



The two-seat Lilium Eagle made its first flight in April. Each canard features two rows of three electric ducted fans, while each wing houses four sets of three fans. (Lilium graphic)

Charging Forward New eVTOL Concepts Advance

“Look! Up in the sky! It’s a car — It’s a plane — No, it’s my UberAIR!”

By **Kenneth I. Swartz**

To those immersed in the world of traditional helicopters, it may take a little time to fully comprehend what Uber Elevate’s on-demand urban air transportation vision actually entails.

Ever since Uber’s ride hailing service (worth \$68B at its last funding round) launched its smartphone app in 2011, the San Francisco-based transportation and technology company has expanded to 450 cities in 73 countries, and now serves 60 million monthly users.

Today, Uber’s portfolio includes several transportation services, but all of its vehicles use the same congested urban roads, tunnels and bridges.

Uber added a third dimension to its business model in late September 2016 at the AHS International-led Transformative Vertical Flight (TVF) workshop when the company’s product

manager of special projects, Nikhil Goel, described Uber’s plans for moving urban transportation to the skies with electric vertical takeoff and landing (eVTOL) aircraft.

The Uber Elevate white paper released the following month, “Fast-Forwarding to a Future of On-Demand Urban Air Transportation,” elaborated plans for an urban air transportation service using thousands of eVTOL aircraft — eventually autonomously piloted — with very low direct operating costs, low noise and zero “tailpipe” emissions. The white paper gave commercial expression to research by NASA scientists and other researchers who hypothesized nearly a decade ago that a new era of transformational vertical flight could dawn with the advent of distributed electric propulsion.

The idea of distributed electric propulsion is to replace the single complex rotor system — cyclic, collective, swashplate, transmissions, gearboxes, shafting, hydraulics, etc. — with multiple simple thrusters, and (ideally) an efficient wing for higher speed/long range cruise. Advocates also believe distributed electric thrusters (propellers, fans, etc.) have huge benefits in terms of safety, emissions, noise and community acceptance.

The Uber Elevate Summit in Dallas, April 25–27, 2017, became a watershed industry event that brought together 500 stakeholders and significantly raised the global profile of the emerging eVTOL industry.

In this article about electric VTOL, we look at the promise and progress of the eVTOL ecosystem discussed at the Uber Elevate Summit. For more information on these companies, aircraft, related news and all of our previous eVTOL stories, go to our new website www.eVTOL.news



Aurora's eVTOL aircraft use eight lifting propellers for vertical takeoff, and a cruise propeller and wing to transition to high-speed forward cruise. (Aurora graphic)

On Demand Urban Air Transport

Uber's business success is based on transporting people from "A" to "B" in a more efficient and user-friendly manner. Along the way, the company has amassed a huge database of urban origin and destination (O&D) data that would be the envy of any transportation engineer or urban planner.

Uber Elevate envisions that "a network of small, electric aircraft that take off and land vertically... will enable rapid, reliable transportation between suburbs and cities and, ultimately, within cities."

In addition to high capacity charging systems, the essential infrastructure includes repurposing the tops of parking lots, existing helipads and even the vacant land in the middle of highway cloverleaves as "the basis of an extensive, distributed network of 'vertiports' (VTOL hubs with multiple takeoff and landing pads, as well as charging infrastructure) or single-aircraft 'vertistops' (a single VTOL pad with minimal infrastructure)."

The Uber business model requires eVTOL aircraft with extremely low seat mile costs to lure potentially millions of commuters from gridlocked highways into the sky in order to reduce travel time and increase productivity.

The eVTOL revolution has actually been underway for some time, as evidenced by the millions of electric drones sold and the exponential growth in the number of drone pilots (in contrast to decades of declining numbers of general aviation pilots), as well as NASA and DARPA electric/hybrid-electric demonstrations — Greased Lightning and VTOL X-Plane, respectively.

Mark Moore, Uber's engineering director of aviation (and previously at NASA, where he worked on Greased Lightning, among other electric aviation projects), believes that the integration of autonomy and robotics into new eVTOL designs will improve piloting and safety, reduce acquisition and operating costs, and ultimately re-invigorate the general aviation industry by inspiring a new generation of aviators — and passengers — to fly.

