



AEROSPACE STANDARD

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Pilot Training and Certification for VTOL-Capable Aircraft

RATIONALE

This document will address the pilot training and qualification for licensing/certification necessary to operate vertical takeoff and landing (VTOL)-capable aircraft (VCA) (also referred to as powered-lift [PL]), which are part of the ecosystem of advanced air mobility (AAM). Regulatory guidance has only recently been developed to address the pilot training and qualification criteria for on-board, off-board, and autonomous operations of these new entrant aircraft, VCA. New technologies and highly automated systems in these aircraft will require pilots to possess specific skills and capabilities appropriate for commercial operations in the global airspace system.

INTRODUCTION

Background

SAE Committee G-35 was formed to develop consensus-based standards for certification of VTOL-capable aircraft and other new aircraft—piloted, remotely piloted, and autonomously operated—as well as standards for pilot training and flight simulator qualification. The primary focus of these standards is to maintain and enhance the outstanding safety record achieved in aviation. New entrant aircraft designs known as PL and VTOL-capable aircraft require a substantial change to certification of aircraft and associated systems and supporting training methods, personnel licensing, and operational environments. SAE G-35 brings together experts in manufacturing, design, operations, regulations, and academia to develop consensus-based standards addressing the needs of the burgeoning AAM industry desiring earliest entry into commercial service. SAE G-35 applies a risk-based approach to ensure these standards meet the safest criteria by leaning on the expertise of its dynamic and forward-thinking membership.

Assumptions

The goal of the airman certification process is to ensure the applicant demonstrates the knowledge, the ability to manage risks, and the skills consistent with the privileges of the certificate or rating being exercised, to act as pilot in command. Safe operation in today's Airspace System requires integration of aeronautical knowledge to mitigate risk and ensure compliance with regulatory and operational standards.

This standard depends on a transition method to safely certificate/license initial groups of VCA pilots appropriate to the aircraft. The initial group of VCA pilots will likely possess at least a commercial pilot license (airplane or helicopter) as a prerequisite to achieving a type rating in a VCA.

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Considering the many different aircraft designs (e.g., multirotor, lift plus cruise, tilt-wing/tilt-rotor), training will follow a performance-based regulatory framework utilizing a competence-based methodology for pilot training and assessment to allow for the various designs, operations, and missions while ensuring a high standard of pilot training and qualification. This approach will deviate from traditional task-based training as necessary and will be inclusive of differing design capabilities without sacrificing required knowledge and skill training. This standard incorporates training and certification/licensing elements from commercial pilot licenses/certificates for airplanes, helicopters, and powered-lift aircraft and design-related elements. Additionally, this standard will define the requirements for the ab initio pilot desiring to operate a VCA as well as instructor pilots and examiners. Anticipating the entry into service of remotely operated VTOLs, this standard will define the requirements for certification/licensing of remote pilots, taking into account appropriate Civil Aviation Authority (CAA) guidance and regulatory requirements.

Training will apply performance-based standards, including demonstrated competency to ensure appropriate pilot qualification for on-board piloted operations as well as off-board, or remotely operated, and a future standard to define autonomous aircraft operations. Traditional hours-based training does not account for the differences in aircraft design, software, automation, and/or differences between individual pilots, including experiences and capabilities. This performance-based and competence-based training approach focuses on pilots achieving knowledge, skills, and attitudes relevant to the emerging technologies and operational environments envisioned with VCA. The Pilot Training Program attached to this standard as Appendices A and B is arranged in a logical sequence, beginning with Preflight Preparation, and ending with Postflight Procedures. Additional theoretical and practical training is included for pilots transitioning from Commercial Pilot Airplane or Commercial Pilot Helicopter, and ab initio pilots, both on-board the aircraft and operating remotely.

As state-of-the-art in-flight modeling and simulation are continuously evolving, it is expected that their utility and application for training and evaluation purposes will increase over time. This is true for flight simulation training devices such as XR devices that replicate the aircraft and environment utilizing new combinations of real and synthetic environments for training and evaluation. Single-pilot, single-seat aircraft will require unique methods for training and qualification as the instructor cannot be seated next to the trainee and does not have access to aircraft controls. This standard can be applied to in-aircraft and in-simulator training and may include innovative methodologies and AI as an enabler, as authorized by the relevant CAA.

International Civil Aviation Organization (ICAO) Annex 1 guidance recognizes that pilot qualification and training shall be based on an aircraft's capabilities. The type rating for VCA will be defined in accordance with the existing Operational Suitability process (e.g., FAA Flight Standardization Board [FSB], Transport Canada Civil Aviation [TCCA] Operational Evaluation Board [OEB], Agência Nacional de Aviação Civil [ANAC] Brazil, European Union Aviation Safety Agency [EASA] Operational Suitability Data [OSD], etc.). The airplane or helicopter license/certificate upon which the type rating is added should be recognized initially, along with ab initio certification criteria as developed.

