FIXED FOCUS

> BETA TECHNOLOGIES KEEPS IT SIMPLE IN CERTIFYING ITS eVTOL

> ALIA SHOWS RANGE POTENTIAL IN CONVENTIONAL FLIGHT

> VERTICAL FLIGHT WILL BE FOCAL TO THE NEXT TEST PHASE

Graham Warwick Washington

BETA TECHNOLOGIES

For Beta Technologies, the most direct path to certifying an entirely new class of aircraft is to keep it simple. The Vermont startup's strategy is to focus on the key innovation and keep the rest of the aircraft as conventional as possible.

Beta is developing the Alia electric vertical-takeoff-and-landing (eVTOL) aircraft. The key innovation is distributed electric propulsion. But the company has designed the Alia to spend as much of its time as possible flying like a fixed-wing aircraft.

Beta has resumed hover testing after completing extensive fixed-wing flights with the Alia engineering prototype.

Unlike the eVTOL prototypes, the Alia has been flown piloted from the outset.

There are no articulating nacelles, no variable-pitch rotors, no gearboxes, no liquid cooling. There are multiple redundant electric motors and battery packs in a lift-plus-cruise configuration designed to combine safe and efficient vertical and horizontal flight.

There are no advanced flight control laws to make the machine easier to fly. A session in the simulator in Beta's Washington office makes clear that the Alia is designed to be flown by a professional pilot. It is a decision intended to simplify the route to certification (see sidebar, page 52).

"The number of requirements that you impose on an aircraft will define your path to certification. Because every one has to be paired with a means of compliance, a test and an objective assessment of the failure mode effects and criticality analysis," says Beta Founder and CEO Kyle Clark.

"So the first step in simplicity is minimizing the requirements," he says. "If we have a flight controller and say, 'No longer is that flight controller required to have airspeed or angle of attack,' those are two things you don't have to test or write a means of compliance for."

Keeping it simple is central to Beta's strategy for FAA certification. "The FAA wants a win here," Clark says. "They've done a great job of laying the groundwork . . . [and have] been very helpful in ensuring we get clarity. Because indecision, in my opinion, is the biggest impediment to our progress.

"It doesn't mean we get the answer that we want, but it is clear," Clark continues. "And I believe what they appreciate about our design is that there's simply less to do."

Where Beta's closest eVTOL competitors all use tilting mechanisms to vector thrust, the Alia has four lift propellors for vertical flight and a pusher prop for wingborne cruise. Shaped like blender blades, the fixed-pitch lift props are stopped in forward flight, aligned fore and aft with the airflow to minimize drag.

To provide the commercial aviation level of safety required, each of the Alia's four lift props is powered by two motors, each of them with dual windings, providing fourfold redundancy. A dual-redundant motor drives the pusher propeller. Up to five independent battery packs power the props.

Outside of those features, the Alia is resolutely conventional, with a long-span wing for low cruise drag and redundant ailerons, elevators and rudders for control in forward flight. In place of retractable gear, the aircraft has "skwheels"—landing skids that incorporate wheels in a low-drag arrangement.

"The No. 1 thing is to take the requirements out," Clark says. "And if you leave it on the ground, it doesn't exist. You don't have to certify it, you don't carry it around, you don't have to pay for it, you don't have to design the system for it. It's just intensely practical to not put it on the airplane."

Simplicity must be balanced with capability. Here the fact that all of Beta's employees are pilots, or becoming pilots, plays a role. "The trick is to find the balance," Clark says. "And if you put somebody in the cockpit every day, they start to learn what's really important, not what they think is important."

The strategy of simplicity threads through Beta's operation from technology to market to funding. Unlike its leading rivals, the startup does not plan to operate its own eVTOLs but instead to manufacture, sell and support them. Beta already has purchase agreements with Blade, UPS and United Therapeutics (see chart, page 58).

The startup also sets itself apart from its direct competitors by expecting that cargo will be the first eVTOL application to scale up, because securing customer and public acceptance will be more straightforward.

Beta has already raised $511 million in private funding and, unlike its rivals, the company is not planning to go public through a merger with a special-purpose acquisition company. Becoming a public company at this stage would unnecessarily complicate Beta's business operations, Clark says.

Instead, the startup has carefully selected private investors directly aligned with its mission and with a

clear understanding of the complexity of certifying even a simple eVTOL. The $368 million funding round in May was led by Fidelity Investments, along with Amazon's Climate Pledge Fund and Redbird Capital. "We elected to take in these investors. They did not have ulterior motives beyond our mission," he says.

Beta's strategy has been shaped by Clark's experience developing highly reliable power electronics for national laboratories and companies such as Raytheon and Tesla—"people who say, 'it's simply not tolerable for this not to work properly,'" he says.

The company's approach "is the result of having built many hundred kilowatts of power systems and recognizing that it is not trivial, especially when you are trying to put [a new technology] into an environment where it has never been before," Clark notes.

