAM world has also introduced new terms that are perhaps more commonly used in some parts of the world than others. The most common of these is '3D Travel'. This term is frequently used in China and across Asia, most commonly in reference to an un-asked


**SPECIAL THANKS TO OUR CONTRIBUTORS**

AEROFUGIA 沃飞长空 · ALAUDA · AMPAIRE · amsl aero · AUTOFLIGHT · EHANG 亿航 · FROGS · GREPOW RECHARGEABLE BATTERY · HONDA · KAI KOREA AEROSPACE INDUSTRIES, LTD. · KARI 한국항공우주연구원 · 牧羽航空 MUYU AERO · PĀNTUO · SKYDRIVE · SMG CONSULTING · supernal · 时的科技 TCab Tech · tetra · VERTAX · VOLANT AEROTECH 沃兰特 · VOLOCOPTER · 小鹏汇天 · ZEROG

question about the difference between electric cars and electric aircraft. An electric car would travel in 2D – forwards, backwards and side to side, whereas an aircraft travels in 3D – forwards, backwards, side to side, and up and down.

There will no doubt be many more new terms to learn in the next few years, and most will appear in future AAM Report editions.

In this report we again take a look at the major OEMs across the Asia-Pacific region, and list their most prominent aircraft, as well as any pertinent dates, including first flights and projected entry into service days. Where known, we have also looked into the OEMs funding, listing out their investors, and how much money they have raised. This data has, in the most part, been validated by the OEMs themselves, although in some cases we haven't been able to receive a direct answer to the funding question, so in these cases we have chosen to say that data is undisclosed.

Elsewhere in this edition we have interviews with AEROFUGIA, Grepow, MuYu, Pantuo, and Vertax from within mainland China, whilst outside of China, we have interviews with Ampaire, Volocopter and SMG Consulting.

Finally, I'd like to take this opportunity to thank every company and individual that has contributed to this edition, no matter how big or small.

Sincerely,
Alud Davies
Editor-in-Chief
Global Sky Media

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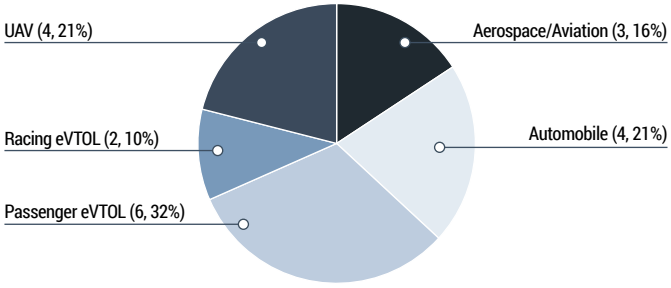
# ASIA-PACIFIC EVTOL OEMS

A new generation of aviation pioneers are building air mobility solutions that will reduce urban congestion and reduce our reliance on fossil-based fuels. This opening section will introduce the Asia-Pacific manufacturers that have announced eVTOL projects as of June 30, 2022, and present a timeline for each, looking at when they announced their projects, and when they expect to gain certification. This section includes manufacturers either headquartered in Asia-Pacific or backed by an APAC company and actively developing crewed/uncrewed passenger eVTOLs.

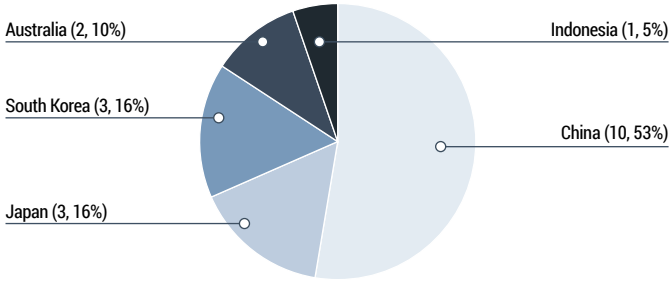
# OVERVIEW

Advanced Air Mobility (AAM), defined by the United States Federal Aviation Administration (FAA), is an air transportation system that will operate and transport passengers or cargo at lower altitudes in urban, suburban, and rural areas. This section focuses on passenger-grade Electric Vertical Takeoff and Landing (eVTOL) vehicles as they provide an alternative solution for people to get around sustainably.

## OEMS BY CLASSIFICATION



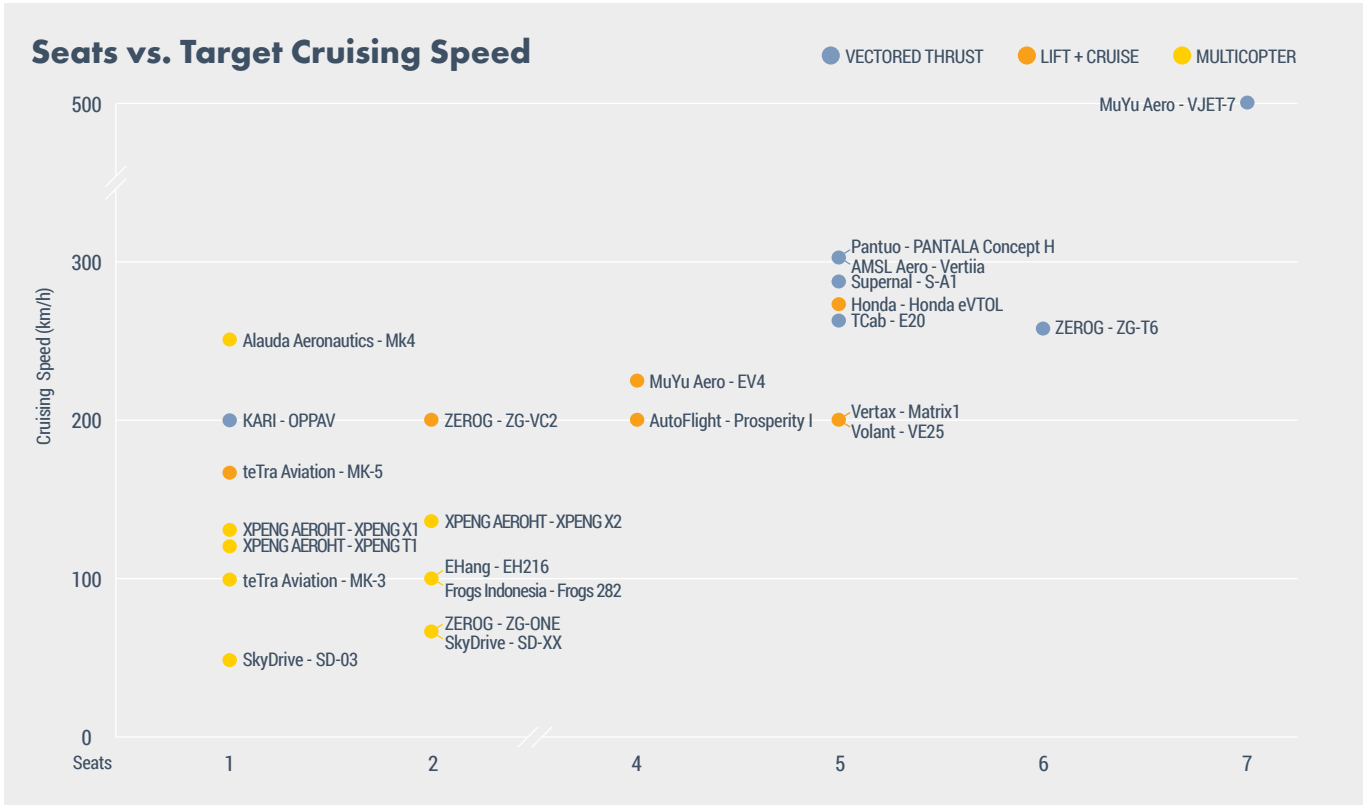

## OEMS BY COUNTRY



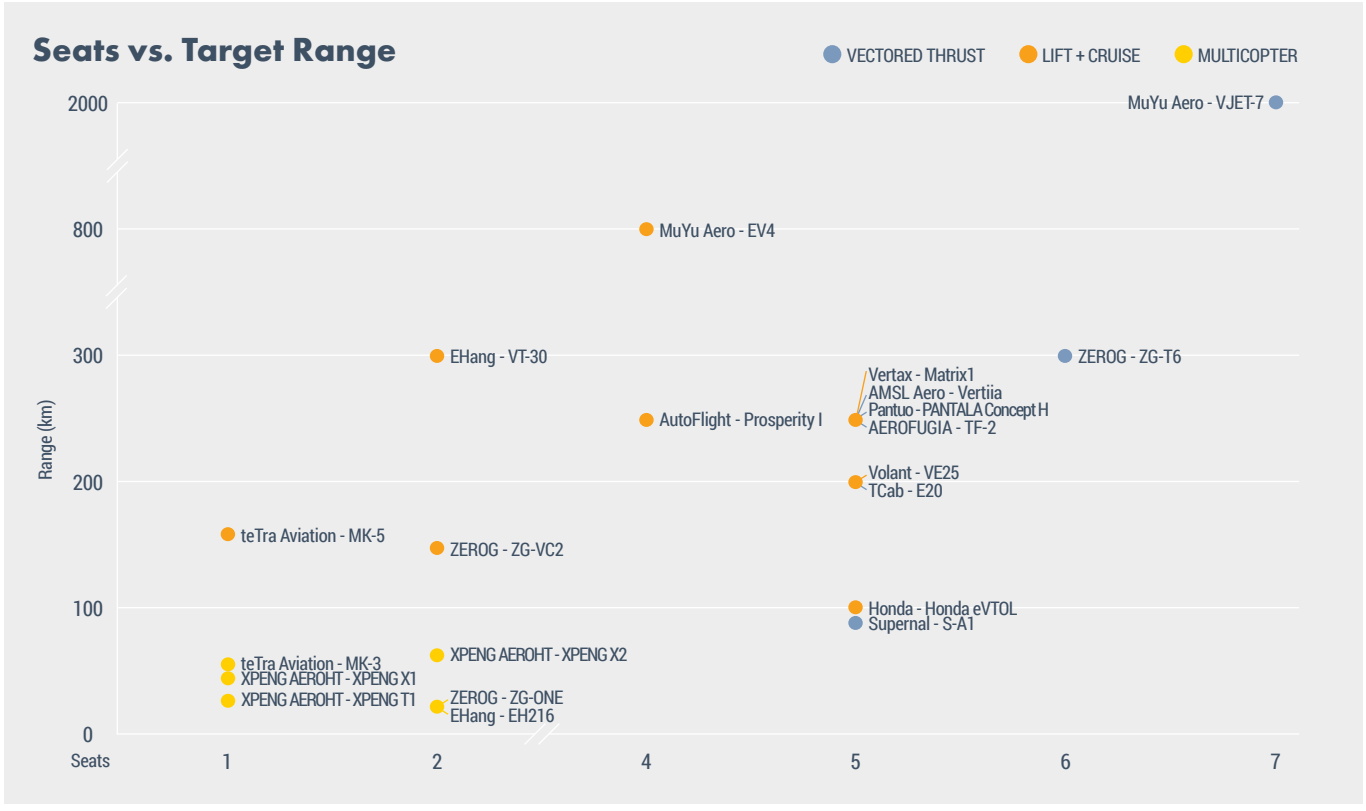

Among the 19 active Original Equipment Manufacturers (OEM) in the Asia-Pacific as of June 30, 2022, four were derived as a subsidiary of automobile manufacturers, three organizations were already in the aviation industry (Honda is in both the automobile and aviation industries), four started their business with cargo drones, two engaged in developing racing models, and six developed passenger eVTOLs only. Car manufacturers are not only interested in providing an advanced mobility solution but they are also interested in establishing an integrated three-dimensional mobility system that connects the sky to the ground. For example, in their concept videos, both Honda and Supernal – formally a division of Hyundai but now a subsidiary) introduced shuttles that linked eVTOL Vports to other destinations. Uncrewed Aerial Vehicle (UAV) manufacturers adopted the technology and experiences gained from cargo drones and applied them to passenger eVTOL development.

More than 50% of Asia-Pacific eVTOL OEMs have their headquarters in China. with most based either in Shanghai, or around the Guangzhou Province. There are three eVTOL manufacturers in Japan, all of which have their offices in Tokyo. South Korea also has three organizations engaged in building eVTOLs, from which one, Supernal, formerly an AAM division and now a subsidiary of Hyundai, established its headquarters in Washington, US. There are also two OEMs in Australia and one in Indonesia.

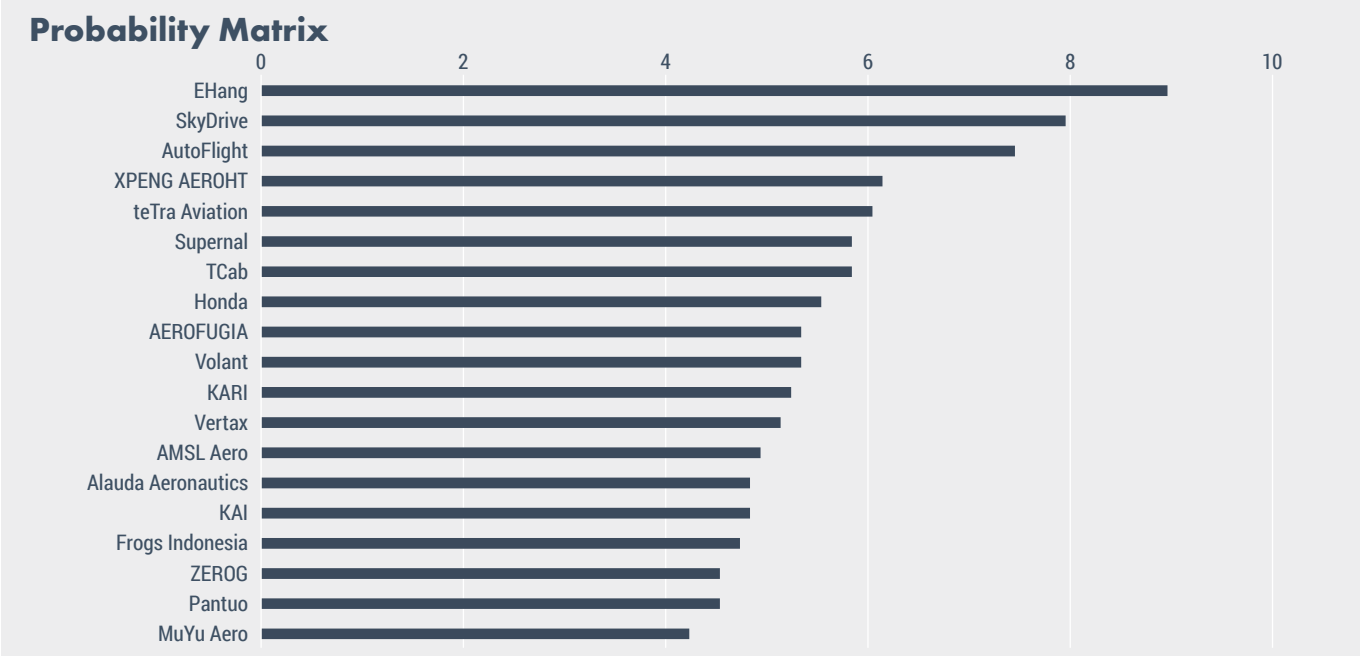
Below is a graph showing the relationship between seats and cruising speeds of eVTOLs developed by the OEMs in APAC. The bottom left portion concentrates on Multicopter eVTOLs as these vehicles usually have one or two seats and a cruising speed under 200 kilometers per hour. Alauda's Mk4 is the only Multicopter that reaches a speed of 250 kilometers per hour since it is a racing model. Aircraft in a Lift and Cruise configuration are either Multicopters or use Vectored Thrust, and have an average speed of 205 kilometers per hour. With a pair of fixed wings, the cabin can have more flexibility in layout as they have heavier takeoff weight than Multicopter vehicles. Vectored Thrust eVTOLs are usually designed to carry more than five passengers and can have a cruising speed above 250 kilometers per hour. In the graph on the following page, OPPAV developed by KARI is a technical demonstrator as the company has not yet revealed the specification for its final model; therefore, it appears to be far from the Vectored Thrust cluster.




Like cruising speed, eVTOLs adopting a Multicopter configuration are clustered towards the bottom left corner in the graph below, as their targeted range does not exceed 60 kilometers. There is no significant trend for vehicles in Lift and Cruise and Vectored Thrust. Their range varies from approximately 100 kilometers to 300 kilometers.



Measured by funding, certification progress, technology readiness, core team, stage of flight test, and the external environment of the eVTOL OEMs in the APAC region, the following chart represents Global Sky Media's Probability Matrix that looks at the probability of the listed OEMs eVTOLs entering service.




The following chart summarizes the OEMs and their vehicles. XPENG AEROHT and EHang were the earliest companies that entered the realm of passenger eVTOLs. More than a quarter of OEMs began their eVTOL projects in 2021. ZEROG is the only manufacturer in Asia-Pacific that announced plans to develop Multicopters, Lift and Cruise and Vectored Thrust vehicles.

| Based Country | Company Name | Project Launch Year | Funding | Products |
|---|---|---|---|---|
| Australia | Alauda Aeronautics | 2016 | $1,000,000 | MK4 |
| Australia | AMSL Aero | 2017 | $7,257,500 | Vertiia |
| China | AEROFUGIA | 2020 | Corporate Backed | TF-2 |
| China | AutoFlight | 2017 | $100,000,000 | Prosperity I |
| China | EHang | 2014 | $172,000,000 | EH216/VT-30 |
| China | MuYu Aero | 2018 | Undisclosed | EV4/V-JET7 |
| China | Pantuo Aviation | 2019 | Undisclosed | PANTALA Concept H |
| China | TCab Tech | 2021 | $10,000,000 | E20 |
| China | Vertax | 2021 | Unspecified | Matrix1 |
| China | Volant | 2021 | Unspecified | VE25 |
| China | XPENG AEROHT | 2013 | $500,000,000 | XPENG T1/X1/X2/6th Gen. Flying Car |
| China | ZEROG | 2021 | Unspecified | ZG-ONE/ZG-VC2/ZG-T6 |
| Indonesia | Frogs Indonesia | 2017 | Undisclosed | Frogs 282 |
| Japan | Honda | 2021 | Corporate Backed | Honda eVTOL |
| Japan | SkyDrive | 2018 | $53,369,249 | SD-03/SD-XX/SD-05 |
| Japan | teTra Aviation | 2018 | $4,258,990 | MK-3/MK-5 |
| South Korea | KAI | 2020 | Corporate Backed | Unnamed vehicle |
| South Korea | KARI | 2019 | $36,878,733 | OPPAV |
| South Korea | Supernal | 2019 | Corporate Backed | S-A1 |

# Alauda Aeronautics

ALAUDA

## Australia | Founded in 2016

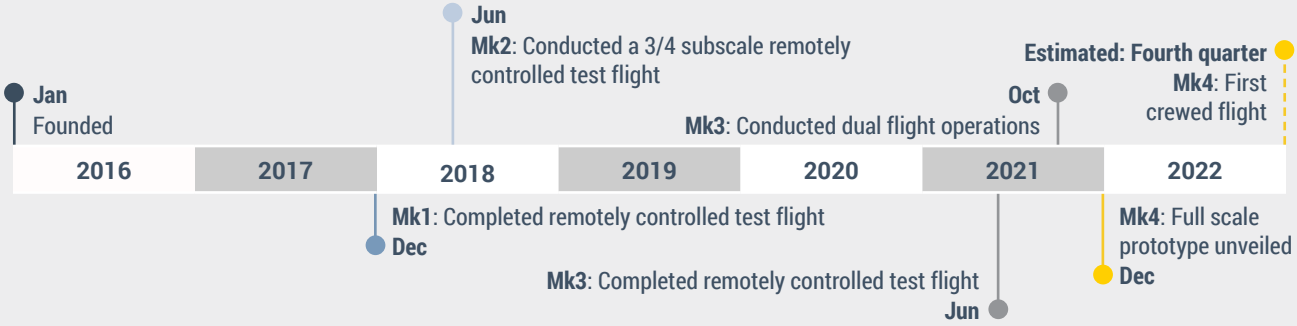
Alauda Aeronautics is a company that develops electric vertical take-off and landing (eVTOL) racing aircraft. It was founded in 2016 in Sydney, Australia, but later relocated to Adelaide, Australia. The eVTOL racing series that Alauda competes in is called Airspeeder, of which the Airspeeder Mk3 is the latest uncrewed racing craft. Airspeeder sees this next generation of motorsports as the key to unlocking the UAM / AAM revolution. The first uncrewed race (EXA series race) was held in May, 2022.

### AIRSPEEDER MK4

| | |
|---|---|
| PROJECT PHASE | Prototype Devt. & Testing |
| TYPE | Multicopter |
| OPERATION | Piloted |
| RANGE | Undisclosed |
| CRUISE SPEED | 250 km/h (racing speed) |
| SEATS | 1 |
| ELECTRIC MOTORS | 8 |

The Airspeeder Mk4 is a modern, streamlined version of the Formula 1 cars of the 1960s. It has eight propellers with electric motor drives and two blades on each propeller and can carry one pilot. The fuselage uses carbon fiber composite. The Mk4 can reach its top speed of 160 kilometers per hour in 2.3 seconds and will be primarily participating in air racing competitions organized by Airspeeder.

