The Quiet Revolution:

Aviation Prepares to Go From Jet Age to Electric Era of Flight

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Electric aircraft were once a hobbyist's fancy in the pursuit of fuel-free and near-silent flight. Today, electric-propulsion aircraft projects are drawing serious investment and attention from a wide range of industry stakeholders – including the world's largest aerospace companies, a crop of longtime electric aircraft pioneers, as well as new upstart players – all poised to usher aviation into a new era as transformational as the dawn of the Jet Age nearly 70 years ago.

Most plans today involve integrating an electric motor into an aircraft design in order to eliminate the use of conventional jet turbine or turboprop engines; some designs follow a hybrid propulsion model akin to passenger vehicles like the Toyota Prius. The stakes for such technological progress toward cleaner and cheaper operations are high for the aerospace industry: US airlines spent $133 billion on fuel in 2016, and the turbofan engine market is worth an estimated $950 billion over the next ten years[1]. It also could lead to a re-thinking of airports and transportation infrastructure, revitalizing short-haul flight in the U.S and helping open air travel to underserved regions worldwide.

Real progress with electric aircraft is evident as companies build on a legacy established by small firms like Pipistrel that have spent the last decade building electric light sport aircraft and gliders for amateur pilots, while also supporting larger-scale demonstration projects. The state of the art today is a two-seater aircraft that can fly 75 minutes with two electric motors, rated between 30 to 40 kilowatts.

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Engines that are 150 to 300 times more powerful will be required for two- to four-hour all-electric commercial flights, so that future may still be a couple decades away. Hybrid architectures, however, provide a more realistic, near-term path for passenger aircraft. At the rate that key enabling technologies are improving – most notably, batteries and high-power electric motors – 50 to 70-passenger regional aircraft could be entering airline fleets as early as 2030. This evolution is a natural – and necessary – one driven not only by battery, motor, and other technical innovations, but also new environmental and economic imperatives.

Going Green, Seeing Green

The quest for an alternative to fossil-fuels is intensifying. It's not just in commercial aviation. The US military is even in on the hunt, testing a synthetic-fuel B-1 strategic bomber for the government's thirstiest user, the Air Force, in 2008. There are differently operational incentives for the commercial aerospace industry, and the tradeoffs for electric-powered flight suit these priorities: Airlines want to fly cleaner, quieter, and more profitably as demand for air travel booms around the world. Ambitious growth plans being hatched in boardrooms depend on it due to a mix of new self-imposed industry rules and government regulations, as well as higher operating standards and a growing roster of global competitors.

The shift on emissions is led from within the aviation industry and involves long-term and near-term steps: the International Air Transport Association pledges to halve emissions from 2005 levels by 2050 because of concern about member airlines' greenhouse gas emissions contributing to global warming. The International Civil Aviation Organization recently announced an emission offset program designed to spur advances in technology, yet also forces airlines to evolve the operational fundamentals of their business. The Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) will begin a pilot phase in 2021.

The move toward environment reforms comes as air traffic worldwide surges at a rate that will see it double during the next 20 years, according to IATA. Airports and their surrounding communities, however, risk bearing the burden of this world-changing expansion because of noise pollution from arriving and departing flights. Indeed, noise concerns are a consistent issue for communities considering whether nearby airports should expand or even be allowed to continue to operate at all. The BBC found that Heathrow International Airport in the UK receives a noise complaint every five minutes. ICAO's approach is to set a new standard for more restrictive aircraft noise limits that goes into effect next year.

With electric propulsion, such "green" gains may offer meaningful bottom-line benefits. Some of this savings will be passed along to consumers who in recent years have seen ticket prices buffeted by fuel surcharges and oil-market driven ticket price volatility. It also could open up air travel to underserved or untapped markets in South America, Asia or Africa, where commercial air transport is financially out of reach. According to NASA, aircraft operating costs could be cut by 30% on planes with electric propulsion. This would come from ditching aviation fuel but also because innovative aircraft designs may yield aerodynamic benefits, owing to the lower profile and distributed arrangements possible with more electric architectures. By how much remains to be seen, but the industry is setting high expectations. Zunum Aero, an electric-aircraft startup partnered with Boeing and Jet Blue Ventures, believes hybrid-electric planes could dramatically lower ticket prices -- by as much as 80%.

Leading the Charge

To reach these ambitious economic and environmental goals, the aviation industry still has to cross certain technological boundaries. Yet there is a clear vision today of how electric propulsion is going to be achievable during the next 10 to 20 years.

The most likely segment of the industry to see such breakthroughs is the commuter and regional jet category, perhaps as soon as a decade away. Whether these planes will be all electric remains to be seen. The most likely outcome for a mass-produced aircraft that inaugurates aviation's "Electric Era" is one with a hybrid-propulsion design, blending refinements in conventional fossil-fuel engines with the leap-ahead potential of electric propulsion.

