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PILOT TRAINING CHALLENGES FOR ADVANCED AIR MOBILITY

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Abstract

The emerging cast of air taxi companies promising to revolutionize urban transportation, has raised billions of dollars and enticed investors. In addition to the final certification of such vehicles and not yet approved flight procedures, now comes the difficult and challenging part: Certifying their pilot training program from regulators such as FAA and EASA. And that's merely among the firsts in a series of exacting technical and operational approvals that air taxi manufacturers must secure before entering the highly regulated world of commercial aviation. The novel design of eVTOL aircraft features technologies (e.g. electric propulsion systems, batteries, electric rotors, simplified vehicle operations and single set of flight controls), do not automatically align with existing standards and may result in additional challenges faced by OEMs to certify their pilot training programs.

Despite the current ambiguity for Advanced Air Mobility (AAM) pilot training, the training program needs to be strong enough, as pilots need to operate eVTOLs in obstacle-rich environments in and around city centers, landing and take- off from some elevated landing pads and on top of that they might be influenced from microclimate weather and unforeseen emergencies. Harnessing the power of digital technologies, artificial intelligence, synthetic training environments and big data are promising solutions to develop and implement pilot training systems for the elevated future of Advanced Air Mobility. Based on the facts presented above, several aspects of daily eVTOL operations will differ from traditional aviation operations. It is the aim of this research to map these differences and propose solutions for reflecting these challenges into pilot training programs. Research findings will provide significant contribution to Academia, given the scarce references on this topic. By doing this, a momentum may be created that will lead to future research ideas.

In addition, through identification and justification of a set of critical factors and challenges for AAM pilot training, industry practitioners and OEMs may create roadmaps and strategic plans for reflecting these challenges into the design of their future eVTOL pilot training programs.

Keywords: Pilot Training, Advanced Air Mobility, Scenario Based Training, eVTOL

1. Setting the Scene – The Need for Pilot Training

We are on the cusp of a new era of aviation – one of Advanced Air Mobility. Disruptive aerospace companies are building cutting edge aircraft and creating a new sector within the industry from the ground up [1, 14]. This growth is expected to create a huge demand for uniquely trained professional pilots to safely fly passengers and cargo at scale across global markets [2, 3, 13].

To date more than $ 8 billion dollars has been invested in the development of electric Vertical Take Off and Landing (eVTOL) aircraft for a wide range of AAM missions, with the expectation that advanced air mobility will generate tremendous demand for eVTOL products and services [14]. While much attention has been focused on advances in electric propulsion, sources of power, and infrastructure, a void exists in the narrative on pilot training. And the fact that AAM pilots will be an integral component of this industry from its inception, should not be underestimated [8, 9].

Besides safely navigating eVTOLs through the National Air Space, they will also serve as the visible interface to the flying customer. Ultimately, the AAM ecosystem envisions to operate fully autonomous vehicles, but until this takes place, having a professionally trained pilot workforce is a vital path to the widespread commercialization and public acceptance of Advanced Air Mobility [2, 16]. According to a McKinsey report, a huge demand for eVTOL pilots – close to 60,000 will be created by 2028. Even if growth is delayed for some years due to unforeseen events, still these figures represent an unprecedented workforce requirement [14, 16].

Although the majority of eVTOL developers expect their aircraft to eventually be-come fully autonomous, human pilots will play a pivotal role in getting the next revolution in aerospace industry off the ground [2, 15, 16]. Technology, the human capacity to integrate it, and how we regulate pilot training will all be of critical importance in ensuring that the eVTOL industry is commercially successful while meeting the same safety standards as current airliners [1, 2]. It is envisioned, that pilots from commercial aviation and rotorcraft industry will step up their efforts to fill the vacant seats, at least initially. Besides traditional flying skills, they will also need additional skills to meet the design, engineering and operating challenges of eVTOLs [13]. Some eVTOL manufacturers are already planning their eVTOL pilot's training continuum, highlighting it as a four-week intensive pilot training program for experienced commercial pilots, with a focus on operating in high traffic in an urban setting [26].

It is overall envisioned, that several aspects of eVTOL operations will differ from traditional aviation operations [11].

To provide insight into this rapidly progressing space, the objective of this research proposal is to highlight the challenges for pilot training for advanced air mobility, as these were portrayed from a subject matter experts focus group study [4] spanning across the AAM Value chain ecosystem. Both Academia and Industry professionals were conducted for reflecting the differences from commercial aviation pilot training and for extracting meaningful implications, the most salient of which are provided as the major outcome of this research.