## MILESTONES




## CERTIFICATION PROGRESS

| DATE | AGENCY | STAGE |
|---|---|---|
| Unspecified | Australian Civil Aviation Safety Authority | Alauda received experimental type certification |

## FUNDING

| DATE | ROUND | AMOUNT | INVESTORS |
|---|---|---|---|
| Nov 4, 2020 | Seed round | USD$1M | Saltwater Capital, Jelix Ventures, and Rad Ventures |
| Dec, 2021 | Series A | Undisclosed | Undisclosed |

## ORDERS

Order information is not available. (Not for public purchase. Private purchase by nominated racing teams only)

## GLOBAL PARTNERSHIPS

| | |
|---|---|
| Sep 7, 2020 | Partnered with **Acronis** and **Teknov8**, where Acronis will provide the collision avoidance systems and Teknov8 will provide cybersecurity solutions |
| May, 2021 | Partnered with **NVIDIA** for advanced processing units and collision avoidance technologies |
| Sep 22, 2021 | Partnered with **Telstra Purple**, where Telstra Purple will provide virtual race-control sysem for Alauda's Airspeeder series |
| Jun 19, 2021 | Entered into a engineering partnership with **IWC Schaffhausen** |
| Dec, 2021 | New manufacturing facility announced in partnership with the **state and federal government** |

*Information in the milestones and global partnerships sections was retrieved from Alauda and it's Airspeeder official website. Funding information was retrieved from i3 Connect. The information cutoff date was June 30, 2022.*

# AMSL Aero

## Australia | Founded in 2017

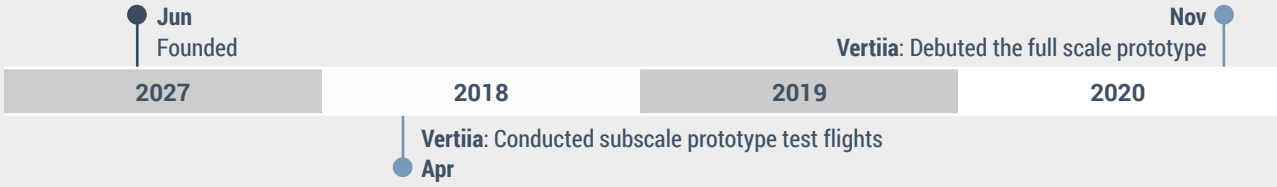
AMSL Aero, founded in 2017, is a start-up company based in Australia. It plans to market its aircraft for AAM applications, personal air transportation, military use, disaster relief, and emergency medical response.

### VERTIIA

| | |
|---|---|
| PROJECT PHASE | Product Devt. & Testing |
| TYPE | Vectored Thrust |
| OPERATION | Autonomous |
| RANGE | 250 km (electric) |
| CRUISE SPEED | 300 km/h |
| SEATS | 5 |
| ELECTRIC MOTORS | 8 |

The Vertiia adopted a Vectored Thrust configuration using four tilting wings with eight propellers. The vehicle has one seat for the pilot and four for the passengers and is designed to connect regional Australia. It can also serve as an air ambulance that carries a pilot, a medic and one patient. Vertiia has a maximum range of 250 kilometers using electric batteries, while hydrogen power allows the vehicle to travel up to 1,000 kilometers.

## MILESTONES




## CERTIFICATION PROGRESS

| DATE | AGENCY | STAGE |
|---|---|---|
| Estimated: 2024 | Australian Civil Aviation Safety Authority | Plans to obtain the type certification |

## FUNDING

| DATE | ROUND | AMOUNT | INVESTORS |
|---|---|---|---|
| Feb, 2018 | Seed round | USD$60,206 | Muru-D |
| Unspecified | Seed+ round | AUD3M | IP Group |
| Feb 12, 2020 | Government grant | AUD3.3M | Australian Government |
| Jul 11, 2020 | Government grant | AUD950K | New South Wales government (the State Government's Regional Investment Attraction Fund) |

## ORDERS

Order information is not available

## GLOBAL PARTNERSHIPS

### AUSTRALIA

| | |
|---|---|
| Oct 12, 2018 | Announced the continuation of the partnership with **Qantas** to provide passenger transport in regional Australia |
| Nov 25, 2020 | Partnered with the **University of Sydney** and **CareFlight** to redevelop Vertiia into an aerial ambulance |

*Information on the certification progress was retrieved from New Atlas; funding was retrieved from Financial Review, AuManufacturing, Australian Government and TransportUP; global partnerships information was retrieved from a presentation at the Qantas AVRO Accelerator Demo Day 2018 and news from the University of Sydney. The information cutoff date was June 30, 2022.*

# AEROFUGIA

AEROFUGIA 沃飞长空

## Mainland China | Founded in 2020

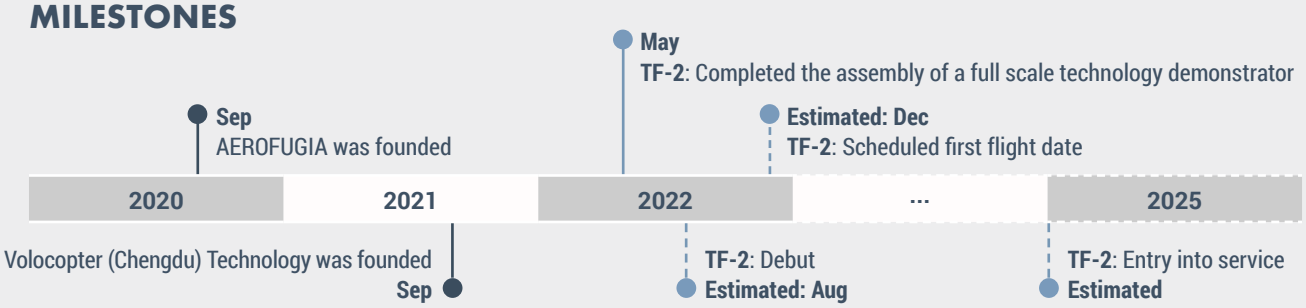
AEROFUGIA, founded in September 2020, is an aviation unit under Geely Technology Group's new general aviation strategy. AEROFUGIA is dedicated to initiating the large-scale commercial operation of low-altitude three-dimensional transportation in logistics and passenger aerial travel markets. In September 2021, AEROFUGIA established a joint venture with Volocopter, a German advanced air mobility company, to promote the commercialization of the passenger-grade eVTOL series from Volocopter in mainland China.

### TF-2

| | |
|---|---|
| PROJECT PHASE | Detailed design |
| TYPE | Vectored Thrust |
| OPERATION | Piloted |
| RANGE | 200-300 km |
| CRUISE SPEED | 250 km/h |
| SEATS | 5 |
| ELECTRIC MOTORS | 9 |

The TF-2 is a five-seat tiltrotor eVTOL aircraft developed by AEROFUGIA. It can carry four passengers and a pilot and will be primarily used for intra and intercity passenger flights, delivering a business or an efficient travel. The TF-2 targets airworthiness certification in multiple countries with the aim of entering in service worldwide.


## MILESTONES




## CERTIFICATION PROGRESS

| DATE | AGENCY | STAGE |
|---|---|---|
| Estimated: Dec, 2024 | Civil Aviation Administration of China | Expected Type Certification |

## FUNDING

Corporate backed

## ORDERS

Order information is not available

## GLOBAL PARTNERSHIPS

| | |
|---|---|
| Apr 19, 2021 | Geely Techonology Group, AEROFUGIA and **Volocopter** exhibited the electric urban air mobility vehicle at the Shanghai International Automobile Industry Exhibition |
| Sep 22, 2021 | AEROFUGIA and **Volocopter** formally established a joint venture company, Volocopter (Chengdu) |

*Information on the milestones and global partnerships section was retrieved from AEROFUGIA's official WeChat account or provided by AEROFUGIA. The information cutoff date was June 30, 2022.*

# AutoFlight

AUTOFLIGHT

## Mainland China | Founded in 2017

AutoFlight, established in Shanghai in 2017, is one of the earliest technology enterprises in China to invest in large-scale autonomous eVTOLs. AutoFlight established an R&D and certification center in Germany, an operation and maintenance center in the United States, and a mass production base for large composite materials in Shandong, China. The current production plan for the eVTOL market includes large-scale autonomous aerial cargo vehicles and passenger-grade aerial vehicles. According to AutoFlight's strategy of "from small to big, from cargo to crew," AutoFlight's autonomous aerial vehicle has completed nearly ten thousand transition test flights[1]. It was one of the first aerial vehicles using eVTOL technology to deliver packages to China's outlying islands, transport organs, deliver PCR test samples and run commercial logistics.

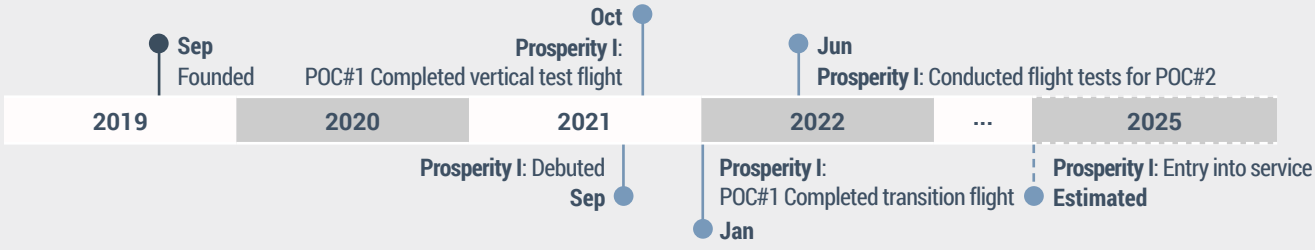
### PROSPERITY I

| | |
|---|---|
| PROJECT PHASE | Prototype Devt. & Testing |
| TYPE | Lift + Cruise |
| OPERATION | Autonomous |
| RANGE | 250 km |
| CRUISE SPEED | 200 km/h |
| SEATS | 4 |
| ELECTRIC MOTORS | 10 |

The Prosperity I is a Lift + Cruise aircraft with eight propellers on top of the fuselage to provide lifting power and two propellers at the rear to give cruise power. The Prosperity I is primarily designed for urban and inter-city passenger travel and has a maximum capacity of four people. The aircraft adopts a multi-redundant[2] flight control system and could opt for a Whole Aircraft Rescue Parachute System.

*Note: 1. During a transition flight, aircraft would transit from hover flight (i.e., flight using propellers) to wing-borne flight (i.e., flight relying on fixed wings).*
*2. It has multiple sets of essential components or peripherals of the same function, often known as redundancy. The vehicle can still function normally if a single point of system or equipment failure happens.*

## MILESTONES




## CERTIFICATION PROGRESS

| DATE | AGENCY | STAGE |
|---|---|---|
| Estimated: 2022 | European Aviation Safety Agency; Civil Aviation Administration of China | Will submit application for airworthiness certification |

## FUNDING

| DATE | ROUND | AMOUNT | INVESTORS |
|---|---|---|---|
| Sep 18, 2021 | Series A | USD$100M | Team Global |

## ORDERS

Order information is not available

## GLOBAL PARTNERSHIPS

### ASIA

| | |
|---|---|
| Nov 25, 2020 | Signed an MoU with the **Aden Group** to work together on air traffic innovation and carbon emission reduction |

*Information on the milestones, certification progress, funding and global partnerships was retrieved from AutoFlight's official website and WeChat account. The information cutoff date was June 30, 2022.*

# EHang

EHANG | 亿航

## Mainland China | Founded in 2014

EHang is a global pioneer in the advanced air mobility industry. It was listed on the US Stock Exchange in 2019, becoming the world's first listed advanced air mobility company. Integrating Uncrewed Aerial Vehicle (UAV) and autonomous flight technology, EHang put forward the concept of an Autonomous Aerial Vehicle (AAV) and launched different products for enterprise users while ensuring these products are being continiuosly updated. Following its EH216 multicopter, EHang launched a Lift and Cruise model called VT-30.

### EH216

| | |
|---|---|
| PROJECT PHASE | Delivery (Cert. in progress) |
| TYPE | Multicopter |
| OPERATION | Autonomous |
| RANGE | 30 km |
| CRUISE SPEED | 100 km/h |
| SEATS | 2 |
| ELECTRIC MOTORS | 16 |

The EH216 series adopts the Multicopter configuration. Each vehicle has eight arms to hold eight axes and 16 propellers. The EH216-S model can carry two passengers and will be used primarily for short-and-mid-haul commuting and aerial tourism, while the EH216-F and EH216-L are for firefighting and logistics, respectively. The Fail-Safe system equipped in each vehicle automatically evaluates its performance. The EH216 can interact with EHang's command-and-control center for real-time data transmission through a high-speed communication network.

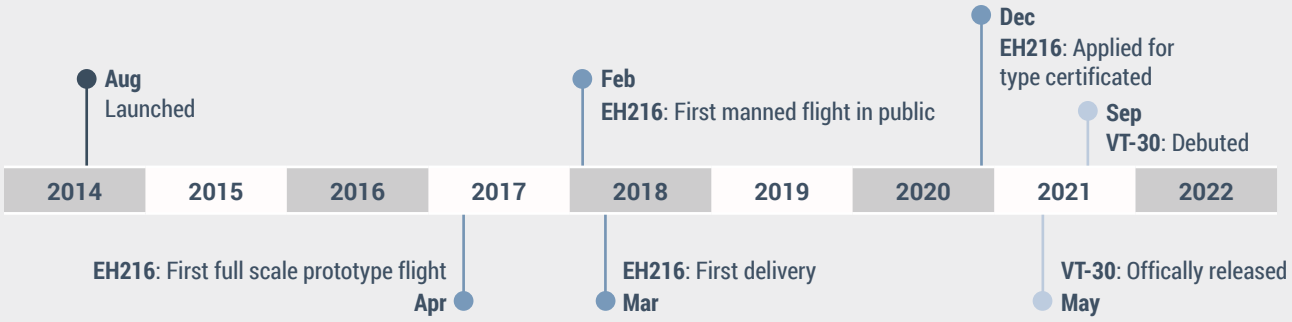
### VT-30

| | |
|---|---|
| PROJECT PHASE | Prototype Devt. & Testing |
| TYPE | Lift + Cruise |
| OPERATION | Autonomous |
| RANGE | 300 km |
| CRUISE SPEED | TBD |
| SEATS | 2 |
| ELECTRIC MOTORS | TBD |

VT-30 adopts a Lift and Cruise configuration and has a pair of fixed wings. The back of the cabin has one propeller that provides cruising power, and the other eight propellers at the side provide lifting power. VT-30 can carry two passengers and is used primarily for inter-city flights. It is equipped with a triplex redundancy[1] fly-by-wire flight control system.

*Note: 1. A triplex redundancy flight control system enables data sharing between triplex control computers. Each control computer has a fault-resilient signature which provides features like fault masking.*

## MILESTONES




## CERTIFICATION PROGRESS

| DATE | AGENCY | STAGE |
|---|---|---|
| May 27, 2020 | Civil Aviation Administration of China | Issued the commercial pilot operation approval |
| Apr 16, 2021 | Civil Aviation Administration of China | Organized a type certification team for the EH216 |
| Feb 23, 2022 | Civil Aviation Administration of China | Adopted the Special Conditions for EH216-S AAV Type Certification |

## FUNDING

| DATE | ROUND | AMOUNT | INVESTORS |
|---|---|---|---|
| Dec 30, 2014 | Series A | USD$10M | GGV Capital, ZhenFund, PreAngel, Nick Yang |
| Aug 24, 2015 | Series B | USD$42M | GGV Capital, ZhenFund, Microsoft Accelerator Beijing, PreAngel, GP Capital, LeBox Capital, Shenzhen Oriental Fortune Capital |
| Dec 12, 2019 | IPO | USD$40M | Listed on Nasdaq |
| Dec 13, 2019 | Post-IPO Equity | USD$40M | GGV Capital |
| Jan 29, 2021 | Private Placement VC | USD$40M | Carmignac |

## ORDERS

| DATE | COMPANY | COUNTRY/SUBREGION | TYPE | VT-30 | EH216 |
|---|---|---|---|---|---|
| Dec 23, 2021 | Undisclosed company in Japan | Japan | Purchase order | 1 | |
| Jan 20, 2022 | AirX | Japan | Pre-order | | 50 |
| Mar 10, 2022 | AEROTREE | Malaysia | Pre-order | | 50 |
| Mar 10, 2022 | AEROTREE | Malaysia | Pre-order | 10 | |
| Apr 11, 2022 | Prestige Aviation | Indonesia | Pre-order | | 100 |
| Jun 27, 2022 | Tianxingjian | China | Purchase order | | 5 |

# GLOBAL PARTNERSHIPS

## Europe

| | |
|---|---|
| Oct 18, 2019 | Announced a strategic partnership with **Vodafone** to collaboratively establish an AAM ecosystem in Germany and eventually across Europe |

### AUSTRIA

| | |
|---|---|
| Nov 21, 2018 | Announced the signing of a strategic partnership agreement with the **FACC** to enhance the current AAV design and foster the actual production together |
| Feb 28, 2019 | Announced that **ProSiebenSat.1 PULS 4** joined the partnership between EHang and FACC to launch AAM services in Europe |

### ITALY

| | |
|---|---|
| Mar 16, 2021 | Announced a partnership with **Giancarlo Zema Design Group**, planning to develop vertiports in Italy together |

### SPAIN

| | |
|---|---|
| Mar 16, 2020 | Announced the signing of an agreement with the **Seville city council** to establish the first AAM pilot city in Spain |
| Mar 18, 2020 | Announced the signing of an agreement with the **Lliria city council** to foster AAM services in Llíria |
| Apr 28, 2021 | Announced the signing of an agreement with the **Zaragoza city council** to build another AAM pilot city in Europe |
| Apr 30, 2021 | Announced the partnership with **Aeroports de Catalunya** to enhance autonomous aerial mobility solutions in Europe |
| Jul 12, 2021 | Announced the formation of a strategic partnership with **Globalvia** to foster the development and implementation of AAM in Iberian Peninsula and the Latin America |
| Jun 28, 2022 | Announced a strategic partnership with **ENAIRE** to advance the U-Space project and the research, development and innovation of AAM in Spain and across Europe |

## Asia

### GREATER CHINA

| | |
|---|---|
| Aug 6, 2019 | Announced the signing of a strategic cooperation framework agreement with the **Guangzhou government** to enable Guangzhou as Ehang's first AAM pilot city |
| Dec 5, 2019 | Announced the forming of a strategic partnership with **Heli Chuangxing Real Estate** to accelerate the development of AAM in Guangzhou |
| Apr 27, 2020 | Announced the signing of a strategic partnership agreement with **LN Holdings** to jointly create a paradigm of new aerial traffic and tourism ecology |
| Dec 28, 2020 | Announced the establishment of an agreement with **Greenland Hong Kong Holdings Limited** to explore the opportunity of trial operation in Forest Lake |
| Jan 12, 2021 | Announced a strategic partnership with **Zhuhai Da Heng Qin Pan-Tourism** Development, **Zhuhai Huafa Sports Operations Management** and **Flying World (Zhuhai) Technology** to implement AAM in Hengqin New Area jointly |
| Sep 15, 2021 | Announced the signing of a strategic partnership agreement with **HELI-EASTERN** to build an integrated AAM airspace in the Greater Bay Area |
| Oct 22, 2021 | Announced the signing of a strategic partnership agreement with **Shenzhen Expressway Operation and Development Company Limited** to implement AAM with helicopters and AAVs under an integrated airspace in Shenzhen |
| Dec 29, 2021 | Announced a partnership with **Guangzhou Development District Communications Investment Group** to jointly launch a 5G Intelligent Air Mobility Experience Center in Guangzhou |
| Jun 27, 2022 | Announced a partnership with **Tianxingjian Cultural Tourism Investment and Development LLC.** to develop low-attitude aerial tourism services in Aizhai Wonder |

### MALALYSIA

| | |
|---|---|
| May 10, 2022 | Announced the signing of a strategic partnership agreement with **Aerotree Flight Services** to enhance AAM services in Malaysia |

### THAILAND

| | |
|---|---|
| May 27, 2022 | Announced the strategic partnership with **Charoen Pokphand Group** to promote Ehang's AAV and foster AAM operations in Thailand |

## EH216 PROTOTYPE DEMONSTRATION FLIGHT

| DATE | LOCATION | DETAIL |
|---|---|---|
| Apr 16, 2018 | Amsterdam, the Netherlands | Conducted demonstration flight at the Johan Cruyff Arena |
| Sep 28, 2018 | Doha, Qatar | Completed demonstration flight at Khalifa International Stadium and the Pearl |
| Apr 4, 2019 | Vienna, Austria | Exhibited at the 4GAMECHANGERS Festival |
| Aug 27, 2019 | Changchun, China | Completed demonstration flight during Northeast Asia Expo |
| Jan 7, 2020 | North Carolina, United States | Received a flight permit and conducted trial flight in Raleigh |
| Sep 7, 2020 | Danxia, China | Conducted uncrewed with passengers trial aerial tourism flights |
| Nov 24, 2020 | South Korea | Demonstrated different use cases |
| Dec 9, 2020 | Austria | EH216 received long-term trial flight permit |
| Feb 23, 2021 | Beijing, China | Conducted trial flight over the frozen Yanqi Lake |
| Feb 25, 2021 | Zhuhai, China | Demonstrated the application of aerial tourism |
| Jun 4, 2021 | Okayama, Japan | Conducted trial flight at the Kasaoka Air Station |
| Sep 3, 2021 | Estonia | Simulated a flight connection scenario |
| Nov 29, 2021 | Bali, Indonesia | Demonstrated the application of aerial tourism |
| Dec 23, 2021 | Japan | Conducted trial flight to futher explore various applications |
| May 1, 2022 | Jishou, China | Conducted trial flight in Aizhai Wonder Tourist Area |
| Jun 10, 2022 | Dali, China | Demonstrated the application of aerial tourism |

*Information on the milestones, certification progress, orders, and global partnerships was retrieved from Ehang's official website and official WeChat account. Funding information was retrieved from Crunchbase and Nasdaq. The information cutoff date was June 30, 2022.*

# MuYu Aero

牧羽航空 MuYu Aero

## Mainland China | Founded in 2018

MuYu Aero, founded in Wuxi, was one of the first Chinese companies to enter the field of Light-Sport Aircraft (LSA). MuYu developed the DOLPHIN 200 Amphibious LSA, the MY-ABC Amphibious Flying Car, and the MY-AH 500 Automatic Uncrewed Coaxial Helicopter. The company is currently developing and testing a four-seat and a seven-seat passenger eVTOL.

