Uber announced its intent to collaborate on e-VTOL at the AHS-led Transformative workshop in September, and published its Elevate white paper a month later. (Uber)

The Demand for On-Demand Mobility

By Richard Whittle

The hurdles are high and there is ample reason for skepticism, but tech entrepreneurs are pushing electric aircraft ideas that could lead to a new era for vertical takeoff and landing aircraft, aka VTOLs (pronounced VEE-talls). The latest entrant is Uber Technologies, the $68B cell phone app rent-a-ride provider, which recently announced it will invest in and promote "on-demand aviation." Uber's vision — shared by a growing number of aviation experts — is to use electric-powered VTOL (e-VTOL) aircraft as "air taxis" to revolutionize transport in and around big cities.

"Flight is a natural extension of what we're doing," said Jeff Holden, chief product officer at Uber, which gave the air taxi movement a tail wind on Oct. 27 by releasing a 97-page white paper titled "Uber Elevate: Fast-Forwarding to a Future of On-Demand Urban Air Transportation." The paper explains why and how Uber wants to develop "a network of small, electric aircraft that take off and land vertically" to "enable rapid, reliable transportation between suburbs and cities and, ultimately, within cities." **(For details, go to www.vtol.org/uber.)**

"We've been looking at it in a cursory way for a while," Holden said, "but now, especially with electric propulsion, battery technology, and electric motor technology, the computer and fly-by-wire capabilities you need in order to control a system of that kind and make it very simple to pilot have all come together to make it something that can be done now." One day, Holden said, Uber hopes to be operating a fleet of e-VTOL aircraft, piloted or optionally piloted, able to carry two to four passengers.

Mark Moore, chief technologist for on-demand mobility at NASA Langley Research Center, said Uber's announcement "is the most important entry of any company into this area." The reason the announcement is so important, Moore said, is that, "Instead of yet another company developing a new VTOL vehicle, Uber offers the opportunity to create feasibility across the entire business model, from infrastructure to city acceptance. Finally we have a user laying down a requirement set for vehicle developers based on real trip demand and economics, which says 'if you build this vehicle, we will buy lots of them'."

Leaping Over Traffic

Major aviation companies and startups, including Silicon Valley entrepreneurs located near Uber's San Francisco, California, headquarters, agree it's high time air taxis got off the ground. So do other experts.

"There is absolutely a market," said John Hansman, a Massachusetts Institute of Technology aeronautics and astronautics professor who directs MIT's International Center

for Air Transportation. Traffic congestion "might be driving all of these rich investors in Silicon Valley," Hansman said dryly. "They live in Silicon Valley and then, when you go to San Francisco, they have to be in traffic for an hour and a half to get to anywhere and it's only seven or 12 miles." Uber's paper estimates that, "Last year, the average San Francisco resident spent 230 hours commuting between work and home — that's half a million hours of productivity lost every day."

Those working on VTOL electric propulsion concepts for the on-demand air mobility market include Airbus Group's self-described "Silicon Valley outpost" subsidiary A^3, (pronounced "A-cubed"); Google founder Larry Page's secretive Zee. Aero and Kitty Hawk companies; Joby Aviation of Santa Cruz, California, which has worked with NASA on distributed electric propulsion concepts; and others in the US and abroad (see sidebar and "Lift Where You Need It," *Vertiflite* Nov./Dec. 2016).

NASA's Moore said enthusiasm is growing because "all of a sudden the technologies relating to electric propulsion for aircraft are coming together to create a pretty exciting opportunity."

That's especially true for VTOL designers, Moore said, because of the drivetrain flexibility and weight reduction that distributed electric propulsion offers compared to combustion engines and mechanical drive trains. Using wires or other conductors instead of driveshafts and gear boxes to transfer power to propulsors means designers can put rotors, propellers or ducted fans nearly anywhere on an airframe and in far greater numbers than on conventional aircraft.

"[With] VTOL aircraft, you have to be able to control the vehicle at any flight speed, hover, any part of transition, etc.," Moore said. "Having this new degree of freedom where you can put the propulsion anywhere on the airframe at any size and not incur penalties — and even more than that, not incur penalties, but *incur benefits* in terms of the control power, in terms of the aerodynamic efficiency — it really is an incredibly powerful new capability that we simply couldn't do before because it would have involved incredible cross-shaft and gearbox complexity."