2. Research Methodology

For formulating the research objectives, a pre-pilot study was performed on December 2021 and January 2022 with five (5) experts spanning on the fields of aviation, advanced air mobility (AAM) manufacturers and management consultancy. The focus study [4] finished on April 2022 and a triangulation of the results was pursued through the support of external professionals - (excluded intentionally from the main study) - to avoid bias.

Based on the focus study, findings have been portrayed from Subject Matters Experts and are presented in the following paragraphs. We will first start with presenting the challenges for developing a Pilot Training program based on eVTOL unique design and AAM ecosystem characteristics; to be followed by presenting actual flying challenges for AAM vehicles. As part of the objectives of this research, these findings have been further assessed for their validity, accuracy and consistency through triangulation. For academic integrity, where possible, findings as well as comments and opinions from Subject Matter Experts are accompanied with related references.

3. eVTOL Unique Design and AAM Ecosystem Challenges for Pilot Training

There are huge projections being tossed around about the potential eVTOL market size and according to Roland Berger 47,000 AAM vehicles will be flying by 2040 [29]. This new market has attracted significant venture capital and private equity from Special Purpose Acquisition Companies (SPACs), automotive manufacturers, legacy aerospace OEMs and tech companies in 2021 [Ref / Roland Berger / Report]. But at the dawn of 2022 reality kicked in, the air taxis shares are in a free fall, and valuation is coming to a realistic level [28]. Part of this realization is that the AAM ecosystem has been focusing too long on the technology and designing eVTOL prototypes and needs to move on by including other building blocks of the ecosystem [28].

Aside from aircraft certification, perhaps the most critical component of the complex new electrical vertical takeoff and landing (eVTOL) market is pilot training. And despite OEM advocacy for automation, training may not yield as simple a solution as they might hope [27]. As a proof, FAA recently injected turbulence into the process, signaling a change of schemes [30].

Until now, developers of winged eVTOL aircraft have been proceeding on the assumption that their aircraft would be certified under the FAA's overhaul of small airplane certification rules that took effect in 2017 (Part 23 – Small aircraft certification rules). Those performance – based regulations were created out of collaboration with industry and kicked off a wave of new entrants emboldened by the opportunities they created to certify innovative technologies. Now FAA is reversing course appears to have largely caught the industry off guard, aiming to certify eVTOL designs as "powered-lift " aircraft [30]. According to FAA, since many eVTOL aircraft are able to fly horizontally, like an airplane and take off and land vertically like a helicopter, eVTOL pilots will need to be skilled in controlling the aircraft in both of these flight modes.

While the full implications of the shift are unclear, it is a proof that FAA was not working in harmony with the industry to provide a clear route to certification.

The novel design of eVTOL aircraft feature technologies (e.g. electric propulsion systems, batteries, electric rotors, Simplified Vehicle Operations and Single Set of Flight Controls) do not automatically align with existing standards and may result in additional time and challenges faced by OEMs to certify their training programs [12].

Simplified Vehicle Operations (SVO) can be conceptualized as the functional decomposition between the aircraft operations that can be fully automated and the ones that still require human intervention [12]. Ultimately, these aircrafts are designed with a lot of safety protocols put in place, featuring designs with varying controls schemes and pilot interfaces, along with advanced autonomy features being incorporated into their fly-by-wire flight controls. This extensive automation, provides envelope protection in the aircraft, helping to keep the pilot for making mistakes [11]. In fact, technology is already in place for this. However, by removing one pilot, you also remove certain redundancies, and some times in the cockpit, things can become extremely busy and puzzled, which may result in task saturation and startle effects.

In addition, cybersecurity challenges (e.g. software glitches and/or shudder hacked controls) need to be resolved for accommodating remotely piloted and autonomous operations. Given that – at least at the moment, no autonomous system can compensate for an incapacitated pilot, establishing guaranteed and secure data links with ground stations is mandatory for certifying single pilot operations [8].

3.1. Autonomous Flight

As noted previously, to some degree we already have self-flying aircrafts, but even the most advanced autopilot requires input from humans, who are also called on when trouble suddenly springs up (i.e. contingencies) and the computer decides that it can no longer cope. For this reason alone, the complete removal of humans from the cockpit – is likely decades away [11, 14].

We have already seen Artificial Intelligence and Machine Learning algorithms to help flight dispatchers to plan routes, conserve fuel, support maintenance repair and overhaul (MRO), organize crew rostering and keep track of missing baggage and unravel the mysteries of ticketing [21, 22, 23].