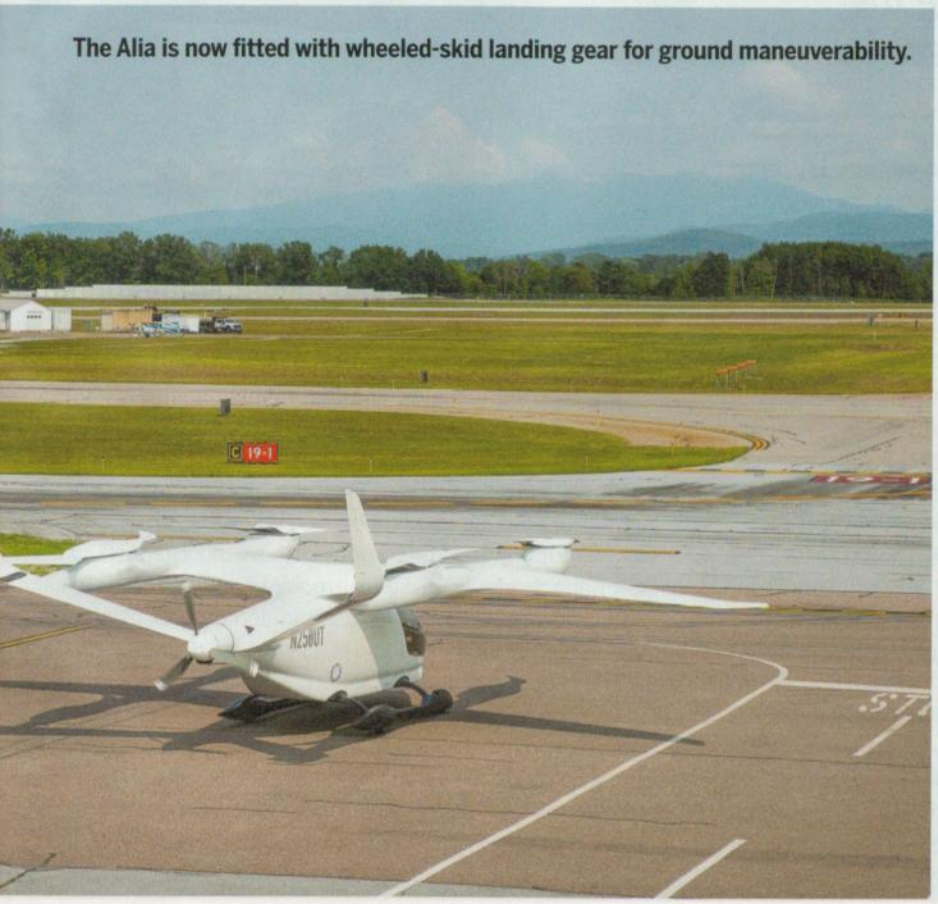
"The only way that it ended up working there, and the only way I believe it is going to work in aviation, is to identify the most valuable feature of the technology you are introducing," he says. "And in our case, it is the fact you are taking all the fuel out of the aircraft."

BETA TECHNOLOGIES PHOTOS

A variable-pitch pusher prop provides propulsion in wingborne forward flight.

Beta's goal is to exploit the benefits of electric propulsion—simplicity, fuel elimination, energy savings and maintenance reduction—and the vertical flight capability of distributed propulsion. The Alia is designed to fly point to point with the ability to take off and land on a 50 X 50-ft. pad.

The Alia is now fitted with wheeled-skid landing gear for ground maneuverability.



With a 50-ft. wingspan, the 7,000-lb.-gross-weight aircraft is designed to carry a pilot and five passengers or 200 ft.^{3} of cargo in a capacious fuselage. The performance target is to fly a 600-lb. payload 250 nm at 145 mph—or 1,500 lb. 200 nm—on a single charge, with recharging taking about an hour.

The Alia has a 330-kWh battery system under the fuselage. In testing to date, the aircraft has flown 205 nm in fixed-wing-only mode with three of the five battery packs installed. "It is a happy, happy CTOL [conventional-takeoff-and-landing] aircraft," says Clark. "It's burning 100 kW doing 105 kt. That's a remarkably efficient aircraft at this weight."

The eVTOL is designed for efficient cruise flight to conserve battery energy, and the power-hungry vertical takeoff and landing phases are minimized. "The hover and transition time at the beginning and the end total between them about 40 sec.," he points out. "You're only spending 40 sec. of a 2.5-hr. mission in VTOL.

"One of our best missions is to take off vertically and land like an airplane, or vice versa, because you get the value of VTOL with the range boost of hitting one end as a CTOL," Clark says. Blade CEO Rob Wiesenthal cites the ability to take off vertically from a helipad in Manhattan and land conventionally at John F. Kennedy International Airport as one of the key reasons he selected the Alia.