These aircraft combine unique propulsion and highly automated systems requiring specific training and instructional techniques that will change the amount and nature of human (pilot) intervention. Their designs include advanced flight control systems that use electronically operated controls such that the pilot has no direct mechanical link to the control surfaces. Advances in automation and the degree of automation and differences from aircraft to aircraft will affect the training and qualification required of VTOL-capable pilots. Pilot intervention in the operation of each type of certificated aircraft depends on variables like envelope protection, levels of automation, mission capability, etc. Therefore, this standard does not prescribe minimum hours for training of pilots on board the aircraft or remotely operating the aircraft. This standard addresses the relevant training and testing for commercial pilots, with additional focus on ab initio pilots of VCA. This standard will also define the training required for instructor pilots and examiners. Remote and autonomous operations are anticipated; therefore, this standard addresses the entry into service for these remotely operated VTOLs with pilots off board. Fully autonomous operations are not addressed in this standard.

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1. SCOPE

This standard is intended for use by original equipment manufacturers (OEMs), regulators, operators, training organizations, and any others who wish to develop curricula for pilot, instructor, and evaluator training courses for new aircraft - VCA. Continuous updates to this standard will be necessary to incorporate advancements in VTOL technologies and training methods. This standard describes the knowledge, skills, and attitudes required to safely operate VCA for commercial purposes. A Civil Aviation Authority (CAA) may, at their discretion, use this standard to aid the development of existing or future regulations. OEMs and operators may use this standard to develop a curriculum for acceptance or approval by civil regulators.

This standard includes a Pilot Training Program developed to address the theoretical and practical training and assessment for VTOL-capable pilot licensing/certification. Additionally, this standard contains the requirements for pilot training and licensing for the operation of VCA with pilots on board or remotely operated (also called off board). The Pilot Training Program will define on-board pilot training requirements and off-board (or remote pilot) training requirements in a parallel effort to ensure OEMs planning to operate without pilots on board the aircraft have a pathway toward pilot certification and licensing. Future standards will address fully autonomous operations of VCA.

Compliance with this document is recommended as one means of assuring the safe operation of VCA under conditions normally encountered in routine aeronautical operations. This standard does not conflict with any regulatory conformity and is not intended to diverge from regulatory policy or guidance.

The scope of this document includes standards for the use of flight simulation training devices (FSTD) in support of pilot training and licensing. This standard is intended to facilitate the development of and define the constraints for the effective use of flight simulation to support, augment, or replace in-aircraft flight training and testing in the demonstration of regulatory compliance while ensuring safe operations. These highly automated aircraft operations support a mission-based and performance-based approach to training and testing because current prescriptive training methodology inadequately addresses the needs of these aircraft and pilots. Pilot skills will differ from traditional airplanes and helicopters and need consideration in training program design. Because these aircraft may not have common characteristics, the need for a comprehensive approach to training and testing will initially support the broad scope of these designs. This training is intended to apply to VCA; however, the approach to training for emerging and advanced technologies can be broadly applied to conventional aircraft that incorporate new technologies. In the future, training programs will incorporate AI and machine learning to analyze pilot performance data, personalize training programs, and predict training needs. These technologies support the enhancement and effectiveness of training by providing real-time feedback and adaptive learning environments.

The existing regulatory framework does not address specific criteria to meet the needs of pilot training for VCA operations. New and amended regulations must be implemented to safely enable future operations of new transportation modalities with pilots on board, off board, and autonomous operations. Initial licensing of pilots will depend on the availability of previously trained, appropriately qualified, and experienced (commercial airplane and/or helicopter licensed) pilots with additional type-specific training to address the unique distinctions of each VCA. These are highly automated, mostly single pilot operations, leading to remotely operated and future autonomous operations. This standard addresses the criteria necessary for existing commercial pilots, ab initio pilots,¹ instructors, examiners, and both on-board and remote pilots who will need to be qualified through training and testing to achieve a type rating in a VCA.

The introduction of new aircraft and new pilot licensing and certification supports a departure from traditional training toward a performance-based, competence-based training methodology. Traditional training is designed to ensure pilot candidates demonstrate the necessary minimum skill, knowledge, and experience to meet the qualification requirements for the license, rating, or privilege. The training methodology described in this standard is designed to ensure pilot candidates possess the required competencies to perform their assigned duties and responsibilities while operating the aircraft safely, efficiently, and effectively. This standard measures competence by evaluating total performance rather than singular tasks.

¹ Ab initio pilots: Pilots who are training "from the beginning," with little or no flight experience who desire to become type-rated VCA pilots. This may include student pilots, private pilots, or others who do not currently possess a Commercial (H/A) license but are seeking a VCA type rating.

