Pilot Training for Advanced Air Mobility

CAE 2021 Report

Your worldwide training partner of choice

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Introduction

We are on the cusp of a new era of aviation – one of advanced air mobility (AAM). Disruptive aerospace companies are building cutting edge aircraft and creating a new sector within the industry from the ground up. This growth will create a huge demand for uniquely trained professional pilots to safely fly passengers and cargo at scale across global markets.

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 urban air mobility, air cargo, emergency response, and other operations will generate tremendous demand for eVTOL products and services.

Today's air transportation system is one of the safest forms of travel for both passengers and cargo. With each major advancement in aircraft technology, checks and balances are put in place to ensure public safety, by regulatory bodies, insurers, local authorities, OEMs, and the operators.

As an emerging air transportation sector that will interact closely with urban communities, AAM services will be under the spotlight. Safety standards must be high to gain regulatory and public acceptance, to significantly reduce the risks of accidents that could have a catastrophic impact on this fledgling industry.

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.

Let's not underestimate the fact that AAM pilots will be an integral component of this industry from its inception. They will safely navigate eVTOLs though the National Airspace Systems and serve as the visible interface to the flying customer. For this reason, the pilot remains an essential link to the success of the industry. Having a professionally trained pilot workforce will be a critical path to widespread commercialization and public acceptance of advanced air mobility.

With a sizeable eVTOL pilot workforce needed, we are at an inflection point in aviation. We must look at this new industry as a clean sheet opportunity for pilot training. New training technologies and processes will enable a paradigm shift to train pilots in an affordable, scalable means that ensures safety and meets the unique needs of Advanced Air Mobility.

A sizeable eVTOL pilot workforce in need of training

The global aviation industry has struggled to recruit and train enough experienced pilots to fill the cockpits of airlines, business aviation and helicopter operators. There is a growing industry realization that the development of eVTOL aircraft and launch of AAM operations will further increase demand for professional pilots commencing by 2023-2025.

COVID-19 triggered a depressed demand for professional pilots, but the industry is showing signs of recovery as major airlines return to operating at full schedule and begin to recruit pilots. CAE's 2020-2029 Pilot Demand Outlook forecasts[1] that the global aviation industry will require over 264,000 new pilots in the next 10 years to meet the demands of the airline industry and business aviation. This does not account for the staffing requirements of the helicopter industry, nor does it address the needs of AAM.

AAM will create an additional surge in demand for pilots, which could, by some estimates, be close to 60,000 pilots by 2028[2]. Even if growth is delayed a few years as other industry reports suggest, this still represents an unprecedented new workforce requirement. We foresee traditional aviation sectors stepping up their efforts to fill vacant cockpit seats as the first AAM services launch operations.

Photo courtesy of Lilium Schweiz GmbH

[1] Airline and Business Jet Pilot Demand Outlook — 10-year view (2020 update). https://www.cae.com/cae-pilot-demand-outlook-2020/

[2] Pelli, Uri; Riedel, Robin; "Flying-cab drivers wanted" (June 2, 2020). https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/flying-cab-drivers-wanted

It is expected that the initial AAM pilot cadre will consist of experienced commercial pilots drawn from both the fixed and rotary-wing aviation communities. These pilots will need the same level of skills as their traditional counterparts, as well as additional skill-sets to meet the unique capabilities and designs of eVTOL aircraft. Additionally, these AAM pilots will be navigating in a challenging traffic management environment, coordinating with traditional airplanes and helicopters while encountering environmental challenges in urban sectors. Synergistic partnerships and training programs linking the AAM industry and the traditional civil aviation industry will aid pilot staffing requirements for both sectors. Pilots of eVTOL aircraft may also find a pathway into airlines, business aircraft, or possibly helicopters, opening new opportunities for aviation careers. Creating these new career pathways will require the collaboration between OEMs, operators, Civil Aviation Authorities (CAAs), and the pilots themselves.