Beta has built two piloted engineering prototypes of the Alia. The company started testing in February 2020

with tethered hover flights at its base in Burlington, Vermont, but then the airport was closed in March 2020 because of the COVID-19 pandemic. In June 2020, the prototype was airlifted by helicopter across Lake Champlain to Plattsburgh International Airport in New York.

"We were going to do a bunch more hover testing before we went to fixed-wing," he says. But after the Burlington airport was shut down, "we said, 'let's bring the fixed-wing testing over to Plattsburgh.' Then Plattsburgh was shutting down to resurface their runway." So after a few hundred hours of fixed-wing flights, the prototype was flown back to Burlington this July.

"We've done a lot of CTOL flying. We have plenty of energy in the bank to get to those ranges," Clark asserts. "And we are hell-bent on completing all our pre-FAA testing to make sure that, aerodynamically, the aircraft does everything we expect it to." The company has now restarted hover testing at Burlington. "We're getting back into gearing up for transition testing on the manned version."

Beta has completed hundreds of transition tests using subscale unmanned models. "Every day we're doing transition testing on the unmanned versions and evaluating the corner cases. And we have high-fidelity simulations in the iron bird," he says.

"One of the coolest tools we have is a rolling wind tunnel. We put the transition props on that and bring it down the runway at 100-plus kt. with those running on top of a 20,000-lb. truck to evaluate all the different inflow angles to the lift props."

Beta also is still using its original Ava XC eVTOL demonstrator as a test asset. This is a modified kitplane fitted with four tilting pairs of coaxial variable-pitch rotors. "We use it as a flight controller test platform, for the battery management system and the fly-by-wire system," Clark says.

The Ava has provided Beta with valuable insight into how to shield the electronic systems against electromagnetic interference from the high-power, high-frequency electric motors. "Your shielding has to be robust to failures. So that airplane and the iron bird are some of our best test assets," he says.

The two Alia prototypes are nonconforming. The aerodynamics are what Beta plans to certify, but the airframe structure is not representative of the production vehicle. The first conforming prototype is planned to fly in 2022, and Beta is targeting FAA Part 23 certification by the end of 2024.

Beta is not as vertically integrated as some of its competitors. "We're doing everything that is enabling internally—so the motors, inverters, batteries, flight controls, and the overall aircraft configuration and integration," Clark says. The startup is going outside for rest.

"This is another one of our secrets to getting through certification—there are already smart people that know how to build actuators and structure, propellers, interiors and avionics," he

In the Cockpit: Making an Innovative Aircraft Feel Familiar

Graham Warwick Washington

BETA TECHNOLOGIES' STRATEGY OF SIMPLICITY WAS underlined when Aviation Week experienced the Alia flight simulator at the company's facility in Washington near Capitol Hill. Running an X-Plane simulation, modeled using real data from flight testing, the fixed-base simulator shows how conventional the Alia is—for most of its flight—and how different it is.

The fixed-based simulator includes a full-scale mockup of the Alia's capacious fuselage, showcasing an unobstructed volume that can accommodate a pilot and five passengers or 200 ft.^{3} of cargo. Large windshield apertures provide unhampered visibility of the curved visual projection screen.

The cockpit has three Avidyne screens. The center display is a certified IFD550 flight management system with minor changes to control electronic circuit breakers and display battery information. The two touch-screen, synthetic-vision primary flight displays (PFD) are more heavily modified to show battery and motor information as well as all the usual flight data.

The pilot has an F-16-style force-sensing sidestick and a lift lever that resembles a helicopter's collective control. Light fore/aft stick force provides pitch control, left/right force for roll and twist for yaw. The fixed pedals provide only differential braking for steering on the ground.

The cockpit features FAA-certified Avidyne displays and flight management system.

The three flight control computers have no airspeed or angle-of-attack inputs, essential requirements for the advanced flight control schemes used in some other electric vertical-takeoff-and-landing (eVTOL) vehicle designs. But more-automated flight control laws and even autonomy could come later.

Pulling up on the lever starts the lift motors. At about 53% torque, the Alia lifts off vertically. In hover, it flies like a multicopter drone, stick movement sending torque commands to the motors to vary lift from the fixed-pitch props. While it

says. "We've chosen to be the best propulsion company in the world. Copper comes in the door, and motors go out."

If simplicity is a Beta strategy, then so is partnering. "If you choose not to include something on your airplane, it makes it cheaper, it will take less time. It's a pretty fundamental truth," he says. "And the parallel to that is that partnering with the best in the world for those elements that are not enabling electric propulsion is the right way to keep our promises to our customers."

Beta's customer base covers three key eVTOL use cases: urban air mobility, express logistics and medical transport. Blade plans to add the Alia to its on-demand helicopter service; package carrier UPS will operate the eVTOL as a small regional feeder; and United Therapeutics will use the aircraft to rush refurbished and manufactured organs to hospitals for transplants.