The small companies that helped lift the electric-propulsion aircraft field to its current state now count the aviation industry's biggest players, including Airbus and Boeing, as peers and competitors.

Until recently, Airbus had been the most visible of the major aircraft manufacturers in the sector. It has established a range of notable partnerships, including an "eThrust" research initiative with Rolls Royce and a series of relationships with smaller e-flight innovators such as Pipistrel and Diamond Aircraft. Yet Airbus' high-profile strategic engagement with industrial giant Siemens has truly

Recent technological developments making e-flight a reality

- Better batteries
- Lower weight materials
- Higher power electric motors
- Power conversion
- New design theories

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helped establish its role as a leading e-Aircraft evangelist. In July 2016, Siemens successfully demonstrated a 260 kW continuous-power motor in a light sport aircraft. With five times greater power than comparable drive systems, the groundbreaking motor will be incorporated into aircraft co-development activities with Airbus. Although Airbus, with the help of Siemens, currently has set the development pace thus far, Boeing is determined to not be outdone by its European foe. In April 2017, Boeing announced an investment in hybrid-electric aviation start-up Zunum Aero, swiftly thrusting the US aerospace giant more visibly into the fray. Notably, and perhaps not coincidentally, Airbus' nearly simultaneous decision to abandon its focus on two- to four-seat "eFan" aircraft production efforts and turn instead to commercial transport applications has all but confirmed that this transatlantic rivalry will live on during the electric era.

While Airbus and Boeing have captured most of the spotlight, other legacy aerospace firms, including Sikorsky, United Technologies Aerospace Systems (UTAS), Honeywell, and GE Aviation, have either been involved in technology demonstrations or publicly expressed interest in electric and hybrid-electric technology. NASA has been a major champion of e-aircraft design research, and several research institutions across the globe have also pursued various technology development projects, such as the University of Tennessee, University of Pisa, and the University of Cambridge.

The growing involvement of players outside the traditional aerospace supply chain is one of the clearest signs that electric aircraft are poised to disrupt aviation and transportation writ large. A notable, albeit smaller scale example of this includes Uber's announcement that it would begin working with Brazilian airplane manufacturer Embraer to develop small electric Vertical Takeoff and Landing (VTOL) transports. Elon Musk has also thrown Tesla's hat in the mix, recently telling shareholders that developing an electric plane is a conceivable future step. Meanwhile, cutting edge airlines such as JetBlue and EasyJet have established partnerships with other Silicon Valley electric aviation start-ups - Zunum (with co-investor Boeing) and Wright Electric, respectively.

Disruptors also may be waiting in the wings. While there are novel flight innovations coming out of China, such as the electric EHANG 184 autonomous passenger quadcopter, large-scale moves toward electric or hybrid-electric commercial aircraft have yet to take place. However, the nation's aerospace industry bears watching, as the high-technology and electronics manufacturing sector within China offers a potentially formidable resource for indigenous aerospace companies or contract manufacturers

that seek to shake up traditional production models. As an example, Chinese firms such as CATL – and the country's leadership in Beijing – reportedly see opportunity in the electric car battery market and are investing accordingly to create a dominant high-capacity battery market position in Asia.

Breaking the Now Barrier: Batteries, Aerodynamics and Energy Conversion

Many of these early initiatives still reflect a measure of caution by the industry's largest players, as they follow in the footsteps of many other small ventures that have come and gone in attempts to bring electric power to aviation. But in 2017, the path to successful commercialization is easier to see than it ever has been. There is a growing chorus of advocates beyond the start-up visionaries and industry champions seeking to revolutionize aviation.

Though for all the alacrity to become the Electric Era of Flight's pioneers, it is important for innovators to acknowledge a number of technical challenges that still must be resolved in order to realize the vision of hybrid-electric air transport in 2030.

None of the following pose an insurmountable challenge but to break through will require capital and time focused on the right problems first.

Technical Challenges:

Batteries

Batteries and energy storage are the key to making electric and hybrid-electric flight a reality. Without progress in batteries, electric aircraft will struggle to break out of their niche. Currently, a two-passenger aircraft can fly about 200 miles for two hours, reflecting the limits of about 200 kW per hour. NASA researchers[2] believe that improvement in battery technology needs to occur at an 8% rate in order to make a nine-passenger aircraft powered by 250 Whr/kg (watts per hour – per kilogram)[3] batteries viable within five to seven years. By comparison, the Tesla cars on the road today use 250 Whr/kg batteries.[4] There are skeptics that this gap can be bridged so quickly. While this is a valid concern, it also underscores the potential of hybrid-electric aircraft that can be put into service sooner rather than waiting until battery technology is perfected.