Advanced training programs have been deployed in business aviation with emphasis on scenario-based training that teach operationally relevant scenarios, building pilot resilience. By collecting data and analyzing normalized 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 like adaptive learning for recurrent courses is proving to be effective, efficient and the way forward for modern training program development. We see progress on this front with self-paced, student-centric training programs (including CAE's own Trax Academy) where immersive training technologies, like commercial off the shelf versions of Virtual Reality / Mixed Reality / Augmented Reality are incorporated into early training programs, and lead to faster and more effective trainee throughput. The United States Air Force Pilot Training Next Program used a similar approach to the Trax Academy and achieved an increase in trainee throughput of over 40%[3].

Further, inclusion of data analytics allows instructors to review an individual student's performance for early intervention and correction, reducing remedial training. Data analytics enable a training organization to make data-driven adaptations to the overall program: if an entire class is demonstrating a rapid adoption of concepts in one segment and a complete lack of proficiency in another, it may be necessary for the training provider to restructure the curriculum or training approach. This is particularly relevant during the early years of the eVTOL market as the industry works to understand the mission complexities and the pilot skillsets needed.

[3] Pope, Talon M., "A Cost-Benefit Analysis of Pilot Training Next" (March 21, 2019). Theses and Dissertations. 2314. https://scholar.afit.edu/etd/2314

Train as you operate

Operators conducting AAM services will require smart and agile flight departments that can safely scale operations.

At the onset, a day in the life of an eVTOL pilot will look similar to today's pilots who conduct commercial, on-demand or scheduled operations. These aircraft will likely be serviced at a base of operations located on an airport, heliport or vertiport. Pilots will receive their daily taskings from their operations department or flight dispatchers. They will review weather Notices to Airmen (NOTAMs), and maintenance records. Pilots will verify the aircraft readiness for flight and ensure batteries are in a proper state of charge for the initial flight. The pilot in command will pre-flight the aircraft and depart on their assigned tasking for the day, transporting passengers or cargo from points A to B.

Several aspects of these operations will differ from traditional aviation operations, and these will need to be reflected in pilot training.

Short cycles

Many of these missions will be short in duration (5-30 minutes) and pilots will transition quickly and often in and out of critical phases of flight. While eVTOL vehicles are being optimized to simplify pilot workload, the critical phases of flight (takeoffs and landings) make up a larger portion of a flight operation than a typical commercial or business aircraft flight operation. An eVTOL pilot could experience 2-4 critical phases of flight per hour rather than 2-4 critical phases of flight per day. Take offs, landings, and transitions have not been fully automated for the majority of these aircraft, so training will need to account for fatigue management in these high cycles of operation.

