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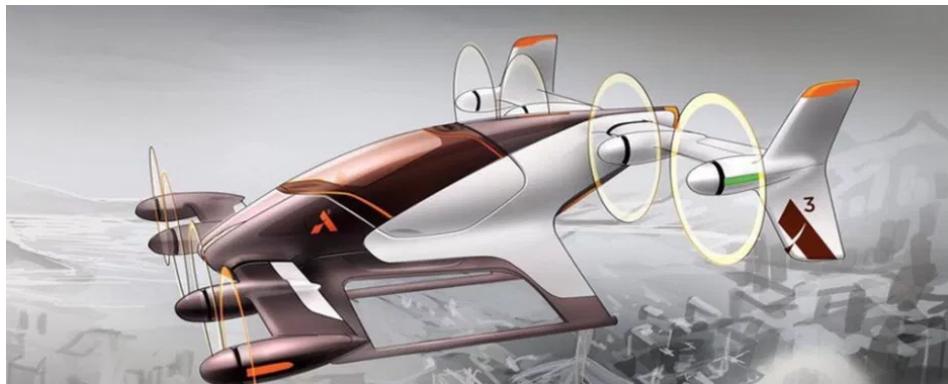
The Electric VTOL News

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Air Mobility Bonanza Beckons Electric VTOL Developers

By Richard Whittle

Vertiflite, Mar-Apr 2017

In this continuation from last issue's article, "The Demand for On-Demand Mobility," Vertiflite reports on companies pursuing visions aligned with Uber's Elevate White Paper.

More information and other articles in this series can be found at www.vtol.org/electric-VTOL.

An aviation gold rush is on. The belief that advances in electric propulsion and autonomy technologies are making cheap, quiet and even fully automated air taxis as feasible as automatic elevators is fueling a frenzy of design and development of small electric vertical takeoff and landing aircraft. Some e-VTOLs are already flying. Others will be soon. Many more are on the drawing boards.

Encouraged by NASA's work on distributed electric propulsion concepts, the rush began when rich tech entrepreneurs got excited by the drone revolution and ventured into aviation. But now major aerospace corporations are also working to develop e-VTOLs, a technology that could take the drone revolution to a new level — if the developers hit pay dirt.

Disrupting the Industry

"We've flown two subscale vehicles," said Zach Lovering, project executive for Airbus subsidiary A³'s "Vahana," a fully autonomous, single-seat, eight-propeller tilt-wing that isn't much larger than a Chevy Suburban sport utility vehicle (SUV). "We're building our third subscale demonstrator, which should be flying in the next couple of weeks," Lovering said in mid-January. "We should start seeing full-scale components being delivered within a month."

A³ (pronounced "A-cubed"), Airbus's fledgling Silicon Valley innovation outpost, is moving fast. The San Jose, California, company expects to finish assembling a full-size Vahana prototype in nearby Santa Clara by this summer, start flight testing in August and fly a demonstration in October, Lovering said.

"We define a demonstration flight as a vertical takeoff, a transition to cruise while avoiding obstacles along the cruise path, converting back to vertical flight, then identifying a landing zone using our sense and avoid system, and landing," Lovering said. "Then the beta phase will be a two-year phase following that, in which we do a demonstration at convincing scale. What that exact demonstration will be is still to be determined, but we imagine having many vehicles doing air taxi-like operations in some controlled area."

The sleek Vahana aircraft, Lovering said, designed with help from renowned outside engineers Bob Parks and Hal Youngren, uses a canard configuration with a forward tilting wing positioned lower than its rear tilting wing. Each wing carries four unducted, variable-pitch, three-bladed propellers (or fans, as A³ calls them) turned by eight 45 kW (60 hp) electric motors. The motors are powered by lithium battery packs. "Every motor propulsion unit — which we define as a motor, variable-pitch mechanism and fan — has the ability to change its RPM and the propeller angle, or the blade angle, independently of every other one," Lovering said.

Lovering said the Vahana prototype will be about 1,600 lb (725 kg) gross takeoff weight and cruise at about 95 kt (175 km/h), flying at up to 1,000 ft (300 m) above ground level for as long as 30 minutes. On the ground, Vahana will sit on skids whose rear fairings act as a tail, improving the aircraft's aerodynamics, he said.