### EV-4

| | |
|---|---|
| PROJECT PHASE | Prototype Devt. & Testing |
| TYPE | Lift + Cruise |
| OPERATION | TBD |
| RANGE | 800 km |
| CRUISE SPEED | 216 km/h |
| SEATS | 4 |
| ELECTRIC MOTORS | 10 |

The EV-4 adopts a Lift + Cruise configuration, with a pair of fixed wings on top of the fuselage. There are eight propellers for lifting and two for cruising, situated on the wings on both sides. The EV-4 is primarily for urban air mobility, capable of carrying four passengers.

### VJET-7

| | |
|---|---|
| PROJECT PHASE | Detail design |
| TYPE | Vectored Thrust |
| OPERATION | Autonomous |
| RANGE | 2000 km |
| CRUISE SPEED | 480 km/h |
| SEATS | 7 |
| ELECTRIC MOTORS | 12 |


The VJET-7 adopts a Vectored Thrust configuration with main ducted fans on either side of the fuselage that can be tilted to provide lift and cruising power. The rear propeller only provides vertical propulsion and may be retracted during cruising, and the aircraft has four motors in parallel to power each rotor. The VJET-7 is primarily for inter-city aerial shared rides or for use as a private jet.

## MILESTONES

**Jun**
Founded

**Jan**
**VJET-7**: 1/5 subscale demonstrator first flight

2018 | 2019 | 2020 | 2021 | 2022

**EV-4**: Full scale demonstrator test flight in mooring condition
**Sep**

## CERTIFICATION PROGRESS

Not yet in the certification progress

## FUNDING

Funding information undisclosed

## ORDERS

Order information is not available

## GLOBAL PARTNERSHIPS

### GREATER CHINA

| | |
|---|---|
| Nov 8, 2018 | Signed a strategic cooperation framework agreement with **AVIC General Aircraft Co.**, to bring both parties' products into the market |

*Information for the milestones and global partnerships section was retrieved from MuYu Aero's official WeChat account. The information cutoff date was June 30, 2022.*

# Pantuo Aviation

## Mainland China | Founded in 2019

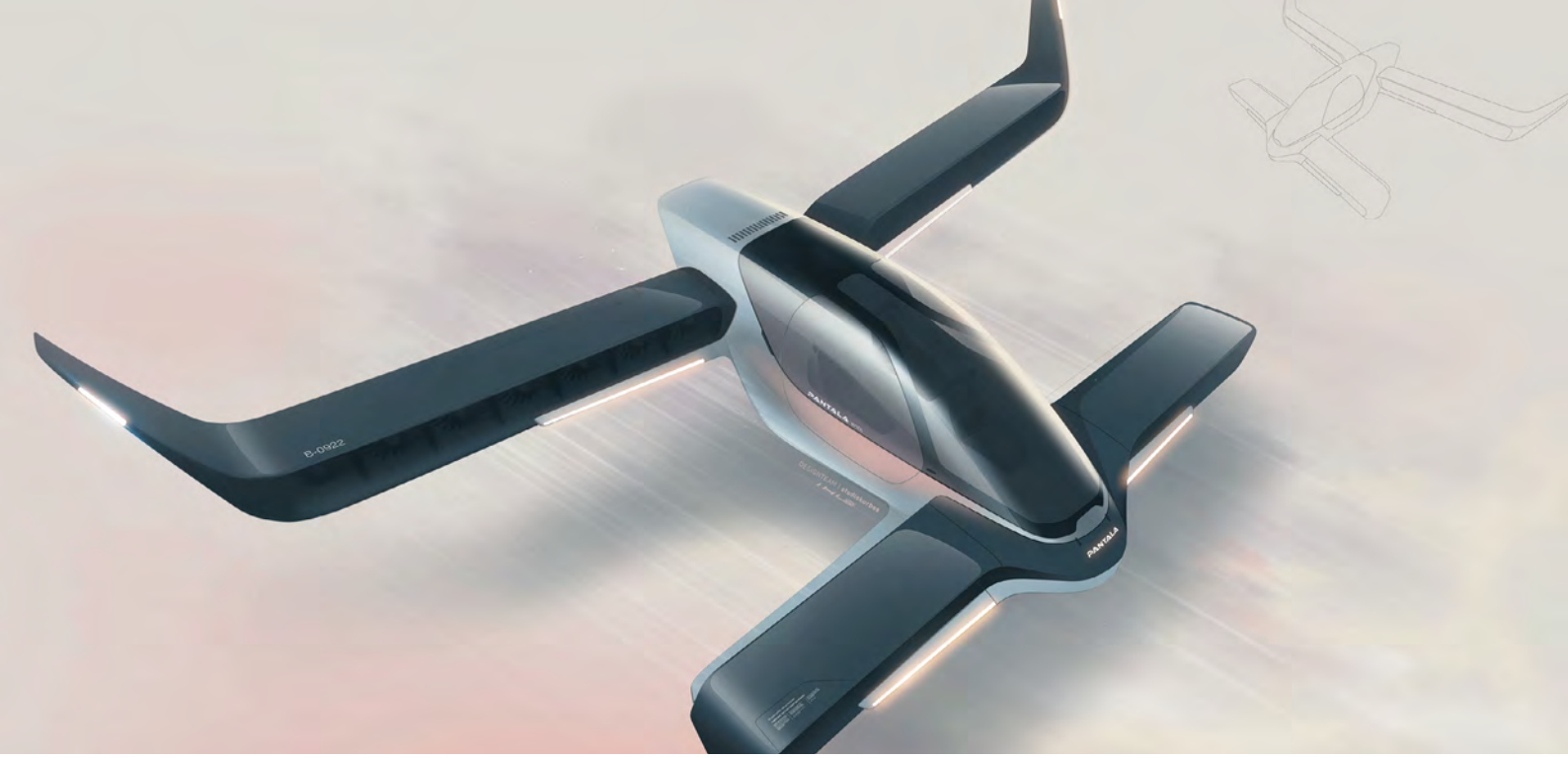
Pantuo Aviation, founded in 2019, is headquartered on the west coast of Shanghai, with its vehicle testing center located in Moganshan, Zhejiang Province. Pantuo's vision is to "shape the future of sustainable human mobility through [the] symbiosis of design, experience and technology." The company is committed to creating aerial vehicles that exceed the passenger experience brought by luxury cars. Core technical personnel are from the commercial aviation or electric vehicle industries.

### PANTALA CONCEPT H

| | |
|---|---|
| PROJECT PHASE | Preliminary design |
| TYPE | Vectored Thrust |
| OPERATION | Piloted/Autonomous |
| RANGE | 250 km |
| CRUISE SPEED | 300 km/h |
| SEATS | 5 |
| ELECTRIC MOTORS | 22 |


The PANTALA Concept H adopts a tilting wing configuration with 22 ducted fans. The tail wings on each side consist of seven ducted fans with winglets, and the front wings on each side incorporate four ducted fans. The vehicle can carry four passengers with a pilot and will be used primarily for intra or inter-city travel, with plans for future use in the medical rescue sector. Concept H features a multi-redundant[1] airborne power system.

*Note: 1. It is equipped with multiple sets of essential components or peripherals of the same function. In the event of a single point of failure of a system or equipment, the vehicle can still function properly.*



## MILESTONES

**Jul**
Founded

**PANTALA Concept H**: Release concept prototype and specifications

**Jun**

2019 | 2020 | 2021 | 2022

**PANTALA Concept H**: 1/2 subscale demonstrator first flight

**Oct**

## CERTIFICATION PROGRESS

Not yet in the certification phase

## FUNDING

Funding information undisclosed

## ORDERS

Order information is not available

## GLOBAL PARTNERSHIPS

### GERMANY

| | |
|---|---|
| Sep 1, 2021 | Partnered with **studiokurbos of Germany** for industrial design |

*Information on the milestones and global partnerships section were retrieved from Pantuo's official WeChat account. The information cutoff date was June 30, 2022.*

# TCab Tech

## Mainland China | Founded in 2021

Founded in Shanghai in 2021, TCab Tech is dedicated to establishing an eco-friendly and sustainable three-dimensional digital transportation ecosystem, and providing safe and convenient air travel services for society. “TCab” means “time cab”. As a manufacturer of eVTOLs, TCab is actively promoting the eVTOL ecosystem.

### E20

| | |
|---|---|
| TYPE | Vectored Thrust |
| OPERATION | Piloted |
| RANGE | 200 km |
| CRUISE SPEED | 260 km/h |
| SEATS | 5 |
| ELECTRIC MOTORS | 6 |

The E20 adopts a tilt-rotor configuration with a single upper gull wing and a cruciform tail. The two propellers in the middle of the wing provide lifting power only, whereas the other four can be tilted. The E20 can carry four passengers and one pilot, and its primary applications are air taxi, emergency rescue and cargo transportation. The airborne equipment and systems have redundancy[1].

*Note: 1. It is equipped with multiple sets of essential components or peripherals of the same function. In the event of a single point of failure of a system or equipment, the vehicle can still function properly.*


## MILESTONES

**May**
Founded

**Third quarter**
**E20**: Completed transitional test flights for the 1/4 scale demonstrator

**Dec**
**E20**: First flight of the 1/2 scale demonstrator

**2021** | **2022**

**E20**: Officially released
**Aug**

**E20**: Released the full scale demonstrator
**Dec**

**E20**: Completed transitional test flights for the 1/2 scale demonstrator
**First quarter**

## CERTIFICATION PROGRESS

| DATE | AGENCY | STAGE |
|---|---|---|
| May, 2021 | Civil Aviation Administration of China | TCab Tech and the CAAC signed the Partnership of Safety Plan (PSP) |

## FUNDING

| DATE | ROUND | AMOUNT | INVESTORS |
|---|---|---|---|
| Sep 6, 2021 | Seed round/Seed round+ | USD$10M | Bluerun Ventures, Decent Capital |

## ORDERS

Order information is not available

## GLOBAL PARTNERSHIPS

| | |
|---|---|
| May 31, 2022 | Announced a partnership agreement with **Safran** to equip the E20 with a Safran motor |

*Information on milestones, certification progress, funding and global partnership was retrieved from TCab's official website and WeChat account. The information cutoff date was June 30, 2022.*

# Vertax

## Mainland China | Founded in 2021

Vertax, founded in April 2021, with a presence in the Yangtze River Delta and the Guangdong–Hong Kong–Macao Greater Bay Area, is committed to building safe and cost-effective eVTOLs with the vision of “letting everyone enjoy the future of urban air travel.” Its eVTOL research and development center is located in Shanghai. The core research and development team members have previously been involved in developing national aircraft models and have accumulated years of experience in flight simulation and flight control technology.

### MATRIX1

| | |
|---|---|
| PROJECT PHASE | Detailed design |
| TYPE | Lift + Cruise |
| OPERATION | Autonomous |
| RANGE | 250 km |
| CRUISE SPEED | 200 km/h |
| SEATS | 5 |
| ELECTRIC MOTORS | 20 |

The Matrix1 adopts a Lift & Cruise configuration with 16 rotors that provide lift and four cruise propellers. This autonomous vehicle is for cargo transportation and urban air mobility.


## MILESTONES

**Apr**
Founded

**Estimated: Sep**
**Matrix1**: Officially released

2021 | 2022 | ... | 2026

**Matrix1**: 1/2 subscale demonstrator first flight
**May**

**Matrix1**: Entry into service
**Estimated**

## CERTIFICATION PROGRESS

| DATE | AGENCY | STAGE |
|---|---|---|
| Estimated: 2023 | Civil Aviation Administration of China | Matrix1 will apply for its airworthiness certification |
| Estimated: 2026 | Civil Aviation Administration of China | Matrix1 expects to obtain its airworthiness certification |

## FUNDING

| DATE | ROUND | AMOUNT | INVESTORS |
|---|---|---|---|
| May, 2021 | Angel investors | Unspecified | Chengtan Network (Danian Chen) |
| Apr, 2022 | Pre-A | Unspecified | V Fund, Winreal Investment |

## ORDERS

Order information is not available

## GLOBAL PARTNERSHIPS

No disclosed partnership agreements prior to June 30, 2022

*Information on the milestones and the funding sections were retrieved from Vertax's official WeChat account and provided by Vertax to Global Sky Media. Information on the certification progress was provided by Vertax. The information cutoff date was June 30, 2022.*

# Volant

VOLANT AEROTECH | 沃兰特

## Mainland China | Founded in 2021

Volant, headquartered in Shanghai, established its assembly and test flight center in Yixing. Its core business includes research and development, design, manufacture, assembly, operation, maintenance, and flight training for eVTOLs. Volant is committed to providing safe, environmentally friendly, and affordable passenger-grade aerial vehicles for everyone. Ninety percent of Volant's team members have experience in civil aircraft development. In January 2022, the Civil Aviation Administration of China East Regional Administration signed the first Partnership of Safety Plan in China with Volant.

### VE25

| | |
|---|---|
| PROJECT PHASE | Prototype Devt. & Testing |
| TYPE | Lift + Cruise |
| OPERATION | Piloted |
| RANGE | 200 km |
| CRUISE SPEED | 200 km/h |
| SEATS | 5 |
| ELECTRIC MOTORS | 10 |

The VE25 adopts a Lift + Cruise configuration with a V-shape twin tail boom design, wings on either side of the fuselage, eight lift propellers on the wings, and two cruise propellers on the tail. The VE25 can carry four passengers and one pilot, and is designed for passenger, medical, and cargo transport. The VE25 equipped with a triplex[1] flight system using manifold control.

*Note: 1. A triplex redundancy flight control system has three sets of essential components or peripherals of the same function, enabling data sharing between the triplex control computers. Each control computer has a fault-resilient signature which provides features like fault masking.*


## MILESTONES

**Jun**
Founded

**Tiny**: 1/3 subscale demonstrator first flight
**Sep**

**Estimated: Aug**
**VE25**: Unveils full scale demonstrator

2021 | 2022

## CERTIFICATION PROGRESS

| DATE | AGENCY | STAGE |
|---|---|---|
| Jan 26, 2022 | Civil Aviation Administration of China | Volant and the CAAC East Regional Administration signed a Partnership of Safety Plan (PSP) |

## FUNDING

| DATE | ROUND | AMOUNT | INVESTORS |
|---|---|---|---|
| Sep, 2021 | Seed Funding | Unspecified | Shunwei Capital, Ventech China |
| Jan, 2022 | Pre-A Round | Unspecified | Future Capital, Qingsong Fund, Welight Capital, Shunwei Capital |

## ORDERS

Order information is not available

## GLOBAL PARTNERSHIPS

### GREATER CHINA

| | |
|---|---|
| Feb 4, 2022 | Signed an MoU with **ACCEL Flight Simulation** and **Anhui Huaming Avionics System Co., Ltd.** to jointly establish a cockpit maneuvering industry alliance |

*Information on the milestones, certification progress, funding and global partnerships section was retrieved from Volant's official WeChat account. The information cutoff date was June 30, 2022.*

# XPENG AEROHT

小鹏 | 汇天

## Mainland China | Founded in 2013

HT Aerospace, the predecessor company of XPENG AEROHT, was founded in 2013 and specializes in developing and conducting test flights of low-altitude aerial vehicles. In 2020, the founder of HT Aerospace and XPeng co-established XPENG AEROHT with the mission "to provide three-dimensional transportation products and solutions in low-altitude traveling, such as urban air mobility, aerial tourism, and emergency response."

### XPENG T1

| | |
|---|---|
| PROJECT PHASE | Prototype Devt. & Testing |
| TYPE | Multicopter |
| OPERATION | Piloted/Autonomous |
| RANGE | 40 km |
| CRUISE SPEED | 120 km/h |
| SEATS | 1 |
| ELECTRIC MOTORS | 8 |

The XPENG T1 is a single-seat eVTOL with an open cockpit, that adopts a Multicopter configuration, where eight propellers are on top of the fuselage. The T1 is primarily for aerial tourism. XPENG AEROHT has not disclosed its mass production plan for the T1.

### XPENG X1

| | |
|---|---|
| PROJECT PHASE | Prototype Devt. & Testing |
| TYPE | Multicopter |
| OPERATION | Piloted/Autonomous |
| RANGE | 50 km |
| CRUISE SPEED | 130 km/h |
| SEATS | 1 |
| ELECTRIC MOTORS | 8 |

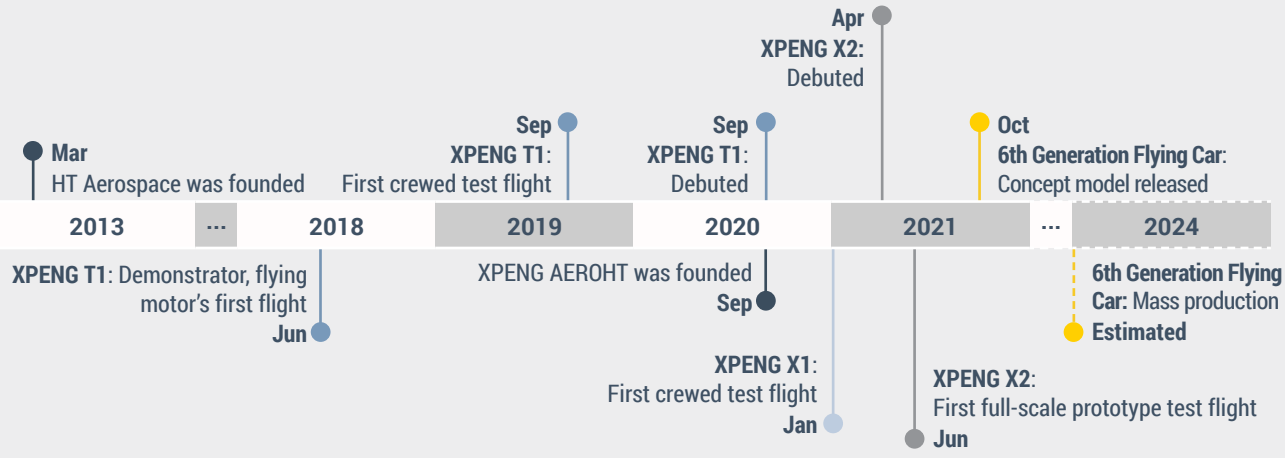
The XPENG X1 is a single-seat version of the 4th generation intelligent electric flying car developed independently by XPENG AEROHT. It adopts a Multicopter configuration with four axes and eight propellers at the end of the four arms extending out from the corners of the fuselage. The X1 will be primarily used in urban mobility, aerial tourism, and emergency response missions.

## XPENG X2

| | |
|---|---|
| PROJECT PHASE | Prototype Devt. & Testing |
| TYPE | Multicopter |
| OPERATION | Autonomous |
| RANGE | 55 km |
| CRUISE SPEED | 130 km/h |
| SEATS | 2 |
| ELECTRIC MOTORS | 8 |

The XPENG X2 is XPENG AEROHT's 5th generation intelligent electric flying car, which uses a carbon fiber airframe with a fully enclosed two-seat cockpit. The X2 also adopts a Multicopter configuration with four axes and eight propellers. The endurance of X2 is 35 minutes, and is suitable for low-altitude flights, including personal travel, aerial tourism, wilderness rescue, and medical transport.