"In my opinion, cargo and logistics will unquestionably be adopted at a faster rate than passenger and other similar missions," Clark says. He expects there to be less emotion associated with customer and public acceptance of eVTOL cargo operations.

This also applies to installing the infrastructure required to enable eVTOL operations. Echoing Tesla's approach to introducing electric cars, Beta is already deploying its own charging stations at airports and hospitals across the U.S. to support its aircraft.

"We've been putting in a lot of recharging systems, both on- and off-airport. And the friction associated with putting in a charging station where you typically bring in cargo and logistics is way lower than in areas where people live," he says.

The charging stations are an integral part of Beta's business plan. While its eVTOL rivals are partnering with real-estate developers on infrastructure, "We have hundreds of permits underway. We are cementing the ground and putting power out to airplanes," Clark says. Beta has infrastructure built or permitted at over 50 sites and expects to reach a deployment rate of two a week.

One product is an off-airport charging station, an "airport in a box" built from shipping containers that includes an elevated landing deck, crew rest and flight planning rooms, as well as chargers for aircraft and vehicles. "We have a number of those deployed and are putting more into hospitals," he says.

Other charging stations in development include an on-airport dispenser. This is a UL 1741-certified product designed to connect to the electric grid and to safely trip offline in the event of supply perturbations. Beta is also developing a mobile system that resembles an airport fueling truck.

"The product vision for the charging systems is fundamental to the success of the aircraft," Clark says. And in addition to deploying charging stations to support the Alia, "we have a couple of partnerships with other manufacturers, and we have their aircraft here now, quietly working," he adds.

The X-Plane simulation uses data from flight tests of the Alia engineering prototype.

BETA TECHNOLOGIES PHOTOS

maneuvers at low speed much like a helicopter, the Alia is not designed to hover and will spend only a total of about 40 sec. of each flight in power-consuming hover and transition.

Instead, once airborne, pushing forward on a thumbwheel throttle on the lift lever starts the pusher prop and Alia immediately begins transitioning to forward flight. At about 65 kt., the aircraft is fully wingborne and the lever is lowered, the lift props stopping in low-drag fore-aft alignment.

Now the Alia flies like any conventional fixed-wing aircraft, stick movement commanding dual-redundant ailerons, elevators and rudders. What is new for the pilot are the battery, motor and inverter power and health indications on the PFD, including flight time remaining and hover time remaining displays.

A white cross-shaped control motion indicator displays the pilot's control inputs and trim settings in pitch, roll and yaw. Power from the lift motors is shown as a green pie at the center of the cross, each quadrant split into two slices for the dual motors powering each lift prop. The slices expand or contract as motors respond to commands—or failures.

To land, the thumbwheel throttle is rolled back to reduce thrust from the pusher prop. At about 65 kt., the lever is raised to start the lift motors. By combined rolling back of the throttle and lifting of the lever, the eVTOL is brought to a halt over the runway without the nose-high braking flare that can restrict a helicopter pilot's view of the landing zone. Lower the lever and the aircraft sets down, props stopping immediately.

The Alia is an aircraft designed to be piloted—and deliberately so at this stage in eVTOL development, in Beta's view. The landing was challenging for Aviation Week's nonpilot editor, but it is clear how this approach could appeal to the FAA because so much about the design is comfortably familiar to a regulator experienced in certifying general-aviation aircraft. What is new and unfamiliar is carefully confined to the propulsion system and entrusted to a trained pilot.

Powering Up

> ADVANCED AIR MOBILITY EMERGING AS A MULTIFACETED INDUSTRY

> ELECTRIC PROPULSION ENABLING DIFFERENT AIRCRAFT CLASSES

> BUSINESS MODELS ARE CHALLENGING TRADITIONAL AVIATION

Graham Warwick Washington

Which is the winning business model in advanced air mobility? Urban or regional; passenger or cargo; piloted or autonomous; vertical, short or conventional takeoff and landing? All of them or none?

It is a question that cannot yet be answered. There are players pursuing all of these ideas, individually or in combination, and they all want a piece of a market that is projected to be worth trillions of dollars but which in reality does not yet exist.

"People ask me about the total addressable market and the industry, and I kind of look at them crooked and say: "There is no addressable market right now. We're creating it,'" says Kyle Clark, founder and CEO of electric vertical-takeoff-and-landing (eVTOL) startup Beta Technologies. "Every purchase order that we accept is creating a market. It's not replacing something; it's an entirely new something."

Vermont-based Beta, in fact, was one of the first eVTOL developers to book orders for aircraft, from the cargo, passenger and medical sectors. Now commitments of various kinds for more than 3,000 vehicles have been announced across multiple manufacturers for aircraft classes and use cases that represent the gamut of possible applications.