To make full autonomy work, engineers will need to introduce all sophisticated technologies that will allow autonomous planes to detect and anticipate danger, to have spatial awareness and make the right decisions every single time [19]. An AI system can simulate millions of miles of flying involving thousands of scenarios much more than a human pilot can do. Even for non-deterministic events that will never arise. It all depends on how you train AI and how it learns. This is where reinforcement learning (RL) comes in autonomous flight [19].

3.2. The Pilot's Dilemma

Even if AI technology overcomes the challenges of fully autonomous flight, there is still one question remaining, the only question that matters: Why ? For airlines and air taxi providers the answer is easy: cost efficiency. Pilots increase costs and the complexity of operation. McKinsey research suggests that the cost per passenger-seat-kilometer of a piloted UAM flight could be up to twice the cost of an autonomous one [16]. Another important challenge raised by the same report involves creating a unique value proposition that will encourage people to embrace careers as AAM pilots despite the expense of basic flight training, the likely unpaid training period, and - most critically - an uncertain future. The AAM industry is quite vocal about the need to automate, potentially limiting the career of an AAM pilot to a few years.

Therefore the net present value for an AAM pilot career could be quite low or even negative. Unless, AAM piloting skills and experience may become transferrable either within or beyond the aviation industry, many aspiring AAM aviators might believe it would be better to pursue other professions.

3.3. Streamlining the Certification of Pilots

Pilots will help the public recognize the value proposition for AAM [10,11]. Before taking flight, however, they must gain experience with this new mode of transport and help compile data about it. Pilots must also understand broader operational issues and help build confidence in the industry's safety and reliability among regulators and the public [10, 11]. The industry and its regulators must develop a new kind of certification for AAM pilots because the current standard simply does not make economic sense for them or the industry. In addition eVTOL design is completely different from current commercial aircrafts and rotorcrafts [10].

Certification and training requirements for today's commercial pilots are complex, lengthy and mainly an expensive investment in both money and time, which AAM pilots might not recoup before automation takes over [15]. Therefore, it is essential to redesign the training—without compromising safety. Such new programs would not only streamline training but also increase the pipeline by opening the business to people who lack traditional credentials or want new kinds of jobs late in their careers [16].

One important area that has to change is the curriculum. The new industry's pilot-training programs should also expand the scope of digital instruction, both for ground school and practical flying lessons [15, 16]. Relatively low-cost simulators, for instance, could replace a significant portion of the time currently needed for flight training in real aircraft, or artificial intelligence algorithms could help adapt training to the needs of individual students in real time—for instance, by identifying areas where they require remedial training.

3.4. Collaboration with Flight Simulator Manufacturers

The use of simulation has a proven and successful track record in helicopters, business aviation, and the commercial aircraft industry. OEMs pursuing simulator development early in their certification efforts may provide significant overall cost savings, as well as significantly accelerating the timeline for the training simulator certification [16].

By collecting data and analyzing pilot performance results, we can better understand industry-specific safety threats. The use of data is key in ensuring an efficient training footprint that meets the safety requirements expected of AAM operations. Modern learning techniques, the usage of simulators that rely more on AR / VR training and virtual motion than in motion fidelity, given the absence of turbo engines and the different behavior from fixed wing aircrafts proves to be effective, efficient and the way forward for modern training program development [15, 27].

The Canadian aviation training group CAE foresees pilot training for Air Taxis to be based on pilot competencies rather than prescriptive models with a Competency Based Training Assessment (CBTA) approach. CBTA is an internationally recognized process that allows OEMs to write a training program once instead of several times for different entities around the world, and especially different civil aviation authorities [15]. Core component of CBTA is "Adaptive Learning Approach", with the aim to customize training for each learner based on his / her competencies, training needs and learning preferences. CBTA is also a potential solution to harmonizing eVTOL pilot training across a wide range of aircraft deigns and with an easier path to adoption by multiple regulators.

In this line, CAE and Burlington, Vermont – based eVTOL manufacturer Beta Technologies [24], jointly announced that they will work together throughout the development and type certification process to support launch customers expected operations with an all - electric model in 2024, including customers from UPS Flight Forward and United Therapeutics.

In addition Volocopter, Bruchsal – Germany, eVTOL based manufacturer announce with CAE their common plans to train pilots for eVTOL aircraft operations [25]. Under the agreement, both companies will develop, certify and deploy a pilot training program to support the launch of commercial operations – anticipated to begin in 2024. Volocopter agreed to purchase a simulator which will be developed specifically for eVTOL aircraft operations and will be used for pilot training program certification as well as for training pilots to fly any of Volocopter's in-development vehicles, including the two-seat VoloCity and the larger VoloConnect model. For this specific simulator, CAE will employ new technologies including artificial intelligence, virtual reality, mixed reality, and data analytics and it will be responsible for developing all courseware for training Volocopter's pilots.