## MILESTONES




## CERTIFICATION PROGRESS

Not yet in the certification phase

## FUNDING

| DATE | ROUND | AMOUNT | INVESTORS |
|---|---|---|---|
| Oct 19, 2021 | Series A | USD$500M | IDG Capital, 5Y Capital, XPeng, Sequoia Capital, Eastern Bell Capital, GGV Capital, GL Ventures and Yunfeng Capital |
| Jun 30, 2022 | Series A (additional investment) | Unspecified | Rockets Capital |

## ORDERS

Order information is not available

## GLOBAL PARTNERSHIPS

### GREATER CHINA

| | |
|---|---|
| Nov 2, 2021 | Started exploring AAM trial operation in a ski resort with **Genting Resort Secret Garden** |

## XPENG X2 PROTOTYPE INTERNAL TESTING

| DATE | ROUND | ROUND |
|---|---|---|
| Mar 24, 2021 | Guangzhou, China | Conducted test flight in Eco Design Town (Guangzhou) Industrial Park |
| Sep 17, 2021 | Qinghai, China | Conducted plateau takeoff and landing tests and crewed flight experiments at 11 degrees Celsius and 4,180 meters above the sea level in the Qinghai Golund Kunlun Mountain |
| Nov 2, 2021 | Zhangjiakou, China | Completed cold-weather testing in snow fields |

*Information on milestones was retrieved from SOHU and XPeng AeroHT's official WeChat account. Information on the funding, global partnership and protype internal testing section was retrieved from XPeng AeroHT's official WeChat account. The information cutoff date was June 30, 2022.*

# ZEROG

## Mainland China | Founded in 2021

ZEROG, founded in 2021 and headquartered in the Hefei High-tech Zone, is dedicated to establishing a new way of traveling and providing low-altitude travel solutions in line with the concept of being "futuristic, eco-friendly and innovative." The core members of ZEROG are from aviation companies, universities or research institutes in mainland China and have participated in multiple national aircraft development programs inside China.

### ZG-ONE

| | |
|---|---|
| PROJECT PHASE | Prototype Devt. & Testing |
| TYPE | Multicopter |
| OPERATION | Autonomous |
| RANGE | 30 km |
| CRUISE SPEED | 75 km/h |
| SEATS | 2 |
| ELECTRIC MOTORS | 6 |

ZG-ONE adopts a Multicopter configuration with six propellers using six axles. The eVTOL can carry two passengers, and is suitable for short-haul urban commuting and logistics. ZG-ONE is equipped with a Whole Aircraft Rescue Parachute System and a triplex flight control system[1] developed by ZEROG that supports autopiloting.

### ZG-VC2

| | |
|---|---|
| PROJECT PHASE | Detail design |
| TYPE | Lift + Cruise |
| OPERATION | Autonomous |
| RANGE | 150 km |
| CRUISE SPEED | 200 km/h |
| SEATS | 2 |
| ELECTRIC MOTORS | 9 |

### ZG-T6

| | |
|---|---|
| PROJECT PHASE | Detail design |
| TYPE | Vectored Thrust |
| OPERATION | Autonomous |
| RANGE | 300 km |
| CRUISE SPEED | 250 km/h |
| SEATS | 6 |
| ELECTRIC MOTORS | 6 |

*Note: 1. A triplex redundancy flight control system enables data sharing between the triplex control computers. Each control computer has a fault-resilient signature which provides features incuding fault masking.*

## MILESTONES

**Mar**
Founded

| 2021 | 2022 |
|---|---|
| | **ZG-ONE**: Officially released **May** |

## CERTIFICATION PROGRESS

| DATE | AGENCY | STAGE |
|---|---|---|
| Estimated: beginning of 2024 | Civil Aviation Administration of China | ZG-ONE is expected to obtain airworthiness certification |
| Estimated: beginning of 2025 | Civil Aviation Administration of China | ZG-VC2 is expected to obtain airworthiness certification |
| Estimated: end of 2026 | Civil Aviation Administration of China | ZG-T6 is expected to obtain airworthiness certification |

## FUNDING

| DATE | ROUND | AMOUNT | INVESTORS |
|---|---|---|---|
| Unspecified | Seed funding | Unspecified | Bluerun Ventures |

## ORDERS

Order information for ZG-ONE, ZG-VC2 and ZG-T6 is not available

## GLOBAL PARTNERSHIPS

Did not disclose any partnership agreements prior to June 30, 2022

*Information on the vehicles and milestones was retrieved from ZEROG's official WeChat account and provided by ZEROG. Funding information was retrieved from ZEROG's official WeChat account. The information cutoff date was June 30, 2022.*

# Frogs Indonesia

## Indonesia | Founded in 2017

Frogs Indonesia, founded under the UMG Idea Lab in 2017, is headquartered in Bantul, Yogyakarta. It is one of the first companies in Southeast Asia to build passenger drones. Frogs Indonesia is dedicated to researching and developing various types of drones in various fields, including surveillance, spraying, logistics, and passenger transport. The company's mission is "leading in smart transportation solutions in Indonesia."

### FROGS 282

| | |
|---|---|
| PROJECT PHASE | Prototype Devt. & Testing |
| TYPE | Multicopter |
| OPERATION | Autonomous |
| RANGE | Undisclosed |
| CRUISE SPEED | 100 km/h |
| SEATS | 2 |
| ELECTRIC MOTORS | 8 |

The Frogs 282 adopts a Multicopter configuration and a coaxial dual propeller design with four arms located beneath the cabin equipping eight propellers. It is an autonomous vehicle with a maximum capacity of two passengers, and is dedicated to intra-city commuting.


## MILESTONES

**Dec**
Founded

| 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|

**Frogs 282**: First full scale prototype test flight
**Mar**

## CERTIFICATION PROGRESS

Not yet in the certification phase

## FUNDING

Funding information undisclosed

## ORDERS

Order information is not available

## GLOBAL PARTNERSHIPS

### INDONESIA

| | |
|---|---|
| Mar 22, 2021 | Signed an agreement with **Gadjah Mada University** to enhance the research, development and certification of Frogs Indonesia's vehicles |
| Mar 19, 2022 | Collaborated with the **Ministry of Industry** to initiate the development of the automotive control system |

*Information on the milestones and global partnerships was retrieved from Frogs Indonesia's official website. The information cutoff date was June 30, 2022.*

# Honda

## Japan | Project launched in 2021

Honda Motor Company was founded in 1948 and headquartered in Minato, Tokyo, Japan. The company specializes in developing and manufacturing automobiles and motorcycles and continues to explore other categories such as power products, marine engines, aero engines, and business jets. On September 30, 2021, Honda announced its initiative in eVTOL, which enhanced Honda's plan to develop a three-dimensional mobility system. The project's core team members previously participated in the development of HondaJet.

### HONDA EVTOL

| | |
|---|---|
| PROJECT PHASE | Detailed design |
| TYPE | Lift + Cruise |
| OPERATION | Piloted |
| RANGE | 100 km (electric) |
| CRUISE SPEED | 270 km/h |
| SEATS | 5 |
| ELECTRIC MOTORS | 10 |

The Honda eVTOL adopted a Lift and Cruise configuration with two stabilizers at the end of the rear wing. Eight propellers at the top provide lifting power, and two at the back provide cruising power. Under the all-electric mode, Honda eVTOL is primarily for intra-city commuting with a cruising range of 100 kilometers. The hybrid mode extended the application to inter-city travelling with a range of 400 kilometers. The Honda eVTOL can carry one pilot and four passengers. Honda plans to leverage sensors, controllers, and actuators in the autonomous driving car for the eVTOL project.


## MILESTONES

**Sep**
Project launched

**Dec**
**Honda eVTOL**: Debuted the 1/5 demonstrator

**Estimated**
**Honda eVTOL**: Entry into service

2021 | 2022 | 2023 | ··· | 2030

**Honda eVTOL**: Conducted wind-tunnel test
**Oct**

**Honda eVTOL**: First prototype flight
**Estimated**

## CERTIFICATION PROGRESS

| DATE | AGENCY | STAGE |
|---|---|---|
| Estimated: 2030 | Federal Aviation Administration; European Union Aviation Safety Agency | Honda eVTOL plans to obtain the type certification |

## FUNDING

Corporate backed

## ORDERS

Order information is not available

## GLOBAL PARTNERSHIPS

### JAPAN

| | |
|---|---|
| Nov 11, 2021 | Established an initial agreement with **Toray**, where Toray will lead the development of carbon fiber for Honda eVTOL |

*Information on certification progress was retrieved from Honda's official website. Global partnerships was retrieved from The Dawn of Gaia. The information cutoff date was June 30, 2022.*

SkyDrive

SKYDRIVE

## Japan | Founded in 2018

SkyDrive was established in 2018 by members of CARTIVATOR, aiming to develop, manufacture and commercialize passenger aerial vehicles and cargo drones. CARTIVATOR, a group of engineers mainly in the automotive and aviation industries, set the foundation for SkyDrive by conducting driving and hovering tests for the SD-00 model. The SD-01, SD-02, and SD-03 models developed by SkyDrive serve as prototypes for the SD-05 model. SkyDrive aims to put the SD-05 model into service in 2025, in time for the Expo 2025 Osaka, Kansai, Japan.

### SD-03

| | |
|---|---|
| PROJECT PHASE | Prototype Devt. & Testing |
| TYPE | Multicopter |
| OPERATION | Piloted |
| RANGE | Undisclosed |
| CRUISE SPEED | 40-50 km/h |
| SEATS | 1 |
| ELECTRIC MOTORS | 8 |

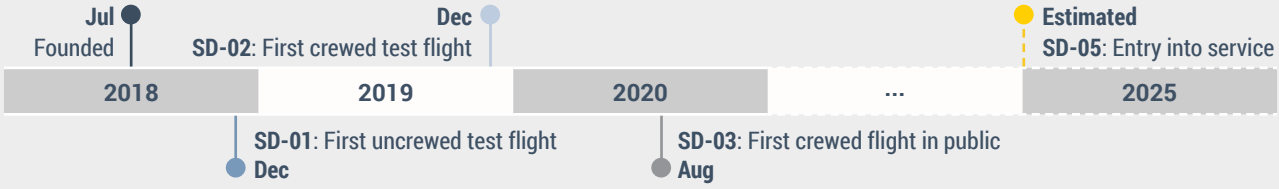
The SD-03 is a prototype that adopted a Multicopter configuration with eight electric propellers on four booms. The set of rotors located on each boom rotates in opposite directions. The two white lights in the front and red lights around the bottom of the fuselage serve as signal lights. SD-03 has the capacity of one passenger.

### SD-XX

| | |
|---|---|
| PROJECT PHASE | Concept design |
| TYPE | Multicopter |
| OPERATION | Autonomous |
| RANGE | Undisclosed |
| CRUISE SPEED | 100 km/h |
| SEATS | 2 |
| ELECTRIC MOTORS | 8 |

The SD-XX is a concept model adopting a Multicopter configuration. The vehicle takes off and lands vertically, while wheels under the fuselage allow it to drive on land with a maximum driving speed of 60 kilometers per hour.

## MILESTONES




*SD-01, SD-02 and SD-03 are prototype models*

## CERTIFICATION PROGRESS

**SD-05**

| DATE | AGENCY | STAGE |
|---|---|---|
| Oct 29, 2021 | Japan Civil Aviation Bureau (JCAB) of Ministry of Land, Infrastructure, Transport and Tourism (MLIT) | The agencies accepted the type certification application for SD-05 |
| Apr 27, 2022 | JCAB of MLIT | The agency endorsed AIM Part II as the basis for type certification |

## FUNDING

| DATE | ROUND | AMOUNT | INVESTORS |
|---|---|---|---|
| Nov 2, 2018 | Seed Round | JP¥300M | Drone Fund |
| Sep 30, 2019 | Series A | USD$14M | Drone Fund, Z Corporation, STRIVE III Limited Liability Partnership, ITOCHU Technology Ventures, Inc. and Energy & Environment Investment, Inc. |
| Aug 28, 2020 | Series B | JP¥3.9B | Development Bank of Japan, ITOCHU Corporation, STRIVE, ITOCHU Technology Ventures, Drone Fund and five others |
| Apr 7, 2022 | Partnership investment | Unspecified | Kintetsu Group |

## ORDERS

Order information is not available

## GLOBAL PARTNERSHIPS

| | |
|---|---|
| May 9, 2019 | Signed an agreement with **Toyota City** and **CARTIVATOR** to enhance the "Flying Car" industry in Toyota city |
| Jun 19, 2020 | 100 corporations signed sponsorship agreement to support SkyDrive's development |
| May 31, 2021 | Signed a supporter agreement with **PERSOL R&D** to accelerate the development of the "Flying Car" |
| Aug 4, 2021 | Joined the industry network organized by **Toyota City** to enhance the development and commercialization of next generation air mobility |
| Aug 10, 2021 | Collaborated with **Japan Aerospace Exploration Agency (JAXA)** to conduct aerodynamic research |
| Sep 14, 2021 | Signed a partnership agreement with **Osaka Prefecture** and **Osaka City** to implement the partical use of eVTOLs |
| Oct 26, 2021 | Selected as a company for the **J-Startup program**, where the program will provide expansion support to SkyDrive |
| Nov 2, 2021 | Signed a supporter agreement with **EY Strategy and Consulting** to enhance SkyDrive's business development |
| Feb 2, 2022 | Signed a supporter contract with **Globe-ing** to strengthen SkyDrive's development |
| Mar 22, 2022 | Established a partnership with **Suzuki** to collaborate in the field of technology and expansion in overseas markets |
| Apr 7, 2022 | Finalizing the partnership agreement with **Kintetsu Group** to implement flying cars by 2025 |
| Jun 7, 2022 | Signed a supporter agreement with **JAMCO**, where JAMCO will be manufacturing the cabin interiors for SkyDrive |

*Information on the milestones, certification progress, and global partnerships was retrieved from SkyDrive's official website. Funding information was retrieved from Crunchbase and SkyDrive's official website. The information cutoff date was June 30, 2022.*

# teTra Aviation

## Japan | Founded in 2018

teTra Aviation, initiated at the University of Tokyo, is an eVTOL start-up based in Tokyo, Japan, mainly engaged in developing personal Advanced Air Mobility (AAM) and racing aerial vehicles. It won the “Pratt and Whitney Disruptor Prize” in the GoFly Prize competition with the Mk-3 racing model.

### MK-5 (SN4)

| | |
|---|---|
| PROJECT PHASE | Prototype Devt. & Testing |
| TYPE | Lift + Cruise |
| OPERATION | Piloted |
| RANGE | 160 km |
| CRUISE SPEED | 160 km/h |
| SEATS | 1 |
| ELECTRIC MOTORS | 33 |

The Mk-5 adopted 33 propellers, where 32 were located around the two pairs of fixed wings to provide lifting power and one at the back to provide cruising power. It is a one-seat personal Urban Air Mobility (UAM) aerial vehicle, with the fuselage using carbon fiber composite material. teTra conducted all the current tests using the SN2 model. The SN3 and above versions incorporated a ballistic parachute.

### MK-3

| | |
|---|---|
| PROJECT PHASE | Prototype Devt. & Testing |
| TYPE | Multicopter |
| OPERATION | Piloted |
| RANGE | 48 km |
| CRUISE SPEED | 100 km/h |
| SEATS | 1 |
| ELECTRIC MOTORS | 4 |

Mk-3 is a single-seat racing eVTOL equipped with four ducted fans set at 50 to 70 degrees, allowing the vehicle to fly vertically and horizontally, skipping the transition state when changing flight attitude. TeTra is also exploring the possibility of implementing the Mk-3 in the scenario of disaster relief.


## MILESTONES

**Jun**
Founded

**Jul**
**Mk-5 SN2**: Unveiled the full scale prototype

2018 | 2019 | 2020 | 2021

**Mk-3**: First uncrewed test flight
**Feb**

**Mk-5 SN2**: First uncrewed flight test
**Sep**

## CERTIFICATION PROGRESS

Mk-3 and Mk-5 were not yet in certification phase

## FUNDING

| DATE | ROUND | AMOUNT | INVESTORS |
|---|---|---|---|
| May 24, 2019 | Seed round | JP¥50M | Drone Fund, Incubate Fund, TomyK |
| Aug 26, 2020 | Corporate round | JP¥50M | Yoshimasu Seisakusho |
| Jun 21, 2022 | Venture round | JP¥450M | MITSUI SUMITOMO INSURANCE Venture Capital, TS TECH, Kyowa Technica, TOKO and Mitsubishi Gas Chemical Company |

## ORDERS

Mk5 (SN3 and SN4) received pre-orders, details were unspecified

## GLOBAL PARTNERSHIPS

### JAPAN

| | |
|---|---|
| Aug 17, 2020 | **Yoshimasu Seisakusho** announced that it will assist teTra in building titanium and aluminum components |
| Jul 7, 2021 | Signed a partnership agreement with **Minamisoma City**, Fukushima Prefecture to strengthen the development of flying cars |

*Milestones information was retrieved from eVTOL News. Funding information was retrieved from Crunchbase. Information in the global partnerships section was retrieved from Nikkei Asia News and Nikkan Jidosha Shimbun. The information cutoff date was June 30, 2022.*

# Korea Aerospace Industries

## South Korea | Project launched in 2020

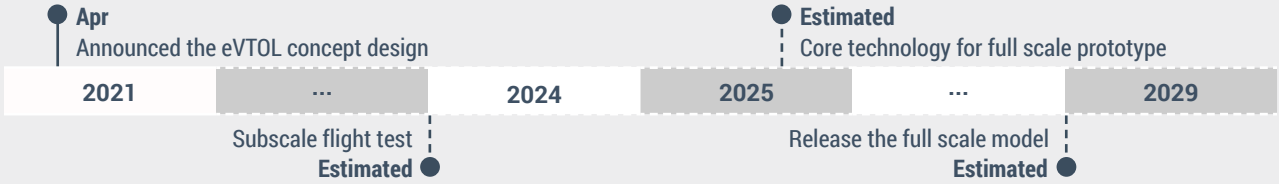
Korea Aerospace Industries (KAI) is an integrated aerospace solution provider founded in 1999. In a press conference held in April 2021, KAI announced that it would invest 2.2 trillion Korean Republic won over the next five years to expand its development of future air mobility, satellites, aviation defense electronics, complex systems for aerial vehicles and simulations. The business concept of KAI is to "become a global leading aerospace firm that fulfills social responsibility and is trusted by consumers by providing the greatest technology and products."

### KAI VEHICLE

| | |
|---|---|
| PROJECT PHASE | Preliminary design |
| TYPE | Vectored Thrust |
| OPERATION | Piloted |
| RANGE | TBD |
| CRUISE SPEED | TBD |
| SEATS | 5 |
| ELECTRIC MOTORS | 8 |

KAI's eVTOL adopted a Vectored Thrust configuration with four tilt-propellers at the front of the fixed wings, and the four located near the back only provide lifting power. The vehicle is currently for four passengers and one pilot, designed for urban air mobility. KAI plans to modify the system so it can operate autonomously in the future.

## MILESTONES




## CERTIFICATION PROGRESS

Not yet in certification phase

## FUNDING

Corporate backed

## ORDERS

Order information is not available

## GLOBAL PARTNERSHIPS

| | |
|---|---|
| **SOUTH KOREA** | |
| Apr 29, 2021 | Signed an MoU with **Seoul National University** to collaboratively develop the core technology on "future vehicles" such as vehicles for AAM, Personal Air Vehicles (PAV) and flying cars |
| Nov 23, 2021 | Signed a contract to invest a 10% stake in **Conan Technology** to develop technologies that are adoptable by AAM vehicles |
| Jun 23, 2022 | Signed an MoU with **Korea Internet & Security Agency** (KISA) to strengthen the cyber security of AAM |
| **UNITED STATES** | |
| Nov 3, 2020 | Invested in **GPMS** to introduce the health and usage monitoring system (HUMS) for KAI's AAM vehicles |

*Information on the milestones were retrieved from KAI's press conference held on April 4, 2021. Information on the global partnerships was retrieved from KAI's official website. The information cutoff date was June 30, 2022.*

# KARI

## South Korea | Project launched in 2019

The Korea Aerospace Research Institute (KARI) is an aeronautics and space research institute funded by the South Korean government, established in 1989 and headquartered in Daejeon. KARI is dedicated to "contributing to [the] solid development of the national economy and enhancement of national life through [the] exploration and technological advancements, development, and dissemination in the field of aerospace science and technology."

### OPPAV

| | |
|---|---|
| PROJECT PHASE | Prototype Devt. & Testing |
| TYPE | Vectored Thrust |
| OPERATION | Piloted/Autonomous |
| RANGE | 50 km |
| CRUISE SPEED | 200 km/h |
| SEATS | 1 |
| ELECTRIC MOTORS | 8 |

The Optionally Piloted Personal Air Vehicle (OPPAV) adopted a Vectored Thrust configuration with eight propellers on a pair of fixed wings at the top of the fuselage. The four propellers in the front are tilt propellers, and the four near the back only provide lifting power. The operational model will upgrade the maximum take-off weight from 650 kilograms to 2,500 kilograms; the maximum capacity from one passenger to five passengers. The finalized model will serve in the Urban Air Mobility market.

## MILESTONES

**Sep**
Project launched

**Jun**
**OPPAV**: 44% sub-scale demonstrator transition flight test

2019 | 2020 | 2021

**OPPAV**: 44% sub-scale demonstrator first flight
**Nov**

## CERTIFICATION PROGRESS

Not yet in certification phase

## FUNDING

| DATE | ROUND | AMOUNT | INVESTORS |
|---|---|---|---|
| Sep 4, 2019 | Government funding | KRW21.3B | Ministry of Land, Infrastructure, and Transport (MOLIT) |
| Sep 4, 2019 | Government funding | KRW23.5B | Ministry of Trade, Industry, and Energy (MOTIE) |

## ORDERS

Order information is not available

## GLOBAL PARTNERSHIPS

| | |
|---|---|
| Sep 4, 2019 | The OPPAV program was sponsored by the **MOLIT** and the **MOTIE**, where the MOLIT will support the certification process and automatic flight control system and the MOTIE will support the development of the demonstrator and ground control system |

*Information on milestones was retrieved from KARI's official website. Information on the funding and global partnerships section was retrieved from the Ministry of Trade Industry and Energy's official website. The information cutoff date was June 30, 2022.*

# Supernal

## United States, formerly South Korea | Founded in 2021

Supernal is a company focused on developing and manufacturing eVTOL aerial vehicles, formerly known as an urban air mobility division of Hyundai Motor Group in South Korea. Supernal is headquartered in Washington, D.C. and plans to introduce eVTOL air taxi services in Miami, Florida, as early as 2028. Hyundai affiliates funded Supernal and continuously supported Supernal technically. The company's mission is "to revolutionize air travel and redefine how people move, connect and live."