All are conditional on the aircraft meeting performance targets and business objectives, and little money has changed hands so far. But for manufacturers and investors alike, they serve as an indicator of interest. And for customers, they represent a foot in the door to a potential transformation of aviation.

The market got its start with Uber's Elevate vision for urban aerial ride-sharing but has expanded to encompass regional transportation and express logistics as well as medical and military applications as developers have come to terms with the benefits and limitations of electrified propulsion technology.

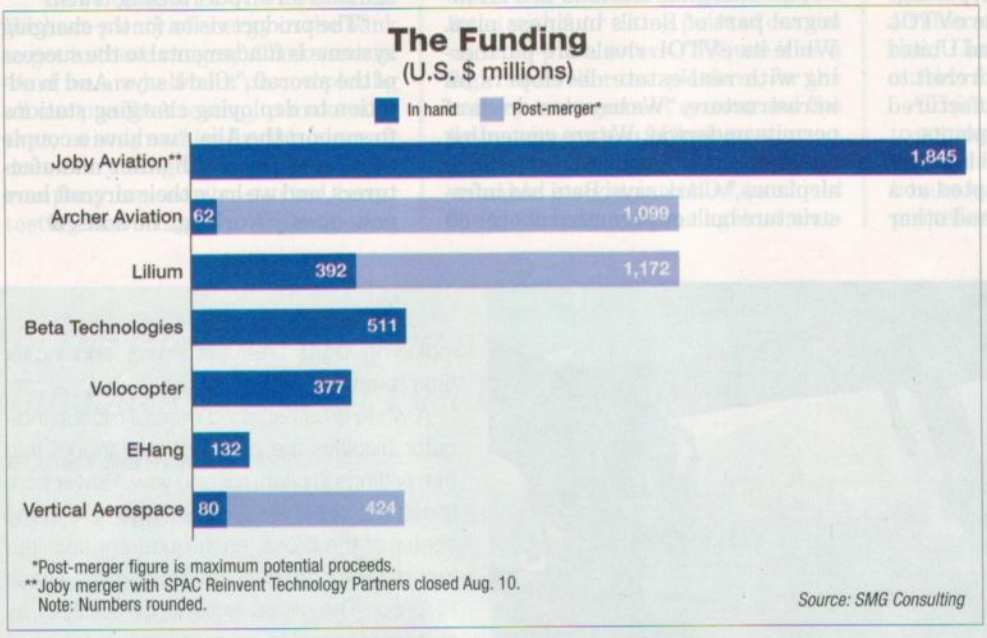
Vehicles in the certification pipeline now range from battery-powered eVTOLs that can fly two people 20 mi. to hybrid- and hydrogen-electric conventional-takeoff-and-landing (eCTOL) aircraft that can fly 19 passengers 500 mi. In between are electric short-takeoff-and-landing (eSTOL) designs that bridge the capability gap.

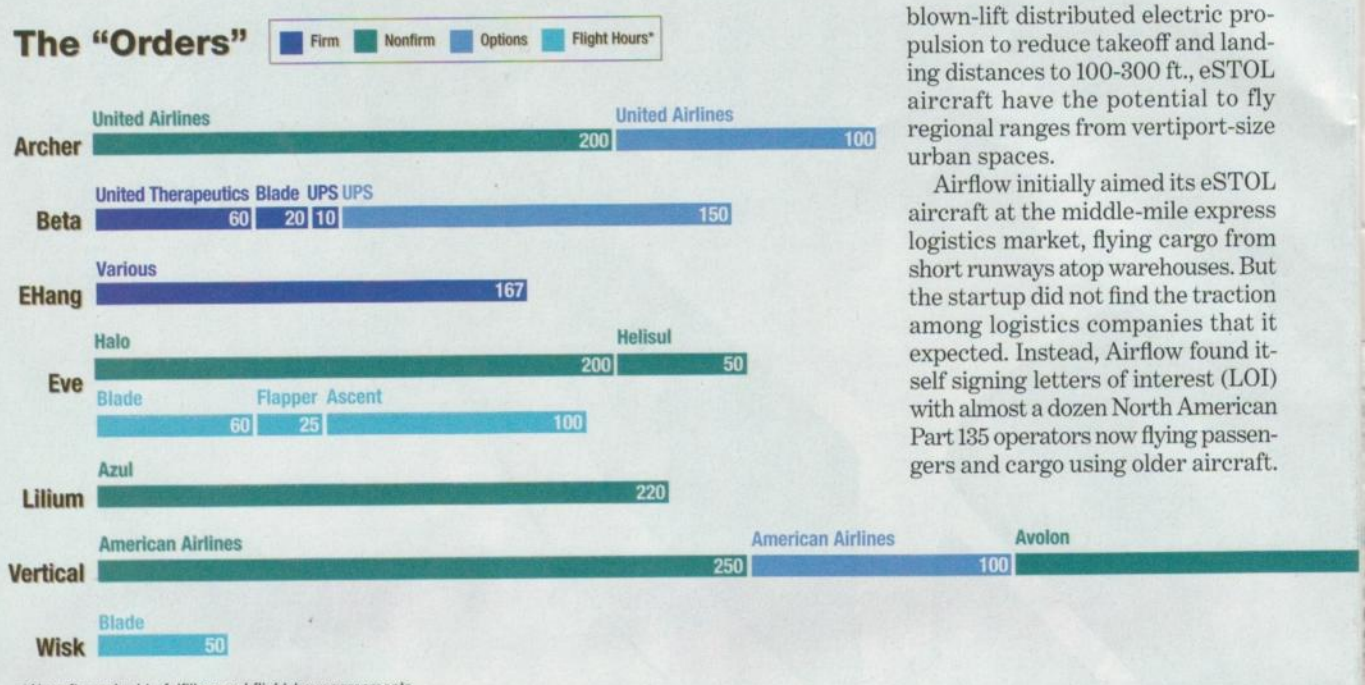
For many of the first movers in what has become known as advanced air mobility (AAM), urban air mobility (UAM) remains the focus. EHang and Volocopter continue to pursue the short-range intracity market with their two-seat multicopter eVTOLs. Both look set to be first to market (see chart, page 60) because of the relative simplicity of their vehicles. But both have launched development of longer-range lift-plus-cruise eVTOLs to extend the reach of their air taxi services into the suburbs.

