

# Electric Airports

In the next few years, it is highly likely that the global aircraft fleet will undergo a transformative change, changing air travel for everyone. This is a result of advances in battery technology, which are making the viability of electric aircraft attractive to industry leaders and startups. The reasons for switching from a fossil-fueled to electric powertrain are not simply environmental, though aircraft do currently contribute around 3% of global carbon dioxide emissions [1]. Electric aircraft will provide convenient, comfortable, cheap and fast transportation for all. This promise provides a powerful incentive for large companies such as Airbus and many small startups to work on producing compelling electric aircraft.

There are a number of fundamental characteristics that make electric aircraft appealing. The most intuitive is that they are predicted to produce very little noise, as the propulsion system does not rely on violent combustion [2]. This makes flying much quieter for both passengers and people around airports. As they do not need oxygen for burning jet fuel, they can fly much higher, which in turn will make them faster than today's aircraft as air resistance decreases with altitude [3].

The most exciting characteristic is that electric aircraft could make vertical take-off and landing, or VTOL, flight a possibility for everyone. Aircraft currently take off using a long runway strip, gaining speed until there is enough airflow over the wings to fly. It obviously doesn't have to be this way, as helicopters have clearly demonstrated. You can just take off vertically. Though helicopters are far too expensive and slow for us to use them as airliners. The aviation industry has been working on a vertical take-off and landing airliner for decades, but nothing has ever been deployed at mass scale. With traditional fossil fuel jet turbines or piston engines, VTOL is noisy, and is complicated by the re-ingestion of hot air from the engine. Electric aircraft solve the noise and hot air re-ingestion issues, making VTOL possible.

The use of stored electricity rather than fossil fuel and the capability for VTOL flight are the two components that will make electric aircraft better on the ground. Just these two characteristics could make airports radically different in the future.

Most aircraft today take off and land laterally, using tremendous horizontal speed to create vertical lift. A typical Boeing 737-800 airliner will take off at 250 km/h, necessitating a runway length of around 1.7 km. For landing, the same aircraft requires a minimum runway length of 2.6 km, as it lands at around 270 km/h [4]. It is useless having a runway shorter than that which you need for takeoff, so the takeoff length is usually built. Also, we're dealing with minimums here; the lightest aircraft, in the best weather conditions, taking off from sea level where lift is best. Most airports that service airliners do not have runways this short; for example, the Boston Logan runway is 3,050 m long and New York's JFK main runway is 4,423 m long [5,6]. These long runways comprise the majority of an airport's land.

With a VTOL aircraft, the landing area need not be a factor of 2 or 3 larger than the aircraft itself. This means that airports could be made radically smaller, eliminating the long runways and safety areas associated with high approach speeds. Aircraft would land by coming to a hover during their approach to the airport and then steadying themselves over the landing pad, much like a helicopter or a Harrier Jump Jet does on an aircraft carrier today [7].

To laterally land safely, an aircraft must approach the airport at a low angle. For the Boeing 737-800, this is between 3.25 and 2.5 degrees [8]. This imposes height restrictions on surrounding buildings, especially around city airports [9].

As it would not be relying on aerodynamic lift for its approach, instead utilizing thrust from fans or blades to stay aloft, a VTOL aircraft would not have to glide in to an airport like today's airliners. Instead it could descend steeply from altitude, avoiding any ground obstructions, allowing development around airports, and placement of airports in new areas [10]. Communities in mountainous regions find it difficult to travel due to the difficulty of building airports that fit in with the terrain. VTOL aircraft could eliminate this problem, as a concrete pad could be squeezed into a valley that would be treacherous for a lateral landing.

A subtle problem with landing laterally is the dependence on weather. When an aircraft is approaching at high speed, it can only tolerate a certain amount of cross wind. During a crosswind approach, an aircraft can crab, turning slightly into the wind to counter its drift effect. In flight, an airliner can crab into almost any wind, however when it lands it must line up parallel to the runway for touchdown, as the landing gear suspension can only take a minimal amount of side load. As an airliner has a limited turn rate, therefore there is a maximum crosswind limitation that is completed unrelated to pilot skill [11]. Because of this, most airports have two or more runways that are perpendicular to each other, effectively doubling the land area requirement.