### S-A1

| | |
|---|---|
| PROJECT PHASE | Prototype Devt. & Testing |
| TYPE | Vectored Thrust |
| OPERATION | Piloted/Autonomous |
| RANGE | 97 km |
| CRUISE SPEED | 290 km/h |
| SEATS | 5 |
| ELECTRIC MOTORS | 8 |

The S-A1 adopted a tiltrotor configuration and has a pair of fixed wings. All propellers can provide lifting power, while four are tiltrotor propellers that can also supply cruising power. The vehicle will first be piloted and capable of carrying one pilot and four passengers. At a later stage, the S-A1 will be autonomous and will take up to five passengers. It aims to make round trips between urban centers and the surrounding suburbs.

## MILESTONES


## CERTIFICATION PROGRESS

| DATE | AGENCY | STAGE |
|---|---|---|
| Estimated: 2024 | Federal Aviation Administration | S-A1 will begin the certification progress |
| Estimated: 2028 | Federal Aviation Administration | S-A1 expects to grant certification |

## FUNDING

Corporate backed

## ORDERS

Order information is not available

## GLOBAL PARTNERSHIPS

### UNITED STATES

| | |
|---|---|
| Jun 23, 2020 | Partnered with **ANRA Technologies** to co-create an AAM ecosystem; ANRA became the first partner of Hyundai's industry consortium |
| Nov 9, 2021 | Expanded its Airspace Management Consortium by establishing partnership with **Skyroads**, **Altitude Angel** and **OneSky** |
| Nov 10, 2021 | Partnered with the **city of Los Angeles** and **Urban Movement Labs** to conduct air mobility research |
| Feb 1, 2022 | Partnered with **National Renewable Energy Laboratory (NREL)** to study aerial transit while collaborating with the **city of Los Angeles** |
| Feb 3, 2022 | Collaborated with **Applied Intutition** to conduct testing , certification and deployment of AAM vehicles |
| Mar 1, 2022 | Signed a Memorandum of Understanding (MoU) with the **city of Miami** to enhace the development of AAM |
| May 26, 2022 | Signed the Space Act Agreements with **NASA** to enhance the development of AAM in the United States |

### UNITED KINGDOM

| | |
|---|---|
| Apr 25, 2022 | Supernal and **Urban-Air Port** debuted a co-developed vertiport called Air-One |

*Information on milestones was retrieved from Hyundai Motor Group's official website. Information on the global partnerships section was retrieved from Hyundai Motor Group's official website, Supernal's official website and Applied Intuition's official blog. The information cutoff date was June 30, 2022.*

# The Rise of China's eVTOL Industry

By Vincent Dong, manager of the "eVTOL" WeChat official account

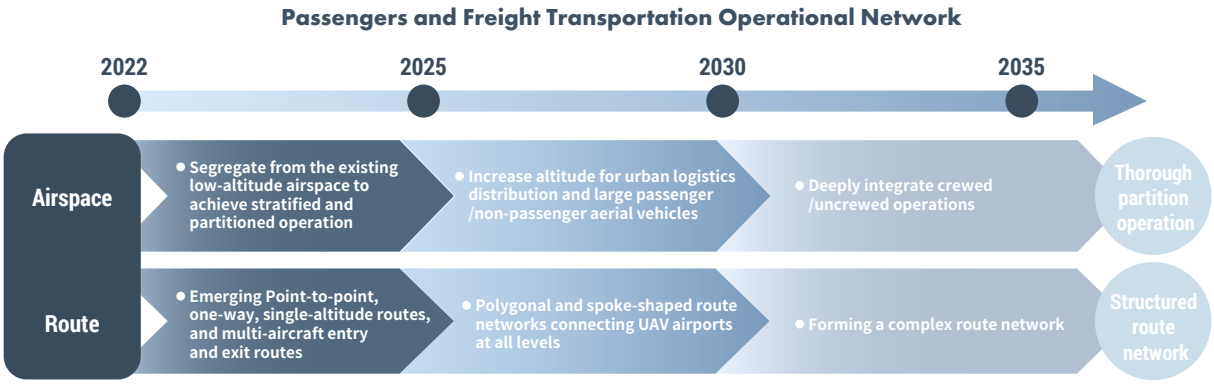
**With many Chinese eVTOL companies receiving financing in 2021 (a conservative estimate based on limited data suggests that more than 5 billion CNY has been raised in total), which in turn has driven rapid changes in China's eVTOL policy support, supply chain support, infrastructure, application scenarios/ demands, etc. This is both an opportunity and a challenge for companies from all backgrounds.**

## Policy Support

Following in the footsteps of the Federal Aviation Administration (FAA) and the European Union Aviation Safety Agency (EASA) supporting the development of similar highly innovative aircraft such as electric vertical take-off and landing (eVTOL) and electric conventional take (eCTOL) by amending their airworthiness validation regulations policies in 2016 and 2019 respectively, Civil Aviation Administration of China (CAAC) has just officially started a brand-new service exploration process. The latest version of the Airworthiness Standards: Normal Category Airplanes (CCAR-23-R4) came into effect on August 1st, 2022. This is mainly in response to the rapid application of turbofan engines, composite materials, and electric propulsion technologies aircraft in CCAR-23 (China's new 'small aircraft' airworthiness standard), in the hope of improving safety while reducing the cost of aircraft certification. Amongst them, the new chapter H "Supplementary Requirements for Electric Aircraft Power Units" is closely related to the airworthiness approval of eVTOLs. Although there are still great challenges ahead in terms of the conformity assessment methods for Distributed Electric Propulsion (DEP), the core eVTOL technology, and integrated control technology, CAAC may also face the same dilemma as the FAA today. After all, the unknown brought on by innovation is something unpredictable, but CAAC undoubtedly benefits aircraft programs that are booming in China and can help China's eVTOL industry attract more financial support. Or perhaps it is the CAAC's earlier work on the revision of CCAR-23 that has brought a key boost to the promotion of China's eVTOL boom in 2021.

In addition to promoting the development of the eVTOL industry through CCAR-23, CAAC has supported the certification of the EHang 216-S autonomous aerial vehicle as early as the beginning of this year through special terms, which is currently the only passenger-grade eVTOL aircraft with airworthiness validation that is being processed by the CAAC in China. According to EHang's latest financial report, the project has already entered the compliance validation stage, and its valuable eVTOL airworthiness validation experience on a pilot trial may bring more substantial value to the enterprises that submit eVTOL aircraft validation in accordance with CCAR-23.

CAAC not only paves the way for the airworthiness certification of China's eVTOL aircraft, but also intends to provide more relevant policy support for the long-term commercial implementation of eVTOLs. Recently, CAAC has released a draft for comments on the




*Passenger and cargo network operation route planning*

"Civilian Unpiloted Aviation Development Roadmap V1.0", which clearly proposes a development path of carrying cargo before passengers, general use before transportation, and isolation before integration. In the specific goal setting, it is proposed that by 2025, the urban short-range low-speed light and small-scale logistics and distribution uncrewed aircraft will gradually mature; by 2035, an uncrewed air transportation system will be established. On the one hand, the benefits brought by this policy point out the direction for China's eVTOL and related aircraft applications, but on the other hand, due to the over-specific description of the support for specific application scenarios, it may also lead to the excessive concentration of industry resources in cargo applications, which may result in a lack of complementary technology development between cargo and passenger aircraft.

Although CAAC has made more favourable policy plans at the top level, the specific promotion and support of implementing the eVTOL industry still need to rely on strong support from local policies, among which the most representatives are the Civil Uncrewed Aerial Test Area (CUATA) led by CAAC and China's low-altitude airspace reform promoted by the Central Air Traffic Control Office. The former is more conducive to promoting the application of UAVs, while the latter is more conducive to promoting the application of passenger / cargo aircraft. The above two policies need the support of more local government policies for further implementation. For the construction of CUATA, CAAC has just recently approved the second batch of seven civil CUATAs (Chongqing, Shenzhen, Shijiazhuang, Taiyuan, Chengdu, Qingdao and Wuzhong). The first batch was issued to 13 cities in 2020, including: Beijing Yanqing District which has realized 374 square kilometres of airspace at Badaling Airport open to local enterprises for free, and the other is Shenzhen's Meituan UAV which has seen more than 140,000 safe flights completed in Beijing and Shenzhen since January 2021 and has operated 11 regular trial routes in Shenzhen, with services covering more than 10 communities and business clusters. On September 1, 2020, National Air Traffic Control Office officially approved the "Hunan Province Low-altitude Airspace Management Reform Pilot Expansion Implementation Plan" submitted by Hunan Province. And, recently the "Hunan Province General Aviation Regulations" was introduced, which mainly focuses on promoting the general aviation low-altitude industry. Of course, all these cannot be separated from the strong support of Hunan Sunward Tech as a rare civil aircraft manufacturer in the upper echelons of the equipment manufacturing industry.

| No. | Subregion | Principal Applicant | Objective |
|---|---|---|---|
| 1 | East China | Jinshan District, Shanghai | Application in island |
| 2 | East China | Hangzhou, Zhejiang | Application in city |
| 3 | Southwest China | Zigong, Sichuan | Feeder services |
| 4 | Central South China | Hezhou, Guangxi | Comprehensive application |
| 5 | Central South China | Anyang, Henan | Application in city |
| 6 | East China | Nanjing, Jiangsu | Comprehensive application |
| 7 | North China | Binhai New District,Tianjin | Comprehensive application |
| 8 | North China | Yanqing District, Beijing | Comprehensive application |
| 9 | Northwest China | Yulin, Shaanxi | Feeder services |
| 10 | Northeast China | Shenyang, Liaoning | Comprehensive application |
| 11 | East China | Dongying, Shandong | Comprehensive application |
| 12 | East China | Anqing, Anhui | Comprehensive application |
| 13 | East China | Ganzhou, Jiangxi | Comprehensive application |

*List of the First Civil Uncrewed Aerial Vehicle Test Areas*

*Meituan UAV delivery drone*

Whether it is crewed or uncrewed aviation for low-altitude flights, these achievements will undoubtedly provide a strong guarantee for the commercial operation of eVTOLs in the future.

## Aircraft Manufacturing

After the gradual implementation of policy support, the manufacturing and mass production capability of eVTOL is definitely a key challenge, and the construction of the manufacturing capability of the complete aircraft usually requires a longer period of research and development. The OEM will consider production only after the completion of the full-scale demonstrator, following the pattern set by worldwide industry leaders such as Joby Aviation. For China's eVTOL manufacturers, as most of them are still in the early stage of aircraft technology validation, they do not need to build complete manufacturing capacity yet. For scaled-down or full-scale demonstrators, they only need to rely on the original UAV industry manufacturing capacity to carry out rapid validation of the prototype, which benefits China, given the cost advantages in UAV production. However, if China's eVTOL manufacturing enters formal pre-production or even mass production, the limited experience in the country's manufacturing of traditional commercial small civil aircraft will create challenges. The available resources are mainly from Commercial Aircraft Corporation of China (COMAC), Aviation Industry Corporation of China (AVIC), and private enterprises such as Guanyi Aviation and Hunan Sunward Tech. Amongst these, it is the latter, private enterprise, that has the talent and experience in terms of reusable skills. Perhaps this is also an important reason why Volkswagen China chose Huan Sunward Tech as the engineering service partner in developing the eVTOL demonstrator.


*Volkswagen China and Hunan Sunward Tech jointly released their eVTOL prototype - V.MO*

## Supply Chain Support

The basic elements of the upstream industry chain of eVTOL aircraft are comprised of design and development tools, electric motor drive system, battery system, propeller, flight control system, high-voltage electrical management system, configuration, and other aspects including avionics, landing gear, cabin interior and peripheral materials.

For the development of China's eVTOL supply chain, the most critical thing at this stage is to develop the 2-ton level high-voltage motor and electric drive products. This has given rise to a multipolar competition situation where traditional motors and electric drives for UAVs are considered separate poles. For example, most of the OEMs will choose high-quality and low-cost UAV-supporting products in the scaled-down validation stage. The products available from Chinese motor companies T-Motor and Intelligence Gull can usually provide a thrust of around 100kg per propeller, which is good enough for a demonstrator of several hundred kilograms in weight. The products of traditional foreign manufacturers are also considered a pole due to their experience in high voltage motors and electric drive products (Megawatt level) that has been accumulated to a certain extent. For example, Safran motors is already in cooperation with Shanghai TCab Tech. Also, Rolls-Royce and Collins Aerospace have already shown interest in market development in China. However, the use of foreign products also brings certain risks to the cost and efficiency of Chinese eVTOL manufacturers. The last pole comes from non-traditional aviation companies. These come from regions such as Guangzhou, Tianjin, Beijing and Nanjing that are developing corresponding products for eVTOL, but have backgrounds in electric vehicle (EV) development, which is consistent with the pattern in the US where we have seen eVTOL companies poaching talent from Tesla and other electric vehicle companies. Some EV companies are already cooperating with China eVTOL OEMs to develop required components. It is widely hoped that after a few years of development, these companies can launch high-voltage electric drive products representing China's unique capabilities.

*Turbogenerator developed by Rolls-Royce*

*1MW class motor developed by Collins Aerospace*

In addition to the electric propulsion system, the flight control system is another key component in the supply chain. However, in the validation stage, the OEM can also use the existing UAV products. Before entering the airworthiness validation stage, the pre-preparation work of the telecontrol systems for airworthiness is needed. In addition to the 618 Research Institute of AVIC, also known as FACRI, there are already two domestic start-up avionics companies dedicated to providing similar flight control system services, including Shenzhen-based Boundary.AI, which recently launched the R3 flight control system for airworthiness and has cooperated in projects with Volant in Shanghai.

There are more challenges in supporting the eVTOL industry in other areas. For example:

- Extremely expensive wind tunnel testing by state-owned companies. Most OEMs can rarely afford it. It is reported that the company Henan Toledo UAV Technology Co. with a Beihang University background is ready to provide commercial wind tunnel test services.
- Lack of detailed engineering design and development services. Groups from Beijing and Nanjing have started to provide design and development services for rotor systems.
- Lack of high-performance propeller custom development capabilities. In addition to the traditional JXF propeller, other groups from the Chinese Academy of Sciences, focus on the development of eVTOL high-performance propellers.
- Lack of special design software for eVTOL. It is believed that based on China's national rotorcraft models and project development needs of the future eVTOL aircraft, China can release its own commercial software.

There are more challenges that are being faced in other areas but, different groups and companies are rising to them on the path to commercialization. Also, China's cost advantage will still exist for a certain time in comparison with the supply chains of developed countries like those in Europe and North America. This will also afford China with a lower trial and error cost.

## Infrastructure

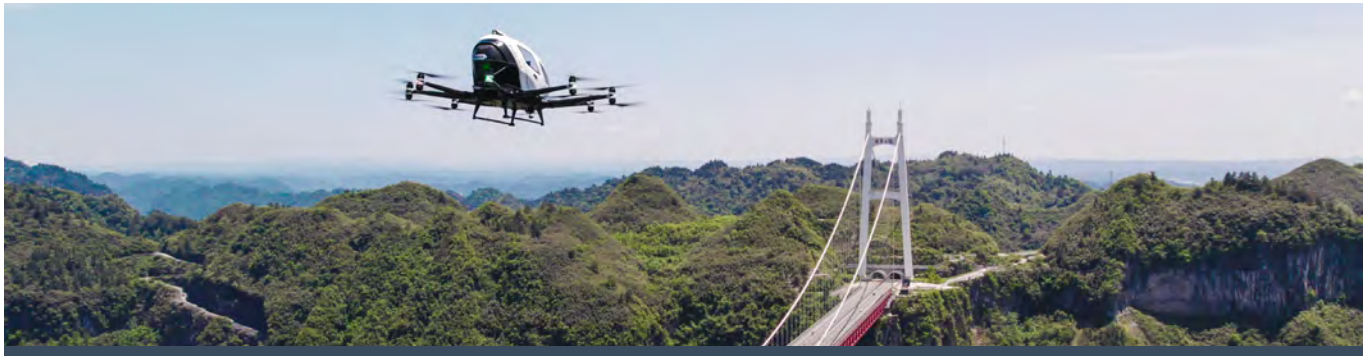
Infrastructure is an indispensable part of the eVTOL ecosystem and will have to include facilities such as micro-climate sensing systems, redundant C2 link airborne communication, customer experience level broadband services, advanced air traffic management systems, easily accessible charging facilities, maintenance services and small city Vertiport platforms that are becoming increasingly important.

For the early commercial verification of eVTOL, in addition to utilizing and improving the traditional urban heliports and helipads, it is also necessary to make full use of the existing navigable airports to carry out passenger services from urban to rural areas where a general aviation airport is located. General aviation airports will form a key part of China's initial strategy for the required eVTOL infrastructure. According to AOPA-China's statistics for 2021, there are only 370 general aviation airports in China. Fortunately, Hunan Province, as the bridgehead of low-altitude airspace reform, was given approval this year to build 55 additional airports, which will bring the number of general aviation airports in China to more than 400. However, considering that the construction of general aviation airports can be more suitable for the need of eVTOL in the future and show the importance of the infrastructure functions in the ecosystem, it is necessary to consider more about the coordinated development of airport facilities and other industries. Taking the redundant Command and Control (C2) links infrastructure requirements as a reference, the industry generally believes that low earth orbit (LEO) satellite constellation will play an important role in future eVTOL operation, both in terms of cost and coverage capacity, to better meet the commercial demands of urban air mobility or advanced air mobility. Therefore, in the short term, the ecosystem construction of domestic eVTOL infrastructure will still focus on pilot projects. In the future, the speed of long-term infrastructure construction will depend more on the development process of China's LEO satellite constellation or other key technologies.

Although the detailed eVTOL infrastructure construction plan has not yet come out, it is estimated that in the near future, eVTOL vertiports or take-off and landing facilities will still be led by local airports and supplemented by aircraft operators, such as Hunan Airport Group and the possible operation of Eastern General Aviation Corporation. Other aspects will be gradually guided and implemented mainly through the construction of the layout of new infrastructure promoted by CAAC. The participants may include: the three major communications operators to lay out the ground-to-air service network, GalaxySpace, to lay out satellite internet services for eVTOL, and the original USS (UAS Service Supplier) service providers to participate in the construction of the large UOM (Unmanned Operations Management) platform system. In the construction of infrastructure by foreign enterprises, the degree of participation may be strictly monitored and controlled due to the national sovereign security issues involved.

## Use Case Scenario / Requirement Analysis

In terms of use case scenarios and requirements, eVTOL is mainly applied to cargo and passenger carrier related scenarios. The simplest approach being considered is to replace the corresponding usage of helicopters. Although eVTOL has the advantage of lower operating costs in the long run, in the short term, its price will probably be equal to the current Bell 407 or similar models of



*EHang plans to develop a scenic flight project at the Aizhai Wonder Tourist Area in Jishou, Hunan*

*The vision of urban air mobility service planned by TCab Tech*


*Shanghai - Zhoushan seafood transportation plan by Autoflight*

helicopters. This is because eVTOLs do not yet have the advantages of mass production and do have the disadvantage of early-stage R&D costs and time investment associated with new technologies. Hence, the early expansion of eVTOL usage will be seen mainly in high value-added business cases. One scenario will be to choose high-income areas for service provision, and another will be to choose low-frequency services within the air business. For example, in the US in terms of commuting, Joby has chosen to expand its business network in California, a notable high-income region. TCab Tech in China expects to provide similar commuting services in Shanghai or the Greater Bay Area in the future. EHang on the other hand, has chosen the air tourism business of scenic spots as it is expected that passengers will be willing to pay higher costs. Similarly, Volocoper is also promoting the air tourism service in Singapore. Other high-value services include eVTOL emergency rescue service provided by EHang, and Zhoushan seafood transportation by Shanghai Safran.

In addition to the selection of application scenarios for demand through payment capacity or added value, the operational risks faced by each application scenario or demand also need to be taken into account. Due to the huge differences in infrastructure and public awareness levels in each country or region, the same business will also show different operational risks. Ultimately, the scenarios with high added value and low operational risk will be the first business targets for eVTOL OEMs or operating companies to try.

In addition, military business is also a direction being targeted by some Chinese eVTOL companies due to its inherent higher risk tolerance for new technologies. However, whether it is personnel transportation service or material distribution service for military logistics, the trial and error of military service scenarios will also follow the basic principle of high added value + low risk.