This standard describes performance- and competence-based training that:

- Enables individuals to reach a level of safe operational capability while ensuring a fundamental level of competence as a minimum standard
- Enables individuals to cope with predictable and unforeseen situations
- Is relevant to the job and the context in which the job will be performed
- Is geared toward retaining and applying learning rather than passing a test
- Makes full use of available training tools and methodologies
- Supports continuous learning and performance improvement

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 AIA Publications

Available from Aerospace Industries Association, 1000 Wilson Boulevard, Suite 1700, Arlington, VA 22209-3928, Tel: 703-358-1000, www.aia-aerospace.org.

AIA. (2023, May). *Metropolitan airspace strategy: Initial advanced air mobility operations*.
<https://www.aia-aerospace.org/wp-content/uploads/2023-Initial-Advanced-Air-Mobility-Operations.pdf>.

2.1.2 ANAC Publications

Copies of these documents are available online at <https://www.gov.br/anac/>.

Regulatory Proposal for License and Rating Requirements for Aircraft with Vertical Takeoff and Landing Capabilities

2.1.3 Code of Federal Regulations (CFR) Publications

Copies of these documents are available online at <https://www.ecfr.gov>.

14 CFR Part 107 Small Unmanned Aircraft Systems

14 CFR Part 137 Agricultural Aircraft Operations

2.1.4 EASA Publications

Available from European Union Aviation Safety Agency, Konrad-Adenauer-Ufer 3, D-50668 Cologne, Germany, Tel: +49 221 8999 000, www.easa.europa.eu.

NPA 2022-06 Introduction of a regulatory framework for the operation of drones: Enabling innovative air mobility with manned VTOL-capable aircraft, the IAW of UAS subject to certification, and the CAW of those UAS operated in the 'specific' category

Opinion No 03/2023 Introduction of a regulatory framework for the operation of drones: Enabling innovative air mobility with MVCA, the initial airworthiness of UAS subject to certification, and the continuing airworthiness of those UAS operated in the 'specific' category

EASA Artificial Intelligence Roadmap

2.1.5 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

Summers, M.M., Ayers, F., Connolly, T., and Robertson, C. (2007, September). *Managing risk through scenario based training, single pilot resource management, and learner centered grading*. FAA.

2.1.6 IATA Publications

Available from International Air Transport Association, Publications Assistant, 800 Place Victoria, P.O. Box 113, Montreal, Quebec H4Z 1M1, Canada, Tel: 1-514-874-0202, www.iata.org.

Competency Assessment and Evaluation for Pilots, and Instructors/Evaluators

2.1.7 ICAO Publications

Available from International Civil Aviation Organization, 999 University Street, Montreal, Quebec H3C 5H7, Canada, Tel: +1 514-954-8219, <https://www.icao.int/>.

Annex 1 Personnel Licensing

Doc 9868 Procedures for Air Navigation Services - Training

2.1.8 JARUS Publications

Copies of these documents are available online at <http://jarus-rpas.org/publications/>.

JARUS methodology for evaluation of automation for UAS operations (JARUS-Doc-AutoMethod.1.0)

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 ANAC Publications

Copies of these documents are available online at <https://www.gov.br/anac/>.

IS 00-002H Padrões para a realização de exames de proficiência de pilotos (Standards for pilot proficiency checks)

RBAC No. 61 Licenças, habilitações e certificados para pilotos (Licenses, ratings and pilot certificates)

2.2.2 Code of Federal Regulations (CFR) Publications

Copies of these documents are available online at <https://www.ecfr.gov>.

14 CFR Part 21 Certification Procedures for Products and Articles

14 CFR Part 60 Flight Simulation Training Device Initial and Continuing Qualification and Use

14 CFR Part 61 Certification: Pilots, Flight Instructors, and Ground Instructors

14 CFR Part 91 General Operating and Flight Rules

14 CFR Part 135 Operating Requirements: Commuter and on Demand Operations and Rules Governing Persons on Board Such Aircraft

14 CFR Part 194 Special Federal Aviation Regulation No. 120—Powered-Lift: Pilot Certification and Training; Operations Requirements

2.2.3 EASA Publications

Available from European Union Aviation Safety Agency, Konrad-Adenauer-Ufer 3, D-50668 Cologne, Germany, Tel: +49 221 8999 000, www.easa.europa.eu.