A³ is moving so quickly partly because Airbus CEO Tom Enders saw his company facing new competition from nontraditional competitors. "Today," Lovering said, "competitors like tech mogul Elon Musk's SpaceX can emerge as strong competitors to segments of Airbus, such as its space division," a core business for the European aerospace giant. Enders, along with Paul Eremenko, former A³ chief executive and now Airbus chief technology officer, decided just over a year ago that Airbus needed to disrupt itself and the rest of the industry before the newcomers did.

Under The Radar

Plenty of companies are already hard at work on e-VTOLs. Some, like prospectors jealously guarding a claim, refuse to talk about the aircraft they're developing. Silicon Valley companies Zee Aero — where A³'s Lovering worked for four years — and Kitty Hawk, for example (two companies co-founded and co-funded by Google co-founder Larry Page) have kept their work under wraps. Unauthorized photos posted on the Internet have shown a full scale multicopter airplane said to be Zee Aero's, while other reports have said Kitty Hawk was developing a quadcopter. Officials of both companies declined requests for interviews.

So did JoeBen Bevirt, an entrepreneur made wealthy by life sciences and unique camera equipment inventions, who previously has talked about his company, Joby Aviation ["Lift Where You Need It," *Vertiflite*, Nov-Dec 2016], and its S4 aircraft, a distributed electric propulsion e-VTOL with six tilting propellers. The S4 is expected to make its first flight this year. Bevirt declined to provide an update for this article, saying in an email, "We are heads down and not taking media requests at the moment."



A³ has developed increasingly representative test models for its Vahana concept. Omega 1 was 17% scale. (A³)



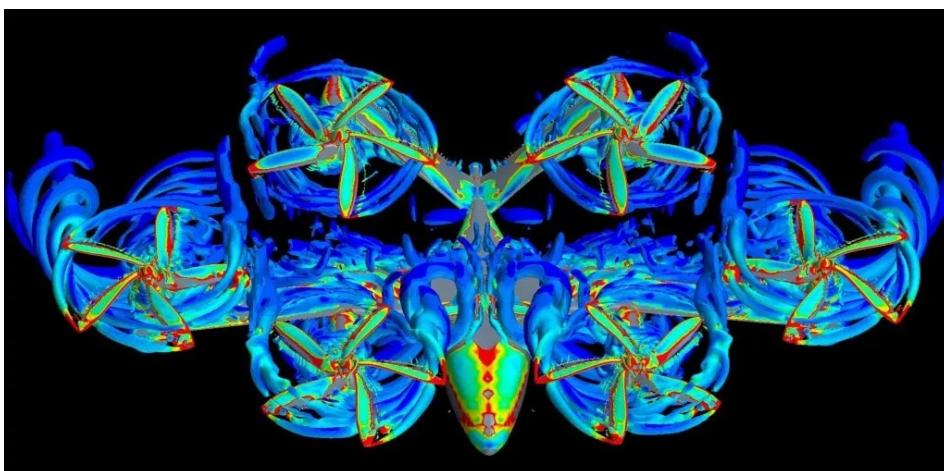
A³ has developed increasingly representative test models for its Vahana concept. Omega 2 was 23% scale. (A³)



A³ has developed increasingly representative test models for its Vahana concept. Omega 3 was 23% scale and first flew in February. (A³)



Zee Aero has been spotted flying its full-scale e-VTOL aircraft at Hollister Municipal Airport in California. (Steve Eggleston photo, used with permission)



After Joby Aviation released this CFD image of its four-seat, hex-tiltrotor S4 in 2015, the company decided to keep a low profile on its activities. Full-scale flight testing is expected this year. (Joby

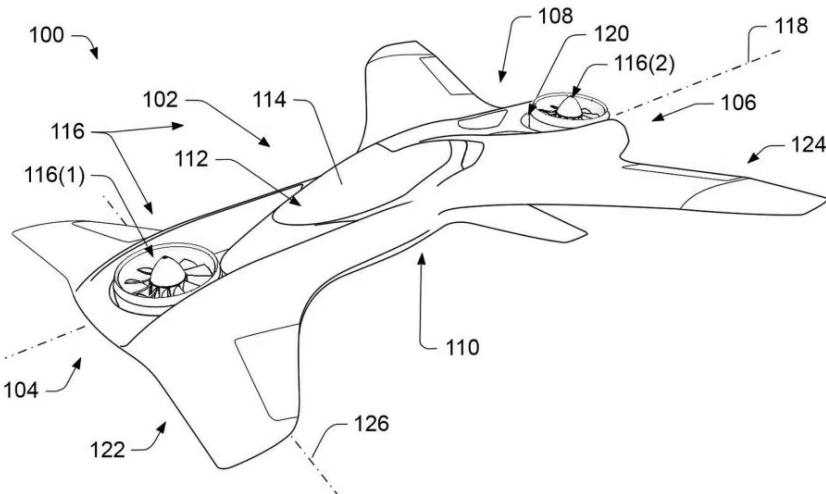


XTI is now developing a four-seat hybrid-electric model, smaller than its six-seat TriFan 600 (shown). (XTI Aircraft)

In addition to distributed electric propulsion approaches, several other companies are looking at VTOL air transport using other forms of electric and hybrid-electric propulsion.