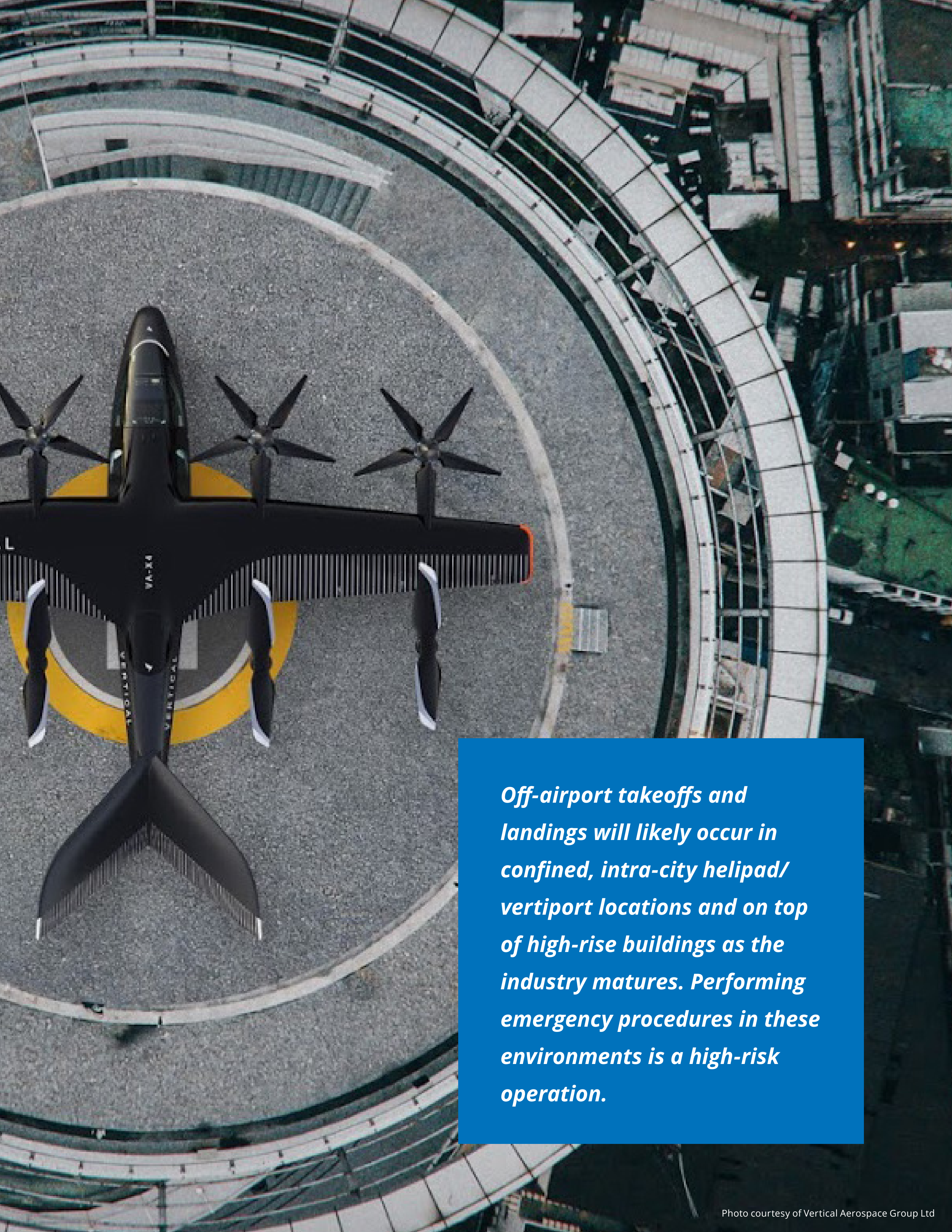
Congested air space

Initial operations of eVTOL aircraft will be conducted in national airspace systems sharing airspace with other aircraft operations, potentially on existing helicopter routes or, in some cases, on early pre-defined flight corridors through specific authorizations. As the demand increases, we can expect more and more aircraft flying along similar pathways, simultaneously, and layered with other commercial air traffic. Pilots will encounter busy radio transmissions in high density airspace and must learn to manage communications with more agility than conventional aircraft operations. Pilots will also need to become capable of managing flights that are closer in proximity to other vehicles, and to be alert and react should other aircraft deviate from the planned course. It will be critical for flight simulator training devices (FSTDs) to have immersive environments populated with air traffic, whether AI-generated or linked to other trainees in FSTDs[4], simulating the challenges of congested airspace.

Urban environment

Off-airport takeoffs and landings will likely occur in confined, intra-city helipad/vertiport locations and on top of high-rise buildings as the industry matures. Performing emergency procedures in these environments is a high-risk operation. With no clear path to divert, the pilot will need to make judgement calls on the safest alternative course or landing site, considering the busy air space, the battery life, and aircraft limitations. Coupling this with local urban and microclimate weather conditions and communication-blackout zones means pilots will face new and unique challenges in training for situational awareness in urban environments. These types of training elements cannot be taught safely in a training aircraft, as the risk is too high to perform emergency procedure training in over populated areas at low altitudes. Training organizations will need to leverage modern training devices that are built on physics-based simulation that incorporates microclimate events and near building/ground effects.

[4] Connecting simulators for conducting real-time platform-level wargaming across multiple host computers is commonly used worldwide in military organizations but has also been used in the field of medicine.



Off-airport takeoffs and landings will likely occur in confined, intra-city helipad/ vertiport locations and on top of high-rise buildings as the industry matures. Performing emergency procedures in these environments is a high-risk operation.