Because it does not need to line up with a runway, a VTOL aircraft would not have this problem. A landing pad is not directional, allowing an electric jet to approach from the best possible angle according to the wind conditions, without fear of a dangerous crosswind [12].

Safety is also an issue with lateral landing. The most dangerous periods of any flight are immediately after takeoff and during landing [13]. The safety problems with lateral take-off do not arise from the lateral take-off itself, but rather from the difficulty of landing if an engine failure occurs. There is a period where an aircraft does not have enough height to glide back to a runway if it loses power, and if the engines fail during this period the outcome is usually a disastrous accident for people onboard the plane and on the ground. This has been avoided occasionally, such as in the recent Hudson river landing incident, but such scenarios are rare.

At first it seems that VTOL aircraft would be much more dangerous if they lost power during take off or immediately before landing. Whilst they offer little safety improvement in the landing scenario, they could be better during take off. When an aircraft loses power at altitude, it has gravitational potential energy. In a traditional lateral landing aircraft, this is either used to glide the aircraft back to a runway for a landing, or to provide the speed for a

deadly collision with the ground. Helicopters, a modern example of VTOL aircraft, have a way of using this gravitational potential energy to avoid fatalities with engine power loss above a certain height. When power is lost, the blades are kept spinning by changing their angle and are actually accelerated as the helicopter drops through the air. Just before the helicopter reaches the ground, the pilot adjusts the angle of the blades so that they push air downwards with the energy they have recovered through spinning up whilst falling. This allows for a smooth landing, and is so safe that helicopter pilots routinely practise it as part of their ongoing training [14]. It is dependent on height however, as there is a height at which too little energy is recovered to maintain a survivable speed before impact. Even with moderate diameter electric ducted fan motors, such an approach is quite feasible. Unless the fan itself is jammed, the fan could be spun up by the airflow, recharging a supercapacitor or emergency battery system that would then pulse thrust to cushion a landing. This would mean that above a certain height, VTOL aircraft may actually be safer than their lateral landing counterparts.

Statistically, landing is the most dangerous part of flight [13]. That is if we look at danger from the fatalities probability perspective. One of the main reasons why landing is so dangerous is that it involves a rapid impact between an aircraft and the ground. Every time an aircraft touches down on a runway, its wheels must accelerate up to the landing speed, which can be 270 km/h in the case of the Boeing 737-800, as discussed before [4]. On touchdown, the landing gear suspension must absorb the weight of 50 tons. In many ways, the current way of landing aircraft is a bit like jumping off a speedboat with water skis. If you are skilled and everything goes to plan, you will slow down reasonably smoothly and safely. However, if anything goes wrong, there is an enormous amount of energy in the system that can wreak havoc. It is quite easy to faceplant into the water.

Meeting the runway at just the right angle and time is not a trivial task. Especially in bad weather, experienced pilots can be misled and impact the ground at full speed just before the runway. Bad weather is not necessary for an early impact however, as the phenomenon of microbursts can also cause aircraft to rapidly drop during the final phases of approach. Even if the pilot gets the aircraft down on the runway safely, there still remains the task of decelerating a massive vehicle from a great speed. There have been many cases of aircraft overrunning the runway due to ice, brake failures or wet weather, despite the redundancy and power of modern braking systems [13].

If lateral landing is like jumping off a speedboat with waterskis, then a VTOL landing is similar to climbing down a ladder. The descent can be smoothly controlled, and if anything goes wrong, the aircraft can maintain the hover or abort to another location. There is no critical decision point, unlike with many scenarios in lateral landing. Large braking systems are not required to convert landing kinetic energy into heat, nor is there a risk of missing the runway, as a pilot can eyeball their target for a few minutes in bad weather [15].