Last but not least, the California based eVTOL manufacturer, Joby Aviation recently announced a partnership with CAE to develop and certify a flight simulation training device that will be used to train commercially-rated pilots to fly its eVTOL aircraft [26].

3.5. Collaboration with Airlines

To ensure an ample supply of AAM pilots, operators must offer them an attractive career path. This path might in sometimes extend beyond operating eVTOLs for a few years (e.g. transitioning to management ranking) or even reskilling and transitioning to piloting commercial jets. The latter option would require mutually beneficial agreements with airlines in which airlines could also subsidize the cost of basic flight training and make it easier for AAM pilots to transition [15,16].

Such and initial agreement was already announced between the Munich-based eVTOL manufacturer Lilium and Lufthansa Aviation Training [20][20]. Together Lilium and Lufthansa Aviation Training will develop a tailor - made Pilot Sourcing and Training program to qualify pilots to fly the Lilium Jet. The program will harness emerging technologies including Mixed and Virtual Reality (MR/VR), artificial intelligence as well as data analytics; opening thus possibilities to recreate the program worldwide and enabling a stable pipeline of qualified pilots to support the growth of industry.

This approach, if materialized, will enable aspiring aviators to start their careers as eVTOL operators and move up to a commercial aircraft, creating thus a natural pathway for career progression.

4. AAM Actual Flying Challenges

As noted previously the first eVTOL pilots will hold existing commercial ratings. They need to have a full operational background, including knowledge of meteorology, extensive flying experience, and knowing how to communicate. Simplified Vehicle Operations, Advanced Human – Machine interface and fly-by-wire technology that makes the control much easier and more intuitive doesn't necessarily mean less training. In fact, more training may be needed to prepare pilots to deal with the increased automation [27], as well as with operation in a congested urban environment in close proximity to buildings. Flying an eVTOL aircraft might be intuitive, but those in the cockpit will need to know how to cope in unexpected emergency scenarios. And pilot training needs to match the capabilities of the aircraft.

Regulatory agencies like the FAA and EASA will eventually introduce specific training requirements for the new aircrafts, but it will certainly take more time than expected, since these permissions will not be issued as a series of exemptions from current rules governing commercial operations of fixed – wing aircraft and rotorcraft [30]. In this line, if these aircrafts are permitted to operate only under visual flight rules (VFR), this would prevent flights in poor weather, which clearly would have a major impact on where and when commercial operations could be conducted.

In either case, following the regulations of commercial aviation, AAM Pilots will receive their daily flight schedule from their operations department or flight dispatchers. They will review weather NOTAMs and maintenance records and perform pre-flight inspection, verifying that the aircraft is ready for flight and batteries fully charged for the first flight. The vehicle's systems will autonomously execute a pre-flight system health check and semi-automatically generate a flight plan to execute the flight mission as safely and efficiently as possible by incorporating geospatial data, weather and air traffic details. Estimated time of Arrival (ETA) will be calculated based on vehicles velocity, payload and wind direction. In the unlike but possible event of emergency, the fly-by-wire system will make the hard decisions and assist the pilot to perform an emergency landing.

The following challenges are directly related to actual pilot skills required for safely operating an aerial vehicle in a dense city center.

4.1. Navigating in a Congested Airspace

Navigating in a congested and challenging air space environment, coordinating with traditional airplanes and helicopters, or even use some pre-defined flight corridors through specific authorizations [10]. Pilots are expected to encounter busy radio transmissions in high density airspace and must be trained to handle communications with more agility. It is critical for Flight Simulator Training to have immersive environments populated with real air traffic, thus simulating the challenges of navigating in a congested air space.

