Circular No.1-031

Policy of special conditions application for electric vertical take-off and landing aircraft

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Airworthiness Division, Aviation Safety and Security Department
Japan Civil Aviation Bureau
Ministry of Land, Infrastructure, Transport and Tourism

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1. Applicable scope

This circular applies when setting special conditions for electric vertical take-off and landing aircraft (hereinafter referred to as "eVTOL") that meet the following conditions.

(1) Vertical take-off and landing aeroplane and multirotor (aircraft equipped with three or more rotating bodies used to generate lift during vertical take-off or landing) that are powered by electricity according to Regulation for Enforcement of the Civil Aeronautics Act (Order of the Ministry of Transport No.56 of 1952)

(2) Maximum take-off weight of 3,175 kg (7,000 lb) or less and a maximum number of passenger seats of 9 or less (corresponding to certification levels 1 to 3 of "Airworthiness Inspection Manual Part II")

(3) Non-pressurized

This circular provides guidelines regarding additional conditions to be considered in Airworthiness Inspection Manual Part II in order to demonstrate compliance of eVTOL with the standards in Annex 1 of the Regulation for Enforcement of the Civil Aeronautics Act.

2. Purpose

The necessity and application of special conditions are determined based on the characteristics of the design of the aircraft, etc. The design features of eVTOL include "vertical take-off and landing," "electrification," and "no pilot on board (automated or remote piloted aircraft systems)," and it includes many unique designs that are not expected in existing aircraft. Therefore, the safety of such unique designs of eVTOL is not assumed in the current Airworthiness Inspection Manual, and special conditions must be applied to ensure the safety of eVTOL. This circular aims to standardize the applicable standards in examinations for type certification, etc. by listing standard special conditions for the unique designs of eVTOL.

Note that a part of or all of the special conditions listed in this circular as shown in the attached sheet may not be applied as a result of the coordination with the Civil Aviation Bureau in the evaluation process of type certification, etc., in view of the detailed design of eVTOL. In some cases, some requirements may be changed and applied. There could be a case where new special conditions are established in addition to the Attached sheet to this circular during the evaluation process for type certification.

3. Special conditions for eVTOL

The standards applied to eVTOL are based on the Airworthiness Inspection Manual Part II, which allows flexible certification methods to be set according to the performance and functions of each model, taking into account that eVTOL has a diversity of aircraft sizes and functions. However, requirements that are not included in these standards or that are more suitable for eVTOL than the standards and that should be additionally considered shall be set as special conditions. The standard special conditions established based on the eVTOL currently envisaged are shown in the Attached sheet.

4. Miscellaneous Provisions

Notwithstanding the provisions in this circular, other means may be used when it is deemed necessary by the Director of the Aircraft Engineering & Certification Center.

Supplementary Provisions (March 22, 2024)

1. This Circular shall be enforced on March 22, 2024.

For questions and comments about this circular, please contact the following:

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Special conditions for eVTOL

1. Definition

The terms used in these special conditions are defined below.

(1) Uplink

Direct or indirect wireless communications from a ground control station to an aircraft in a C3 link or C2 link. (Related document: JIS W 0141:2019)

(2) Remote control

Performing the operations such as climb, hovering, level flight, and descent in the air by utilizing ground control stations. (Related document: JIS W 0141:2019)

(3) Line margin

A ratio (unit: dB) of C/N0 obtained by the relevant C3 link or C2 link to the required C/N0. Note that C/N0 is an abbreviation for Carrier to Noise density ratio and the ratio of carrier power to noise power density.

(4) Overvoltage

A situation where the voltage in a circuit or part of it is raised above its upper design limit. (Related document: SAE ARP8676)

(5) Overcurrent

A situation where a larger than intended electric current exists through a conductor. (Related document: SAE ARP8676)

(6) Ground handling

A wide range of services for aircraft on the ground, mainly the work related to embarkment and disembarkment of passengers, crew changes, aircraft maintenance, and battery charge.

(7) Navigation

Correctly navigate through the planned flight position, in the flight direction, etc., or its function. (Related document: JIS W 0141:2019)

(8) Autopilot

Controlling the aircraft motion (direction, altitude, speed, etc.), attitude, etc. or its function by automatically operating the propellers, control surfaces, etc. with the incorporated program in response to the changes in the aircraft attitude during flight or the set flight condition. Note that this is different from "autonomous" and "autonomous flight," which enables to continue automatic operation safely in any situations encountered during flight without depending on the direction from the ground. (Related document: JIS W 0141:2019)

(9) Control limits

The limits of flight control performance that enable the aircraft to operate safely.

