Airports and the rise of eVTOL

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Abstract

A new form of aircraft — electric Vertical Take-off and Landing (eVTOL) — holds the potential to upend the transportation industry. Some eVTOLs are crosses between a helicopter and a traditional aeroplane, combining the vertical take-off of helicopters with the horizontal flight of aeroplanes. Others take on a more drone-like appearance. They are the next wave in aviation innovation and are expected to be flying as soon as 2025. As with any new and evolving industry, there are a myriad of questions to be answered. Here we discuss the advent of the eVTOL industry, why airports should be paying attention, and the impacts this new form of transportation may have on airports and their functions, including eVTOL-specific energy, aviation, regulation, emergency and infrastructure needs.

Keywords

eVTOL, energy, infrastructure, regulation, commercial, aviation, emergency

INTRODUCTION

Technological advances are ushering in a new form of transportation called electric Vertical Take-Off and Landing (eVTOL) aircraft, that, with the speed of a racing car, hold the potential to whisk people to destinations affordably and accessibly. This burgeoning wholly electric transportation form takes on different designs. While all eVTOL designs consist of aircraft with multiple engines, they may take on different shapes and sizes. Some are crosses between a helicopter and a traditional aeroplane — combining the vertical take-off of helicopters with the horizontal flight of aeroplanes. Others take on a more drone-like appearance.

With roots stemming from tiltrotors used in the military, as well as from the newly emerged drone industry, eVTOLs may fly like traditional Aeroplanes and helicopters, but they have major differences — most notably, eVTOLs are powered by electricity that is stored in batteries on board, which reduces their carbon emissions resulting from flight. With the capacity to carry up to six passengers, eVTOLs are often considered the equivalent of flying cars, with their ability to take off and land in untraditional locations, facilitating connections between and within rural and urban areas. And, because they are powered by electricity, eVTOLs are also quieter than traditional helicopters or aeroplanes. Considered a possible alternative for car, rail, or even regional aeroplane travel, eVTOLs have a shorter range than traditional aircraft but can effectively provide intercity and intracity transportation — an eVTOL recently flew 150 miles on a single battery charge[1] and another completed a 1,400-mile trip by flying seven 200-mile legs.[2] The maturation of the eVTOL industry holds great implications for the airport industry and yet few are developing plans to integrate these aircraft into their transportation network.

This paper discusses why airports should be interested and paying attention to this new industry, along with the associated developments in energy, infrastructure, aviation and regulation and the questions that still must be answered to make this revolution a reality.

A NEW INDUSTRY WITH NEW OPPORTUNITIES

While many airport operators are sceptical about the feasibility of this new transportation mode, demonstrable improvements in eVTOL design — as well as plans to create adaptable airports known as vertiports on unconventional small flat land areas in settings like high-rise rooftops, multi-storey car parks, shopping malls, or even platforms out at sea — are driving exponential growth in the eVTOL market. The global industry is expected to reach US$55bn by 2030 and US$1tn by 2040.[3]

According to a McKinsey report,

> Efforts to build vertiports are already underway. In the USA, air taxi developers Archer Aviation[4] [Figure 1] and Joby Aviation[5] have said they intend to develop a network of vertiports in multiple cities. They're expected to begin offering flights as soon as 2024. Worldwide, a division of Hyundai and U.K.-startup Urban-Air Port, announced their intention to build 65 international 'electric air mobility hubs' by the end of 2026.[6]

These aircraft present opportunities and obstacles for airport operations.

Figure 1 eVTOL image courtesy of Archer Aviation

eVTOLs can broaden airport catchment through their ability to land in small, unconventional spaces and by using them as short-hop air taxis. While initially costly, these vehicles are designed for widespread public use — at operational maturity, an eVTOL fare is expected to be priced about the same as an UberXL or Lyft and can cut a typical one-hour commute by train or car to a ten-minute hop, making them a competitive transportation option. eVTOLs have the additional advantage of providing point-to-point travel, meaning they are more flexible than current transportation infrastructure options such as rail, which must grapple with manoeuvering around towns and mountains while also contending with the contours of the land.