He expects companies will spend the next two to three years developing prototype two- and four-seat eVTOL designs with experimental certifications proceeding under 14 CFR Part 21.195 (first

used for the AW609 tiltrotor) as the Federal Aviation Administration (FAA) works out electric propulsion certification rules.

Flight testing will be well underway by 2020, followed by certification, low-volume production and entry into service in the 2023–2025 timeframe.

Moore estimates the initial cost to develop a flight demonstration aircraft will be \$10M–\$20M per concept, and the probable cost of aircraft certification and initial production tooling will be \$150M–\$300M per program.

Uber's first demonstration projects, potentially with test customers requesting rides via its UberAIR app, will begin in 2020 in Dallas-Fort Worth, Texas, in the US and Dubai in the United Arab Emirates.

New Air Vehicles

The Uber Elevate Summit was a very public launch pad for an array of transformative eVTOL aircraft.

Five aircraft companies have signed on as Uber Elevate partners — Bell, Aurora Flight Sciences, Embraer, Pipistrel Aircraft and Mooney — while many other companies have also begun developing eVTOL aircraft for similar or related applications.

According to Uber's white paper, the Elevate eVTOL economic model is based around:

- 4-place capacity (including pilot, if there is one)
- Average load factor of 67%
- Gross vehicle weight of 4,000 lb (1,800 kg)
- 400 Wh/kg specific energy batteries at the pack level with a life of 2,000 cycles
- 500 kW of power for short-term takeoff power with 1 minute of full power at takeoff and landing, with 71 kW power required at 150 mph (130 kt or 240 km/h) cruise and 120 kW required at 200 mph (175 kt or 320 km/h)
- Annual utilization of 2,080 hours (40 hours per week)
- Electricity cost of \$0.12 per kWh

"Advocates believe distributed electric propulsion has huge benefits in terms of safety, emissions, noise and community acceptance."

Uber doesn't expect full capability "right out of the box" with its per-mile fare structure. It assumes there will need to be eVTOL pilots in the beginning who will eventually be replaced with autonomous avionics, that the vehicle cost will go down as production rates increase to thousands or tens of thousands of units per year, and that battery costs will continue to drop as technology improves. None of the eVTOL concepts revealed to date resembles a production helicopter, which highlights just how disruptive the future of vertical flight might be.

For those aircraft without autorotation capability, a ballistic parachute recovery system (as standard on a Cirrus SR22 light aircraft) could be standard safety equipment.

Aurora Flight Sciences

Aurora Flight Sciences' two-seat eVTOL air vehicle concept was unveiled at the Summit and features four electric propellers distributed along each of two booms, plus a single propulsion motor to power the aircraft at 124 mph (107 kt or 200 km/h) on three lifting surfaces (a canard, wing and tail).

The first flight test vehicle, a quarter-scale prototype, has already demonstrated transitions between vertical takeoff and landings, and forward flight. The full scale aircraft will be about 26 ft (8 m) in length and width.

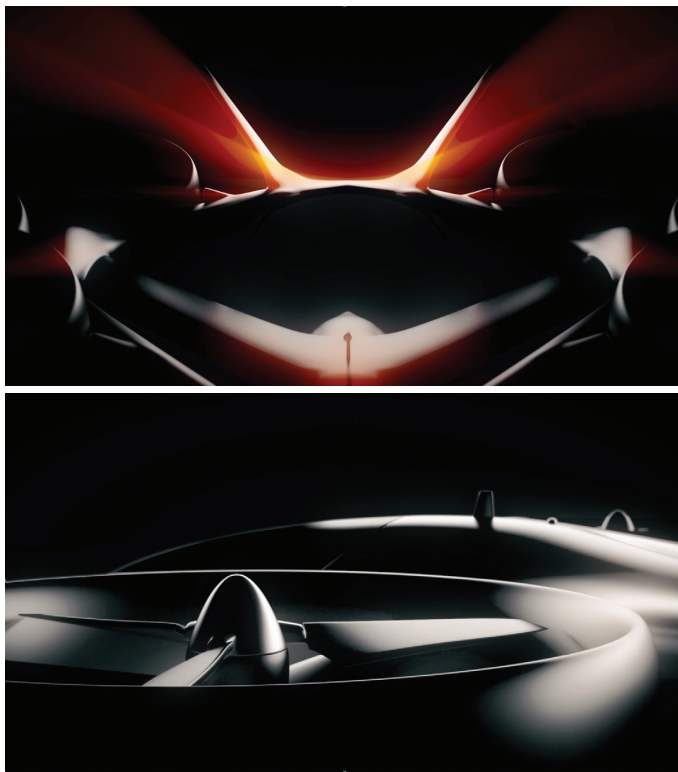
John Langford, Aurora's CEO, said the new design draws on three key technologies — autonomy, electric propulsion and composite structures — with the most complex task being the “man rating” of the design.