Photo courtesy of Vertical Aerospace Group Ltd

The challenges of developing a training program for eVTOL aircraft

An experienced aircraft manufacturer of a conventional airplane or rotorcraft with an established training and licensing structure will typically launch the program development at least 36 months before start of commercial operations.

This includes the development of the syllabus, courseware, and training equipment. These programs must be reviewed and approved by CAAs before any non-experimental pilot training can take place – a precursor to operators building the first cadre of pilots to operate these vehicles.

The novel nature of eVTOL aircraft (electric propulsion systems, varying control schemes and pilot interfaces) will result in OEMs facing additional challenges in developing training programs that meet the approval criteria of CAAs. This will require early engagement with regulators, training device manufacturers, and training organizations to meet publicly forecasted business timelines.

Currently, the regulatory requirements for eVTOL pilot training and aircrew licensing have not been defined. Early entrants into the market will need to rely on existing regulations with added special conditions. The onus will be on OEMs to demonstrate a data- or process-driven approach to training program design.

This in and of itself is a challenge, as the number of pilots that have flown eVTOL aircraft, at the time of this writing, is extremely limited, specifically to flight test pilots only. Subject matter expert (SME) inputs are needed when making definitive decisions regarding training programs. The industry can make certain assumptions based on existing pilot training programs and engineering inputs. Will this be sufficient when the aircraft deviate so far from what is presently in production and type certificated? For example, will these aircraft with simplified vehicle operations, lacking turbine engines, require simulators with motion cueing capability for representative training? SME feedback from manned flight experiences and from the experiences of test pilots of eVTOL aircraft will be valuable. These SMEs are critical for the development of pilot training, including the design and qualification of training equipment.

The majority of these aircraft will be operated by a single pilot and have a single set of flight controls. Current regulations require in-aircraft instruction with fully functioning dual controls. Aircraft that have been approved for single pilot operation, (ex: Hondajet, Phenom-100/300, M2, etc) leverage training in the aircraft that are equipped with full dual controls. OEMs may consider a training version of the aircraft equipped with dual controls to enable flight training in the aircraft. Exceptions could be pursued for eVTOL designs where the configuration allows a second pilot seat, provided that it could be demonstrated to CAAs that the instructor has full flight controls, and the flight may be conducted safely. The expense and time to achieve additional certification of such dual-controlled aircraft may be unacceptable for OEMs.

The alternative to conventional training in the aircraft could be a zero-flight time training (ZFTT) approval of a simulator-based training program. A pilot who has gone through a ZFTT program can fly revenue-generating flights without having prior in-aircraft experience. ZFTT approval requires a qualified simulator with Level C or Level D fidelity and is directly tied to the AOC's training program approval. It is commonplace in the fixed wing world to use Level C or D simulators within a ZFTT program. This is not the case in the rotorcraft world where, under EASA and CASA, an AOC pilot training program may be approved for trainees to complete most of the training, including the check-ride, in a simulator, but where the pilot is still required to demonstrate take-offs and landings in an actual aircraft thereafter.

For the AAM operational model to be a success, operators, developers, OEMs and other stakeholders involved must find cost-effective means to certify eVTOL pilots. The Level C and D qualifications described previously are only given to full flight simulators (FFS) at present. These are large pieces of equipment that require specific facilities and can be a notable capital investment. If the industry ramps up across global markets as many are forecasting, industry stakeholders will need to look for new ways to train pilots at scale. In this innovative new industry, can we be equally disruptive with training? This will surely require data and clear process that demonstrates equivalency of emerging, innovative technologies compared to traditional equipment solutions.

Fortunately, the pragmatic approach contemplated under ICAO Doc 9625 links training tasks achievable by a FSTD equivalent to the simulator's qualification[5]. By demonstrating the simulation features are equivalent/ exceed the minimum FSTD requirements for an FSTD fidelity level, defined by being "specific" to the aircraft, "representative", "generic" or not available at all. As a result, defining the training tasks, even if preliminary in the aircraft program, will give OEMs more opportunity to work with training equipment manufacturers to tailor simulation solutions to the pilot's actual training needs and be optimized for their unique aircraft features. Approval for use by CAAs will take time, this needs to start early, but there is an openness by regulators to accept innovative approaches in this emerging industry.