XTI Aircraft unveiled its TriFan 600 in August 2015 with a well-publicized equity crowdfunding (see “Industry Briefs,” Vertiflite, Nov/Dec 2015). The six-seat, fixed-wing airplane uses three ducted fans to power the aircraft from vertical takeoff and landing to 340 kt (630 km/h) and a range of 1,000 nm (2,222 km). The company is currently building a two-thirds-scale technology demonstrator powered by an HTS900 turboshaft engine. Now, the new XTI chief executive Bob LaBelle, formerly the CEO of AgustaWestland North America, responded that the company “will soon reveal a four seat-model that will incorporate a hybrid-electric drive system,” but would not comment further.

Paul DeLorean, the CEO and chief designer at DeLorean Aerospace (and nephew of US automotive legend, John DeLorean) also demurred. A patent he filed in 2012, however, shows a Star Wars-inspired personal aircraft with ducted fans fore and aft along the aircraft centerline.



DeLorean Aerospace is not releasing any information about its two-seat e-VTOL personal air vehicle, but this image was included in US Patent 9,085,355 filed on Dec. 7, 2012 and granted on July 21, 2015. (US Patent Office)

Carl Dietrich, a Massachusetts Institute of Technology aeronautics Ph.D. and the chief executive of Terrafugia, Inc., similarly declined to comment on its hybrid-electric VTOL aircraft, the TF-X. However, the company still has significant information on its website. Terrafugia (whose name is Latin for “escape the earth”) is based in Woburn, Massachusetts, just north of Boston.

Terrafugia achieved widespread publicity after its first prototype flew in 2009 — the company calls the fixed-wing Terrafugia Transition “the world’s first practical flying car” — and the first customer deliveries are planned for 2019. [Note: Although no other company is actually designing a roadable aircraft — aka a “flying car” — the media unfortunately refers to all VTOL personal air vehicles and urban air taxis by the misnomer, “flying car.”]

In May 2013, Terrafugia unveiled its vision for a four-seat VTOL plug-in hybrid-electric flying car. The company revised the outer mold line (OML) in July 2015, steering the design away from the “open-grill” appearance of the Transition; a one-tenth scale wind tunnel test model of the TF-X, based on the new OML, was displayed that month at AirVenture in Oshkosh, Wisconsin.

In late 2015, Terrafugia received a Section 333 exemption from the US Federal Aviation Administration (FAA) to begin to flight test a one-tenth scale TF-X vehicle (approximately 2 ft, or 60 cm, long). An exemption from the FAA was necessary at that time in order to conduct commercial research and development flying a small unmanned aircraft system (sUAS). In February 2016, Terrafugia announced that it had completed static load testing of one-tenth scale carbon fiber wings.



Terrafugia has built a 1/10-scale wind tunnel model and a 1/10-scale unmanned demonstrator of its hybrid-electric tilt propeller “flying car.” For high-speed forward flight, the TF-X would fold back the blades and use a large ducted fan at the rear for thrust. (Terrafugia)



Carter Aviation Technologies has been studying electric-powered aircraft that would fulfill the Uber

Elevate missions using its Slowed Rotor/Compound technology. This version is capable of powered hover and swivels the tailrotor to provide anti-torque. The battery is in the nose. (Carter)



E-volo flew the world's first manned e-VTOL aircraft on March 30, 2016. Company cofounder and managing director Alexander Zosel was the passenger. (e-volo)



In June, e-volo conducted various dynamic flight maneuvers with the Volocopter at higher altitudes and speeds for the first time. (e-volo)

The model was to be tested at the MIT Wright Brothers wind tunnel — the same tunnel that was used to test models of Terrafugia's Transition — to measure forces in simulated hovering flight, transitioning to forward flight and full forward flight. However, the company has not released any information on its TF-X project since that time.