## Operators

At present, companies expecting to operate eVTOLs in China mainly fall into three categories: OEMs, existing aviation operators and new businesses Some OEMs, will provide commuting services similar to urban air mobility by self-operation, for example, both EHang and TCab Tech have self-operation business plans. The second category is the operation by traditional general aviation enterprises that hope to adopt eVTOL to replace helicopters in their original business, including Eastern General Aviation Corporation and China Southern Airlines General Aviation. The last one is businesses willing to invest and experiment, where they have specific industry resources in related areas. For example, Tianxingjian, a partner of EHang, has rich resources of tourism scenic spots, and Uber, which once promoted the development of eVTOL, has resources in traditional connected ground travel services in the U.S. market.. Of course, eVTOL will not only change traditional helicopter operation services, but will overcome the once insurmountable difficulties of expensive helicopter passenger commuting. Its great significance is that it will give more people the opportunity to make short vertical flights and also take advantage of integrated and multimodal transport services.


# AEROFUGIA: GEELY's Move From Electric Cars To Electric Flying Cars

## An interview with AEROFUGIA Technology



**Liang Guo**
President & Chief Scientist
AEROFUGIA Technology

Founded in 2020, AEROFUGIA is a subsidiary of Geely Technology Group. The company focuses on low-altitude solutions including UAVs and passenger eVTOLs. In 2021, AEROFUGIA formed a joint venture with Volocopter.

### What is the role of AEROFUGIA in Geely Technology Group's aviation strategy?

Geely Technology Group's low-altitude division focuses on the urban air travel business, as well as laying out related industrial applications to form a complete system comprised of general aviation aircraft and UAV R&D, design, manufacturing, and joint service operations. AEROFUGIA is a technology company that makes low altitude travel, consumer drones, and provide smart solution for various industries at its core.

### What is AEROFUGIA's product strategy and what kind of users are you targeting?

We are dedicated to delivering intelligent low-altitude commercial operations. Our focus is on the technological development of a new generation of low-altitude aircraft, which includes new energy solutions, vertical take-off and landing, and smart swarm flying controlling. We are developing two major markets: low-altitude logistics, and air travel. As for low-altitude logistics, AEROFUGIA expects that its low-altitude logistics initiatives will lead to faster distribution than traditional ground logistics. Low-altitude logistics, can realize much higher efficiency through point-to-point logistics that cover sub-regional areas (within 500 km). In terms of low-altitude travel, AEROFUGIA plans to provide fast air travel services within city clusters with four -five times greater time and cost efficiency, and create a one-hour travel circle covering city clusters.

For the above-mentioned scenarios, AEROFUGIA will, on the one hand, sell aircraft to low-altitude travel/logistics operators and provide continuous airworthiness support; on the other hand, it


will maintain and help operators with their service provisions to their end customers.

In terms of products, in August 2022, AEROFUGIA will launch an independently developed pure electric five-seat eVTOL, the TF-2.

## What are the design highlights of TF-2?

The core highlights of the TF-2 are:

- Pure electric power, with zero emissions;
- No runway required as it is a vertical take-off and landing aircraft, flexible deployment can be applied in various scenarios;
- Low noise, and support for large-scale urban operations;
- Intelligent solutions with the ability to automate task planning, recommend actions, and full fly-by-wire flying assistance capabilities;
- Cost-effectiveness, carrying one pilot and four passengers in a comfortable cabin at low cost;
- Full airworthiness and high safety standards, with a 10-9/h class safety index[1] and a Development Assurance Level A (DAL-A)[2].

## The TF-2 adopts the upper single wing distributed tilt power design. What are the advantages of this type of configuration compared to other designs?

Firstly, compared to multi-rotor or lift-propulsion composite configuration eVTOLs, the tilt power form does not carry “dead weight” (multiple motors, electric regulators, propellers, etc.), This gives the aircraft  longer range, whilst shorter flights can benefit from high speeds and lower fuel consumption.

> *“In addition, thanks to the technological advantages of distributed electric propulsion (DEP) systems, the reliability and safety problems of the traditional tilting mechanisms can be perfectly overcome by dissimilar redundancy[3] design, thus ensuring the safe, reliable and efficient operation of the aircraft.”*

Secondly, with the upper single wing, the rotor can be placed high to fully ensure safe access to the cabin for the pilot, maintenance personnel and passengers, whilst allowing the aircraft to be deployed in different types of environments. The aircraft can take-off and land in simple conditions, such as dirt, grassland and river banks, without necessarily requiring a hard runway or a dedicated helicopter landing platform. It also provides sufficient access and space for large items of cargo.

## What is the progress and plan of the TF-2’s  development and airworthiness certification?

Currently, the airworthiness certification of the TF-2 is progressing steadily as planned. We expect to complete the submission of the airworthiness certification and the required test flights before the end 2022. After the first flight, the system design assurance review, approval of the certification plan,

*[1] This classification means the likelihood of an accident occurring is extremely improbable, as the probability is once in every 100 million hours.*
*[2] It is the level of design assurance that can be applied to airborne software and hardware and an A level is the highest one. The level is measured by examining the effects of a failure condition in the system.*
*[3] Dissimilar redundancy means using different types of each components for the same purpose with the expectation that different things are unlikely to contain identical flaws.*

compliance verification method, prototype development, and continuous test flights will be carried out. At the same time, our Wuhan plant will simultaneously build the production quality system and manufacturing conformity review work. After obtaining the type certificate, the aircraft is expected to be put into service in various scenarios gradually in 2025~2026.

## In what way does AEROFUGIA plan to operate the passenger aircraft?

In addition to our own innovations with the TF-2 eVTOL, we are also actively collaborating with several international organizations, and established a joint venture in September 2021 called Volon Airtech, with Volocopter, the global leader in advanced air mobility (AAM). With a goal of providing joint operations and services, Volon Airtech will provide product service and after-sales guarantees for both AEROFUGIA and Volocopter aircraft. AEROFUGIA and Volocopter will jointly promote the airworthiness certifications of both company's products, and actively cooperate with partners in infrastructure construction, ground operations, and air traffic management.

Oriented to the travel needs of end users, AEROFUGIA will actively engage with travel service providers to integrate with safe and efficient low-altitude air travel to deliver complete multimodal solutions for the public. Thanks to the flexibility, cost-efficiency and environmentally friendly characteristics of eVTOL aircraft, AEROFUGIA 's travel services will be considered environmentally friendly, convenient, and economical, making low-altitude travel accessible to the general public.

## In which cities will Volon Airtech, your JV with Volocopter, start operations in China?

No specific cities or city clusters have been identified yet. However, we have very good communication and collaborations with local governments and strategic partners in the Guangdong-Hong Kong-Macao Greater Bay Area, the Yangtze River Delta city cluster, the Beijing-Tianjin-Hebei city cluster, the Chengdu-Chongqing city cluster, and the middle reaches of the Yangtze River city cluster. When the time comes, we will actively promote the rapid implementation in as many regions as possible.

# MuYu's Logistics-First eVTOL Strategy – Cargo to Passenger!

## An interview with MuYu Aero

**Yong Wang**
General Manager
MuYu Aero

MuYu Aero, founded in 2018, is a Chinese eVTOL manufacturer based in Shanghai, China. The company is currently developing a four-seater and a seven-seater passenger eVTOL.

### What is the development strategy and plan for MuYu Aero's eVTOLs?

Based on the safety requirements of passenger aircraft and the operational safety requirements of urban airspace, as well as the incompatibility of current airworthiness regulations and control measures, our strategy is to develop heavy-load logistics eVTOL drones first, and then gradually transit to passenger-carrying flights, that is, to use logistics eVTOLs to provide the technical forerunning for passenger eVTOLs. We plan to get the airworthiness certificate of our logistics eVTOL in about three years.

At present, we plan to have two types of cargo eVTOL and two types of passenger-grade eVTOLs. The cargo models are AT1200 and AT8000, with take-off weights of 1.2 tons and 8 tons respectively, and a payload of 0.5 tons and 4 tons, respectively. The passenger-grade versions are the EV-4 and VJET-7, with take-off weights of 1.2 and 2.5 tons and four and seven seats, respectively. In the future, the AT8000 will also be developed into a passenger eVTOL when it matures, and it will then be able to carry 25 – 30 passengers.

### What is the difference in market positioning between V-JET7 and EV4? What are the different designs adopted in terms of configuration?

The V-JET7 is targeted at the future vertical take-off and landing business aircraft and the inter-city and rural air express markets, which all require a relatively long range and a high cruising speed . Its maximum range is 2,000 km and it has a cruising speed of 450 km/h. The choice of configuration is mainly based on the application scenario and the maturity of the technology. Therefore, the V-JET adopts the ducted power and tilt configuration, which can guarantee the take-off and landing performance while considering the requirements of flight speed and flight efficiency. At the same time, the aerodynamic factor

should be considered more in the external design. In fact, its appearance is more like a cute dolphin.

The EV4 is designed for short-range, low- and medium-speed flights, which is why the composite wing configuration is a balanced solution between efficiency and technical risk. The appearance of the EV4 will change later, mainly due the requirements of passenger and equipment space.

## How does the V-JET7 design achieve its "business jet" positioning?

First, an additional benefit of using the ducted rotor is that noise levels are much lower than that of an open propeller, as well as the excellent sound insulation of the composite sandwich fuselage, which makes the passengers more comfortable inside the cabin. And since this is an electric aircraft, the noise of the motor can almost be ignored. In addition, the interior and cockpit of the aircraft is also developed in cooperation with former members of Italian automotive designer Giorgetto Giugiaro. We believe it will have good performance and bring a better experience to customers.

## What are the requirements of EV4 and V-JET7 for battery, motor and flight control systems?

The form of energy we have confirmed so far is the hydrogen fuel cell, which is more suitable than lithium battery in terms of safety, energy density and charging time , and environmentally friendly. We are also working with a well-known domestic fuel cell manufacturer to jointly develop a fuel cell system suitable for aviation, which will have a power density of 1.7kw/kg.

The self-developed power motor is a permanent magnet synchronous motor for our own aircraft. The key consideration in the design is reliability, and to increase the power density as much as possible on the premise of guaranteeing functional reliability.

The flight control computer and operating system are being jointly developed with third-party companies, but the flight control law[1] is being developed internally by our own engineers.

## Some tilt-rotor manufacturers are planning to equip their aircraft with short take-off and landing (STOL) and conventional take-off and landing (CTOL) capabilities. Will there be similar adjustments on V-JET7 in the future?

No. We have seen several eVTOL aircraft with small, ducted power systems claiming to add STOL, which we consider unnecessary and will not work very well because conventional landing gear must be added, thus increasing the drag. If the landing gear is retracted, the weight would be greatly increased.

> *"Therefore, we believe that there is a technical risk behind an extravagant design. A design is not only for aesthetic considerations but also for the engineering implementation method and the feasibility behind it."*

[1] *A flight control law is a computer software algorithm that enables the pilot to control the movement of the aircraft by joystick or yoke.*

## Will the EV4 and V-JET7 be crewed or uncrewed?

Crewed. The current airworthiness authorities will not consider fully uncrewed flights for the next ten years, so there is basically no choice.

## How are the flight tests of the EV4 and V-JET7 progressing?

The EV4 is in continuous flight test as a full- scale prototype, while the 1/5 scale-down demonstrator V-JET7 has completed the test flight in the V-tail configuration and is now testing the improved T-tail configuration, which we will compare to see which one works better.

## When do you expect the EV4 and V-JET7 to start commercial operation? What is the specific operating model?

In our current development plan, the aircraft will enter into service around 2030; however, the commercialization of the passenger model - I mean the commercial operation that can have a certain scale and can break even - will probably be after 2035.

Then there may be two specific operating models. One is vertical integration, where although the overall investment in this model will be large, it is easier to raise capital. The other is the traditional relationship between OEMs and operators. Manufacturing and operations are separate, which is a relatively traditional model. It is difficult to promote in the initial stage, but it is relatively easy to expand the scale in the future.

## What challenges did MuYu encounter in the R&D of vertical take-off and landing aircraft?

The imperfection and immaturity of the industry chain are probably the biggest problems faced by all eVTOL companies, which is a big challenge for R&D companies. MuYu has 18 years of experience in the industry and has very strong engineering capabilities. All of the aircraft design, production of molds, tooling, test rigs and almost all components, including the power motors, are done in our own factory, which will greatly shorten the R&D cycle and investment costs.

## Does MuYu have any plans to participate in urban air transportation infrastructure?

There is no such plan at present.

## MuYu Aero has not disclosed any financing information. Can you share your future financing plan?

Currently, we are in contact with investors.

# PANTALA Concept H – A Unique Design by Pantuo Aviation

## An interview with Pantuo Aviation



**Louise Lu**
Marketing Director
Pantuo Aviation
www.pantuo.mobi

Pantuo Aviation, founded in 2019, is a Chinese eVTOL manufacturer based in Shanghai. On June 6, 2022, Pantuo Aviation released a video showing the first flight of its 1/2 scale ducted fan eVTOL, PANTALA Concept H.

### Market Positioning

Pantuo wants to build a fast, safe and comfortable aircraft that can fly between cities, connect transportation hubs and operate crewed emergency rescue missions. Its first eVTOL, the PANTALA Concept H, has a maximum speed of over 300km/h, and a maximum range of 250km. "This aircraft helps those who value their travel time to live in a more efficient way, whether it's for business travel, leisure travel or other scenarios." says Lu.

### Configuration Choice

"Few ducted fan configurations are seen in eVTOL designs worldwide, not to mention tilt-wing ducted fan configuration, which has a higher challenge of technical feasibility. Both market and technology perspectives lead us to this configuration." says Lu.

"From a market perspective, aircraft with ducted propellers can provide passengers with a greater sense of safety. especially in China where the general aviation market is not well-developed. The requirement for noise reduction in advanced air mobility is much higher than in other operational environments. Travel scenarios are diversified inside cities, whilst the advantages of flying vehicles in getting rid of ground traffic congestion and saving travel time are especially prominent in mid-long distance trips." says Lu.

> *From a technical perspective, ducts not only provide protection that avoid fan blade harm in emergency situations; at the same time, ducts can effectively reduce the operation noise of the aircraft. Ducts have a better static performance than open propellers, and the annular wings also work better in cruise. Considering safety, noise reduction and efficiency, we chose the tilt-wing ducted fan configuration."*

## Battery, Motor and Flight Control System

Due to the size constraint of ducted fans, the power requirement of the battery system is higher compared to open propeller configurations, which prompts highly efficient thermal management system and propulsion system. To meet the 250 km flight range, Pantuo requires lithium batteries with a high discharge rate, with energy density 25% higher than current mainstream lithium batteries that are used in electric vehicles. As a certain number of cell suppliers can currently provide batteries of this level, Pantuo will balance the high performance from cutting-edge battery technologies such as solid-state batteries, ultra-high nickel cathode and silicon anode based Ni-Co-Mn (NCM) batteries with cell safety design. For the flight control system, extra control input channels and hence more control patterns to be optimized, imposes an interesting challenge that we are ready to tackle with.

## Take-off and Landing

PANTALA Concept H was designed with short take-off and landing (STOL) and conventional take-off and landing (CTOL) capabilities at the very beginning. "In this way, the aircraft could save power during take-off and landing, which in turn increases the range of the aircraft. Since the infrastructure of civil aviation airports and general aviation airports are relatively well-developed, making full use of existing facilities will enhance eVTOL operation"

## Safety

Pantuo believes that achieving high aircraft safety level is accomplished through enhancement of subsystem safety level as well as holistic aircraft system design. While applying safety analysis methods and processes inherited from conventional aircraft development, Pantuo will also seek interactive communication with certification authorities as new technologies and operation conditions will be implemented. Meanwhile, Pantuo will also ensure safety objectives are viable and even improvable for subsystem suppliers through an integrated cooperation model.

## Exterior and Interior Cabin Design

The exterior of the PANTALA Concept has been designed in collaboration with studiokurbos, an international leading design studio headquartered in Germany. The premium character of the aircraft is evident at first glance of the exterior through the generous surfaces, few component separations and dynamic lines, providing people with a futuristic and elegant feeling. "PANTALA Concept H provides passengers with a higher level of safety. The vehicle design fits in the public's perception of future mobility. In the design of interior space, we tried to restore the layout and space of a passenger car, which is the most familiar and comfortable way of commuting for users. We will use a simplified cockpit concept and integrate flight controls into a central screen and a side stick to enable a safe, simple and fun flight."

## Certification

Although no eVTOL has obtained airworthiness certification, and neither the FAA, EASA, nor CAAC has issued clear standards about the certification of eVTOLs, Pantuo believes that it will be a combination of traditional Part 23 (Airworthiness Standards: Normal Category Airplanes), Part 27 (Airworthiness Standards: Normal Category Rotorcraft) and related "Special Conditions". PANTALA Concept H full-size model will be kicked-off at the end of 2022 and it is expected to obtain certification and enter into service within five years.

"Based on Pantuo's experience in commercial aviation projects, the PANTALA Concept H is on track to achieve CAAC airworthiness certification by the end of 2027, based on assumptions that the market environment is stable, resources are sufficient. To obtain certification, Pantuo, like all eVTOL companies, will further improve the aircraft design according to the regulatory requirements from CAAC, FAA and EASA.

## Market Prospects and Commercial Operations

Pantuo believes that unlike the traditional helicopter charter, which serves only the high-end travel market, eVTOLs bring a more efficient and convenient way of travel to a broader range of people. “eVTOLs will replace some helicopters on existing missions and some mid to long distance ground transportations. With their low operating noise and operating costs, eVTOLs could realize advanced air mobility market, stimulate more diversified travel demands and create a blue ocean market.” says Lu. PANTALA Concept H will enter commercial service after obtaining its Type Certificate (TC) in 2027. “We will actively cooperate with helicopter operators to carry out existing missions, using existing take-off and landing infrastructure and approved routes to enter the market. Trial operations will start on fixed routes and areas with low population density. With the establishment of the route network, ground infrastructure, laws and regulations, and the development of technology, eVTOLs would be used in more operation scenarios. The overall operational costs will continue to decline in forming a positive cycle of business growth.”

## Infrastructure

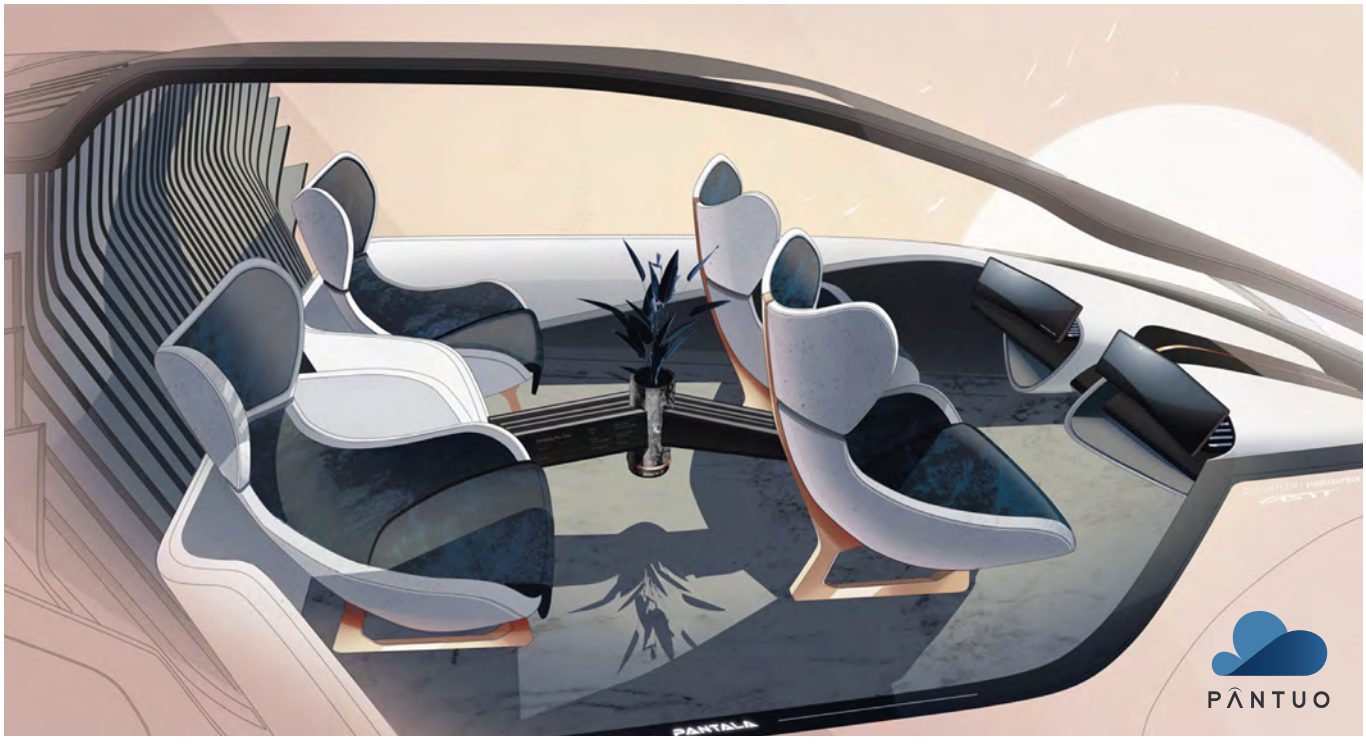
There are almost 50 cities around the world that are considering the feasibility of urban air passenger transport, still the infrastructure is not sufficient. As an eVTOL OEM, Pantuo not only looks at the needs of users, but the constraints brought by infrastructure are also the key factors when designing an eVTOL. “Conducting research on infrastructure is necessary in early stages of aircraft R&D. We will proactively share our understanding of UAM and will deeply involve ourselves in the definition of infrastructure.” says Lu.