For Archer and Joby Aviation, the initial focus is urban also, but with an eye to longer routes. Joby's piloted four-passenger S4 tiltprop eVTOL has achieved its targeted 150-mi. range, and the company believes it can fly farther as battery technology improves. "We have the size of vehicle to make the economics work and the acoustics to get into the marketplace, and we know this aircraft can go much further and much faster than it's flying on our current energy source," says CEO JoeBen Bevirt.

For German startup Lilium, regional air mobility has been the focus from the outset. For short-range UAM to work, the company argues, vertiports must be located conveniently close to customers, which implies substantial investment in infrastructure to create a viable network. Lilium believes high-speed regional air transport networks can get started using existing infrastructure at airports and in cities and can offer greater trip-time savings for which passengers will be prepared to pay higher prices.

Lilium is not alone in seeing greater profit potential in regional rather than urban air mobility. The eSTOL developers are aiming to offer the convenience of eVTOL with the reach of eCTOL. By exploiting the ability of





*Aircraft required to fulfill annual flight-hour agreements.

Source: SMG Consulting

blown-lift distributed electric propulsion to reduce takeoff and landing distances to 100-300 ft., eSTOL aircraft have the potential to fly regional ranges from vertiport-size urban spaces.

Airflow initially aimed its eSTOL aircraft at the middle-mile express logistics market, flying cargo from short runways atop warehouses. But the startup did not find the traction among logistics companies that it expected. Instead, Airflow found itself signing letters of interest (LOI) with almost a dozen North American Part 135 operators now flying passengers and cargo using older aircraft.

JOBY AVIATION

"Over the last year and a half, we have talked to many customers in different industry segments," says co-founder and CEO Marc Ausman. "The other segments did not sign LOIs, but this one did, and it is sub-regional passenger and cargo transportation over ranges of 50-500 mi. These are operators flying trips today and looking for an aircraft that is newer, quieter and sustainable."

Many of the deals being signed by AAM startups are an LOI, memorandum of understanding (MOU) or some other form of agreement that stops well short of a purchase order but secures the customer a position in the delivery queue and a role in helping ensure the aircraft meets the market needs.

Typical of these agreements is the MOU signed in August by eSTOL startup Electra and Bristow Group, an established operator with a large fleet of fixed- and rotary-wing aircraft performing oil and gas transportation, search-and-rescue and other commercial and government missions.

The MOU covers collaboration "to help Electra design and build the next generation of aircraft that fully utilizes the eSTOL concept in existing and new end markets," says Chris Bradshaw, Bristow president and CEO. The companies will explore new markets in which Bristow could operate eSTOL aircraft, focusing on time-sensitive logistics for retail distribution. This could lead to an order for 50 aircraft, says Electra.

There is debate over whether eVTOL and eSTOL are complementary or competitive, and the answer may depend on demographics. A representative market is Melbourne, Australia, which Elevate selected in 2018 as a launch market for its Uber Air aerial ride-sharing service. The Elevate team was eventually acquired by Joby, but Melbourne's air-taxi ambitions have been rekindled in recent weeks.