4.2. Urban Environment and Weather Challenges

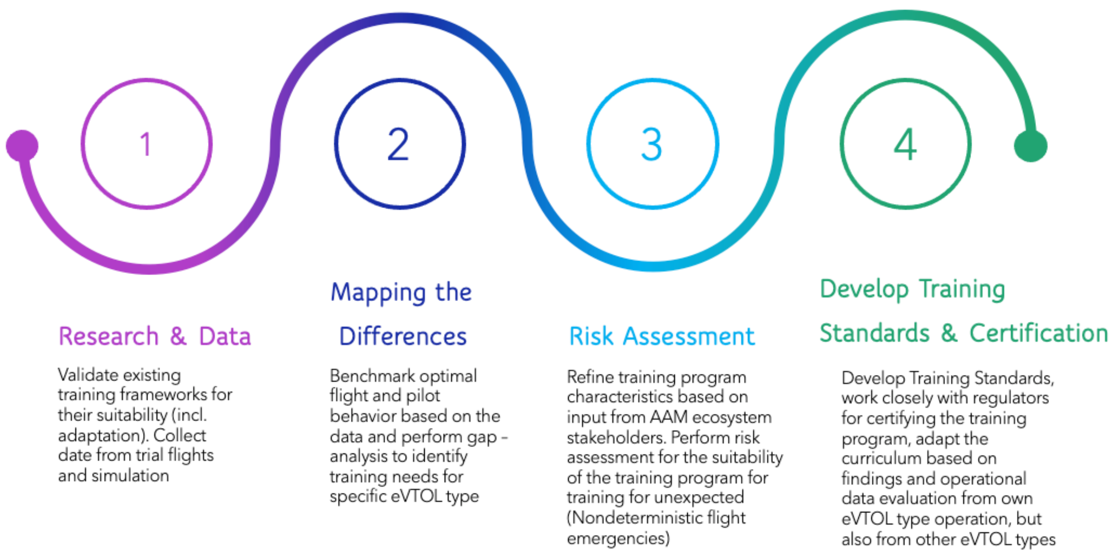
Off – airport take offs and landings will likely occur in confined intra-city vertipads or vertiports, and on top of high-rise buildings as the industry matures. Performing emergency procedures in these environments is a high risk operation [10]. In emergency situations, pilots need to make judgement calls on the safest alternative course or landing site, considering battery and aircraft limitations, surrounding buildings and unforeseen microclimate weather in congested urban areas.

This calls for unique challenges in training for situational awareness in urban environment. Given that this kind of training cannot be performed with real aircraft for safety reasons, simulation equipment that incorporates real physics, real microclimate weather events and real building / ground effects is essential.

5. Sustainability of an eVTOL Pilot Training Program

Sustainability of an eVTOL pilot training program requires an innovative approach to training. As concluded from our work with AAM subject matter experts, no “off-the-self” solution for eVTOL Pilot training exists. The challenge of evolving vehicle technologies and designs and the fact that there are little operational flight data creates ambiguity around the pathway to certify the pilot training program of each eVTOL manufacturer. What is certain however, is that the training program needs to be strong enough, as AAM pilots need to operate eVTOLs in obstacle-rich environments in and around city centers, landing and take- off from some elevated landing pads and on top of that they might be influenced from microclimate weather and unforeseen emergencies. In addition, and at least the industry matures, the training program will be unique for each eVTOL manufacturer.

Based on authors’ experience and information collected from our focus group study, we crafted a four - step framework with the aim to assist the AAM industry to identify the required pilot training devices and determine a pilot training program structure. The framework is presented as follows:



6. Summarizing Comments

We are at an exciting inflection point in aviation and mobility. Across the globe, companies are leveraging new technologies to create radically different aircraft designs that will enable more freedom to maneuver and transport cargo in cities, towns, and communities. The once unimaginable means of transportation is becoming a reality. Properly trained pilots are critical to making this vision of aviation's future a safe reality. Establishing and certifying AAM pilot training programs is a priority. Fresh concepts in pilot training and certification must be planned for now to ensure the overall success of Advanced Air Mobility. While AAM's long-term future will be autonomous, the industry must initially recruit, train, certify, and manage tens of thousands of pilots. Stakeholders across the spectrum—manufacturers, operators, flight schools, regulators and employment agencies – must collaborate to tackle the significant challenges the piloted ramp-up period is certain to pose.

It is overall envisioned, that several aspects of eVTOL operations will differ from traditional commercial aviation. Mitigating risk through timely and effective training designed and implemented in conjunction from both eVTOL OEMs and aviation training organizations is incredibly important because if one accident occurs in the industry, it can set it back years. To provide insight into this rapidly progressing space, the objective of this research was to highlight the challenges for pilot training for advanced air mobility as these were portrayed from an ongoing subject matter experts focus group study finished on April 2022. Both Academia and Industry professionals were conducted for reflecting the differences from commercial aviation pilot training and for extracting meaningful implications, the most salient of which are provided as the major outcome of this research.

It is imperative for all eVTOL stakeholders to collaborate and look at pilot training as a preventative versus reactive lens. Only if we act proactively and collaborate with all value chain partners, we will be able to better understand how AAM will look like in reality as opposed to experimental prototypes. Only by acting as orchestrators we can actively shape and create an AAM pilot training ecosystem that will allows in the long term to experience the advantages that the eVTOL aircraft has to offer to the world.

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8. Copyright Statement

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