## Challenges

For most people in China, eVTOL is a new term. With the IPO of overseas leading eVTOL companies, the capital markets began to show interest, which accelerates the development of the industry. Lu says: “In China, peoples’ understanding of eVTOL market, engineering, certification and operation is not thorough enough to objectively assess the challenges and life-cycle of the project. It is also difficult to find qualified talents and industrial partners in China.”

## Financing

Unlike other eVTOL startups, Pantuo has always been a self-financing startup that maintains close ties and partnerships with major suppliers around the world. Pantuo is currently seeking the right investors, “We have just started our first round of funding, and we welcome institutions and investors of all kinds to come for a talk.”




# Let Everyone Enjoy the Future of Urban Air Travel

## An interview with Vertax



**Ling Xie**
Chief Executive Officer
Vertax

Vertax is a Chinese eVTOL manufacturer. The company was founded in 2021 with a research and development center in Shanghai. It's subsidiary, FCOURIER, develops and manufacture Uncrewed Aerial Vehicles (UAV).

### What is the strategic development plan for Vertax?

Our vision is to "let everyone enjoy the future of urban air travel." As for the product strategy of Matrix1, we will follow the path of "cargo first, then passenger" and "segregated from the national airspace system first, then integrated into it" to enable the public to benefit from the convenience of urban air mobility. We also intend to participate in the development of UAM infrastructure.

### How would the experience gained from previous projects transfer to the design of Matrix1?

Our members were the core technical personnel of national aircraft models such as the ARJ21 and the C919 before we established Vertax and its subsidiary, FCOURIER; thus, we have been designing "small aircraft" in the same way as "big aircraft" which differentiates us from other drone and eVTOL companies. FCOURIER has successfully developed and manufactured the first generation of a fixed-wing UAV called E6. In our past design practice, we accumulated profound experience in autonomous flight control systems and Multiphysics simulation. We have flight control algorithms, flight control software- and hardware, battery management systems, and motors all under control. Our competitive advantage in technology allows us to take the initiative in the development cycle, supply chain, cost, and risk management.

Given our experience in developing flight control and simulation systems, the development of Matrix1 is going very smoothly.

## What are the factors determining the design of Matrix1?

The overall design of Matrix1 builds on two main factors - safety and cost.

> *"The current phase of the advanced air mobility sector is equivalent to the early stages or automotive and aircraft design. Therefore, achieving a high level of safety at an acceptable cost, building confidence for the government and society, and shortening the airworthiness certification cycle are the keys to the business success of eVTOL."*

As for the aircraft's safety features, we carefully analyzed the reliability level of the existing supply chain and implemented multiple redundancies into the distributed power system. We also created a unique design for the flight control system, adopting a higher redundancy and management algorithm to provide a higher level of safety in hardware and bus technology.

## What is Matrix1's airworthiness certification plan?

We plan to conduct the first full-scale prototype flight in early 2023 and submit the airworthiness application in the same year. We expect to obtain the airworthiness certificate in 2026, after which the Matrix1 will enter service. Since we have accumulated a decent amount of experience in autonomous control from our UAV, our goal is to implement autonomous control on passenger vehicles, which we believe is the key to the future success of the passenger-grade version of Matrix1. Before obtaining the airworthiness certification for the finalized passenger-grade model from the Civil Aviation Administration of China (CAAC), we target to obtain the airworthiness certificate in non-passenger-carrying areas first, such as intercity cargo. We want Matrix1 to enter into service as soon as possible so that we can acquire operational data as early as possible.


# Near-term Sustainability for Air Transport – Ampaire's Hybrid-electric Aircraft

## An interview with AMPAIRE



**Susan Ying**
SVP Global Operations
Ampaire, Inc.
www.ampaire.com

**Ampaire is a hybrid-electric propulsion manufacturer established in Hawthorne, California. In July 2022, its Electric EEL set a new benchmark for hybrid-electric aircraft, with a nonstop flight in the US of 1,135 miles.**

Susan Ying thought she had retired. As a distinguished aerospace engineer by trade, Ying had spent much of her career with Boeing as a director for research and technology, before moving to Shanghai to work with the Commercial Aircraft Corporation of China (COMAC) on its ARJ21, C919 and C929.

Although she did not know it at the time, it was during her stay with Boeing that the seeds for her move to Ampaire were being sowed. As part of her role back then, Ying tried to recruit a young man from Stanford University, who decided to join Northrop-Grumman instead. Years later, a friend reintroduced the pair and that young man she once interviewed turned out to be Cory Combs, Co-Founder at Ampaire.

After listening to Combs talk through Ampaire's vision and goals, she relished the opportunity to join what she describes in her own words as "this revolution" in aviation, not the next revolution.

"It's way too exciting to be on the side lines watching this happen. I want to be in it, you know, roll up my sleeves and do it."

The first revolution was powered flight, when the aviation pioneers stuck engines onto aircraft and had the ability to control where the aircraft went. The second was the jet engine, which revolutionized commercial air travel, making it possible to connect cities and countries flying faster, farther, and higher.

"This revolution right now, is that we are going to improve our flight so that it will be cleaner, greener, and quieter, and the best part is that it will be more affordable so that we can really connect all of the remote parts of the world," says Ying.

Ampaire's first aircraft is a modified Cessna 337 SkyMaster, which the company calls the Electric EEL. The 337 is unusual in that it employs a push - pull configuration for its engines, with one at the

front of the fuselage, and one at the rear. Whilst this configuration is relatively uncommon, it helped the company convert the front engine to electric power first to act as a prototype "flying test bed", whilst the rear engine remains in its original state.

Ampaire's first commercial product involves a hybrid-electric powerplant that works similarly as some hybrid-electric cars being independent of the charging infrastructure. A traditional piston engine is joined on the shaft by an electric powertrain, all of which are capable of powering the aircraft. This is referred to as "integrated parallel" system architecture, different from that of the Electric EEL which is an "independent parallel" system architecture.

According to Ying, Ampaire's solution revolves around what she describes as "using electric where it makes the most impact." For example, on take-off an engine must produce maximum power to speed up the aircraft to the point that it can lift off, then it must keep producing enough power to make the aircraft climb. To "energy optimise" for the whole mission, we use electric power appropriately as boost in take-off and climb to avoid the excess fuel required by the combustion engine, and minimise the electric and fuel usage for the cruise by a more efficiently sized combustion engine, which not only cuts down on fuel costs, but also cuts down on harmful emissions. Ampaire says that on a typical flight the fuel cost savings could be between 50 - 75%, depending on the length of the flight.

"The best part is that we can do that today. Once we have the certification in 2024, it could basically be introduced into service right away," says Ying. "We don't have to wait for a decade for a brand new airplane to be certificated."

Since the EEL's first flight in June 2019, the company has taken the opportunity to carry out several demonstration flights, almost at opposite ends of the earth. The first was in Hawaii, where the EEL flew from one side of Maui to the other in 15 minutes, a distance that Ying says would take at least a couple of hours by car.

The second took place in the Scottish Highlands, where the aircraft was used to connect the mainland to some of the smaller islands, with Ying saying that the aircraft would make commuting between different towns and islands possible, whereas before the trips would necessitate an overnight stay somewhere.

But the longest flight took place when Ampaire took the EEL to Oshkosh for the EAA AirVenture event. Having left the company's Camarillo homebase for a short hop and night stop at Mojave, the aircraft departed the next day for Hayes, Kansas, with the 1,135nm-journey becoming the furthest that a hybrid-electric aircraft has flown to date.

The EEL should be viewed as just a technology demonstrator, a way of proving the technology can work, before scaling up to larger aircraft. The first of those will be the Cessna 208 Caravan, or, as Ampaire calls it, the Eco Caravan.

The Caravan, which first flew in 1982, is a single engine aircraft that can carry up to 1,436 kg of freight, or 13 passengers when in a passenger configuration, although with Ampaire the max seating is reduced to nine, and the payload to 1,133 kg. With more than 3,000 Cessna Caravans built, its operators appreciate its low acquisition and operating costs as well as its rugged design, which makes it ideal for connecting remote communities, whether it is carrying passengers or freight.

Ampaire announced the first orders for the Eco Caravan during the EAA AirVenture event where the EEL was being displayed. The order was placed by southwest USA-based air mobility company WingTips, which placed an initial firm order for five aircraft, as well as taking out options on a further 20 aircraft.

“Fuel saving is at least 50%, 50-70%, and once again, that depends on how you optimize that,” says Ying. “Operating costs will be reduced around 25% or so, of the total operating cost.”

That could just be the beginning though, as both companies say that they are looking into an agreement for a further 175 aircraft, which could come in stream as WingTips expands nationwide in the US. The two companies are also looking at larger aircraft, with the DHC-6 Twin Otter as the front runner. Ampaire has already been working on a hybrid engine for that aircraft, having originally won a USD$6.4 million grant from NASA for its research and development.

Although the company says it would be possible to work on smaller aircraft than the 337, Ying says the market for hybrid or electric general aviation aircraft is already getting crowded.

> *“Our goal is not going down small, its scaling up high. Because we believe that to really make a difference in terms of sustainability, we cannot stay at nine-passenger aircraft.”*

What that looks like in the future could well depend on battery technology, both in capacity and physical size. It’s clear that Ampaire has 737 or A320 sized aircraft in its sights with the most pollutions due to the installed base.

“The immediate problem that we can solve is for regional air mobility,” says Ying, “we can go cleaner, greener, and quieter more affordably today!”

# Advancing AAM in Southeast Asia

## An interview with Volocopter



**Hon Lung Chu**
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Volocopter GmbH
www.volocopter.com

**Since joining Volocopter in September 2020 as its Head of APAC, Hon Lung Chu has spent most of his time building up the local team, and working closely with the Singapore government to prepare for the commercial launch of Volocopter's air taxi services in the Lion City.**

A Harvard Business School graduate, Chu joined Volocopter from AirMap, where he was head of the company's Asia-Pacific business operations. His experience with AirMap, which provides intelligent airspace solutions, held him in good stead for his task of launching AAM services in Singapore.

"We spent the past two years aligning with the government's efforts in Singapore towards our launch," says Chu. That alignment has included many different government departments, as well as the local tourist board.

"Coming up with solutions and then bringing everyone to the table so that we are aligned on making this launch happen for Singapore," says Chu. "Of course, it's a big deal for Volocopter as well as it is the first Asia-Pacific city, but it is also a big deal for Singapore, and the benefits which we have outlined in our road map."

The roadmap that Chu mentioned was released earlier in 2022 during the Singapore Air Show. The document outlines the company's plans to start operations and gives realistic start dates for different phases of its plans.

But before Volocopter can launch flights it has the small matter of a type certificate for its first eVTOL aircraft – the VoloCity, to contend with. No small feat, as it is likely to be one of the first eVTOLs in Asia to be certificated outside of mainland China.

As a German company, Volocopter will certify its first eVTOL, the VoloCity, in Europe with the European Aviation Safety Agency (EASA) first, which will later be validated by Singapore's own aviation authorities, the CAAS. The process for doing this has been sped up, following a December 2020 agreement that will see the CAAS concurrently approve EASA design approvals, and work towards type certifications in close collaboration.

If all goes well, then the company plans to begin operations in 2024, with tourist flights around Marina South, and Sentosa, an island resort off the southern coast of Singapore.

> *"From a launch perspective, for Singapore we are very clear it's touristic flights to start with, then we go across the border into nearby city centers,"*

says Chu.

"As you can imagine, we are looking at other destinations, including Seletar (Singapore's business and general aviation airport) and Johor Bahru (Malaysia), as well as Batam (Indonesia) and of course in Singapore's Changi Airport," says Chu. 'I think these are really the obvious places that we would see cross-border activities also happening, and then of course Marina South and Sentosa could also be expanded to support cross-border operations."

By the time the company is ready to launch cross-border flights, its second aircraft, the VoloConnect is likely to be in service. Whereas the VoloCity is designed for short hops inside urban areas, the VoloConnect is designed to connect cities, less than 100km apart. The first aircraft made its first flight in May 2022 and Volocopter expects that the aircraft will be certified and enter service in 2026.

Certifications and regulations are important - authorities all around the world will need to make sure that aircraft are safe in the air, and people are safe on the ground before services can be formally launched. But almost as important, certainly from a commercial perspective, is public perception. After all, you might have built the safest aircraft ever built, but if the public doesn't trust the aircraft, they will not be willing to fly on it. Unfortunately, altering the public's perception of something can be very hard. Once people's minds are made up, it is then difficult to make them change.

Volocopter hopes to overcome this through an exhibition that it is running in Singapore, which has been designed in a way to demonstrate the real-world benefits of AAM. It includes a full-scale model of a VoloCity aircraft, as well as a model of a vertiport, and several informational videos. Although the exhibition is open to the public, Volocopter's own staff conduct tours.

"We are really at the stage now where we are trying to prepare the general public for the arrival of our service," says Chu. "When we launch an air taxi service, it affects not just the ministry of transport for example. It is not just a transportation tool, it's not just an environmental thing and it's not just about economic development. It is about all of those things and more. Therefore, in Singapore, we have had the benefit of working with multiple government agencies, including the Economic Development Board, MOT, and CAAS."

The exhibition opened in July 2022, and is currently scheduled to run for a year, although Volocopter has the option to extend.

According to Chu, the company felt that it needed to launch the exhibition, not only to prepare the public for the launch of its own operations, but also to educate them about AAM in general, as well as new technologies that will be used.

"The feedback has been overwhelmingly positive," says Chu. People are very engaged and excited. They can see the aircraft and they can sit in it. They can turn on and off the aircon, and charge their phones using the USB ports. They can also play with the inflight entertainment system, which adds a different level of reality, so that they can see everything for themselves, and picture themselves flying."

Chu says that the exhibition has so far been such a success that the company is already looking for further opportunities where it can achieve broader engagement, and, if possible, take a deeper dive into the upcoming AAM world.

'It is important for us to really engage as deeply and as early as possible," says Chu. 'Our goal is to turn those people that visit the exhibition into ambassadors for air taxis, and also for Volocopter in Singapore."

# SMG Consulting – Rating the Likelihood of eVTOL OEMs to Successfully Bring their Aircraft to Market

## An interview with SMG Consulting



**Sergio Cecutta**
Partner
SMG Consulting
smg-consulting.com

**Sergio Cecutta and his team at SMG Consulting have the unenviable task of sifting through the ever-increasing mountain of eVTOL manufacturers to see which ones are the most likely to succeed.**

Think of them as eVTOL experts, talking periodically to existing companies, whilst always keeping an eye out for new ones. The information that they gather goes into building up the company's AAM Reality Index, which ranks eVTOL manufacturers by the ones it thinks are most likely to succeed. If tracking the hundreds of eVTOL manufacturers wasn't already enough, it also tracks infrastructure companies.

"The two indexes cover two pieces of the ecosystem," says Cecutta. "If we look at the ecosystem as made up of different pieces when it comes to advanced air mobility, the first is the advanced air mobility index, which covers the first side of the house, specifically it tries to understand the likelihood of the OEM to certify as well as produce a specific vehicle that was indicated in its business plans."

The index is purely driven by data, with Cecutta saying that it takes into account five different sets of criteria: funding, experience of the team behind it, technology development, the progress towards certification and their manufacturing readiness. All the data is then mixed together, to effectively give the company a score out of ten, which the company calls an ARI (AAM Reality Index) score. Topping the list at the time of writing is Joby, with an ARI of 8.7.

"Joby is one of the oldest companies out there, having been founded in 2009," says Cecutta. "It is also one of the companies whose aircraft will enter into service in 2024, and they are also underway in building their [production] conforming aircraft and starting actually flying for credit with the FAA."

Just with any other type of ranking, ranking the chances of an a EVTOL manufacturer successfully bringing its aircraft to market, and it being a commercial success, can be quite subjective. That's especially true in a nascent industry such as the AAM market, where no aircraft similar to eVTOLs have ever even attempted to gain certification.

It's this uncertainty that drives us towards closer towards data, and the conclusions that can be directly drawn from it.

"We have always tried in all of our work to take out subjectivity and introduce parameters with specific milestones and measures,' says Cecutta. "Therefore, whatever the ranking is, it is just an algorithm based on the achievement of the company."

Keeping on top of that data, and all of the changes and additions that need to be made, is no small feat, especially with new eVTOL manufacturers popping up regularly.

However, despite the plethora of eVTOL companies out there, not all of them make the AAM Reality Index. Instead, companies are grouped into three different buckets; those in the index, those that could in the future be in the index, and those that the company is keeping a watchful eye on, with Cecutta saying that if the company does not have a solid product or business plan, then the SMG will not take the time to research them.

"New companies come about weekly, both worldwide, and especially in China where there are more and more companies coming out,' says Cecutta. But if you look at all of the companies, we basically look at each and every one of them when they first come up. And I would say that there are some companies that are in the index, and there are some other companies that will possibly join the index in the future, and then there is a slew of other companies that we basically monitor to see how they are going to do."

According to Cecutta, the Vertical Flight Society's eVTOL tracker lists around 700 aircraft, and whilst a few are from companies that are either in, or could soon be in, the AAM Reality Index, many of the companies behind them are not as solid as those on the list. All in, the company tracks around 40 – 70 manufacturers.

To make it into the index, a new company first gets compared to the existing companies in the index, and then the SMG team asks what makes them different from those companies. Cecutta admits that this approach creates a 'high bar', although he later says that to get into the index a company does not necessarily have to be better than the three or five companies at the top of the index.

> *"We want to make sure that the companies that we are introducing are companies that are not just going to flame out and disappear."*

says Cecutta. Consolidation will come, but at the same time we are very conservative when it comes to adding companies, even if there are companies that are on a 'wait' list."

Cecutta says that each one of the top five companies has a solid aircraft that has been engineered to be successful and whilst on the surface that might seem like a strange comment to make, one only has to look at the wide variety of different eVTOL designs that different companies have come up with to understand exactly what he means.

In such a young industry working with new technologies, there is always the temptation to overdesign a product. With so many different companies coming out with new eVTOLs all of the time, new designs also need to stand out, to help differentiate themselves from everybody else, and it's because of this that we have seen many designs that have left us scratching our heads.

But the aircraft of the top five companies in the index share one thing in common; they all look how we would expect an aircraft or eVTOL to look. That helps not only when it comes to certificating the aircraft, but also when it comes to raising funds for their development, so it should come as no surprise that the top five companies are also those that have raised the most money.

'There is a certain amount of money that companies need in order to be at the top of the index,' says Cecutta. 'These vehicles are extremely expensive to develop, let's not forget that these are airplanes and airplanes take a lot of money to develop, with the figure, and this is just a ballpark figure, around USD$1 billion as far as developing something in the West."

Although SMG Consulting is perhaps most known for its AAM and Infrastructure indexes, that is only a small part of what the company does.

Having been in business now for ten years, the company specializes in helping its clients grow in the aerospace, defense and automotive industries, be it through market reports, business plans or investments in other companies.

"We have a diverse group of customers," says Cecutta, "And as you can image, in a growing industry nobody wants to release their names. But we help them with anything connected to the growth side of their business. Whether it is understanding the market, creating a go to market strategy, or developing a business plan, all the way to consulting with them on investments, as well as mergers and acquisitions.

# THE KEY THINGS TO KNOW ABOUT *EVTOL BATTERIES*

The move to electrification might have popularized by the automotive industry, but the energy, and therefore the battery size, needed to power a car is far lower than the power need for an aircraft to fly. And whilst the physical size and weight of a battery that powers a car is important, it is more so in an aircraft, as it affects its payload / range capabilities, especially in the first stage of flight – if a battery is too heavy, the aircraft might not even be able to lift itself off from the ground. Therefore, improving the battery performance per unit weight will be more crucial than equipping heavier batteries on aircraft.

Batteries for electric VTOLs face critical challenges in achieving high specific energy, high specific power, charging speeds, and long lifecycles. Despite the challenges that the battery industry faces, improving battery technology is crucial to the future development of electric aerial vehicles.

This section will introduce current battery technology, as well as its direction for the future.

## Basic concepts

- Specific power
- Specific energy
- C-rate
- Cycle life

## Impact on eVTOLs

- Load capacity
- Range
- Operational intervals
- Lifespan

## Next-generation battery technology

- Solid-state batteries
- Sodium-ion batteries
- Hydrogen fuel cells

## 1. Basic concepts

Before moving on to the difficulties of battery technology, this subsection will introduce the four fundamental concepts of batteries. These four concepts are the primary indicators to evaluate battery performance and form the foundation of discussion on a vehicle's range, charging time, cost, and other characteristics.

**a. Specific power (SP)**

SP describes how much power is in a unit weight of a battery, usually defined as W/kg. SP depends on battery chemistry and packaging. SP determines the capacity of the aircraft and the required battery weight.

**b. Specific energy (SE)**

SE describes how much energy is in a unit weight of a battery and presents the performance of the battery, usually defined as Wh/kg. SE depends on battery chemistry and packaging. SE determines the range of the aircraft and the required battery weight.