Avolon		Virgin Atlantic
310	190	150

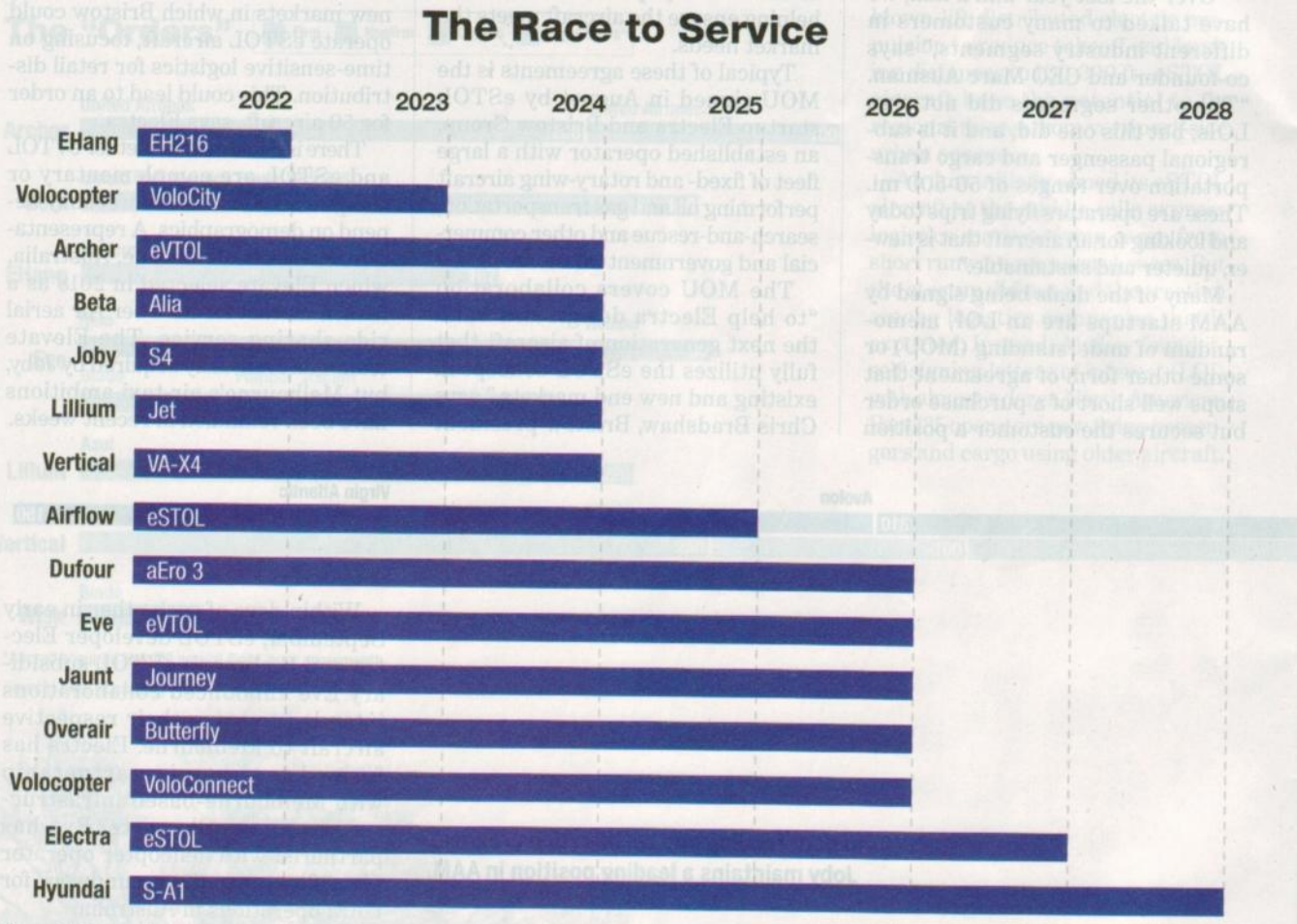
Within days of each other in early September, eSTOL developer Electra and Embraer's eVTOL subsidiary Eve announced collaborations intended to bring their respective aircraft to Melbourne. Electra has formed a strategic partnership with Melbourne-based infrastructure company Skyportz. Eve has partnered with helicopter operator Microflite to lay the groundwork for UAM operations in Australia.

Microflite and Skyportz have been working together since 2015 and jointly supported Melbourne's bid to become Uber Elevate's third test city. Microflite also has worked with Eve and airspace manager Airservices Australia to develop a concept of operations for UAM in Melbourne. But Skyportz has come to believe that regional eSTOL is better suited to Australia's demographics than urban eVTOL.

"I have moved away from the Uber Air inner-city vision of aircraft jumping around between rooftops," says Skyportz Founder and CEO Clem Newton-Brown. "I don't think we are dense or congested enough in our cities in Australia to justify this sort of operation. But longer-range flights linking regional cities and activating the thousands of little aerodromes on urban fringes would be a really viable service."

Such calculations—relieving urban congestion or enhancing regional connections—are likely to play out in other geographies around the world, and the answers each time could be different. Both could find a place.