Whether it is revenue from operations or take-off and landing fees, and depending on the business model, eVTOLs can also provide airports with an additional revenue source; for example, with vertiports that provide passenger services such as dining and shopping. Larger airports could eventually replace regional aeroplane routes with eVTOL passenger transportation. eVTOLs can take off and land in tight spots, providing a unique capability to quickly move freight in and out of difficult to access rural areas to airports where, when needed, goods can be transported across countries and continents.

The other important consideration for airport operators is that, at present, most eVTOL orders are from airlines, meaning their key customers are scaling up for this new technology. A few major US air carriers have signed provisional purchase agreements with eVTOL companies that plan to manufacture once the aircraft are properly certified. Many of these agreements are based on the business model that eVTOL air taxis would be used to transport passengers to and from urban airports, providing point-to-point access to airliners for long-distance travel. To be ahead of the game, airports need to help these clients advance the process by providing the facilities and required infrastructure for eVTOL operations.

Currently, there are two potential models of service for eVTOLs. They might operate on a schedule, seamlessly linking passengers to their scheduled commercial flight. Or they might operate in a mobility-as-a-service mode, where passengers would book the aircraft to arrive on their own individual schedules, like using Lyft or Uber. The actual form that might take could vary from location to location, depending on local needs and regulations. Logically, the first eVTOL operators are expected to be airlines, because they already own the customer base and have a relationship with the early adopters that allows integrated point-to-point travel.

This industry is new and the seamless transfer of business model knowledge from current air cargo or airline operations to this emerging industry may not be as simple as expected. Aviation industry executives will need to be open to new ideas and have the flexibility to enable this innovative new industry — which has already disturbed the norm in many good ways — to flourish. Over time, as the model grows beyond airports as the origin and destination, platforms such as Uber and Lyft are likely to emerge as operators.

Freight and cargo movement are currently at the forefront of the eVTOL industry and making room for these aircraft may be another consideration for airport owners and operators. With dramatic increases in e-commerce and time sensitivity, eVTOLs can help speed movement of goods to full freight flights. Shipping and shopping firms such as FedEx, UPS and Amazon are looking into integrating eVTOLs into their feeder

routes to enhance their shipping networks. These initial eVTOL aircraft may provide further insight into use cases and operations, expanding the understanding of best practices for the industry as it develops.

While eVTOLs generally present opportunities for airport operators, there are some obstacles. For example, on shorter journeys these aircraft may eventually enable travellers to bypass airports. This may be more of a future concern as eVTOLs evolve and their range expands. Few regional flights are less than 200 miles, and while an eVTOL recently flew several 200-mile legs, generally the aircraft are currently limited to about 150 miles. But range expansion for eVTOLs is thought to be a when and not an if. And when this does occur, these vehicles may be in competition with regional airlines, as travellers may prefer to take a direct flight on an eVTOL.

DEVELOPING INFRASTRUCTURE

As with any new industry, building infrastructure is an important component and a factor that airport operators and eVTOL developers may have to work on together. In this instance, infrastructure priorities take two forms: developing vertiports, which are needed for passenger access and aircraft maintenance, and establishing the energy infrastructure that makes charging these new electric vehicles possible.

Some eVTOL developers envision a network of vertiports around city peripheries using existing infrastructure that will then feed into the major airports. These vertiports may be sited atop existing infrastructure, such as multi-storey car parks or buildings that may already have the capability to support helipads or can easily retrofit to enable this capability. One such example is in São Paulo, Brazil, where a consortium comprising Avolon, Corporación América Airports, GOL, Grupo Comporte and Vertical Aerospace have partnered to study the requirements needed to develop infrastructure that would bring electric passenger flights to Brazil within the decade.

