The Age of Electric Aviation Is Just 30 Years Away

Lilium Aviation

Every vision of the future of flight involves electric aircraft—air taxis hopping from one skyscraper to the next as airliners cruise silently over oceans. After all, what kind of future traveler would rely upon fossil fuels?

One who wants to go anywhere.

For all the hype electric aviation gets, the concepts put forth by aerospace companies and startups are just this side of impossible. Flying requires extraordinary amounts of energy, and doing so under electric power requires at least one massive leap forward in battery tech. Or, as aviation expert Richard Aboulafia puts it when reviewing yet another flying car idea: "Insert miracle."

The problem is, batteries simply do not offer the power-to-weight ratio or cost needed to be feasible, and will not for some time. The technological advancements that allowed Tesla to squeeze 335 miles from the Model S and Chevrolet to get 200 out of the Bolt are not enough to power anything more than the smallest aircraft for the shortest distance.

The question, then: Just how big a miracle does this flying future need, and how likely is it to get it?

A terrestrial survey offers reason for optimism. Tesla's most robust Model S sedan will go 335 miles on a charge, though it'll cost you six figures. Chevrolet is now selling the Bolt EV, a $30,000 compact car with 238 miles of range. This summer, Tesla should fire back with the Model 3, further solidifying the battery electric vehicle's status. Meanwhile, the gas-free aircraft closest to takeoff are one- and two-seaters best used for training, so they don't even have to venture from one airport to another.

“I think everyone looked at electric cars and thought it would play out the same with electric airplanes,” says Richard Pat Anderson, who runs the Flight Research Center at Embry-Riddle Aeronautical University. “But they have different requirements. Cars need batteries to be affordable and compact, but with airplanes we don't care about cost as much, or even volume. It's weight that's critical.”

Critical Density

The need to keep weight down without sacrificing range or power makes energy density the all-important figure. Right now, the specific energy of batteries is roughly 2 percent that of liquid fuel. Factor in the efficiency of electric powertrains compared to internal combustion engines, and yet get closer to 7 percent—so 1,000 pounds of jet fuel yields about 14 times more energy than a 1,000-pound battery.

“There’s already been a lot of progress,” says Venkat Srinivasan, a battery scientist at Argonne National Lab in Chicago. Battery energy density is rising by a non-negligible 2 to 3 percent per year. Tesla’s cars go farther with each iteration. “It’s not the same ballpark as Moore’s Law progress because it’s chemistry, not electronics, but it’s still very good.”

Besides, batteries don’t need to match liquid fuel pound for pound to catch on. If it can get to five times its current density—that would be 1,000 watt-hours per kilogram—it would work for small-scale commercial aviation, says Don Hillebrand, director of the Argonne's Center for Transportation Research. Estimated time of arrival: 2045.

“That 1000 watt-hours/kg number reflects the approximate equivalent of one third the energy density of gasoline, but that’s enough,” Hillebrand says. “At our current pace of innovation, and factoring the relative differences in efficiency of the powertrains, that’s when we can expect batteries to be good enough to power small aircraft for practical uses.”

Others suggest a shortcut of sorts. “Electric propulsion permits new design architectures,” says Venkat Viswanathan, a battery scientist at Carnegie Mellon University. “Future electric aircraft will look nothing like the aircraft of today, and they will be able to fly with much less energy—as little as 400 watt-hours/kg—thanks to distributed motors and reduced drag. We’ll redesign aircraft around electric motors.” Faster said than done. Because aircraft development times are measured in decades, it’s unlikely the planes Viswanathan imagines will arrive before those 1,000 watt-hours/kg batteries.

New Chemistries

So how do you get to that kind of energy density? The likeliest route is a new battery chemistry to unseat the current favorite, lithium-ion. Magnesium batteries excel in the density game, but the technology remains immature, and decades from commercial readiness. “Solid-state lithium is also kind of cool because it’s non-flammable, but it doesn’t have the cycle life,” Hillebrand says—meaning it loses its potency as it’s depleted and recharged. “Sodium-ion batteries are very exciting for their high cycle life, but their energy density is not very inspiring.”

Argonne’s Srinivasan bets some form of lithium-metal battery will be the next step. That’s based on the advances researchers have made in reducing “dendrites,” which can form in batteries over the course of many charge and discharge cycles. They can cause short circuits, which in turn can lead to fires. “The last five years have seen tremendous progress,” Srinivasan says. “Five years ago I wasn’t optimistic, but now I’m very optimistic that lithium-metal could work.”

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Argonne National Lab

Once that problem is solved, he says, it could open the door for more materials, including sulfur or oxygen. This latter is the potential solution being chased most aggressively by Viswanathan and his colleagues at Carnegie Mellon, who are pursuing a lithium-oxygen battery that could prove perfect for aviation.

“A lithium-air battery, as it’s called, could reach an energy density of 400 watt-hours/kg, which would enable flights of

Battery Scientist Venkat Srinivasan

200 to 400 miles," Viswanathan says. That won't get you across the ocean, but it would cover plenty of short distance routes.

The key enabler here is that oxygen dissolves in the electrolyte between the battery's anode and cathode, potentially providing a more stable electrolyte that can withstand harsh charging and discharging environments. And many aircraft already carry the pure oxygen the system needs to operate. "It naturally integrates with the system," Viswanathan says, adding that the oxygen that's pumped in during discharge is recovered while charging, and can thus be reused.

Still, there's a gulf between a viable technology and one that's ready for commercial applications. "We need something practical. It needs cooling. It needs to fit in a box. All that puts a drag on weight and volume," says Argonne's Srinivasan. "Our job here is to look at technologies and work to scale them. But it takes time for a breakthrough in the lab to be marketable, and also buildable in large enough quantities to satisfy the market forces."

It doesn't help that battery research is dispersed among secretive corporate efforts and more open university labs, making it difficult for breakthroughs and market forces to sync up. Compared to the more open semiconductor industry, battery tech lacks a community effort. "We need an ecosystem like the semiconductor guys have," Srinivasan says. "We need a close connection between scientists like me trying to invent something, and companies working with those scientists, all driven by the market. It's the only way to get there."

Sure, battery researchers face an immense challenge. But there's reason to hope even today's disjointed efforts will pay off. "Autonomy, for instance, in both cars and aircraft, will be the great enabler of electrification," Hillebrand says. Mastery of autonomous navigation will encourage the development of drone taxis. That will push electrification, which has extra appeal in an urban network. "All things start to converge at some point. Autonomous vehicle technology, electric vehicles, drone development, and electric aviation will all enable each other, and may be pushing these technologies along faster than anybody realizes."

Check back in around 2045.