[5] Simulation features comprise of: cockpit layout & structure; flight model; ground handling; aircraft systems; flight controls & forces; sound cues; visual cues; motion; cues; environment – ATC; environment – navigation; environment – weather; environment – airports & terrain.

When to start thinking about simulation

OEMs have increasingly used simulation to reduce risks and costs for design, development, flight test, certification, and training.

Bringing a new aircraft to market requires enormous capital and is very time consuming. Errors, if only discovered in the flight test phase, can set the program back significantly, both in time and cash burn.

Across disciplines, simulation is widely used to rapidly iterate and optimize designs. As an example of its use in aviation, Airbus leveraged a high-fidelity engineering simulator to compress the flight test schedule for the A350XWB aircraft in half, spanning just 12 months, by moving many certification tasks upstream and receiving credit for time flown in the Integrated System Test/ Certification Rigs (ISTCR) in support of flight testing.

Acceptance of high-fidelity engineering simulators (ESims) and hardware-in-the-loop ISTCR serve to gain credit toward type certification for procedures “flown” on the ground. The use of ESims to find and fix integration issues and to demonstrate failure modes provides value in the certification process. ESims allow for human factors assessment and acceleration of the cockpit design. ISTCRs reduce flight time and systems testing, with the added value that edge of envelop tests can be performed with sufficient repeatability and without putting the safety of test pilots at risk.

The use of high-fidelity simulation has a proven and successful track record in helicopters, business aviation, and the commercial aircraft industry. OEMs pursuing high-fidelity simulation and concurrent 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.

Why is this important? The prototype simulator certification process can range from 16 months to 24 months, depending on the simulator specifications and the completeness of an OEM’s aircraft data. Missing data or model inaccuracy can significantly shift the scope and structure of a simulator program. Importantly, a delay to the training equipment program certification will delay the type certification of the aircraft and, if not careful, can delay the critical path to entry into service (EiS).

Photo courtesy of Beta Technologies Inc

The relevance of training to type certification

When an aircraft manufacturer embarks on a type certification program for their new design, they are responsible for ensuring that the aircraft is safe for operation in the airspace system, demonstrating that the aircraft can be safely flown under all of the operational conditions the aircraft manufacturer is seeking to have approved.

To achieve vehicle Type Certification, an OEM must first conduct an Operational Evaluation (OE). This is a process where regulators evaluate all aspects of the operational program to ensure safety. This includes post-aircraft delivery aspects such as manuals, pilot training programs, training equipment, etc. This means that every aircraft manufacturer, conventional or eVTOL, must have a team focused on the pilot training requirements in advance of Type Certification.

It is essential that courseware and simulators be available ahead of the OE to support a timely EiS. New entrant aircraft can't begin operations and generate revenue if the pilot training program isn't approved, and certificated pilots are not available to operate these aircraft.

Photo courtesy of Beta Technologies Inc

Structuring an eVTOL Pilot Training Program

Commercially certificated pilots have the general aviation knowledge and skills to safely operate aircraft but will need to be trained to operate unique eVTOL designs in challenging environments.

Traditional pilot training is task- or qualification-based: its goal is meeting the regulatory requirements of the CAA. These regulations prescribe specific training program inputs (e.g., hours of study, hours of practice, etc.), to meet a CAA's testing criteria and qualification criteria.

The new AAM industry is pushing regulators to use the present re-examination of standards as an opening to adopt fresh training concepts. An opportunity exists to center training around pilot competencies (the outcome of training), rather than prescriptive models (the inputs of training). A Competency-Based Training and Assessment (CBTA) approach is a potential solution to harmonizing eVTOL pilot training across a wide range of aircraft designs and with an easier path to adoption by multiple regulators. The desired result will ensure approvals for timely and global eVTOL aircraft operational integration.