Uber doesn't plan to develop aircraft on its own, but is talking with aircraft developers. "Rather than manufacture VTOL hardware ourselves, we instead look to collaborate

A^3 by Airbus Group is working on two VTOL concepts, and plans to fly its Vahana prototype in 2017. (A^3)

Joby Aviation has moved from its 12-tiltprop, two-seat S2 (depicted here) to the six-tiltprop, four-seat S4, which will fly in the coming months. (Joby)

with vehicle developers, regulators, city and national governments, and other community stakeholders, while bringing to the table a very fertile market of excited consumers," the Uber paper explains.

To promote on-demand mobility (ODM), Uber plans to convene "a global Elevate Summit to bring together a wide set of vehicle manufacturers, regulatory bodies and public and private sector city stakeholders," the white paper said. Holden said the summit would be held "sometime in the first quarter of 2017," though the location has not been announced as of this writing. But the main thing Uber has to offer, Holden said, is a waiting market of 40 million customers who regularly use its automobile ride service each month.

"It's very rare for a startup, for example, in any space, to have essentially a guaranteed market ready and waiting for the product to sort of arrive," said Holden, who earned a degree in computer science from the University of Illinois Urbana-Champaign, worked closely with Amazon founder Jeff Bezos for years, and most recently created Uber's Advanced Technology Center to build autonomous cars in Pittsburgh, Pennsylvania.

"In this case," Holden said, "it's very clear that if we were to put a new option in the Uber app that says, 'Fly there, you can get an UberX or you can get an Uber flight,' if the price was right, that would be consumed very quickly and aggressively by our customers. The value proposition is so clear."

Back to the Future

If those pursuing on-demand mobility by air succeed, they will realize a dream many had for the helicopter in the 1930s and '40s that never quite panned out.

"The idea of vertical aerial mobility to overcome chokepoints in urban

complexes was popular with many of the most well-known planners and architects of the mid-twentieth century — Le Corbusier, Frank Lloyd Wright, Norman Bel Geddes," said Roger Connor, rotorcraft and unmanned aircraft curator at the Smithsonian National Air and Space Museum. "In some cases, this meant small taxi type aircraft, for others, helicopter buses or personal air vehicles." But while the aviation technology was there, other factors undercut that vision.

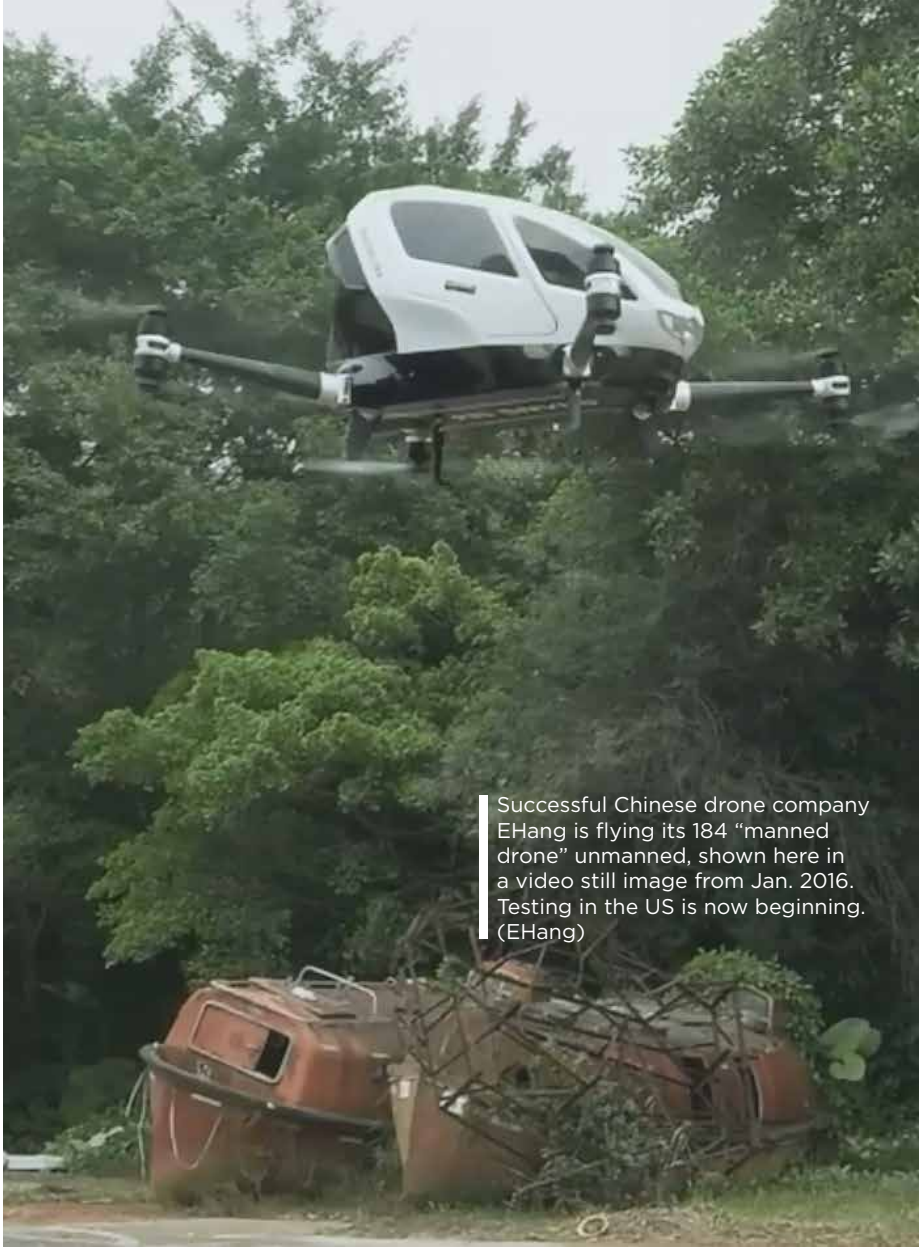
"Once helicopter mail and airline service began in the first decade after World War II," Connor said, operators found that to take off and land in cities, "they needed an entirely new class of rooftop that imposed significant structural costs in building design and exorbitant insurance assessments." That infrastructure burden, plus cost and noise, have kept the use of helicopters for on-demand mobility extremely limited.