Aurora has developed more than 30 unmanned aircraft and is currently developing DARPA's XV-24A LightningStrike, the largest hybrid-electric VTOL aircraft to date.

Langford believes Aurora's eVTOL demonstrator vehicle can be scaled up to a man-rated air vehicle by 2020, stating, “It can be done...and will be done.”

“We are excited by the idea of having thousands of these aircraft operating over our cities,” added Diana Siegel, Aurora's eVTOL aircraft program manager.

Aurora's approach has been to “keep it simple ... design for efficient cruise...and base the design on existing technology” with a focus on conserving battery power on the longer cruise segment of the flight, said Siegel.



Bell Helicopter has only released teaser video clips of possible modular eVTOL concepts. These images show a configuration with six tilting ducted propellers. (Bell video captures)



Mark Moore (Uber) presents the AHS V/STOL Wheel at the Elevate Summit as part of the panel with speakers from A³, Aurora, Bell, Carter, Embraer, Lilium and Pipistrel. (AHS photo)

Two fundamental design decisions were the use of a wing “which is three times more efficient than a multi-copter in cruise” and separate direct-drive, fixed-pitch propellers for hover and cruise. Aurora considered using tilting rotors and tilting wings before opting for the simpler design.

The front-loading Uber aircraft will operate from dedicated vertiports and will be designed for fully autonomous taxi and takeoff, but will initially fly with a safety pilot. Aurora expects that the noise at takeoff will blend in with background road traffic noise at a height of 60–100 ft (18–30 m), and the aircraft will be “inaudible” from the ground when in cruise flight.

The design is optimized for an average commuter mission of 25 miles (40 km) and a maximum range of about 30–40 miles (50–65 km).

An animated video of the aircraft had received well over 100,000 views on YouTube by mid-June.

Bell Helicopter

Bell Helicopter signed on as an Uber Elevate partner and is now developing new modular aircraft concepts that will have multiple uses, including as an urban air taxi.

Michael Thacker, Bell's executive VP for technology and innovation, asserted that “the technologies exist today” to create an entirely new air vehicle.

Scott Drennan, director of engineering innovation, said Bell's eVTOL design will be “modular, adaptable and scalable” and will feature a modular cabin that can be converted from “UberBLACK (professionally driven black car service) to UberX (everyday cars for everyday use).”

Drennan emphasized that “direct operating costs are everything” for the Uber mission, which means designing for cost and affordability, as well as manufacturing and maintainability.

“If you prepare the aircraft the right way, it will be electric, hybrid-electric or anything the future offers us,” Drennan added. The Bell vehicle will probably have active noise treatment to provide a more comfortable ride, and Drennan said the use of electric power allows designers to change the tip speeds, frequencies and phasing of multiple propellers to reduce external noise.

Bell hasn't released any images of its modular eVTOL aircraft concept(s), but teaser videos shown during the Summit (and again at Forum 73) contained multiple partial images of ducted propellers.

“The Uber Elevate Summit was a very public launch pad for an array of transformative eVTOL aircraft.”

Embraer

Embraer of Brazil has become one of the world's largest aerospace companies, thanks to the expansion of its commercial and business aircraft product lines in the 1990s and 2000s.

Since the early 1970s, Embraer has delivered 8,000 aircraft ranging in size from 4–130 seats. Collectively, they have flown 46 million flight hours, carrying 145 million passengers by operators in 70 countries.

For the past 15 years, Embraer has delivered aircraft with fly-by-wire flight controls, including E-Jet airliners (E175 and E190) and Legacy 450 and 500 business jets; the company is currently completing development of its KC-390 military transport.