When queried, Dr. Dietrich responded: “Although there has been some significant work on the program, our primary focus continues to be Transition, and we are not prepared to release new information about TF-X at this time. Our board has taken this tact partially in response to other companies in this sector that have chosen to operate under the radar.”

In addition, other companies are now looking at potential applications of their technologies to the Uber Elevate White Paper. Carter Aviation Technologies completed a conceptual study of their slowed rotor/compound concept to the air taxi mission, comparing battery-powered multicopter tilt-propeller configurations versus hovering or jump takeoff CarterCopter configurations, against a conventional gas turbine baseline.

Flying High

In Karlsruhe, Germany, meanwhile, e-volo GmbH's cofounder and managing director, Alexander Zosel, is more than happy to discuss his company's two-passenger Volocopter VC200 "White Lady," a manned but largely automated e-VTOL multicopter resembling a giant hobbyist drone, which Zosel himself flew last March. Zosel's company, a startup supported by Ascending Technologies (now owned by semiconductor giant Intel) has won government permission to fly tests in German airspace of the VC200, which — like other e-VTOLs — is largely made of lightweight composite materials.

The VC200's configuration is starkly different from other e-VTOLs unveiled to date — a multicopter with 18 non-tilting, two-bladed rotors arrayed in three-rotor triangles held by six booms, or "arms," connected by a circular frame. Each arm holds three electric motors — one for each propeller — and the helicopter-style fuselage carries nine batteries, each powering two motors. Climb and descent, airspeed and turns are controlled by adjusting rotor speeds individually. The VC200's highly automated controls are one revolutionary aspect of the aircraft, which has a joystick for the pilot but no rudder pedals, collective or throttle. The pilot uses the joystick to instruct the computerized flight controls where to go and pushes buttons on the joystick and dashboard to select desired speed, but all other guidance is automatic.



The prototype of the two-seat “Lilium Jet” is expected to fly in the first quarter of this year. (Lilium)



Powered by 36 electric ducted fans, the Lilium Jet vectors thrust down or back; the canard rotates, while the fan thrust on the wing is directed downward or backward. (Lilium)

“Stalling, pitch adjustment, gliding angle, the components that are difficult to master aeronautically are mastered through the operation of a simple joystick,” e-volo’s web site assures. “Well in excess of 130 microprocessors and a large number of different sensors ensure it can take off, land and be flown in a relaxed manner and without any worries. It is amazing! Flying becomes so easy as the aircraft automatically compensates for turbulence.”

Zosel said the Volocopter can reach a forward speed of 55 kt (100 km/h). It was held to a mere 300 kg (660 lb) gross takeoff weight to ease the path to certification by German authorities as a sport aircraft, which e-volo sees as a stepping stone to developing derivatives suitable as urban air taxis or for other missions.

“We are developing technology for future transportation,” Zosel said, but e-volo will “enter first a market that is only for sports aviation. There are no commercial applications allowed for that. But we have the possibility to test and prove the aircraft with people [on board] and it will be really good proof [to] the authorities for its safety.”

Ready for Takeoff

Another German startup working to make on-demand mobility a reality is Lilium GmbH, founded by four young Technical University of Munich graduates who promise to fly a two-seat prototype of their “Lilium Jet” in the first quarter of this year. Lilium hasn’t released all the aircraft’s specifications, but Daniel Wiegand, Lilium chief executive, said the vehicle’s gross takeoff weight will be about 1,325 lb (600 kg), including a payload as much as 440 lb (200 kg). The company has flown three subscale demonstrators of slightly different configurations and posted videos to its web site. (See “German Ultralight VTOL Innovations,” Vertiflite, Sept-Oct 2016.)

The two-passenger Lilium Jet relies on 36 small ducted fans: 24 in a rear wing and 12 in a stubby forward canard. Powered by individual electric motors, the fans can vector down or back; the canard rotates, while the fan thrust on the wing is directed downward for vertical or backward for horizontal flight by four independent tilting flaps. Although similar in concept to Aurora’s XV-24A LightningStrike (see sidebar, “Hybrid-Electric LightningStrike”), Wiegand notes that, “The difference here is that we don’t tilt the whole wing, we just have the four independent flaps tilting. That gives us many structural benefits and also benefits on the side of redundancy and safety.”

The Lilium Jet’s transition from vertical to horizontal flight is highly automated. “Everything is fully fly-by-wire controlled,” Wiegand said. “As a pilot, you just push the stick to the front and then the computer controls the thrust of the engines and the angle of the engines, both in the front and in the back, independently. There is an optimum setting for every speed or acceleration that you are demanding as the pilot, there is an optimal angle for the engine and optimal thrust point, and this is basically controlled by the computer.”