"Future proposals for similar urban vertical transport will face similar risks," Connor predicts.

Uber and others pursuing ODM are well aware of the barriers beyond maturing the electric propulsion, batteries, avionics and autonomy technologies needed. Other challenges, outlined in the company's paper, include:

- Infrastructure: "The greatest operational barrier to deploying a VTOL fleet in cities is a lack of sufficient locations to place landing pads," Uber's paper said.
- Regulatory: New Federal Aviation Administration and European Aviation Safety Agency electric aircraft certification regimes, new systems of air traffic control, new safety standards and new pilot training protocols will be needed.
- Cultural/political: Safety, noise and emissions levels — all of which will be better with electric aircraft than helicopters, advocates promise — will have to gain popular acceptance. As with the driverless cars that Uber and other companies are developing, autonomous aircraft will have to be trusted by potential customers as well as regulators. Partly for this reason, Uber wants first to use electric aircraft that carry a pilot, even if the machines are nearly autonomous.

"The reason for that is because we think the certification path to get to autonomy will be longer than to get to piloted, and the path to autonomy is actually fastest through a piloted path," Holden said. "We're saying within the next decade this vision will come to fruition."

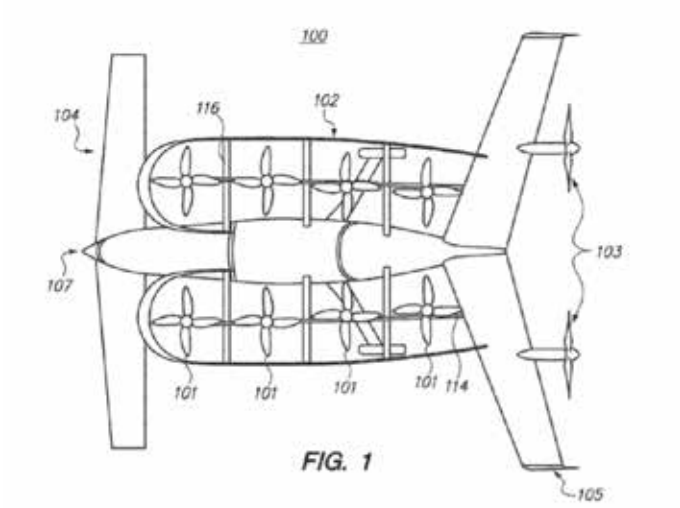


Successful Chinese drone company EHang is flying its 184 "manned drone" unmanned, shown here in a video still image from Jan. 2016. Testing in the US is now beginning. (EHang)

"Finally we have a user laying down a requirement set for vehicle developers based on real trip demand and economics, which says 'if you build this vehicle, we will buy lots of them'."

Aerospace engineers studying the prospects are more guarded in their optimism and projections for electric aircraft, primarily because of the difficulty of storing or producing electric energy on board at acceptable weights.