(10) Cell

A single electrochemical unit which exhibits a voltage across its two terminals and is used as a component of a battery module. (Related document: SAE ARP8676)

(11)Cell balancing

A function to equalize the energy capacity of each battery cell in order to optimize available capacity and to minimize the occurrence of cell overvoltage, cell undervoltage, or cell reversal in a lithium-ion secondary battery system. (Related document: RTCA DO-311A)

(12)Sensing function

A function of measuring and quantifying the information necessary at the ground control station to monitor for the safe flight and continued operation of an aircraft.

(13)Downlink

Direct or indirect wireless communications from an aircraft to a ground control station in a C3 link or C2 link. (Related document: JIS W 0141:2019)

(14)Ground control station

A component on the ground of the remotely piloted aircraft system containing the equipment used to pilot the remotely piloted aircraft. (Related document: ICAO Annex 8 Part I)

(15)Signal resilience

The ability for a receiver or the receiving section of a transceiver to distinguish desired waves (target signals) and unnecessary waves (interfering waves).

(16)Predicted signal strength

One of the indicators related to the operational performance of the C3 link or C2 link, which is the predicted value of the received radio field intensity arriving at an aircraft or a ground control station using a radio wave propagation model and three-dimensional map information.

(17)Electric engine (engine powered by electricity)

A minimum of components including the electric motor, associated electronic controllers, disconnects, wiring and sensors that provide propulsion to the aircraft, which transform electrical power to mechanical power. (Related document: SAE ARP8676)

(18)Thermal runaway

An uncontrollable phenomenon with rapid self-sustained heating of a battery cell driven by exothermic chemical reactions of the materials within the cell. (Related document: RTCA DO-311A)

(19)Bit error rate

One of the specifications indicating communication quality, which is the ratio of the number of incorrectly received codes during a certain period to the total number of transmitted codes during that period (transmission error frequency).

(20)Undervoltage

A situation where the circuit voltage drops cause the difficulty of ensuring voltage necessary to operate the device, or the incorrect operation in the internal circuit of the device.

(21)ATC data

Input/output information of onboard equipment related to air traffic control.

(22)BIT function

The abbreviation for Built-In Test, which is a function that automatically and manually checks the equipment health at start-up and during operation.

(23)C2 link

A data link between the remotely piloted aircraft and the ground control station for the purposes of managing the flight. C2 is an abbreviation for Command and Control. (Related document: ICAO Annex 8 Part I)

(24)C3 link

A data link between the remotely piloted aircraft, the ground control station, and the air traffic control for the purposes of managing the flight. C3 is an abbreviation for Command, Control and Communication.

(25)Return Home function

A function which performs self-operating return flight to the departure/arrival point according to the occurrence of malfunction of an airframe or the direction of a RPIC. (Related document: JIS W 0141:2019)

(26)RPIC

The abbreviation for Remote Pilot-in-Command, which is the remote pilot designated by the operator as being in command and charged with the safe conduct of a flight. (Related documents: ICAO RPAS Concept of Operations, ICAO Annex 1)

2. Special conditions (aircraft flying with any flight crew on board)

The following are the special conditions to be considered to certify the airworthiness of aircrafts regarding the characteristic functions of eVTOL. Note that each section number is selected to match the numbers of the Airworthiness Inspection Manual Part II.

(1) Chapter 1 General

None.

(2) Chapter 2 Flight

§ eVTOL 23.2105 Performance data

(a) Performance at minimum operating speed

The following must be determined over the ranges of aircraft weight, altitude, and temperature for which certification is requested.

(1) The in-ground effect (IGE) hovering ceiling with:

(i) Take-off power;

(ii) The landing gear extended; and

(iii) The aircraft in-ground effect at a height consistent with normal landing procedures; and

(2) The out-of-ground effect (OGE) hovering performance

(3) Chapter 3 Structures

§ eVTOL 23.2250 Design and construction principles

(a) The aircraft must be designed to ensure safety after a likely bird strike during flight.

(b) It must be impossible for rotors installed on the aircraft to contact the ground during normal take-off and landing procedures. If a rotor guard is required to show compliance with this requirement:

(1) Suitable design loads must be established for the guard; and

(2) The guard and its supporting structure must be designed to withstand those loads.

(4) Chapter 4 Design and Construction

§ eVTOL 23.2300 Flight control systems

The flight control systems must be designed to allow the flight crew to be aware of the control limits.

§ eVTOL 23.2320 Occupant physical environment

Each windshield and its supporting structure directly in front of the flight crew must withstand, without penetration, a likely bird strike during flight.

§ eVTOL 23.2325 Fire Protection

The aircraft must be designed to meet the following requirements to minimize the risk of fire initiation and the impact on emergency response.