In both funding and certification progress, Joby maintains a leading position in AAM.



Source: SMG Consulting, based on manufacturer statements

In Florida, for example, as Lilium is building the foundations of a high-speed regional network linking cities, Archer and Joby are targeting Miami as a launch market for urban air taxis.

Archer and Joby have both partnered with U.S. parking garage operator Reef Technology to identify rooftops that can be converted to urban vertiports with minimal structural modification. Archer says it has selected the first five locations in each of its launch cities, Miami and Los Angeles. Both companies plan to start commercial service by the end of 2024.

Compared with eVTOL, eSTOL proponents say a short ground roll reduces demands on energy storage and increases payload and range with existing battery technology while still enabling use of many of the same vertiports. "Basically, eSTOL is going to have comparable infrastructure requirements to helicopters," says Electra Founder and CEO John Langford.

Not everyone agrees. Mark Moore, the ex-NASA electric propulsion pioneer who co-founded Uber Elevate, describes himself as a "recovering eSTOL zealot." "For years at NASA I was pushing for eSTOL to make sense," he says. "If you are targeting a 100-ft. ground roll, in my opinion it is way, way harder to achieve that with an eSTOL than it is to develop an eVTOL."

The reason, Moore says, is the "insanely high" lift required to enable such short ground rolls and the sensitivity of the blown wing to changes in wind velocity at such low airspeeds. He doubts an eESTOL will have the maneuverability to follow a major urban artery, to hide in the noise, then make a 90-deg. turn to land on an adjacent rooftop vertiport. "You're going to have to have a straight approach, and you better have the winds line up with you," he says.

Langford disagrees. "They are highly maneuverable. With blown lift, you get powerful control moments, both from blowing the aerodynamic surfaces and from thrust vectoring," he says. "The parking garage is exactly the sort of place we're planning to operate eSTOL airplanes.

"No one is claiming that 100% of the places you can put a vertical-lift vehicle are going to be open to eSTOL, but something like 70-80% of the market is," Langford continues. "There will always be a place for vertical lift just as there is today, but the economics are going drive you to the lowest direct operating costs, and the operating costs of eSTOL are going to be much lower than the operating costs of eVTOL."

"There will be many types of electric aircraft in the future, and there will be many winners," Ausman says. "So there's plenty of room in this market going forward for both eVTOL and eSTOL. There are areas where they'll overlap and areas where they'll

have different missions, and they'll each be successful."

That is expected to extend to eCTOL as well. Already the market is showing a willingness to embrace more than one class for essentially the same mission. UPS has ordered Beta's Alia eVTOL for time-sensitive deliveries in the small and medium-size market, while DHL Express has ordered Eviation's Alice eCTOL as a feeder freighter. UPS hails the Alia's ability to land on-property; DHL lauds the Alice's sustainability.

And the AAM options being enabled by electrified propulsion are not limited to eVTOL, eSTOL or eCTOL. There are startups pursuing the idea of taking to the water to connect coastal cities. Regent is developing the seaglider, an electric vehicle designed to take advantage of wing-in-ground-effect (WIGE) aerodynamics to fly even more efficiently than eCTOL aircraft.

The U.S. startup foresees seagliders operating services up and down the North American seaboards, relieving runway congestion at coastal hub airports by taking over from regional aircraft. Similarly, in Norway, startup Elfly aims to connect the country's geographically isolated communities with an electric regional seaplane service flying along the coast and into the fjords. And Flying Ship Technologies is developing an electric cargo WIGE aircraft to provide fast, low-cost delivery to coastal locations.

There are many options not only for electric aircraft designs but also for business models. Of the top 10 eVTOL developers, seven also plan to operate their own air-taxi service using their vehicles. And within those, there are different approaches to the operation. Joby, for example, is working to obtain its own FAA Part 135 air operator's certificate (AOC). Lilium plans to partner with local AOC holders, beginning in Europe with business-aircraft operator in Luxaviation and in Brazil with airline Azul.

Some major carriers are looking toward acquiring and operating their own eVTOL fleets: United Airlines signed purchase agreements with Archer, and American Airlines placed pre-orders with Vertical Aerospace. But another group showing early interest in AAM is on-demand private aviation providers such as Blade Urban Air Mobility.

Eve has signed flight-hour agreements with Blade in the U.S., Flapper Tecnologia in Latin America and Ascent Flights Global in Asia to provide access to aircraft owned and flown by third-party operators. Boeing/Kitty Hawk joint venture Wisk has a similar deal with Blade. It is a business model offering a route to AAM that brings together established aviation operators with app-based service providers.

With such a variety of aircraft classes and business models vying for dominance in an emerging market, it will take time for the true shape and scope of AAM to become clear. But as manufacturers advance toward certification and production and customers and operators place their initial bets, the outline of a new industry is beginning to be filled in.