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Making Electric Aviation a Reality

Flying high on an environmentally friendly commute

MAKING ELECTRIC AVIATION A REALITY

FLYING HIGH ON AN ENVIRONMENTALLY-FRIENDLY COMMUTE

By Megan Crouse

Imagine a future in which commuting by air is less expensive and more environmentally friendly than taking a train. That's the future envisioned by Omer Bar-Yohay of Eviation, a manufacturing company which displayed a prototype of its electrically-powered aircraft at the 2017 Paris Air Show.

"In the next four years, Eviation aims to make regional air travel a cost-effective and clean option that rivals any existing form of transit today," said Bar-Yohay. "With people working and commuting across greater distances than ever before, we believe the solution will bring mid-range cities like Seoul and Beijing, or London and Paris, closer together through all-electric air travel."

They want to do it with the Alice Commuter, an 11-seat (9 passengers, 2 crew), 250-knot electric aircraft with 3D-printed parts and two unique electric motors mounted at the tips of the wings.

Bar-Yohay said the original inspiration for the electric

Figure 1. Conceptual rendering of the Eviation Alice Commuter. (Image courtesy of Eviation)

airliner came from his work with the PPlane Project, a joint effort between the European Union and the United States to prepare for the future of aviation. His interest in electric planes was also stimulated by his work with A Better Place, a company that provided battery swaps for electric vehicles as a faster alternative to charging stations. His chance meeting with Aviv Tzidon, head of a company developing aluminum-air battery technology, who was interested in working on the electric aircraft helped set the project that would become Eviation in motion.

The project had several initial goals. The first was to create the Orca, a small-scale, remotely piloted aircraft with a scaled-down version of the propulsion system they plan to use in the production airliner. The next step was a one-third scale prototype they will use to verify many the design features of the actual plane.

To achieve their ambitious goals of a 250-knot cruise speed and a 600-mile range, Eviation's designers took a "clean-sheet" approach to the plane's shape, structure and propulsion systems, as well as the techniques they'd use to develop them. Figure 1 shows an artist's concept of the Eviation Alice Commuter.

A NOVEL STRATEGY FOR A NOVEL AIRCRAFT

"A trend in the last couple years is to look at what we can simulate and then go out and fly it," Bar-Yohay said. "Wind tunnels are good for answering very specific questions [and] computational fluid dynamics (CFD) simulation can allow you to predict what will happen, and then the ability to test data basically ends at the point where you have a three meter model. [Instead], we choose our airform with the wind tunnel to answer specific questions and then go out and fly it. It took some iterations, but in early 2016 we got to the point where we had a credible process with [a] highly directed design CFD cycle."

They repeated this process for the airfoils and the propeller. To address issues such as aeroelasticity, which is difficult or impossible to simulate, they did ground testing on critical components using prototypes built by FBM Composites.

The Eviation team also used this hybrid design process to create an airframe that would deliver the combination of high performance, comfort, and safety customers would want and expect from a high-tech commuter plane.

"It's a fast machine with high wing loading, which means the wing area compared to the rest of the plane is not very big," said Bar-Yohay. "It has closer wing loading to a business jet than a general aviation light aircraft. We did that because it's aerodynamic and efficient, but more important is the flight experience. We know from testing we get high stability and very nice flight behavior. It will be a very stable and fun plane to fly at relatively low altitude."

With several good ideas already in play, Eviation could choose from the ones that would best help them achieve one of their primary goals: making the plane fly as efficiently as possible at speeds equivalent to its turbine-powered competitors'.

"This is one of the amazing things when you start looking at propulsion. The design space really changes. Many ideas all probably have merit. Our goal was the most efficient flight we could get at roughly 250 knots. We have proven with the Orca that putting the wingtip front and center cuts through the wingtip vortex and reduces drag," Bar-Yohay said. "That is essentially 'regained' propulsion because we put the propeller at the apex of that vortex."

Bar-Yohay recalls that he told Eviation's design engineers "don't think about what you've done before. Think about the best place to put the propellers. And if you think you can't put a motor there, I don't want to hear about it. For decades we've been putting props where it makes sense to cool an engine, not where it makes sense to put a prop."

The weight, vibration, and cooling issues associated with piston and turbine power plants made wingtip-mounted props impractical, but a preliminary analysis showed that compact, cool-running electric motors might work. Re-thinking Orca's propeller placement paid off, and was one of several innovations that helped the aircraft achieve a theoretical lift-to-drag ratio of between 95 and 97 percent.