Known for developing aircraft in very short cycles, the Brazilian company now has a US aircraft production line in Melbourne, Florida, and technology offices in Boston, Massachusetts, and Silicon Valley in California.

Embraer doesn't have a strong historical association with vertical flight, but Brazil does: São Paulo (population 12 million), the country's financial capital, is home to the world's largest concentration of privately owned helicopters (more than 400), which utilize more than 300 rooftop helipads to fly business executives and wealthy residents over the megacity's gridlocked roads.

Pipistrel Aircraft

Pipistrel Aircraft of Slovenia is the only aircraft manufacturer in the world currently building and delivering electric-powered fixed-wing aircraft.

In 2007, Pipistrel developed the Taurus Electro, the world's first two-seat electric production aircraft, which evolved into the Taurus Electro G2 in 2012, with an electric motor replacing a BRP Rotax piston engine.



The non-VTOL Pipistrel Panthera is available with a piston/electric-hybrid: “Fly 4 people for 1000NM cruising at 200 KTS with 10 gallons per hour.” (Pipistrel photo)

The self-launching glider has a retractable electric engine and is now marketed with the Solar Trailer, which is equipped with external solar panels that offer 1 kW of usable energy to charge the aircraft battery for free.

The Alpha Electro, a two-seat trainer, is Pipistrel's fifth electric aircraft project and the second to result in a commercial product. It has energy for one flight hour (plus reserves), and can recharge in 45 minutes or have its batteries replaced in 5 minutes.

Pipistrel also developed the Taurus G4, the world's first four-seat electric aircraft. With funding from the European Union HYPSTAIR project, the company is now developing its Panthera general aviation aircraft, which can be powered by a piston engine, hybrid-electric/piston engine, or 200 kW pure electric powertrain.

Pipistrel has won four major prizes for the development of electric aircraft, including the 2011 NASA Green Flight challenge.

The innovative company is now completing a new production aircraft (electric or conventional) every two business days and gearing up to apply its experience with lightweight composite structures, electric power, hybrid power, batteries, charging systems, human machine interface, active noise control and ballistic rescue systems to Uber's eVTOL requirements.

Like Bell, Pipistrel isn't sharing any details of its eVTOL configuration at this time.



Carter and Mooney have teamed to develop the electric SR/C Air Taxi; the tail propeller rotates for forward thrust. (Carter graphic)

Mooney and Carter

Mooney International Corporation has partnered with Carter Aviation Technologies to develop and certify the electric Carter Slowed-Rotor/Compound (SR/C) Air Taxi.

Mooney's Kerrville, Texas, plant is currently manufacturing the M20V Acclaim Ultra and M20U Ovation Ultra. Both aircraft are derivatives of the 242 kt (448 km/h) M20TN Acclaim Type S, which was the world's fastest single-engine, piston-powered aircraft at the time of its certification in 2006.

Founded 88 years ago, Mooney was hit hard by the recession in the late 2000s, but was subsequently rescued in 2013 when Soaring America Corporation and its Chinese investors purchased it.

Jay Carter, president, CEO and principal design engineer of Carter Aviation, said that the electric SR/C Air Taxi will have a 4,000 lb

(1,800 kg) maximum gross weight, 800 lb (360 kg) maximum payload and 175 mph (150 kt or 280 km/h) cruise speed. Key features include a high aspect ratio wing optimized for cruise efficiency, a 10 ft (3 m) diameter scimitar tail propeller that swivels to provide counter-torque for hover or thrust for forward flight, and a battery pack (with 300 Wh/kg energy density) placed in the nose to balance the tail weight. The aircraft will have tandem-seating for two in a 54 inch (137 cm) wide cabin, a 34 ft (10.4 m) diameter rotor and a 36 ft (11 m) long fuselage.

Carter said the SR/C Air Taxi's low disc loaded single main rotor can operate at low tip speeds while hovering to reduce takeoff and landing noise, and can be slowed in cruise for high-speed efficiency on par with a fixed-wing aircraft. The company's press release noted that "with the high inertia rotor always turning, it can operate in effect as a built in parachute, but one that can be 'deployed' at any altitude or any airspeed, and one which allows for directional control all the way down to the ground."