Don Hillebrand, director of the Energy Systems Division at federally-funded Argonne National Laboratory near Chicago, Illinois, said that, thanks to investment by the automotive industry, the energy density of batteries has been increasing 2–3% each year, which he called "a phenomenal speed." But aviation gas still packs roughly 100 times as much energy per kilogram as batteries do, Hillebrand said. "It's difficult to do a direct comparison between them," he added, "but yes, there is still a hundredfold difference." He added, though, that "the energy efficiency of aviation gasoline isn't improving at all right now and it never will." So, in theory at least, batteries



(Top) In patent 9,242,738 (granted Jan. 2016), Zee.Aero illustrated a high-mounted series of vertically mounted electric propellers. (US Patent Office)

Zee.Aero has been hovering (unmanned) its full-scale e-VTOL aircraft at Hollister Municipal Airport in California. Steve Eggleston at DK Turbines spotted the aircraft being towed out to the runway. (Steve Eggleston, used with permission)

could catch up. Hillebrand said he had seen at least one study contending the energy density of batteries could match aviation fuel by 2045 or 2050.

Richard "Pat" Anderson, an Embry-Riddle Aeronautical University professor who is working on several electric conventional and VTOL aircraft projects, said the good news for on-demand mobility advocates is that pure electric propulsion is likely to be most feasible for small aircraft going short distances. "I've come up with some equations that relate aerodynamic efficiency to specific energy," Anderson said. His calculations suggest that "there is no solution for maximum range that beats a gas turbine" but that cost, emissions and noise can be better in small electric aircraft flying short hops.

Anderson and others, though, find it hard to imagine the FAA and other regulators moving fast enough to enable Uber's vision of electric air taxi service becoming a reality within the next decade. The FAA is leery, for example, of the kinds of automated controls that may be needed, he said.

MIT's Hansman said that, "It's going to take 10 to 20 years for these [e-VTOL] vehicles really to be developed and certified and come in." But given the inexorable growth of roadway congestion in the world's major cities, he said, consumers may not wait that long for electric aircraft. Instead, they may turn to a different option.

AHS Transformative Vertical Flight Initiative

The August 2013 joint International Powered Lift Conference (IPLC) was hosted by AIAA (as part of its Aviation Forum) and supported by AHS International, SAE International and the Royal Aeronautical Society. Conversations there between AHS representatives with the AIAA Transformational Flight Program Committee and the AIAA V/STOL Technical Committee were followed at the January 2014 AIAA SciTech conference. The end result was to establish a joint AHS-AIAA Transformative Vertical Flight initiative to help nurture the burgeoning interest in distributed electric propulsion and other innovative propulsion approaches that promise to revolutionize the possibilities of aircraft design and operations.

The first joint AHS-AIAA-ASTM-SAE Transformative Vertical Flight Workshop was held in August 2014 in Arlington, Virginia; NASA Ames in Mountain View, California, hosted the second workshop in August 2015; and the third workshop was held as part of the SAE-led joint IPLC in September 2016 in Hartford, Connecticut. Details, briefings and proceedings from the workshops can be found at **www.vtol.org/transformative**.

The objective of the workshops has been to engage industry, academia and government agencies in developing a preliminary roadmap that will aid in the advocacy and pursuit of emerging technologies and approaches, such as electric/hybrid power and distributed propulsion, that offer the potential to fundamentally transform Vertiport-capable flight configuration designs and operational concepts.

The result of these workshops and the work by the individuals, companies, universities and government agencies has been a groundswell of enthusiasm by developers, innovators, investors and potential operators (i.e. Uber) who have had the chance to network, learn from each other, and lend credence to the belief in transformative performance through these innovative electric/hybrid power and distributed propulsion approaches.

NASA's Mark Moore, the de facto leader of the Transformative Vertical Flight initiative, notes that, "Over the past three years, the Transformative Vertical Flight Concepts workshops have given birth to the electric VTOL urban air-taxi market. For those of us who have spent our entire career working powered-lift aeronautics, we've been able to experience the genesis of a new opportunity for civil vertical flight. The sense of community that has developed across all the vehicle and technology developers has been a catalyst to raise the tide for all, with a comradery and friendly competitiveness.