A larger pusher propeller in the plane's tail serves at its primary propulsion unit. In its normal flight mode, the plane will have all three motors running, but it can fly on either the wingtip motors or the tail motor under emergency conditions. If either wingtip motor fails, the other is shut down automatically during landing in order to prevent excessive yaw.

With propeller placement finalized, Eviation set out to find motors to drive them. Austrian-based Rotax, and Emrax, a Slovenian company known for its high-performance electric motors, powered the Orca drone. The one-third scale Alice prototype uses a set of hyper-efficient brushless DC electric motors from Britain-based YASA Motors. These cutting-edge motors all have impressive power/ weight ratios, ranging from 3 to 6 kilowatts per kilogram. For example, the YASA model 750 motor driving the scale model's tail prop weighs roughly 37 kilograms (81 pounds) and turns more than 95 percent of the 200 kW (over 250 HP) it consumes at peak output into thrust. Motor selection for the production aircraft has not been finalized with Siemens and YASA both under consideration.

The wingtip propellers are one of the most advanced aspects of the plane. They are in constant communication with the onboard computer that uses them to stabilize the plane in what Bar-Yohay calls "a complex system of pitch control." The fly-by-wire system can adjust the props' pitch and rotational speed up to 400 times per second to help the plane handle more predictably and cancel out the unwanted effects of gusts, control inputs, and other perturbations. The electronic controls will also eventually be able to configure the motors and propellers as "regenerative air brakes", capable of partially recharging the plane's batteries from the energy they capture as the plane slows or descends.

Bar-Yohay said that since all of Alice's controls will be fly-by-wire, they could easily be adapted for remote or autonomous operation.

"We're basically doing that because we can," he said with a chuckle in his voice. "When the plane is empty it should come back alone. That should save an insane amount of money, if we can do it in the existing regulatory environment. We're trying to be leaders in that but we have to build the plane first."

Figure 3. The ORCA drone helped verify much of the technology and construction techniques that will go into the Alice Commuter. (Image courtesy of OIDA Strategic Intelligence)

3D PRINTING IN FLIGHT

3D printing is playing an important role in the aircraft's development. "We have used a lot of 3D printing," said Bar-Yohay. "It occurred to us because we had access to a printer because of a company that was physically nearby." Once they saw how 3D printing could accelerate their development process, they teamed with 3D printer manufacturer Stratasys on a wide range of projects, including visualizing and creative prototyping of aerodynamic elements. "One of the easiest ways to validate parts such as the propeller is to build and fly it. So we decided to use 3D printing for this," he continued. In another example, while the team was waiting for the final motors to ship, Eviation printed up a set of stand-in units in a matter of hours.

One key part of the aircraft engineered with the help of 3D printing was the wingtip motor. Engineers produced a functional prototype in 20 hours using the Stratasys Fortus 450mc Production 3D Printer in FDM ABS material (see Fig. 2). Eviation Eviation also used 3D printed parts to make curved surfaces to reduce drag.

Some of the tooling for the Alice will also be 3D printed, beginning with many of the initial molds for test articles. Eviation is also planning printing much of the lay-up tooling used to form the aircraft's carbon composite hull and wings.