Lilium hasn’t yet decided on how large a battery pack to use but “with existing batteries we achieve around 300 km range [160 nm],” he said. The prototype, designated the “Eagle,” has fiberglass springs for landing gear, Wiegand said, but the “final product” will have retractable landing gear.



Aurora Flight Sciences’ XV-24A LightningStrike hybrid-electric demonstrator should fly next year.
(Aurora)



Drone-maker EHang unveiled its single-passenger 184 “manned drone” at CES in January 2016.
(ETC-USC photo, used by CC BY 2.0)

Safety will be vital to making on-demand air mobility feasible, Wiegand said, and for that reason, all flight-critical systems on the Lilium Jet will be redundant. The aircraft will also be equipped with a parachute to ease it to the ground if necessary, he said. The Eagle will need a pilot, but like others, Lilium envisions a time when its aircraft will be fully automated.

“The first stage we will do as a piloted aircraft,” Wiegand said. “This is the first step, the first product that we’ll bring to the market. Then the next step will be gradual steps toward autonomy or automation. The first thing you will see is lots of efficiency systems, but you still have a pilot on board. The second step will be automation. Maybe the last step will be autonomy. But we will start as a piloted aircraft.”

A Manned VTOL Unmanned Aircraft System

Chinese unmanned aircraft technology and service company EHang, headquartered in Guangzhou, is skipping to Lilium’s last step first with its EHang 184 Autonomous Aerial Vehicle, a one-passenger, pilotless quadcopter. The 184 has eight unducted 5.25 ft (1.6 m) diameter propellers stacked in upper and lower coaxial pairs that turn in opposite directions at the tips of four arms. EHang, which has offices not only in China but also in Silicon Valley and Düsseldorf, Germany, said in responses to questions from *Vertiflite* that the designator “184” stands for “1 passenger, 8 propellers, 4 arms.”

When EHang unveiled the 184 at the Consumer Electronics Show in January 2016, the company called it “the world’s first passenger drone.” The design is reminiscent of the company’s popular Ghost quadcopter, which also has propellers mounted below the motors at the arm tips, a somewhat unique configuration.

Richard Liu, an EHang vice president, said the 184’s fuselage is about 13 ft (4m) long and a little less than 5 ft (1.4 m) tall — smaller than a Lincoln Town Car — with an empty weight of about 530 lb (240 kg) and a maximum gross takeoff weight just under 800 lb (360 kg). “We have been conducting internal flight tests,” Liu said by email, adding that while the 184’s lithium polymer batteries currently give the drone 30 minutes of endurance, “We hope to enable a two-hour or more flight duration for EHang 184 AAV in five years.”

EHang signed an agreement with Nevada last year allowing it to use that state’s FAA UAS test site for flight testing and development of the 184. The company plans to put the design into production and start selling 184s this year or next, Liu said.

The Gold Rush Bonanza

The rush to develop e-VTOLs got a boost recently from Uber Technologies, the car ride on-demand app company, which announced that it wants to add on-demand air mobility to its service by buying air vehicles capable of the mission (as described in the previous issue in "The Demand for On-Demand Mobility").

Uber is actively consulting with e-VTOL developers and plans to convene a major summit this spring. But as rapidly as such aircraft seem to be coming along, how quickly — or whether — the FAA and other authorities are likely to allow them to be used for air taxi service in urban areas or other commercial purposes is unclear. Airbus A3's Lovering is optimistic.

"There has been a lot of work at NASA and the FAA to push the certification forward for these types of systems," Lovering said. "I could see in the next few years, maybe by 2020, that these regulations will have changed sufficiently, or the certification methods will exist, for these vehicles to be enabled."

Whether there's truly "gold in them thar electric VTOL hills," of course, is impossible to know. But in gold rushes, optimism is a prerequisite for success.



EHang is currently flight testing a prototype of its e-VTOL concept, which can fold up for storage.
(EHang)

About the Author

Richard Whittle, a regular contributor to Vertiflite, is the author of *The Dream Machine: The Untold History of the Notorious V-22 Osprey* (Simon & Schuster, 2010) and *Predator: The Secret Origins of the Drone Revolution* (Henry Holt & Company, 2014).

Mike Hirschberg, AHS Executive Director, also made contributions to this article.



A³ plans to fly its first Vahana prototype in August and fly a full demonstration in October. (A³)

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