Aerodynamics

Electric propulsion systems may afford aircraft designers new possibilities in terms of designing this next era's iconic planes, namely through smaller but more numerous propulsors rather than the twin-engine paradigm that is the norm today in commercial air transport. Imagine looking from your seat out to the wing and seeing a half dozen small propellers arrayed laterally across the wing's leading edge – or even the fuselage.[5] This arrangement helps a plane increase lift at lower speeds, which is more efficient. A key concept is Boundary-Layer Ingestion, which involves essentially putting the propellers flush with the airframe and changing airflow around the wing.[6] These benefits are important because they can meaningfully lower the amount of power required through reduced drag. Given the weight of batteries and the complexities of building a low-weight, high-power motor, composites and other lightweight materials will play crucial roles cutting the weight of wiring, aero-structures, and interiors.[7]

Energy Conversion

Certain key breakthroughs will be invisible, but no less important than the potentially stunning changes to aircraft design. When it comes to energy conversion moving power from batteries to onboard systems and propulsors, electrical and power management architectures are an integral but easily overlooked set of technologies. Taking power stored in a battery and getting as much of it as possible – ideally all of it – to its destination is a big leap from current capabilities.[8] This will require new semiconductor designs, among other discoveries.[9] Given the critical importance of passenger and crew safety, as well as reliability, circuit protection poses another technical challenge; another current task for researchers is the development of inverters that can safely handle Megawatt levels of power in the confines of an aircraft fuselage.[10]

Aerospace Suppliers Can Expect a Jolt

With such notable changes coming to aircraft design and performance, the impact on the aerospace industry will be significant and widespread. The most obvious effect will be on the aircraft supply base, as the shift from a mechanical aircraft architecture to a more electric one will reduce and eventually eliminate turbofan engines and a myriad of associated high-value parts (e.g., disks, fan blades, shafts, etc.). An increase in available electric power will further erode hydraulic and other electromechanical component requirements – helping reduce an airline's maintenance bill as the number of moving parts falls, but potentially putting many suppliers and repair shops under duress. As well, new engineering and economic factors will influence the design and production of cockpit displays, control systems as well as passenger interior components and systems.

The Electric Era will mean disruption beyond just manufacturing and will likely have an impact across the entire commercial aerospace economic lifecycle. For one, the supporting infrastructure for hybrid aircraft and e-jets will require a massive overhaul, as jet fuel demand wanes and demand for new electric charging methods surges. New maintenance, repair and overhaul (MRO) regulations, processes, capabilities and skill sets will be required to sustain a completely unique fleet type. A wide range of financial assumptions will need to be closely scrutinized, as well: reduced airline operating costs could enable greater reinvestment and faster technology improvement cycles. Yet a spike in demand for specialized new materials like rare earth metals for batteries could inflate manufacturing costs. In addition, traditional supply chain inventories and assets over time could become liabilities as the global fleet mix adjusts to this new era.

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At the Threshold of a New Era

Although a number of technical challenges must be solved before the first hybrid-electric passenger aircraft takes to the skies, the Electric Era of Flight is coming sooner than many may think possible. Industry heavyweights and new contenders alike are beginning to make sizable investments as they look to establish an early foothold in this future landscape.

For well-established aerospace competitors, ongoing analyses of the stakeholder landscape and electric aircraft architectures will be essential building blocks of an early-stage strategy. Portfolio risk will not change overnight, but the growing momentum means leaders need to understand how current engineering and manufacturing capabilities will align in the Electric Era, while also recognizing where current product or service positions risk displacement.

Start-ups and new aerospace entrants can literally create new markets with breakthrough concepts and demonstrators. But they must carefully pilot a course through a complex regulatory environment, high-barriers to entry and long development timelines. Building a go-to-market approach based on a thorough assessment of investment and regulatory requirements, viable on-ramp projects, and industry partnerships can pay long term dividends even when facing strategic, operational, and financial challenges.

All this points to the threshold at which the aerospace industry finds itself when it comes to electric propulsion. It is a moment when aviation's dreamers can join legacy aerospace champions in seeing their greatest ambitions transformed into business plans that can revolutionize commercial flight.

About the Author

Jay Carmel is a Senior Associate at Avascent, where he leads Avascent's aerospace practice. He specializes in delivering strategic growth, value capture, and M&A due diligence services to firms and financial sponsors that require insights on the commercial, civil, and military aviation domains. Jay supports a wide range of clients across numerous market segments, including tier 2/3 component manufacturers looking to solidify their growth strategies, as well as avionics OEMs and network specialists that require an improved understanding of the aircraft connectivity landscape. Jay also serves both private equity investors and major aircraft systems providers with acquisition screening and M&A due diligence analyses.

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Endnotes

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