The question for airport operators considering eVTOLs is how to best integrate vertiports onsite at the airport and the role of eVTOL manufacturers and developers in this process. Currently, the vertiport standards are being revised to better fit this new industry. The US Federal Aviation Administration (FAA) and the European Union Aviation Safety Agency (EASA) continue to work through regulations on this nascent industry. What is clear is that vertiports will be customised and are dependent on available airport land. Airports situated in areas where land is at a premium may consider repurposing an existing structure, for example, on top of hangars and an adjacent space. Alternatively, where land is more available, operators may opt to build a new facility.

Amenities present additional questions that are yet to have definitive answers. Will the vertiport have the same sorts of amenities that a traditional airport might have to capture additional revenue streams? Here, the eVTOL trip duration may factor in. Amenities might not be needed for eVTOLs that make short hops to the airport or carry freight but may be important for eVTOLs that fly on longer regional trips.

Charging capacity is another factor to consider with vertiport development. There is a variety of vertiport manufacturers and eVTOL developers, each with different charging times and needs. The airport vertiport will need to be 'agnostic', like airport facilities, holding the

ability to accommodate maintenance and charging for a range of different eVTOL aircraft. This includes standardised taxi equipment that can handle different models of eVTOL. Based on the frequency of take-off and landing, moving eVTOL off the final take-off and landing area as quickly as possible is a priority. This will need to be done in several ways, as eVTOLs do not follow a standard method for taxiing — some will have self-propelled systems used to taxi, others will need a tug to navigate them to the stand. Some will land on skids, others will land on wheels.

Regardless of the type of eVTOL, vertiports will need to reserve space specifically for charging, and the type of charging may affect what infrastructure is developed. The eVTOL battery type is also a key consideration and will require standardised equipment that can handle a variety of batteries, some of which may be rapid charging and others may be interchangeable. Charging may be quick for eVTOLs that undertake short hops and do not use the full battery charge. But a long journey where the battery is substantially run down may require a relatively long charging period. Each of these aspects will factor into airport operators' calculations on the kind of infrastructure needed and developed.

And finally, the question yet to be determined is who pays for the vertiport: the eVTOL operator and manufacturers? The airport operator? Or some combination of these entities? Whoever it is, it is important to have a financially feasible business case which can demonstrate sustainable development and operation.

ENERGY

Energy impacts on airports are two-fold: the charging infrastructure required to meet the increase in personal and commercial electric vehicles and the charging infrastructure needed for eVTOLs. These aircraft require substantial power draws from the energy grid — with each charging, an eVTOL's airframe could potentially consume more power in 20 minutes than ten homes in Southern California on a summer day.

Utilities across the United States and Europe recognise the need to upgrade energy grids to meet the challenges presented by electric vehicles. This is particularly concerning to airports, as many are already at the limit of their energy supply without these additional energy demands. Adding to the complexity are the new regulations governing charger stand size and the infrastructure to cover the passenger cabin that some eVTOLs require for cooling. Collaboration with utility companies and eVTOL manufacturers and developers may be key to delivering the energy required.

For eVTOL operators, and airport operators, viability depends on aircraft turnaround. Because these aircraft only carry up to six people, including a pilot, operators will need a speedy turnaround, comparable to a Formula One pit stop. In this instance, getting in and out of the vertiport quickly will enable eVTOL operators to maximise rotations, a factor that is essential for profit.

As with efforts within the broader electric vehicle sector, with the introduction of the International Electrotechnical Commission 61851 standard,[7] an international standard for electric vehicle conductive charging systems, the advanced air mobility industry must consider measures that allow the utility companies and airport operators to plan for evolving market needs, including battery type and proprietary charging methods on the energy grid.

Charging speed is expected to have the greatest impact on gate time, so it will be important to get the energy infrastructure right. This means balancing short-term charging infrastructure investments with the ability to support this market's rapid innovation with the likely medium to long-term changes to the charging process.

Deploying a scalable strategy can establish a vertiport that supports short-term and long-term charging needs. This might include using batteries to accommodate anticipated surge charging over short periods, while also anticipating programmatic impacts that potential innovations and even alternative fuels may introduce.