Following a Competency Based Training Assessment (CBTA) approach to training program design, serves several purposes for the eVTOL industry. First, it follows a globally accepted set of pragmatic workflows which identify the necessary pilot knowledge, skills, and attitudes to validate the tasks necessary to safely operate an aircraft[6]. This will provide the framework for a successful and efficient pilot training program to transition a currently certificated pilot with a rotorcraft or airplane rating to eVTOL proficiency. Additionally, the core of CBTA is defining assessment criteria to monitor pilot performance and gather data regarding the effectiveness of the training to determine what may need to be revised to enable a continuous improvement cycle. This is essential to any new aircraft pilot training program.

Data gathered from pilot performance in a CBTA program will serve to evaluate the quality of the training program. By grouping pilot core behaviors into "Pilot Competencies", pilots and instructors have a relatable context to discuss training performance. Observable behaviors are modeled behaviors for a given competency allowing the pilot to better understand how putting the Pilot Competencies into practice results in safety of operations. CBTA is intended to have a more wholistic approach to training and assessment of pilot performance, compared to traditional task or qualification-based training. The inclusion of scenario-based training (following the competency-based format) in pilot training activities has proven to reinforce resilience in pilot decision making, leading to safe and consistent outcomes.

Following the CBTA process may provide a cost-effective, safe, and comprehensive means to develop a pilot training program where a gap currently exists. The development of such a training program may help to recommend industry consensus standards and a path forward for operation of eVTOL aircraft in global markets. Creating an eVTOL Pilot Training Program, customizable for the uniqueness of aircraft design, will help OEMs speed their aircraft into service.