Easy Access Rules for Aircrew (Regulation (EU) No 1178/2011), Annex I (Part-FCL)

Easy Access Rules for Air Operations (Regulation (EU) No 965/2012)

Easy Access Rules for Unmanned Aircraft Systems (Regulations (EU) 2019/947 and 2019/945)

Easy Access Rules for Operational Suitability Data (OSD) Flight Crew Data (CS-FD)

Easy Access Rules for Aeroplane Flight Simulation Training Devices (CS-FSTD(A))

Easy Access Rules for Helicopter Flight Simulation Training Devices (CS-FSTD(H))

2.2.4 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

Airman Certification Standards (ACS)

2.2.5 ICAO Publications

Available from International Civil Aviation Organization, 999 University Street, Montreal, Quebec H3C 5H7, Canada, Tel: +1 514-954-8219, <https://www.icao.int/>.

Annex 6 Operation of Aircraft

Doc 9625-1	Manual of Criteria for the Qualification of Flight Simulation Training Devices - Volume I - Aeroplanes
Doc 9625-2	Manual of Criteria for the Qualification of Flight Simulation Training Devices - Volume II - Helicopters
Doc 9995	Manual of Evidence-Based Training
Doc 10011	Manual on Aeroplane Upset Prevention and Recovery Training
Doc 10019	Manual on Remotely Piloted Aircraft Systems (RPAS)
Doc 10103	Guidance on the Implementation of ICAO Standards and Recommended Practices for Tilt-rotors

2.3 Definitions

The terms and definitions used in this document are not intended to represent the only definitions used across industry.

2.3.1 ADVANCED AIR MOBILITY (AAM)

Operations with novel aircraft designs that do not fall into a traditional category, including vertical takeoff and landing (VTOL) capabilities and distributed propulsion features, and may be operated in unmanned/uncrewed configurations that are conceived to offer a new air mobility for people and cargo, based on an integrated air and ground-based infrastructure. AAM describes a diverse array of aircraft types (such as manned and unmanned) whose designs are enabled by ongoing innovations particularly in the areas of hybrid and electrification of propulsion systems, energy storage, lightweight materials, digitalization, and automation. These innovations have made possible an array of novel designs spanning drones, multi-rotor, tilt-wing, tilt-rotor, and powered wing, offering short takeoff and landing (STOL) through to VTOL capabilities.

2.3.2 ARTIFICIAL INTELLIGENCE (AI)

“Technology that can, for a given set of human-defined objectives, generate outputs such as content, predictions, recommendations, or decisions influencing the environments they interact with.”² AI is not a prerequisite for autonomy. It enables highly automated, cooperative, passenger or cargo-carrying air transportation services in and around urban areas.

2.3.3 ARTIFICIAL INTELLIGENCE (AI) INTEGRATION

The incorporation of artificial intelligence technologies into pilot training programs to analyze performance, provide adaptive learning, and enhance training outcomes.

2.3.4 AUGMENTED REALITY (AR)

Augmented reality is an interactive experience of a real-world environment where the objects that reside in the real world are enhanced by computer-generated perceptual information, sometimes across multiple sensory modalities, including visual, auditory, haptic, somatosensory, and olfactory. AR can be defined as a system that incorporates three basic features: a combination of real and virtual worlds, real-time interaction, and accurate 3D registration of virtual and real objects. The overlaid sensory information can be constructive (i.e., additive to the natural environment) or destructive (i.e., masking of the natural environment). This experience is seamlessly interwoven with the physical world such that it is perceived as an immersive aspect of the real environment. In this way, augmented reality alters one's ongoing perception of a real-world environment, whereas virtual reality completely replaces the user's real-world environment with a simulated one.

² Refer to AIA Initial Advanced Air Mobility Operations (May 2023).

2.3.5 AUTOMATED

The allocation of a task or operation, which may have previously been executed manually, to automation—in whole or in part.

2.3.6 AUTOMATION/AUGMENTATION

The application of technology to perform tasks and operations in a way that reduces the need for human intervention.

2.3.7 AUTONOMOUS

Independently (system) determined operations when there is no predefined rule(s) to achieve goals/objectives.

2.3.7.1 LEVELS OF AUTONOMY

Methods of expressing different types of human-machine collaboration.³

2.3.7.1.1 HUMAN WITHIN THE LOOP (HWTL)

Human is always in direct control of the systems.

2.3.7.1.2 HUMAN ON THE LOOP (HOTL)

- a. Human has supervisory control of the systems.
- b. Human actively monitors the systems and can take full control when required or desired.

2.3.7.1.3 HUMAN OVER THE LOOP (HOVTL)

- a. Human has supervisory control of the systems.
- b. Human passively monitors the systems and is informed by automation if, and what, action is required.
- c. Human is engaged by the automation either for exceptions that are not reconcilable or as part of rule set escalation.

2.3.7.1.4 HUMAN OUT OF THE LOOP (HOOTL)

- a. Human delegates all authority to the system once the execution of the function is enabled.
- b. Automated processes are in control of the system and have the authority to perform actions without the human having awareness of the actions being taken.