Determining the right mix of energy investments is among the greatest challenges for airport operators and the eVTOL manufacturers and developers, who must determine the most practical and cost-effective means of accessing energy, given the evolving nature of this industry. While most eVTOLs are currently powered by electricity and have a battery on board for storage, as the industry matures, eVTOL operators may consider switching fuels — for example to hydrogen fuel cells, which are currently considered the most viable alternative to battery-based eVTOLs.

Hydrogen power will probably reduce weight, improving eVTOL range and economics. Green hydrogen currently could be generated off-site and transferred to vertiport storage tanks like airport fuel tanks. As hydrogen infrastructure capabilities develop, it will become increasingly feasible to integrate it into a scalable vertiport. Airport operators can combine this approach with limited electrical infrastructure investment and power for the initial eVTOL network rollouts, with the capacity to feed an onsite electrolyser and hydrogen storage and fuelling system. This will support increased operations without affecting the local utility grid and can conserve financial resources that may be needed for additional projects as eVTOLs ramp up.

AVIATION

With eVTOL implementation seemingly just around the corner, a revolution waiting to happen, integrating these flights and flight operations will become an important part of the FAA's and EASA's calculations. Initially, at least, eVTOLs will have a pilot on board flying the aircraft who will be subject to regulations.

One concern that airport operators have are operational delays. Airport operators do not want to have one aircraft ready for take-off on the runway with six aircraft in line waiting for an eVTOL to get out of the way. To prevent these scenarios, it may be beneficial to adapt existing helipads, where possible. Those flight routes may be the most expedient for eVTOLs because the take-off and landing routes are already established. In airports without these existing resources, owners and operators will want to see the potential for integration before considering building a vertiport (Figure 2).

In the USA, the FAA requires federally funded airports to depict the vertiport infrastructure or equipment on their airport layout plans[8] before allowing them to incorporate eVTOLs into their operations. This includes converting a helipad into a vertiport.

Either scenario requires airport operators to evaluate the costs and benefits. They may elect to build and operate these facilities themselves or may opt to have a developer build it and operate it at no cost to the airport. Those airports electing to build and manage these facilities will first need to see the business case

Figure 2 eVTOL image courtesy of Vertical Aerospace

behind the eVTOL to ensure cost effectiveness and practicality.

Maintaining operations is vital to airport owners and operators. Evaluating vertiport location in relation to the airport's runway placement, the impact of the wind and typical wind shifts will be vital in preventing airspace conflicts and operational interruptions. The FAA requires the vertiport landing area be situated 300–700ft away from the centre line of an aeroplane runway,[9] with the distances determined by airport runway sizes and locations. The FAA and EASA will also need to consider how to integrate eVTOLs into controlled airspace. According to the US Concept of Operations developed by NASA, eVTOLs are likely to be operating at altitudes between 1,000 and 4,000ft.[10] Air traffic controllers may need to divert a southbound eVTOL taking off at a vertiport located north of the runway first north and then east or west by 5 nautical miles before turning south, enabling the eVTOL to fly under air carriers departing from the airport's runway.

There are numerous scenarios for integration into operations. In controlled air space, eVTOLs will be directed by the existing air traffic controllers, who will integrate them into the national airspace system. eVTOLs will follow the same visual flight rules as private and non-private aircraft, which require the pilot to stay clear of clouds and visually prevent incursions. What has yet to be determined is if the FAA may require eVTOLs to solely operate between 1,000 and 4,000ft, similar to the 400 foot regulation that has been enforced by the FAA with drones.