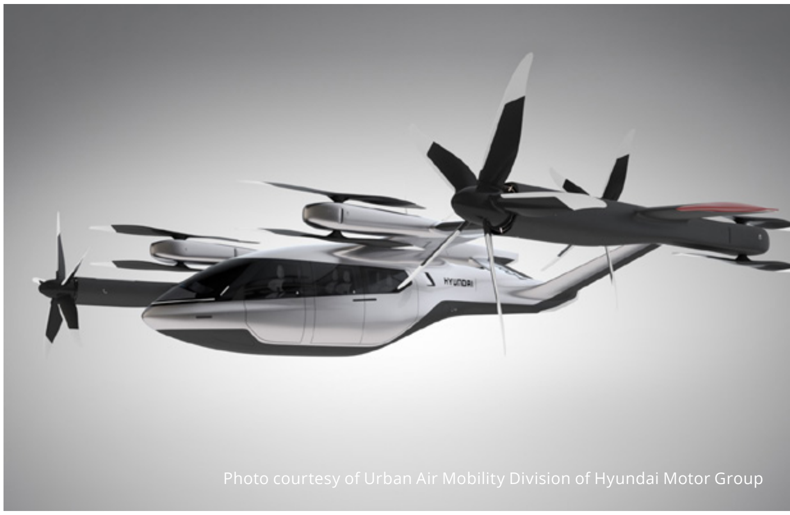


Photo courtesy of Urban Air Mobility Division of Hyundai Motor Group

[6] CBTA process can be found in ICAO Doc 9868

How to get started

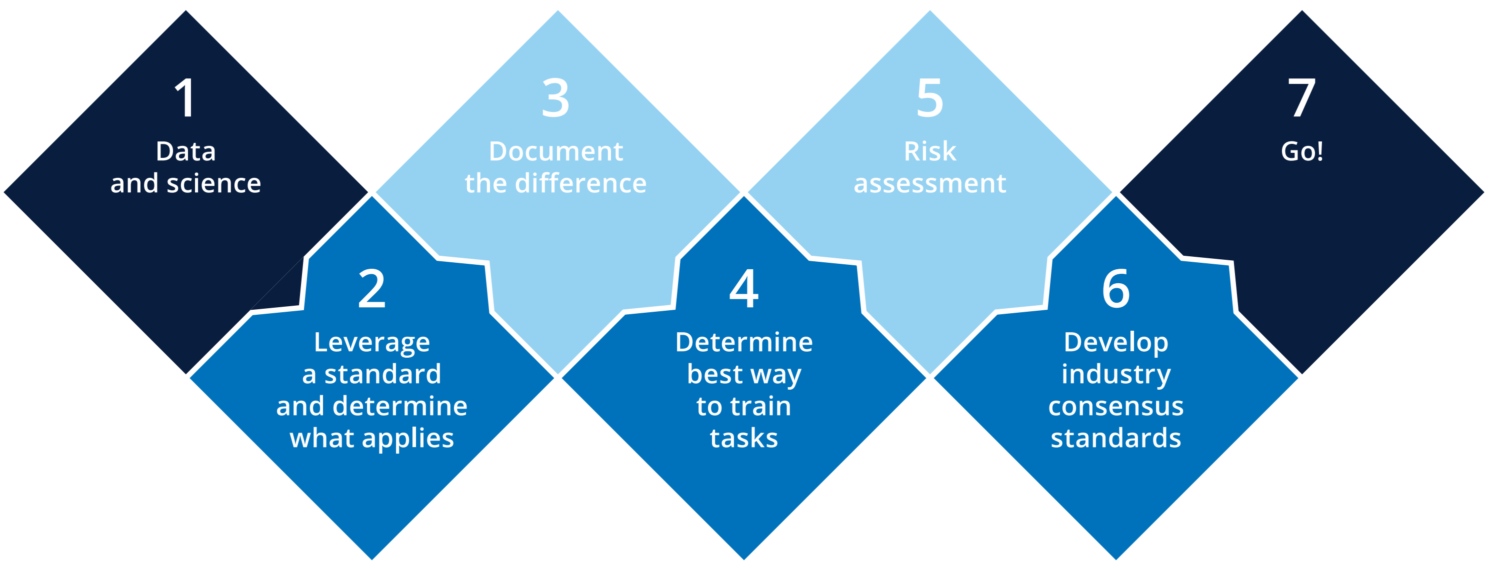
The commercial viability of eVTOL operations requires a smart approach to training.

Currently, no “off-the-shelf" eVTOL solution for pilot training exists. The challenge of evolving vehicle designs and the fact that there is little operational flight data along with rapidly evolving technologies creates ambiguity around the pathway to regulatory compliance. CAE recognizes a path forward to a unified approach that could harmonize the industry.

The seven-step model below may support a pathway to regulatory approval and certainty in determining appropriate pilot training devices and pilot training program structure.

This process will involve numerous stakeholders: OEMs, regulators, training equipment manufacturers, and the training program developer.

CAE has already completed Step 1 and, in collaboration with our vehicle partners and industry working groups, is launching activities to establish a generic task list that would support industry-wide decisions on the general pilot competencies required for these aircraft of the future.



1. Find scientific articles, research and data to validate recommendations for training technologies and approaches.
2. Benchmark legacy commercial regulatory standards of airplane, rotorcraft and UAS for eVTOL applicability and training gap-analysis.
3. Once commercial tasks are filtered by applicability, define a generic eVTOL task list.
4. Refine eVTOL task list with input from OEM and industry stakeholders. Develop matrix on what device is recommended to train the tasks.
5. Risk assess tasks, training devices and determine suitable mitigation.
6. Regulatory agencies, OEMs, ATOs and other stakeholders develop standards and have these standards accepted by regulators.
7. Launch development of training curriculum, materials and training devices. Ongoing work on certification and operational evaluation.

Conclusion

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 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. Fresh concepts in pilot training and certification must be planned for now to ensure the overall success of AAM.

Through advances in immersive technology, we have the capability to create the most progressive, adaptive pilot learning experience in more than a generation. With a data driven approach, this technology can and will promote community acceptance, instill confidence in the public, influence regulators to implement rules and policies that will stimulate growth, and ensure safety in this emerging industry.

About CAE

CAE is a high technology company, at the leading edge of digital immersion, providing solutions to make the world a safer place. Backed by a record of more than 70 years of industry firsts, we continue to reimagine the customer experience and revolutionize training and operational support solutions in civil aviation, defence and security, and healthcare. We are the partner of choice to customers worldwide who operate in complex, high-stakes and largely regulated environments, where successful outcomes are critical. Testament to our customers' ongoing needs for our solutions, over 60 percent of CAE's revenue is recurring in nature. We have the broadest global presence in our industry, with approximately 10,000 employees, 160 sites and training locations in over 35 countries.

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