2.3.7.2 LEVELS OF AUTOMATION³

2.3.7.2.1 LEVEL 0

Manual operation: The human is fully responsible for function execution, with no machine support.

³ Refer to JARUS methodology for evaluation of automation for UAS operations (April 2023), p. 21.

2.3.7.2.2 LEVEL 1

Assisted operation: The machine operates in an out-of-the-loop supporting role to the human in executing the function, for example, by the provision of relevant information.

2.3.7.2.3 LEVEL 2

Task reduction: The machine operates in an in-the-loop management role in reducing human workload to accomplish the task. For example, the machine could provide a “conflict alert” and “resolution advisory” (advice as to what action to take) based on predicted flight paths.

2.3.7.2.4 LEVEL 3

Supervised automation: The machine executes the function under the supervision of the human who is expected to monitor and intervene as required.

2.3.7.2.5 LEVEL 4

Manage by exception: The machine executes the function alerting the human in the event of an issue. The human is not required to monitor the function in real time and is able to intervene at any time after being alerted by the machine to an issue.

2.3.7.2.6 LEVEL 5

Full automation: The machine is fully responsible for function execution. The human is unable to intervene in real time either due to practical limitations or deliberate exclusion within the operational design domain (the conditions and limitation under which a system is designed to function).

2.3.8 AUTONOMY

A characteristic of a system describing the level of human oversight and control of that system. It is represented by a scale and can be achieved with or without the application of AI technologies and methods.

2.3.9 BATTERY STATE OF CHARGE (SOC)

State of charge describes the ratio of charge of an electric battery relative to its maximum capacity. It is usually expressed as a percentage, where 0% indicates an empty battery and 100% indicates a fully charged battery.

2.3.10 BATTERY STATE OF FUNCTION (SOF)

The state of function is a measure of a battery's ability to perform a specific task. It depends on the SOC and the available capacity of the battery. SOF reflects the maximum instantaneous output power of the battery and shows the degree of performance degradation over time. SOF is a useful parameter for evaluating the functionality or reliability of the battery system.

2.3.11 BATTERY STATE OF HEALTH (SOH)

State of health is a measure of a battery's ability to store and deliver electrical energy compared to a new battery. It describes the overall condition of a battery, not its current charge. Remaining energy varies by the change in operating temperature and SOC.

2.3.12 COMPETENCE-BASED TRAINING AND ASSESSMENT (CBTA)

Training and assessment that are characterized by a performance orientation, emphasis on standards of performance and their measurement, and the development of training to the specified performance standards. CBTA is a performance-based training program designed to integrate continuous monitoring and evaluation throughout the course. “Under CBTA, the training system performance is measured and evaluated through a feedback process in order to validate and refine the program and ascertain that the organization program develops pilot competencies and meets the training objectives.”⁴ CBTA incorporates a system of competence measurement that looks at the total performance rather than single tasks.

2.3.13 CONVERSION

The phase of an aircraft's flight from forward to vertical flight.

2.3.14 DISTRIBUTED PROPULSION

Distributed propulsion (generally associated with electrically powered aircraft) is an arrangement in which the propulsive and related air flows are distributed over the aircraft. The purpose is to improve the aircraft's aerodynamic, propulsive, and/or structural efficiency over an equivalent conventional design. It may include battery-electric, hybrid-electric, or hydrogen-electric as a prime source of power. Multiple propulsion units are distributed across an aircraft, typically in a decentralized manner to enhance efficiency and maneuverability and allow for innovative aircraft configurations.

2.3.15 EVENT-BASED TRAINING (EBT)

An event-based approach to training is used to guide the design of scenario- or simulation-based training. It is usually incorporated into a training program encompassing information, demonstration, practice, and feedback.

2.3.16 EXTENDED REALITY (XR)

Extended reality is a term referring to all real-and-virtual combined environments and human-machine interactions generated by computer technology and wearables, where the “X” represents a variable for any current or future spatial computing technologies (e.g., it includes representative forms such as augmented reality, mixed reality, and virtual reality and the areas interpolated among them).

2.3.17 FLIGHT SIMULATION TRAINING DEVICE (FSTD)

Flight simulation training device is an umbrella term for various equipment used to simulate aircraft, all aspects of pilot training, and normal, abnormal, and emergency procedures. The FSTD concept encompasses full flight simulators (FFSs), flight training devices (FTDs), flight navigation procedures trainers (FNPTs), and basic instrument training devices (BITDs) as well as XR technologies.

2.3.18 GROUND CONTROL STATION (GCS)

A ground control station (GCS) is made up of sets of ground-based hardware and software that allow operators to communicate with and control a UAV or VTOL and its payloads. The GCS serves as a central command hub for managing various aspects of operations. The design and features of a GCS can vary based on the complexity of the aircraft and the specific requirements of the mission. It can be used to set parameters for autonomous operation or to allow direct control of a UAV/VTOL.