Ceiling and Visibility Conditions

All flight operation falls into four different types and is contingent on the current weather and visibility conditions. These ceiling and visibility condition classifications define the following weather minimums for all fixed wing flight operations. (Courtesy of the FAA)

Low Instrument Flight Rules (LIFR)	Ceiling less than 500 feet and/or visibility less than 1 mile
Instrument Flight Rules (IFR)	Ceiling 500 to less than 1,000 feet and/or visibility 1 to less than 3 miles
Marginal Visual Flight Rules (MVFR)	Ceiling 1,000 to 3,000 feet and/or visibility 3 to 5 miles inclusive
Visual Flight Rules (VFR)	Ceiling greater than 3,000 feet and visibility greater than 5 miles; includes sky clear

Figure 3 Most eVTOL are expected to fly under visual flight rules, as defined by the FAA. This regulation may impose some operating limits

At least in the initial years, eVTOLs are expected to be flying under visual flight rules (VFR), per FAA regulation, meaning eVTOL aircraft will rely on what the pilot is able to view from the cockpit (Figure 3). As a result, they will not be able to fly in foggy conditions or when there is high cloud cover. In some areas, eVTOLs will be subject to visibility conditions and only permitted to fly with cloud ceilings greater than 3,000ft and visibility greater than 5 miles. In some instances, eVTOLs may be able to use marginal VFR with a ceiling of 1,000–3,000 feet and/or visibility inclusive of 3–5 miles. But permitting flight in those conditions is likely to be an operator decision. This is a significant limitation affecting the hours of eVTOL operation — especially during winter months, with a resulting impact on operating economics.

COMMERCIAL

Development of eVTOLs and vertiports is a private sector enterprise that is attracting significant inflows of private capital. This private capital will demand a return on investment. As a result, it is important that the economics of eVTOL operation and vertiports stack up.

The potential to monetise this new form of transportation may incentivise airport owners and operators to attract eVTOL operations. As a fresh revenue stream, eVTOLs can provide additional income, which will be required to offset the costs of their initial infrastructure investments as well as maintenance and facilities use. As the industry evolves, collaboration between airport owners and operators and vertiport and eVTOL operators will be key. Working together on pricing strategies to support industry sustainability will ensure its viability for all (Figure 4).

In the short term, as the market matures, it is likely that vertiport operators will experience a monopolistic market environment. It is important that eVTOL services are not priced out of the market as a result. Equally, it is essential that airport operators avoid overcharging vertiport operators for infrastructure provision and services. Doing so could result in the development of an independent competing vertiport on their doorstep, providing no tangible direct financial benefit to the airport operator. Positive early development