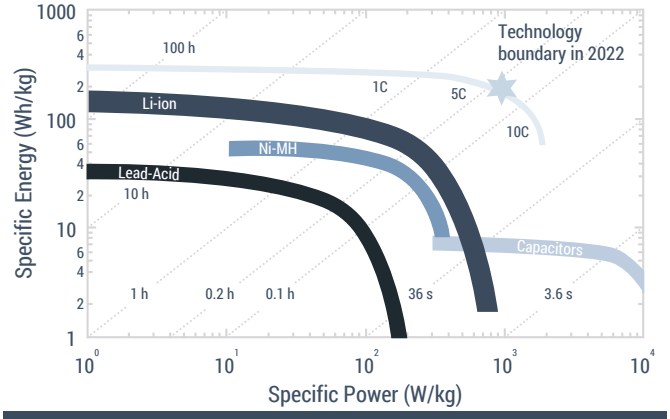
**c. C-rate**

C-rate is a parameter to measure how fast a battery can be fully charged or discharged, where a higher C-rate means a shorter charging time. For example, a C-rate of 1C means the battery can be fully charged or discharged in an hour. The upper limit of the C-rate depends on the type of electrolyte and electrode material used in the battery. C-rate also determines the driving performance of a vehicle. In cases where larger lift or thrust is required, the C-rate is subsequently larger. For example, during vertical takeoff or landing, the gravity to be overcome is greater than in a horizontal cruise, resulting in a higher C-rate; faster acceleration and cruise requires higher discharging power, also resulting in a higher C-rate. The chart shows the relationship between each component.

**d. Cycle life**

Cycle life is the number of discharge-charge cycles the battery will experience before it fails to meet the lowest power demand of the aircraft. The cycle life depends on the C-rate, depth of cycles, temperature, and battery type. The depth of cycles refers to the percentage of electricity discharged in a cycle. A greater percentage means a deeper depth of discharge. Cycle life determines the life of the battery.

**Interrelationships between specific power, specific energy, C-rate, and cycle life**



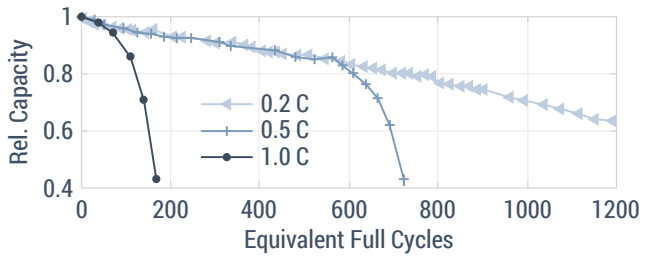

*Battery performance trends*

*Source: Expanding the Ragone Plot: Pushing the Limits of Energy Storage (McCloskey, 2015)*

The SP, SE, C-rate, and life cycle all correlate to one another. For the same cell (in the chart below, the bands in different colors represent different electrical devices), SE and SP changed reciprocally (although they can only do so in the corresponding band). The SP cannot be infinitely large, as the corresponding SE will drop rapidly after reaching a certain level; hence, there is a balance point between SP and SE needs to be met to meet power demands. A discharge rate of 5C (as shown by the diagonal dotted line in the figure below) is an appropriate reference standard, as it balances maximum specific power and specific energy, with a relatively fast discharging rate.


*C-rate introduction chart*

However, whilst a rate of 5C would seem to be ideal, it would mean that the battery's lifecycle would be fairly short. This is because as the cycle of charges and discharges increases, the battery will age, and its performance, such as capacity and specific energy, will decrease. A higher C-rate causes the battery to age more quickly. Therefore, eVTOL batteries need to balance SP, SE, C-rate, and lifecycle.




*Capacity development vs. equivalent full cycles depending on the C-rate*

*Source: Lifetime Analyses of Lithium-Ion EV Batteries (Keil, Schuster, Lüders et al., 2015)*

## 2. Impacts on eVTOLs

Improving specific energy and specific power whilst achieving fast charging and long battery life are the four main challenges in developing eVTOL batteries. The four concepts mentioned in the previous section are particularly important for evaluating the performance of batteries and aircraft, and unfortunately, they can be mutually restrictive.

This section will further discuss the specific impact of battery performance indicators on eVTOLs, based on existing technical levels and actual needs, and introduce ways to improve battery performance.

Ground crew loading batteries for Vahana

*Source: Airbus*

**a. The specific power limits the vehicle's load capacity.**

The different power requirements of the aircraft in each flight phase are more evident in the eVTOL. A typical eVTOL trip has five stages: takeoff, climb, cruise, descent, and landing, where the power output required by the battery at distinct states of the vehicle's flight is different. Most eVTOLs use the most power whilst taking off and landing.

In addition, the need for specific power varies by thrust design. Different power layouts will change the minimum power requirements in the takeoff and landing, and cruise phases.

| Type | Minimum specific power (W/kg) |
|---|---|
| Multicopter | 400 |
| Slowed Rotor | 450 |
| Vectored Thrust | 500 |
| Lift + Cruise | 700 |

*Specific power requirements for different power types of eVTOL*

*Note: The data in the table was extracted from Challenges and key requirements of batteries for electric vertical takeoff and landing aircraft, Joule (Yang, Liu, Ge, et al., 2021).*

At a discharge rate of 5C (a typical discharge rate needed for hovering), battery technology can currently achieve specific power of 1 kW/kg. However, this will hopefully reach its target performance of 2.5 kW/kg for eVTOLs by 2040. This current barrier might be overcome by using new materials and redesigning battery cells.

**b. The specific energy limits the vehicle's range.**

The battery's specific energy determines the upper limit of the vehicle's range.

According to the Fast-Forwarding to a Future of On-Demand Urban Air Transportation report published by Uber in 2016, eVTOL vehicles should have a minimum effective range of more than 100 miles (about 160 kilometers). Using this potential minimum range, the required minimum available specific energy of the battery would be around 230Wh/kg. However, considering system efficiency, backup energy, and battery pack design, only 50% to 60% of the specific energy is available during the flight. Therefore, the specific energy of the whole battery pack should be about 380~460Wh/kg to fulfill the minimal SE demand. Taking this into consideration, current generation batteries would only be able to power eVTOLs on short-distance flights of less than 50 kilometers.

Specific energy can be increased by:

- Using more advanced electrode material in design
- Applying a more compact battery pack design

*New battery packs for eVTOL*

*Source: Luminati Aerospace*

**c. Battery recharging speeds limit operational intervals**

As stated previously, the goal is to reach a 5C charging speed. This rate is theoretically feasible, yet one needs to consider battery life in practical applications. An excessive charging speed can lead to a drastic reduction in battery life; thus, manufacturers did not widely adopt this rate, but limited the charging rate to under 1C to prolong battery life.

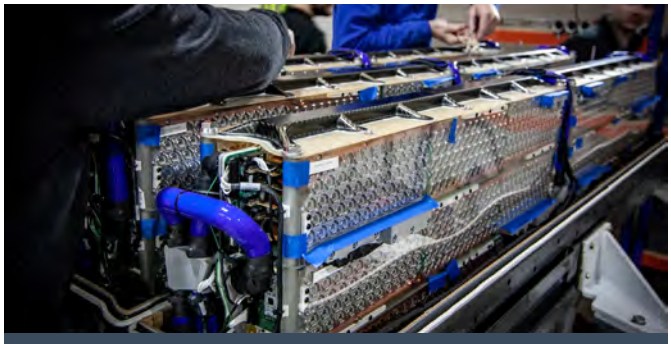
Only a limited amount of energy remains in the aircraft after landing, and the vehicle requires recharging before the next takeoff. The aircraft can be recharged before the next group of passengers board the aircraft, or the battery could be swapped out directly for a fully charged one, however, purchasing multiple batteries for replacement is likely to be expensive - battery cost currently ranges from 20% to 50% of the overall manufacturing cost of aerial vehicles.

To increase the operational efficiency of eVTOL flights, charging times should be as short as possible, especially during busy times. If the eVTOL needs to take off 12 minutes after landing, it requires a 5C charge rate. If the operator needs to reduce the changeover time by half, the charge rate must be doubled.

**d. The aging of the battery at a high C-rate limits the lifespan of eVTOL.**

At a 1C discharge rate, the number of cycles in a battery's lifecycle is around 1500. Batteries for eVTOLs need to operate under high charge-discharge current which reduces the battery's life if it is charged quickly at the current level of technology. If charged at 5C speed, the battery's lifecycle will be around 1,000 charge / discharge cycles. Thus, a major challenge for batteries is the need to ensure their lifespan to reduce operating costs. Even if the aircraft only performs three flights a day and charges three times, the battery needs to be replaced once a year, which is likely to be expensive.

An asymmetric temperature modulation (ATM) method that charges the battery at a specific temperature and voltage can significantly slow the rate of battery aging. It was reported that a battery charged under 6C with ATM method can retain 92.3% capacity after 2000 cycles.



*Assembling battery pack*

*Source: Manufacturing Technology Centre*

## 3. Next-generation battery technology

The impact of new battery technology on the future development of eVTOLs should not be underestimated. Lithium-ion batteries are no longer the only choice, solid-state batteries, sodium-ion batteries, and fuel cell technology are also emerging. These new technologies meet different needs such as long range, large payloads, and fast charging, offer unique battery performance characteristics, and provide a solution for future large-scale applications of eVTOLs.

**a. Solid-state battery**

A solid-state battery is a battery technology that uses solid electrodes and a solid electrolyte, which theoretically means that the capacity and power of these batteries will be higher than lithium batteries. Semi-solid-state batteries are already in mass production, whilst , full-solid-state batteries are expected to enter mass production in 2025.

**b. Sodium-ion battery**

Sodium-ion batteries are similar to lithium-ion batteries but use sodium ions as the charge carrier. Compared to lithium-ion batteries, current sodium-ion batteries have somewhat higher costs, slightly lower energy density, better safety characteristics, and similar power delivery characteristics.

**c. Hydrogen Fuel Cell**

A hydrogen fuel cell is an electrochemical cell that converts the chemical energy of hydrogen and uses an oxidizing agent to run electricity through a pair of redox reactions. The most significant feature of hydrogen fuel cells is their high specific energy and their replacement of the hydrogen bottle, which cuts down the time to charge when compared to lithium batteries.

## 4. Key Take Outs

Battery technology impacts the development of eVTOL profoundly, as it affects the range, carrying capacity, charging time, and maintenance costs. Compared to batteries for electric cars, eVTOL batteries require a higher level of performance, such as having higher specific energy and power, shorter charging times, and the ability to work continuously at a high discharge rate while still having a suitable life span. Traditional battery technology cannot fulfill all of these requirements at once. Due to the intricacy of battery requirements, batteries for passenger-grade aerial vehicles are more complicated to develop and manufacture. Solid-state batteries, hydrogen fuel cells, and other next-generation batteries, already being adopted on a small scale, may provide the solution to meet the desired performance level.


# Providing Power to eVTOL OEMs

## An interview with Grepow



**Peng Du**
Vice Sales Director
Grepow Battery
www.grepow.com

Based in Shenzhen China, Grepow Battery was founded in 1998. The name "Grepow" refers to green power. Grepow entered the lithium battery field and established battery brands Geshi, Gen Ace, and TATTU, which can be found in Uncrewed Aerial Vehicles (UAV), as well as model aircraft and cars. The company currently has five factories, over 200 engineers and technicians, and more than 2500 overseas sales outlets. Besides lithium batteries, Grepow researches and develops batteries and charging equipment for a variety of customers' power requirements.

### What are the differences and difficulties when developing batteries for eVTOLs versus small UAVs?

Compared with small-scale UAVs, eVTOLs have a heavier load and higher battery requirements, with battery voltages over 100 volts and currents up to 100 to 300 amperes. High voltage and current batteries require more series and parallel connections. EVTOLs demand a higher charge/discharge rate and consistency between cells. Assembling modules requires uniform heat control and dissipation, making the manufacture batteries more difficult. Batteries for eVTOLs should be highly reliable and need a balance between high C-rate, high energy density, and long cycle life.

### What is the collaboration strategy for battery development and airworthiness certifications with eVTOL OEMs?

In terms of research and development, we will work together with OEMs to further research the requirements for customized batteries and develop battery standards in line with the development of passenger aircraft. We will also develop and verify our battery technology, thereby improving the reliability and safety of the batteries. Different eVTOL OEMS are designing many types of eVTOLs for different mission profiles, so they have varying battery performance requirements, such as voltage and thermal control during flight , where the voltage demand may vary from 100V to 800V. Some battery packs use a single large module, while others use multiple smaller modules, such as 12 to 24 batteries that have lower voltages. The currents under different flight phases and altitudes are different. We will customize the discharge rate of the cells according to the actual situation and design the power battery to fit the customer's needs according to the battery charging efficiency, charging speed and life cycle.

Since no eVTOL OEMs in China have received their airworthiness certifications yet, each OEM is developing its aircraft in its own way. Electric vehicles have a unified industry standard right now, whereas eVTOLs do not. Batteries can be certified independently for airworthiness.

> *We are working with eVTOL OEMs in China and exploring the possibility that after the OEM obtains its airworthiness certification from the CAAC, the battery on the vehicle would meet the airworthiness standard simultaneously. We will then apply for the airworthiness certification for the batteries based on this technical standard, which is recognized as the industry benchmark."*

However, because each model performs differently, the requirements for cell type, formula, and discharge performance will vary; hence, there is no unified or general standard for airworthiness certification. We are also waiting to see if there will be minimum battery standards for eVTOLs as there are with Electric Vehicles. The government and the industry are already in communication about this. The industry standards are mainly referencing those in Europe and the United States. China would let companies explore the industry first, then set applicable rules after it reaches scale. Differing from China, the United States and countries in Europe set the standards before developing the industry.

## Under different charge/discharge rates, what specific power, specific energy, and life cycle can Grepow batteries reach? How do they compare to other battery manufacturers?

In the eVTOL industry, the 5C charge/discharge rate is a trend and it is one of our strengths. Currently we have achieved power density up to 1600W/kg, energy density up to 280Wh/kg, and life cycle over 1000 times under 1C fast charging; a power density up to 1400W/kg, energy density up to 245Wh/kg, and life cycle over 1000 times under 5C fast charging.

In the electric vehicle industry, the specific energy of a single cell of semi-solid-state battery (NCM811) can reach 300 to 350wh/kg. This type of cell has a high energy density but cannot achieve a high discharging rate due to its material properties. Grepow focuses on developing a high-rate power battery, which can have a 5C fast charging and 10C high discharge rate with 240Wh/kg high energy density.

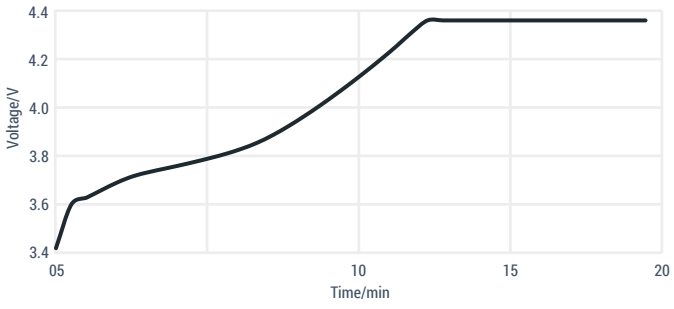
## What are the technical difficulties for improving the charge/discharge multiplier of batteries? How can we improve this? What is the expected battery performance by 2025?

Energy density and charge/discharge multiplier are generally constrained by each other. If we were to enhance the charge/discharge rate, the energy density will decrease. It is necessary to develop materials with a higher specific capacity, highly compacted, and better performance under high rates, such as high voltage high nickel ternary cathode materials, silicon carbon cathode materials, and so on, to improve charge/discharge rate under a sufficient energy density. As for the performance improvement of power batteries in 2025, we believe that the high-rate battery will increase in energy density, ideally reaching 280 to 300wh/kg. It depends on the development of the raw materials.

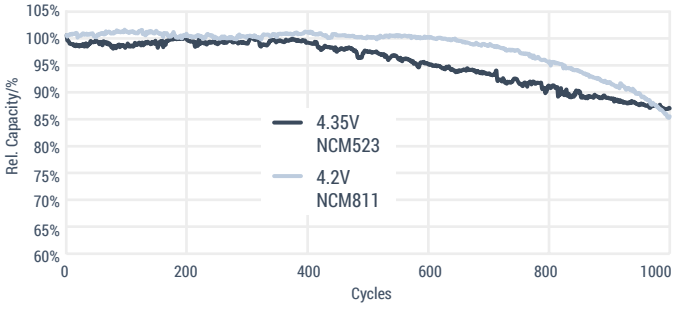
## Maintaining battery life at high charge/discharge rates is one of the problems that eVTOL power batteries face. What technologies and methods could extend battery life?

Batteries that are under high temperature and high voltage, and during the charging and discharging process, the unbalanced

**5C Charging Curve**




**Cycle Capacity Retention Curve**



temperature distribution of the battery cells will reduce the life of the battery. In terms of battery packaging, cell-to-cell consistency (capacity difference, voltage difference, and internal resistance difference) is also one of the critical factors that causes a decrease in battery life. There are different ways to improve battery life. We can optimize the design of the single cell, such as improving the multiplier performance and optimizing the cell size to reduce the temperature rise of the battery during charging and discharging. We can also optimize the module structure design to improve the heat dissipation and soaking, reducing the battery from heating and ensuring the consistency of the temperature distribution.


*Lithium-ion Polymer (LiPo) Battery*

The battery packaging technology is closely related to the aircraft's design structure by the OEMs. We will develop a corresponding battery module structure to fit the OEM's structural design and adopt technologies and concepts of CTP and CTC battery packaging. In the past two years, we continued to improve the capacity of single cells, introduced laser welding technology, and adopted lightweight assembly materials to improve the energy density of the whole battery pack.

## What are your thoughts on the development of solid-state batteries and their application to eVTOLs?

The development direction of power batteries is mainly to improve energy density, reliability, and safety, and solid-state batteries have advantages in terms of safety. If possible, the main development direction is to develop and achieve the mass production of more stabilized batteries with a breakthrough in high-rate charging and discharging technology. But the problem is that solid-state batteries are difficult to mass produce in the short term. This situation is similar to graphene batteries where production on a large scale is difficult. Optimistically, we can expect solid-state batteries to reach mass production in the next three to five years.

> *"Controlling the current output of eVTOLs is a challenge, requiring the battery to discharge smoothly, but the existing solid-state batteries cannot achieve this. We think there is still a transition period for the application, probably applying it to electric vehicles first and then to eVTOLs. However, we don't see this happening at least until 2025."*

Grepow is still focusing on developing a semi-solid-state battery for now, which can achieve an energy density of 275 to 300wh/kg and expects to bring it into mass production in 2023. The all-solid-state battery cannot meet the requirements of a high charge/discharge rate at this stage due to its low electrolyte conductivity, so it is hard to apply it to the aerial vehicle market in the short term. We will continue to follow up on the development of solid-state batteries.

## Are there any other development directions for battery technology besides solid-state batteries in the future? What is Grepow's development plan for power batteries?

Besides solid-state batteries, hydrogen and sodium batteries also show good development momentum. The industry has been seeking a high energy density to enhance the range of EVs. However, the social concern about battery safety has risen in recent years as there is more media coverage in this regard, so the development of batteries will also focus more on this area. Hydrogen energy is a good development direction. Japan and South Korea are vigorously developing hydrogen energy. Due to safety issues, building hydrogen energy plants in China is difficult. Hydrogen storage is dangerous, and the government has not relaxed the corresponding safety standards. The sodium battery is stable, but the energy density is low, so the probability of using it in power batteries is not very high in its current state.

Grepow's products are mainly high-rate batteries. We will continue to develop high rate and high energy density power batteries with an energy density between 300 to 350Wh/kg while meeting a 5C to 10C fast charging and long cycle life of more than 1000 times.

ASIAN SKY GROUP

# 5 REASONS TO CHOOSE ASIAN SKY GROUP

## AN INTERNATIONAL AIRCRAFT DEALERS ASSOCIATION (IADA) MEMBER

### 01 CHOOSE AN ACCREDITED AIRCRAFT DEALER

Asian Sky Group is an International Aircraft Dealers Association (IADA) Accredited Dealer, regulated by independent accreditation, ensuring strict compliance with IADA's 14-point Code of Ethics. With headquarters in Hong Kong and offices around Asia, we are uniquely qualified to advise & manage aircraft transactions in Asia.

### 02 CHOOSE A TEAM OF CERTIFIED IRCRAFT BROKERS

Asian Sky Group's team of IADA Certified Brokers each passed a written test administered by an independent consulting firm. IADA Certified Brokers are required to participate in regular continuing education and be re-certified every 5 years.

### 03 CHOOSE A PARTNER WITH A PROVEN HISTORY OF SUCCESS

IADA aircraft dealers are responsible for 40% of the world's pre-owned sales. IADA Accredited Dealers buy and sell more aircraft by dollar volume than the rest of the world's dealers combined, averaging over 700 transactions and $6 Billion in volume per year. Asian Sky Group is the only IADA member in Asia.

### 04 CHOOSE A PARTNER THAT CAN ACCESS THE MOST EXCLUSIVE AND TRUSTED GLOBAL MARKETPLACE

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### 05 CHOOSE A PARTNER THAT CAN ACCESS BEST-IN-CLASS PRODUCTS AND SERVICE PROVIDERS

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- DISCRETION
- EXPERIENCE
- TRANSPARENCY
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- GLOBAL NETWORK

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