"As I've participated in aggressive research at NASA over my 32-year career, one of the key lessons learned that I would share with those wishing to innovate and change the status quo is that it takes a village to develop highly integrated advanced concepts. The complexity of the future solutions which society requires isn't going to be developed by lone inventors thinking they can do it all — but through collaboration and networking. There have been many times over the past several years where I'll find another company developing electric VTOL aircraft, and these development efforts could have saved so much time, effort, and money if they'd attended just one workshop and benefited from the collective intelligence of those pioneering the next generation of vertical lift. We all realize that it isn't about a single company being successful, but creating the market opportunity for many companies to have successful products and services. For those who are struggling each day to provide new aviation products to the world, it's so helpful to have professional societies like AHS supporting educational and community outreach, as well as GAMA supporting manufacturing and certification outreach."

Following e-volo's successful manned flights with its VC200 two-seater, the company is now imagining other concepts, such as the VC400 shown here. (e-volo)

"We actually have vehicles today that can accomplish the mission," Hansman said. "We call them helicopters." And he wasn't joking.

"I think that ground congestion is going to get bad enough that, even if helicopters are expensive, people are going to be willing to pay for it, if you can find a way to operate them in the places you need to operate them," Hansman said. "But that's the same problem the on-demand mobility people have to solve. I personally see the helicopters as the pathfinders for on-demand mobility. Then the electric helicopters or electric vehicles should come in behind as that technology becomes mature and capable."

In a sense, Uber has already been testing the market for on-demand helicopter rides with UberCHOPPER, a service offered off and on since 2013 to carry deep-pocketed passengers from Manhattan to the Hamptons during summer, as well as to special events, such as the Sundance and Cannes film festivals. Uber has also partnered with another mobile app company, Blade, that offers regularly scheduled and crowdsourced charter flights from in and around New York City to nearby destinations.

"Even at a very high price, we've done a bunch of promotional things with helicopters, like in São Paulo and New York, and we always completely sell out of the available trips that we have with those helicopter operators because people are just really looking for ways to get from Point A to Point B much faster," said Holden. "With the aircraft we're talking about and the experience we're talking about in the white paper [it] is a radical improvement."

NASA expert Moore, a leading advocate of distributed electric propulsion for VTOL aircraft, agreed. He said the advantages electric propulsion offers are clearly delineated in Uber's Elevate paper.

"They clearly understand the barriers that need to be addressed to achieve a vibrant and feasible market; and best of all, they have no interest in just creating a token market for the rich," Moore said. "They've been doing their due diligence prior to releasing the Elevate white paper, not only with the analysis and studies they've shared, but with their initial operations with helicopters in select cities, which have clearly indicated to them that helicopters are insufficient to accomplish their objectives."

In short, Uber is giving ODM advocates a lift. "I've never been more excited for the future of vertical lift and urban air-taxi," Moore said. "There isn't a company better positioned to make urban VTOLs real."

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)

Leading e-VTOL Developers
Companies known to be building full-scale prototypes

A³ by Airbus Group
Santa Clara, California
Financed by Airbus Group. Exploring tilting Distributed Electric Propulsion on Vahana. Graphics show an 8-prop 1-seater. Flying prototype planned in 2017.
www.vahana.aero

EHang
Guangzhou, China and Redwood City, California
EHang 184 = 1 passenger, 8 propellers, 4 arms. Unmanned flight testing in Nevada planned for 2016/2017.
www.ehang.com/ehang184

e-volo
Karlsruhe, Germany
VC200 multicopter first unmanned flight in November 2013. First manned flight March 30, 2016. Speed 69 km/h (37 kt) in July. World's first 2-seat electric VTOL aircraft with 18 non-tilting propellers. Supported by Intel's Ascending Technologies, DG Flugzeugbau GmbH and others.
www.Volocopter.com

Joby Aviation
Santa Cruz, California
Joby S4 = 4-seat Distributed Electric Propulsion VTOL with 6 tilting propellers. Flying prototype in 2017. Funded by JoeBen Bevirt and Paul Sciarra.
www.JobyAviation.com

Kitty Hawk
Mountain View, California
Details unknown, though alleged to be a quadrotor, privately funded by billionaire Larry Page, with talent from AeroVelo, etc.
www.KittyHawk.aero

Lilium
Gilching, Germany
36 electric ducted fans. 2-seater demonstrator in development. Full-scale unmanned prototype to fly in 2017. Supported by Atomico, the European Space Agency (ESA), European Union and the Technical University of Munich.
www.Lilium-Aviation.com

Zee.Aero
Mountain View, California
Surreptitious photos show multicopter concept similar to patent applications filed since 2010, privately funded by billionaire Larry Page.
www.Zee.aero