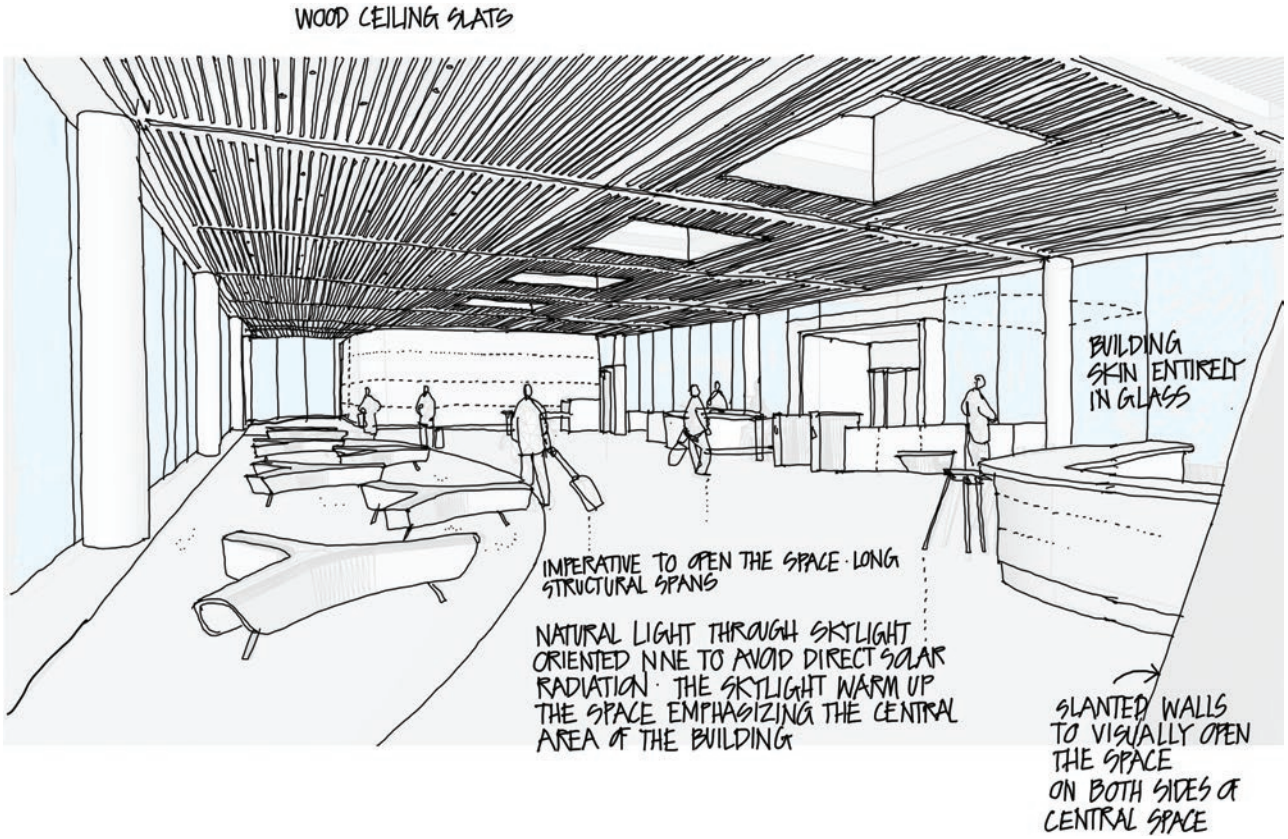

Figure 4 Reflecting the innovative nature of eVTOL aircrafts, vertiports with flexible and modular elements will enable these terminals to expand as passenger demand grows

of this sector will rely on the formation of ecosystems, so successful development of vertiports will require cross-stakeholder collaboration.

There are several revenue models, which vary depending on the operating model adopted by the airports. An airport may adopt the landlord model, where it leases a plot of land to a vertiport developer and operator, such as Ferrovial Vertiports, in return for the payment of a lease to the airport operator. This lease could be structured as a fixed annual payment, or with a fixed and variable component, depending on the vertiport's annual throughput. The alternative is for the airport to be the developer and operator, in which case airports may model fees for eVTOLs based on a similar structure to those for commercial airlines, charging fees for each eVTOL that lands and takes off from the airport's vertiport, as well as parking fees, aircraft registration, passenger and security fees, and electricity supply. Airports may also determine if the vertiport itself will be more functional — meaning it is a quick pass through for passengers — or if the facility holds shopping and food and beverage outlets that allow passengers to dwell. This is likely to evolve as the range of eVTOLs increases over time.

REGULATION

While the regulatory process is multi-layered and complex, the first step towards integration is establishing flight and safety standards. In the US, NASA is taking the lead on this process, developing standards that, once approved, will be administered by the FAA. In the European Union, EASA is working to develop standards and certifications. Each of these agencies is beginning to provide guidance to eVTOL operators, manufacturers and developers, as well as to airport operators, which will be important as the industry gains its foothold.

In Europe, the guidelines may be slower to circulate as countries across the European Union translate the information and adapt them to fit their national networks. In addition, in European countries many airports are privately owned or have public–private partnerships. As a result, the push to continue developing these guidelines is coming from locally formed consortiums. Urban Blue — an eight-airport consortium sponsored by the Italian Aviation Authority, headed by Rome airports and other Italian airports including Bologna and Venice, as well as Nice airport in France — is developing its own ecosystem, creating strategies and workshops to push the regulatory process forward. This combination of high-level guidance, local regulation and general best practices can provide a framework in which eVTOLs can begin commercial operations. Similar ecosystems are being developed across the world, bringing together key stakeholders, including aircraft developers, vertiport developers, and regulators and municipalities, to develop vertiport networks across and between cities where a strong use case has been identified.