One aspect of modern airports that is much more obvious to passengers than safety problems is queueing. Because it would be wildly inefficient to only allow one aircraft to use the entire airport at a time, airports have separate gate servicing areas and runways.

Connecting these two components are taxiways, which are usually quite long and add to flight times and emissions [16].

Airports currently have many more gates than runways, because it would be very inefficient to build a runway for each gate, and the runways would be under utilized. The main reason why this would be impractical is the area requirements of a runway, as we discussed earlier. A runway for every gate would eliminate queuing and taxi times, but would make airports much more vast than they currently are. For maximizing efficiency, it is optimal to have a high runway to gate ratio. Though in practice the runway to gate ratio is very low due to area limitations, leading to the problem of queuing. As we all know, the high demand for runways and the restricted supply can lead to long delays where the aircraft is stuck on the ground, burning fuel and money for the airline, and wasting the time of passengers. In fact, if you eliminated all queuing from airports in the New York City region you would save around \$2.6 billion dollars a year in the regional economy [17]. That statistic is absolutely nuts.

Because VTOL aircraft only require a small landing area, it may be possible to decrease the effective gate to runway ratio whilst keeping an airport compact. This could drastically reduce taxiway queuing times.

The sight of aircraft sitting lined up is frustrating for anyone, but there is a more subtle inefficiency that most people don't see. It happens in the skies, and can only be seen sometimes in the traces of contrails. For a lateral landing, an aircraft needs to be lined up many kilometers in advance. Air traffic controllers must coordinate this line up with many aircraft, and can usually only use a handful of runways to land aircraft. This means that they must often put aircraft in holding patterns, like delays on the ground, which is a waste of passenger's time, causes extra greenhouse gas emissions and costs an airline money [18].

As an aircraft approaching an electric airport would have a variety of approach paths and landing pads to choose from, it would be much less likely that it would need to queue in the air, allowing for higher traffic volume.

So what will the airport of the future look like? We must be careful with future predictions, as they will never be quite right, and will certainly not be right if we just assume that they will come true [19]. However, if we are industrious and work towards it, the global aviation system could look very different by the halfway point of this century.

The main point that has been made here is that the potential VTOL capability of electric aircraft holds enormous potential. However, the potential upsides to VTOL have been known about since as early as the 1960s, with studies such as Project Hummingbird [20]. The idea that VTOL could be a wonderful technology is nothing new. Visions of compact, efficient airports have been the dream of airport designers for decades, but they haven't come to be as a hovering fossil fuel airliner is not an appealing prospect. Electric aircraft could finally make that dream real.

Some of these plans, especially those put forth through 1940-1945, involve the idea of a vertical skyscraper airport [21,22]. The idea is a building comprised of an aircraft landing

area on the roof, then boarding, maintenance and parking facilities on lower floors. Such an airport would be very convenient for travellers and would increase airline revenues by making the possibility of travelling to another city for the day more appealing. Imagine touching down and strolling out of the airport into Central Park. That was the promise.

Experts in the aviation industry quickly identified the noise and pollution problems with such a facility. An airliner taking off would disturb office workers throughout the city, and the hot exhaust gases would make what is already an unhealthy environment much worse. Electric aircraft, however, could make this particular type of airport possible, with their low noise and emissions.

Locating an airport within a city center would also eliminate the need for train lines, highways or other expensive transport infrastructure required to move people out to the airport complex. It would be feasible for some people to head to the airport on foot or a bicycle. A city airport would also free up land outside the city for other uses, such as housing for city workers.

Currently, to get to an airport one must make the journey out of the city to a large, often depressing area crowded with travellers. In theory, that could be reduced to a short ride on the subway or a stroll outside and an escalator ride to the top of a building. It would be about as close as you could get to “Beam me up, Scotty” without real teleportation.

That is how I see the airport of the future. A special city building with clean, quiet aircraft efficiently arriving and departing, peacefully providing society with rapid transport. This dream depends on the full development and adoption of electric aircraft with VTOL capability, something that is within our reach. The airport of the future could actually be somewhere you want to go, not a depressing place you pass through.

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