2.3.19 INCEPTORS

Advanced flight control input devices referred to (in AAM) as being different from conventional cyclic/pedal/collective flight controls. Inceptors are flight-critical controls that pilots use to direct and maneuver the aircraft. They are commonly referred to as “sticks” and include side sticks, center sticks, throttles, cyclics, and collectives.

⁴ Refer to IATA Competency Assessment and Evaluation for Pilots, and Instructors/Evaluators.

2.3.20 INNOVATIVE AIR MOBILITY (IAM)

EASA (refer to NPA 2022-06) defines IAM as “the safe, secure and sustainable air mobility of passengers and cargo enabled by new-generation technologies integrated into a multimodal transportation system.” This is similar to AAM (defined here).

2.3.21 LIFT PLUS CRUISE

The lift plus cruise VTOL design separates the vertical lift thrust production from the forward flight thrust production. The design allows for some propulsion units to generate lifting thrust, while others are used for forward thrust (lift rotors and cruise propellers).

2.3.22 LOSS OF POWER CONTROL (LOPC)

Loss of the ability to control power systems resulting from propulsion malfunction, malfunction of power distribution system, battery malfunction, and control system failure that results in a critical situation.

2.3.23 MACHINE LEARNING

A subset of AI that involves training algorithms to recognize patterns and make decisions based on data and is used in pilot training for performance analysis and adaptive learning.

2.3.24 MIXED REALITY (MR)

Mixed reality (MR) is a term used to describe the merging of a real-world environment and a computer-generated environment. Physical and virtual objects may coexist in mixed reality environments and interact in real time. Mixed reality may incorporate haptics and may be referred to as visuo-haptic mixed reality or augmented reality (AR).

2.3.25 MULTIROTOR/MULTICOPTER

A multicopter or multicopter is an aircraft with more than two lift-generating rotors.

2.3.26 PERFORMANCE-BASED TRAINING (PBT)

Performance-based training is a strategy that trains pilots to achieve their targeted performance goals and/or objectives. A personalized learning approach highlights the results to be achieved, enhancing and refining performance, and prioritizes practical, “hands-on” training over theory-based methods.

2.3.27 PILOT CERTIFICATION/PILOT LICENSING

Terms have the same meaning depending on which civil aviation authority issues the certificate (FAA) or license (EASA).

2.3.28 POWERED-LIFT

An aircraft capable of vertical takeoff, vertical landing, and sustained low speed flight with lift generated primarily by tilting engine/motor-driven rotors which are repositioned on movable nacelles and/or wings for these flight regimes. A heavier-than-air aircraft capable of vertical takeoff, vertical landing, and low-speed flight, which depends principally on engine-driven lift devices or engine thrust for the lift during these flight regimes and on non-rotating airfoil(s) for lift during horizontal flight.⁵

2.3.29 REMOTE PILOT

Remote pilot is an individual who operates an aircraft from a location other than the aircraft itself. The term “remote pilot” is often used in the context of aviation and aircraft regulations to distinguish individuals who control aircraft from the traditional notion of a pilot who is physically on board an aircraft.

⁵ Refer to ICAO Annex 1, Chapter 1.1, Definitions.

2.3.30 SCENARIO-BASED TRAINING (SBT)

SBT is a training method that uses a highly structured script of real-world experiences to address aviation training objectives in an operational environment. Such training can include initial training, transition training, upgrade training, recurrent training, and special training.

2.3.31 TILT-WING/TILT-ROTOR

An aircraft capable of vertical takeoff, vertical landing, and sustained low speed flight which depends principally on engine-driven rotors mounted on tiltable nacelles for the lift and/or tilting wings for lift during these flight regimes.

2.3.32 TRANSITION

The phase of an aircraft's flight from vertical to forward flight.

2.3.33 UNMANNED AERIAL VEHICLE (UAV)

An aircraft piloted by remote control or on-board computers without a human pilot on board.

2.3.34 UNMANNED AIRCRAFT SYSTEM TRAFFIC MANAGEMENT (UTM)

"Traffic management" ecosystem for uncontrolled airport operations that is separate from, but complementary to, the FAA's Air Traffic Management (ATM) system. UTM development will ultimately identify services, roles and responsibilities, information architecture, data exchange protocols, software functions, infrastructure, and performance requirements for enabling the management of low-altitude uncontrolled drone operations.

2.3.35 URBAN AIR MOBILITY (UAM)

UAM is a subset of the AAM concept under development by the Federal Aviation Administration (FAA), National Aeronautics and Space Administration (NASA), and industry. As a subset of AAM, UAM focuses on operations moving people and cargo in metropolitan and urban areas.