All eVTOL manufacturers in the USA are looking to receive three main types of certificates. The first is Part 135 certification, which allows for on-demand commercial air taxi operations — currently, only one eVTOL developer, Joby (Figure 5), has received Part 135 certification.[11] The second type of certification denotes approval of the aircraft and all its component parts, such as the propeller, engines and control stations, and signifies that the design is in compliance with applicable airworthiness, including noise, fuelling, venting and exhaust emission standards. And finally, the production certificate allows for the manufacturing of duplicate products under an FAA-approved design.

Several major companies in the eVTOL industry are testing prototypes as a means of working towards EASA and FAA certification. According to McKinsey & Company, because the aircraft must first be certified before the industry can become active, 98 per cent of the research and design budget is spent on the aircraft, leaving only 2 per cent for vertiport development. However, eVTOL companies do understand that building safe and effective vertiports is key to success, especially since the FAA and EASA are already focused on establishing regulations for vertiports, since they are expected to be situated in heavily populated urban locations.

According to a report by McKinsey, depending on size and mission, the cost to build each vertiport facility could vary greatly, ranging between US$200,000 and US$7m.[12] EASA[13] recently published a 179-page document providing official guidance for airport operators and decision makers, as well as for eVTOL and vertiport manufacturers, for building vertiports. Incorporating feedback from original

Figure 5 eVTOL image courtesy of Joby Aviation

eVTOL equipment manufacturers, vertiport companies, eVTOL operators and manufacturers, and experts across the European Union, the EASA document lays out specific guidelines for vertiports, including a unique funnel-shaped area above each vertiport designated as 'obstacle-free volume' zones.

This EASA document, which was created as a means of developing vertiport design specifications, includes feedback from these stakeholders around dimensions, maximum take-off mass, lateral manoeuvering area during take-off, recommended approach and departure paths compared to ICAO heliport specification, required take-off distances needed and aircraft characteristics for rejected take-offs, taxiing, ground movement, parking requirements, and recommendations for downwash protection for safe operations and minimal hazards.

The publication included initial prototype vertiport technical design specifications, even as the agency continues to work towards a full set of regulatory requirements for vertiport operations. Those rules are expected to deliver detailed design specifications, qualifications for vertiport operational requirements and operational oversight, and could be foundational for airport operators and owners as they work to develop these facilities.

Safety and security issues are a significant point of concern for the two agencies and are also likely to spur regulations

for airport owners and operators. In the USA, the FAA[14] posed questions to airport owners and operators as it examined design and safety features of eVTOLs to determine what should be incorporated and required at US vertiports. The document notes that firefighting techniques for eVTOL aircraft are still unknown and may differ from model to model. Providing adequate fire protection for eVTOL aircraft on vertiports will require a full understanding of the hazards, such as a thermal runway, related to the specific aircraft that will be using the vertiport. This also applies to the utility infrastructure needed to charge the eVTOL aircraft.

CONCLUSION

As eVTOLs continue to blaze a new path across the transportation network, they are poised to bring rapid changes to airport operations and functions. Driven by private industry, what had once been considered the stuff of science fiction is now becoming a reality. As the industry continues to evolve, new questions continue to arise for airport owners and operators across such factors as regulation, energy infrastructure, vertiport development, airport operation integration, aviation and safety, and financing and investment.

While eVTOLs do present challenges to airport operators and owners, those that embrace the potential for these aircraft and collaborate with eVTOL manufacturers and operators may find a new and significant source of revenue in addition to increased airport traffic through a new form of air travel that is driving the development of advanced multi-modal transportation options. Those airport owners and operators that understand the potential for eVTOLs and begin to take this new industry seriously may position their facilities for prosperity for years to come. Those that remain sidelined may miss the opportunity to shape, influence and profit from this aviation revolution.

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