(a) Minimize fire initiation due to a survivable emergency landing;

(b) Minimize heat generation, energy dissipation, flammable fluid/gas dissipation and system failures, which may lead to fire initiation.

(5) Chapter 5 Powerplant

§ eVTOL 23.2430 Energy storage and distribution systems

(a) Likely errors during ground handling of the aircraft must not lead to a hazardous loss of stored energy.

(b) Each system must have:

(1) The battery cell balancing function;

(2) The function to estimate the battery's state of charge;

(3) The function to estimate the battery's state of degradation; and

(4) The BIT function for the entire battery system including the control section.

(c) The state of the battery cells must be monitored and the battery cells must be protected from the adverse conditions of overvoltage, undervoltage, overcurrent and overheating.

§ eVTOL 23.2435 Lift/thrust installation support system

The aircraft must allow the flight crew to be aware of the physical configuration of lift/thrust unit if the lift/thrust unit of the aircraft has multiple physical configurations that affect aircraft performance and operating procedures necessary for safe flight crew operations.

§ eVTOL 23.2440 Powerplant fire protection

(a) There must be a means to isolate and mitigate hazards to the aircraft in the event of fire or overheat of the electric engine.

(b) There must be a means to isolate and mitigate hazards to the aircraft in the event of fire or thermal runaway of the batteries that provide the electric engine with the power for lift/thrust.

(6) Chapter 6 Equipment

§ eVTOL 23.2510 Equipment, systems, and installations

Each system and equipment must be designed and installed such that each catastrophic failure condition does not result from a single failure.

(7) Chapter 7 Flight Crew Interface and Other Information

None.

3. Special conditions (the aircraft with devices that allows flight without any crew on board)

The following special conditions should be taken into account for the aircraft equipped with devices that allow flight without any crew on board, in addition to the special conditions in paragraph 2.

(1) Aircraft: Matters related to the flight control system and the propulsion system

§ RPA1-1

Each sensing function of the flight control system and the propulsion system of the aircraft must be designed and installed appropriate to its intended function. These functions must not be affected by other equipments and systems such that the level of safety of the aircraft is reduced.

§ RPA1-2

The automatic function of the aircraft flight control system must be designed and installed appropriate to its intended function. This function must not be affected by other equipments and systems such that the level of safety of the aircraft is reduced.

§ RPA1-3

The aircraft must provide RPIC with information about the setting and the monitoring associated with the automatic function of the flight control system.

§ RPA1-4

The automatic function of the aircraft flight control system must be designed which shall either automatically deal with, or enable RPIC to deal with the failures and the abnormal operations based on the results of the assessment in the design process about the consequences of all foreseeable failures in advance.

§ RPA1-5

During a flight with an autopilot function activated, the function that automatically deals with failures and abnormal operations of the flight control system and the propulsion system of the aircraft must be designed and installed appropriate to its intended function. This function must not be affected by other equipments and systems such that the level of safety of the aircraft is reduced.

§ RPA1-6

During a flight with the autopilot function activated, the aircraft must provide RPIC with information about the setting, the monitoring and the health status associated with the function

that is capable of automatically dealing with failures and abnormal operations of the flight control system and the propulsion system of the aircraft.

§ RPA1-7

The aircraft must be designed which shall either automatically deal with, or enable RPIC to deal with the failures of the function described in §RPA1-5 based on the results of the assessment in the design process about the consequences of all foreseeable failures in advance.

(2) Aircraft: Matters related to the energy storage and distribution system

§ RPA2-1

The aircraft must provide RPIC with information about the setting and the monitoring associated with the operating status of the energy storage and distribution system of the aircraft.

§ RPA2-2

The aircraft must provide RPIC with information about the health status of the sensing functions associated with the operating status of the energy storage and distribution system of the aircraft.

§ RPA2-3

During a flight with the autopilot function activated, the aircraft must provide RPIC with information about the setting and the monitoring associated with the function that is capable of automatically dealing with failures and abnormal operations of the energy storage and distribution system of the aircraft.

§ RPA2-4

The aircraft must be designed which shall either automatically deal with, or enable RPIC to deal with the failures of the function described in §RPA2-3 based on the results of the assessment in the design process about the consequences of all foreseeable failures in advance.

(3) Aircraft: Matters related to the navigation system

§ RPA3-1

Each sensing function of the aircraft navigation system must be designed and installed appropriate to its intended function. These functions must not be affected by other equipments and systems such that the level of safety of the aircraft is reduced.