2.3.36 VIRTUAL REALITY (VR)

Virtual reality is a simulated experience that employs position tracking and 3D near-eye displays to give the user an immersive feel of a virtual world. The use of computer modeling and simulation that enables a person to interact in an artificial three-dimensional (3D) visual or other sensory environment. VR applications immerse the user in a computer-generated environment that simulates reality using interactive devices.

2.3.37 VTOL-CAPABLE AIRCRAFT (VCA)

A power-driven, heavier-than-air aircraft, other than airplane or helicopter, capable of performing vertical procedures by means of lift and thrust units used to provide lift during takeoff and landing.⁶

⁶ Refer to EASA Opinion No 03/2023.

3. TRAINING AND LICENSING/CERTIFICATION REQUIREMENTS FOR VCA TYPE RATING

3.1 Overview

This training and testing process will ensure the candidates have the knowledge, skills, and attitude to safely operate a VCA. Type rating testing criteria ensures a high standard of performance and capability when operating VCA. This standard does not prescribe hours-based training; rather, it considers a competence- and performance-based approach to airman qualification. It incorporates a blend of scenario-based and task-based training with observable outcomes to achieve the safest level of qualification. Individual CAAs may require specific hour requirements for experience; however, this standard does not address these requirements.

3.2 Privileges and Limitations

Pilots are authorized to exercise the privileges of the type rating for the VCA in accordance with the company's authorizations (e.g., FAA-issued Operation Specification [OpSpecs], etc.). Pilots are limited to flying only the VCA for which they are type rated. Specific type training and company training (including mission training) are required prior to conducting revenue operations. A thorough description of the training requirements is included in this standard. Pilots operating VCA in non-revenue operations (not for compensation or hire) may be required to complete type-specific training and testing prior to operating in any National Airspace System.

3.3 Theoretical

This standard includes theoretical knowledge as an integral part of any pilot training. This training includes areas unique to VCA. It will also provide complete theoretical knowledge for the ab initio pilot seeking to achieve a rating in a type-specific VCA. While there are many established areas of theoretical knowledge currently applied to pilot training, this standard has determined that the proposed operational missions of VCA include subject areas not previously trained or considered. These include but are not limited to:

- Knowledge of flight control systems (inceptors, cyclic, collective, etc.)
- Theoretical knowledge of the specific type of VCA
- Principles of lift and performance in VCAs
- Control logic and flight management software rules and manner of human interaction in VCAs
- Power management including balance and thrust in VCAs in off-nominal situations
- Battery state of function/charge/health/available performance/power
- Fuel or energy management
- Spatial disorientation and human factors in VCAs
- Environmentals
- Wake downwash/outwash, vortex ring state, fountain flow
- Principles of transition, conversion
- New landing site operations (vertiport, etc.)
- Micro weather (e.g., urban canyon, etc.)

3.4 Practical

The Pilot Training Program in Appendices A and B demonstrates the training methodology, emphasizing performance-based and competence-based processes for training and assessment. Performance-based objectives set measurable and reasonable goals that describe the desired performance of the student. The objectives are clearly stated, measurable, and repeatable. Performance-based training reinforces the skill, conditions, and criteria expected of pilot candidates. Performance-based requirements define what criteria needs to be met to accomplish training tasks without prescribing how they will be met. The target of this performance-based approach is to provide an acceptable level of safety without utilizing a prescriptive method of training. This allows for a variety of technical solutions that could meet the requirements. For example, the wording of a prescriptive- or compliance-based standard for a steep, 360-degree turn may specify no more than 100-foot change of altitude, heading within 10 degrees. A corresponding performance-based requirement may specify a minimal change in altitude during the maneuver while maintaining attitude and directional control, recognizing and correcting for any deviation.

This training approach centers around pilot competence and outcomes rather than taking a prescriptive approach. New training processes leverage advanced technologies along with modern learning techniques to develop competent and safe pilots. The Pilot Training Program uses scenario-based training structured to replicate the real-world training necessary to operate VCA in realistic situations. Scenario-based training incorporates actual flight scenarios that require the candidate to exercise sound judgement and make timely decisions. The scenarios for VCA represent realistic flying scenarios that may differ from those of traditional aircraft. Candidates must mitigate risk and address each scenario appropriately to achieve a successful outcome.

Pilots will be assessed throughout their training, emphasizing observable behaviors and measuring total performance rather than single tasks. Traditional training ensures that pilot candidates demonstrate the necessary minimum skill, knowledge, and experience levels to meet the qualification requirements of the license, rating, or privilege. Competency-based training and assessments ensure the pilot candidates possess the required competencies to carry out their assigned duties and responsibilities safely, efficiently, and effectively as pilot in command. This Pilot Training Program will focus on outcomes rather than single-task performance. The pilot training will include multiple observations or assessments across the entire training regime to ensure continuous learning rather than simply passing a test. Candidates need to demonstrate that they have obtained the competencies, through observable behaviors, and by performing at the defined level (competency standard). The training includes a task list that outlines the minimum list of training tasks that a candidate needs to complete during a course to develop all the necessary competencies. These task lists do not have any hourly prescription, with the option of course developers, OEMs, operators, or others to add additional tasks if deemed necessary.