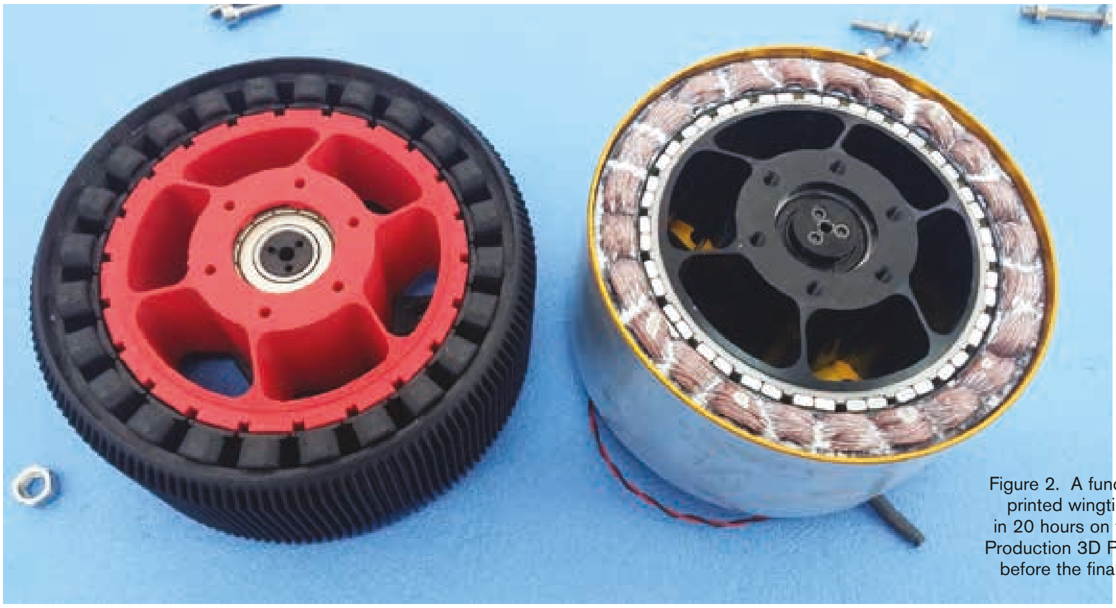

Figure 2. A functioning prototype of the 3D printed wingtip motor (left) was produced in 20 hours on the Stratasys Fortus 450mc Production 3D Printer in FDM ABS material, before the final motor (right) was available. (Image courtesy of Eviation)

Although Bar-Yohay emphasized he doesn't believe 3D printed plastic is strong enough to replace metal in most use cases "[but], when you want to build a light, tough, clever piece of plastic to say, demonstrate a partition in your battery or a part of your cabin, there's no better way to manufacture something light and complex." He added, "Today there are several printed parts in Orca," referring to several non-structural parts of the drone's hull and some aerodynamic fillets.

"There will be several in Alice. They're not weight-bearing, but they are parts that made sense to print. I believe we'll see more of this in Eviation and other companies."

POWERING ALICE

Eviation plans to use commercially available lithium-ion batteries to power its first production airliners, in large part because they are easiest to acquire and certify. As a result, the first-generation battery pack will comprise 63.5 percent of the aircraft's maximum takeoff weight, but subsequent developments that deliver higher energy densities will enable users to choose between a longer range or larger payload capacity. To minimize the potential for the thermal problems that some Li-Ion batteries are subject to, Eviation will actively cool their batteries with, as Bar-Yohay puts it, "a clever set of vapor chambers and liquid cooling solutions."

Eviation says that a state-of-the-art 400 kW charger will only need 40 minutes to pump enough power into the battery pack for an hour's worth of flight. Since nearly all flights will only use part of the battery's capacity, most recharge cycles will take much less than the 2.2 hours needed to go from fully drained to a full charge.

The company is also exploring aluminum air batteries under development by an Israeli startup called Phinergy as a future power option. These are not chargeable in the traditional sense, operating more like a fuel cell made of aluminum plates. Their chemistry enables extremely high energy densities but, for the moment, it remains a promising option to be explored once the technology matures a bit more and a path to certification is defined.

THE ECONOMICS OF ELECTRIC FLIGHT

Although electric aviation offers many potential environmental benefits, its most compelling argument is its ability to reduce aircraft operating costs by between 75 percent and 80 percent. Only part of the savings come from the lower cost per equivalent gallon of electricity versus aviation fuel. Additional savings are achieved by eliminating the complex turboprop power plants used by most competing aircraft. Besides having a purchase price that's a fraction of an equivalent-sized turboshaft engine, electric motors don't need the regular maintenance and periodic overhauls that add hundreds of dollars per hour to a turbine's operating costs. Even using today's Li-Ion battery technology, which will require replacement of the battery pack every 2-3,000 flight hours, Eviation expects that the plane's total DOC (direct operating costs) will fall below $200/hour in practically all territories. This translates to a per-seat-mile cost of $0.10 to $0.15, a small fraction of the cost for a Beechcraft King Air, Cessna 400 series, or other conventional aircraft of comparable speed and capacity.

As a result, Bar-Yohay said he believes that he can pitch customers on both the performance of their aircraft, and on what he calls "insurance" for the low direct operating costs. While petroleum-based aviation fuels will fluctuate wildly in cost as they inevitably become more expensive, he bets that Eviation can guarantee its aircraft will cost less to operate as battery technology improves.

Now that the the drone has verified the basic technology and the 1/3 scale model is complete, Eviation's next goal is to begin the construction of a full-scale prototype, which will be 12 meters long with a 15-meter wingspan. They hope to fly it by mid or late-2018 and apply for FAA certification and European certification in early 2019. Commercial production is anticipated to begin in 2021.

"You're gonna see a lot of fun machines out there," Bar-Yohay said when talking about the placement of the wingtip propellers. "Sooner than you think. And that's because this is possible." PDD