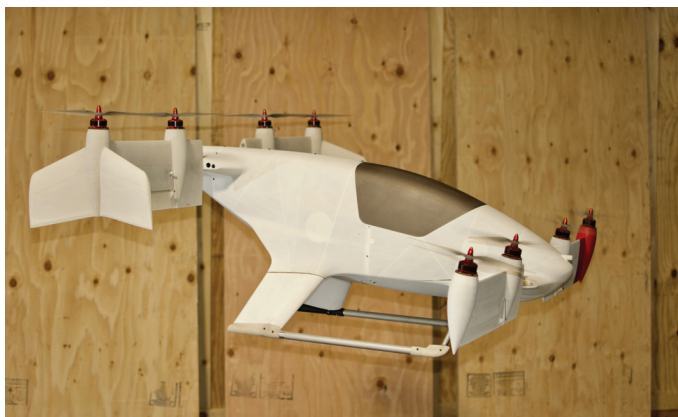
Mark Beyer, Mooney's new chief engineer, said the company's research and development team located in Chino, California, has a long history of certifying aircraft through the FAA's Aircraft Certification Office (ACO) in Dallas, Texas. Beyer joined Mooney in early 2017 after previously serving as engineering manager of flight sciences at Virgin Galactic's The Spaceship Company. He had previously supported many development and certification projects, including the Cirrus Vision Jet and several Cessna programs.

A³ by Airbus Group

Arne Stoschek, head of autonomous systems at A³ (pronounced "A-cubed") — the advanced projects and partnerships outpost of Airbus Group in Silicon Valley — said it is time for urban commuters to "go up" and escape the mind-numbing world of long and slow car commutes.

A³ believes the advent of electric propulsion, availability of low cost electronics, introduction of intelligent systems and autonomy, and tremendous progress in machine learning make now the time that air taxis will fly.

In early 2016, A³ began developing Project Vahana as a self-piloted aircraft with the preliminary design featuring four distributed electric propellers each on tandem tilting wings. Vahana is designed to carry one passenger or cargo at speeds of 143 mph (124 kt or 230 km/h) over a 62 mile (100 km) range.



A³ by Airbus has flown three subscale models of its Vahana concept. The 23% scale Omega 3 began flying in February. (A³ photo)

Stoschek said that a one- or two-seat design will be marketed as a fleet vehicle (not for individual passenger ownership) with the potential to autonomously transport millions of passengers per year.

A³ sees three key enablers of urban air mobility: safety, affordability and scalability.

"Seventy to eighty percent of aircraft accidents are related to human error," said Stoschek, and A³ sees an opportunity to transfer autonomous systems from the road to the air to improve safety, situational awareness and risk analysis. A³ anticipates a 67% reduction in operating costs with a shift from helicopters to eVTOL technology (from \$530 to \$175 per flight hour) and a further 11% reduction with self-piloting operations (\$155 per flight hour), for a total savings of 78% over a conventional helicopter.

Stoschek also noted that the current helicopter industry requirement for a pilot to have 1,500 flight hours before his or her first job "is not a scalable solution" when eVTOL demand takes off, but that the expected pilot shortfall can be addressed through self-piloting solutions.

Lilium

"We believe in a world where anyone can fly, anywhere and at any time," said Daniel Wiegand, co-founder and CEO of Lilium Aviation — a startup founded in 2015 that now employs an international team of 100 people in Munich, Germany.

Lilium autonomously flew its full-scale two-seat "Eagle" Lilium Jet prototype featuring 36 distributed electric fans near Munich in early April. The Eagle has a row of twelve fans along each wing flap (which deploy to vector the thrust downwards) and two rows of three fans on each side of the rotatable canard. (The idea was also to have the canards retract for forward flight, though it is unclear how the concept would have adequately provided pitch control.)

Wiegand told the Elevate audience that the design has a very low drag coefficient, and that the first flight demonstrated a very smooth transition from vertical to horizontal flight.

The position of the electric fans in the flaps provides high lift over the wing. Each fan is very simple in design with a single moving part (a shaft and rotor supported by two bearings) resulting in very little vibration. Safety features include a fan cowling that will contain blade loss and a whole aircraft parachute.