Pilots operating these novel aircraft will need training that addresses the automation capabilities of the aircraft in relation to the pilot. Whether pilots are on board the aircraft or off board, operating remotely, knowledge of automation capabilities and the role of the pilot in relation to those capabilities is critical. The pilot may not have direct influence or control over the automation; however, the authority for decision-making will always remain with the pilot in command. Human-machine interface raises two basic questions:

- a. How do we communicate with the machine?
- b. How does the machine communicate with us?

To address these two questions, we first need to clearly define roles and responsibilities: who is doing what task (i.e., human or machine). This may differ based on the levels of automation and, additionally, whether these vehicles employ human and machine teaming or human-autonomy teaming, i.e., humans and machines working and thinking better together.

Training must address the interface between pilot and automation and define the role or ability of the pilot to influence the automation and what control the pilot maintains or does not maintain and then what actions can be taken. Because these aircraft are highly automated, pilots will be required to have more/different trained skills and knowledge. Highly automated aircraft prompts the question of what piloting skills remain essential when manual flying skills become less important. These could include things like situational awareness, judgment, decision-making, and the ability to respond correctly in an emergency—does the human manage the failure, does the human manage the system, or does the system manage the failure and is there a human-machine interface? All of these qualities will be critical for ensuring the safety of advanced and urban air mobility operations. This standard cannot fully describe the varying aircraft configurations and levels of automation, but it is expected that the OEMs will define the roles of pilot and automation when developing the certification criteria for the aircraft; is the pilot on-the-loop, over-the-loop, or out-of-the-loop?

4. FSTD TRAINING

Flight simulation training has been utilized to train pilots for many years. Numerous benefits, including safety, cost-efficiency, and repeatability, have positively shaped the aviation industry, with flight simulation becoming an indispensable aspect of flight training programs. Emerging technologies such as virtual reality (VR) and mixed reality (MR) continue to enhance the versatility of flight simulation and are an important part of training for the VCA ecosystem. As these capabilities develop, the bridge between theoretical ground instruction and actual flight training is strengthened. Training pilots in FSTDs has become commonplace, and the value of simulation devices as a method of enhancing training and expanding training opportunities has been recognized for many years. VCA present new challenges and opportunities in pilot training. The development of FSTDs representative of these new VCA provides the environment conducive to learning new skills and techniques prior to operating in the real aircraft. Some or all of pilot training may be accomplished in simulators that exactly replicate the aircraft, ensuring the training is adaptable to live flight scenarios and situations. New simulation devices incorporating VR/MR can offer valuable training opportunities combined with new and novel approaches to developing safer, well-trained pilots. The Pilot Training Program described in Appendices A and B demonstrates the use of competence-based training and assessment (CBTA) as one method of ensuring pilots develop the knowledge, skills, and attitudes necessary to safely operate VCA. Building on competence-based training and developing well-trained pilots means leveraging all available tools (including emerging technologies such as AI and ML) to analyze simulator data that will enhance and assist instructors in evaluating student performance and personalizing student training.

As new and different training devices develop and gain approval, so too will methods of training in FSTDs. Off-board instructors and AI instructors will enter the mix of training methodologies.

FSTDs allow trainees to practice a wide range of flight scenarios, enhancing their skills and confidence in a safe, repeatable environment for practicing procedures and emergency scenarios. The aim of any simulation training device is to replicate the flight environment for the trainee in such a way that the scenarios in the real world will be familiar and performed with competence and proficiency. FSTDs will be essential for the training and qualification of off-board pilots and enabling future autonomous operations. Benefits of FSTD training include:

- Emergency training: FSTDs can simulate emergencies and provide valuable training on how to respond effectively.
- Environmental conditions: FSTDs can replicate various weather conditions, enabling trainees to practice in adverse situations.
- Time efficiency: Training sessions can be scheduled at any time, making it more convenient for both instructors and trainees.
- Safety: FSTDs provide a controlled environment, reducing the risk associated with in-aircraft flight training.
- Single pilot training: FSTDs allow efficient training not able to be conducted in a single control aircraft.
- Endurance: FSTDs offer the opportunity to train for longer durations than some, or many, VTOLs.
- Skill development: Simulators allow trainees to practice a wide range of flight scenarios, including repetition of maneuvers and procedures, enhancing their skills, confidence, and conceptual understanding.
- Data analysis: Simulators can record and analyze pilot performance, helping instructors provide targeted feedback for improvement.