§ RPA3-2

The aircraft must provide RPIC with information about the setting and the monitoring associated with the aircraft navigation system. Radio wave conditions associated with the aircraft navigation equipment must be monitored, and predicted signal strength and signal status must be provided.

§ RPA3-3

Each sensing function of the aircraft navigation system must be designed that enable RPIC to deal with the failures of the function based on the results of the assessment in the design process about the consequences of all foreseeable failures in advance.

§ RPA3-4

Each sensing function for the aircraft ATC data must be designed and installed appropriate to its intended function. These functions must not be affected by other equipments and systems such that the level of safety of the aircraft is reduced.

§ RPA3-5

The aircraft must provide RPIC with information about the setting and the monitoring associated with the aircraft ATC data. Radio wave conditions associated with the aircraft ATC equipment must be monitored, and predicted signal strength and signal status must be provided.

§ RPA3-6

Each sensing function for the aircraft ATC data must be designed that enable RPIC to deal with the failures of the function based on the results of the assessment in the design process about the consequences of all foreseeable failures in advance.

(4) Aircraft: matters related to the communication system

§ RPA4-1

The antenna control function of the aircraft must be designed that enable RPIC to deal with the failures of the function based on the results of the assessment in the design process about the consequences of all foreseeable failures in advance.

§ RPA4-2

The aircraft must provide RPIC with information about the setting and the monitoring associated with the antenna control functions of the aircraft.

§ RPA4-3

The uplink receiving function of the aircraft must be designed that enable RPIC to deal with the failures of the function based on the results of the assessment in the design process about the consequences of all foreseeable failures in advance.

§ RPA4-4

The uplink bit error rate and line margin must be determined to allow the aircraft to operate safely.

§ RPA4-5

The uplink receiving function of the aircraft must have signal resilience.

§ RPA4-6

Predicted strength information of the C3 link or C2 link communication must be provided for RPIC through the uplink receiving function of the aircraft when flying with passengers on board, or no passenger without the Return Home function.

§ RPA4-7

The uplink receiving function of the aircraft must be configured to be able to deal with failures of the external infrastructure when using the external infrastructure as its C3 link or C2 link. Note that the external infrastructure itself is not subject to the airworthiness evaluation.

§ RPA4-8

The downlink transmitting function of the aircraft must be designed that enable RPIC to deal with the failures of the function based on the results of the assessment in the design process about the consequences of all foreseeable failures in advance.

§ RPA4-9

The downlink bit error rate and line margin must be determined to allow the aircraft to operate safely.

§ RPA4-10

Predicted strength information of the C3 link or C2 link communication must be provided for RPIC through the downlink transmitting function of the aircraft when flying with passengers on board, or no passenger without the Return Home function.

§ RPA4-11

The downlink transmitting function of the aircraft must be configured to be able to deal with failures of the external infrastructure when using the external infrastructure as its C3 link or C2 link. Note that the external infrastructure itself is not subject to the airworthiness evaluation.

§ RPA4-12

Each sensing function of the aircraft communication system must be designed that enable RPIC to deal with the failures of the function based on the results of the assessment in the design process about the consequences of all foreseeable failures in advance.

(5) Aircraft: Matters related to the structure and the landing system

§ RPA5-1

Each sensing function of the aircraft configuration, etc. must be designed and installed appropriate to its intended function. These functions must not be affected by other equipments and systems such that the level of safety of the aircraft is reduced.

§ RPA5-2

The aircraft must provide RPIC with information about the setting and the monitoring associated with the aircraft configuration, etc.

§ RPA5-3

Each sensing function of the aircraft configuration, etc. must be designed which shall either automatically deal with, or enable RPIC to deal with the failures and the abnormal operations based on the results of the assessment in the design process about the consequences of all foreseeable failures in advance.

(6) Matters relating to the ground control station

§ RPS1-1

The ground control station must be designed:

(a) To be appropriate to its intended function. This function must not be affected by other

equipments and systems such that the level of safety of the aircraft is reduced;

(b) To provide the RPIC with all information necessary for its operation; and

(c) To configure to be able to deal with failures of the external infrastructure when using the external infrastructure as its C3 link or C2 link for the following functions. Note that the external infrastructure itself is not subject to the airworthiness evaluation.

(1) The uplink transmitting function; and

(2) The downlink receiving function.

(d) The remote control function must be designed which shall either automatically deal with, or enable RPIC to deal with the failures and the abnormal operations based on the results of the assessment in the design process about the consequences of all foreseeable failures in advance.

§ RPS1-2

The Instructions for Continued Airworthiness must include the equipment that corresponds to the ground control station. The contents to be described in the Instructions must be coordinated with the Japan Civil Aviation Bureau.