The new five-seat Lilium Jet design features a longer, fixed canard. For both lifting surfaces, the fans are mounted on split flaps that vector down for vertical lift. (Lilium photo)

In conjunction with the news of its first prototype flight, the company announced that the objective design is now a five-seat vertical takeoff Lilium Jet. The major configuration changes are that the fans in the canard are now all in a single row, and the canard is no longer retractable, nor rotatable; instead, the fans are vectored down with the flaps, in the same manner as on the wing.

Lilium said its operational eVTOL will have a 186 mph (160 kt or 300 km/h) cruise speed and a 186 mile (300 km) range, and have energy consumption comparable to an electric car.

The speed and capability of the eVTOL will provide “a five times larger radius of life for users, which translates into 25 times the possibilities,” said Wiegand. “It is like the step change from a bicycle to a car that we have today.”

For instance, the Lilium eVTOL will be able to transport a passenger 43 miles (70 km) in 15 minutes during rush hour in the San Francisco Bay area compared to a 7.5 mile (12 km) journey in 15 minutes by road.

Kitty Hawk

Kitty Hawk selected April 24th, the day before the Uber Elevate Summit, to unveil photos and videos of their proof-of-concept eVTOL Flyer recreational vehicle featuring a single seat, simple controls, eight downward facing rotors, a protective screen and a set of pontoons for overwater flights and landings.



Todd Reichert demonstrates the capabilities of the Kitty Hawk Flyer in a promotional ad. (Kitty Hawk video capture)

The Kitty Hawk team is led by Canadian engineers Dr. Todd Reichert and Cameron Robertson. Both men founded AeroVelo (now written “Aerovelo”), which developed the Snowbird human-powered ornithopter in 2010, the Atlas human powered helicopter that won the AHS International Sikorsky Prize in 2013, and the Eta bullet-shaped bike that Todd Reichert used to set a new human-powered speed record of 89.59 mph (144.18 km/hr) in 2016.

The Flyer is aimed at the recreational market, and the company’s lifestyle video shows the craft zooming over the water, hovering next to a boat and landing on a floating dock (Reichert pilots the craft and Robertson is also seen in the video). The well-timed media release garnered Kitty Hawk widespread publicity, as well as some public roasting for the ostentatiousness of the video.

The new eVTOL aircraft would not be out of place on a lake flying next to a Bombardier Sea-Doo personal watercraft or a Ski-Doo

snowmobile in winter, both of which are ironically powered by the same Rotax engine now widely used to power ultralight aircraft and gyroplanes.

Kitty Hawk plans to launch a production version of the experimental category rotorcraft later this year, but noted: “For our first Flyer prototype displayed in this image [see figure], we’ve built an aircraft designed to fly over water and in uncongested areas. We’re hard at work building the next version of Flyer that will be available for purchase later this year.”

Kitty Hawk is one of two eVTOL programs reportedly funded with a total of \$100M by Larry Page, co-founder of Google; Page is also the main backer of Zee Aero, which began developing a distributed electric propulsion aircraft several years ago (see “The Demand for On-Demand Mobility,” *Vertiflite*, Jan-Feb 2017).




Zee Aero has been testing its full-scale Z-P1 eVTOL aircraft in Hollister, California. (Steve Eggleston photo, used with permission)

Flights of Fancy?

To some, Uber’s vision of “On-Demand Urban Air Transportation” is something right out of an action comic book or a science fiction movie — which is how many of the concepts regarding manned space flight gained popularity in the 20th century.

The last decade has provided numerous examples of new and innovative technology disrupting established industries and companies. One has to look no further than Elon Musk’s investments in SpaceX and Tesla to see the impact of fresh ideas and investment in the space and automotive industries.

Now hundreds of millions of dollars in new investment are flowing to vertical flight (see “Uber Elevate Summit Outlines eVTOL Flight Plan,” page 30). The vehicles we may see flying over cities in a few short years will mark the arrival of the new era of electric VTOL. 

About the Author

Ken Swartz runs aerospace marketing communications agency Aeromedia Communications in Toronto, Canada. He specializes in freelance writing, contract public relations and social media marketing for the aviation and aerospace industry. He has reported on the helicopter industry for 40 years. In 2010, he received the HAI “Communicator of the Year” award. He can be reached at kennethswartz@me.com.