

ED-298

GUIDANCE ON MINIMUM PRIMARY FLIGHT INSTRUMENTS FOR VTOL AIRCRAFT

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CHAPTER 1

INTRODUCTION

1.1 PURPOSE AND SCOPE

This document contains minimum requirements for the display of primary flight information in VTOL aircraft to support in-part, the requirements of SC.VTOL.2165. Additional requirements for displaying navigation and lift/thrust unit (LTU) information are out of scope, since the former are dependent on the requirements set by the Air Traffic Management (ATM) system for Urban Air Mobility (UAM), and the latter are heavily dependent on the specific VTOL design and are difficult to capture in a single standard. Furthermore, this document does not consider the display of information trends and limitations, which will be addressed in a new version of this document at a later date, or a separate document altogether, as to be determined by Eurocae WG-112.

Compliance with this document is recommended as one means of assuring that the equipment will perform its intended function(s) satisfactorily under all conditions normally encountered in routine aeronautical operation.

1.2 DEFINITIONS AND ABBREVIATIONS

ACAH	Attitude Command Attitude Hold
ATC	Air Traffic Control
ATM	Air Traffic Management
FCL	Flight Control Laws
FCS	Flight Control System
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
LTU	Lift Thrust Unit
PH	Position Hold
RCDH	Rate Command Direction Hold
RCHH	Rate Command Height Hold
TRC	Translational Rate Command
UAM	Urban Air Mobility
VFR	Visual Flight Rules
VTOL	Vertical Take-Off and Landing

1.3 REFERENCES

1. EASA Special Condition Vertical Take-Off and Landing (VTOL) Aircraft
2. ADS-33E-PRF Aeronautical Design Standard Performance Specification Handling Qualities Requirements for Military Rotorcraft

1.4 RELATIONSHIP TO SC-VTOL

Whilst this standard was developed with a particular view to the European legal framework, namely the EASA Special Condition VTOL Issue 1, it may be applied to support other regulatory frames.

As regards the EASA SC VTOL, this standard supports the showing of compliance with the following requirements and/or complements the following related Means of Compliance:

- VTOL.2615 – Flight, navigation, and lift/thrust system instruments.

CHAPTER 2

GENERAL REQUIREMENTS

2.1 GENERAL

This means of compliance document presents minimum requirements for the display of primary flight information for VTOL aircraft, following comparison with the existing regulations for rotorcraft, and whilst considering the flight control response or flight control laws of VTOL aircraft, in different visibility conditions with associated differences in the external visual cues.

Whilst the document refers to flight *instruments*, it is recognised that VTOL aircraft will likely move away from the traditional concept of a single instrument for a single piece of information (e.g., an altimeter for altitude information). The use of 'instruments' maintains consistency with the title of the specific paragraph in SC.VTOL to which this MOC relates. However, rather than exhibiting classical individual instruments, VTOL aircraft may utilise multi-function displays capable of presenting all information on a single screen. This document therefore uses terminology such as 'a means to measure and display' to define the information required, which also aligns with the text of Part-IAM (Innovative Air Mobility), currently being developed for the VTOL industry.

2.2 STAGES OF FLIGHT PROFILE

Installed systems must provide the flight crew member the information necessary to set and monitor the flight parameters during each stage of flight. For the operational scenarios of VTOL aircraft, the minimum flight information has been considered in three stages of a typical VTOL flight profile as follows:

1. Low-speed ground referenced flight
2. Low-speed to forward flight transition
3. Forward flight

For low-speed ground referenced flight, the pilot controls the aircraft with primary reference to external visual cues (even in degraded visibility conditions), generally in close proximity to the ground. The flight control laws will likely be tailored accordingly. For low-speed forward flight transition, there is a blending between external visual cues and the flight indications. For forward flight, generally applicable to the en-route phase, external cues in good visual conditions are generally at long visual range, such as the horizon line (irrespective of whether the VTOL design enables wing-borne flight).

2.3 EXTERNAL VISUAL CUES

The required minimum flight instruments are dependent on the external visual cues available to the pilot. The external visual cues are the ones used by the crew to either perform their tasks, which include controlling the trajectories of the aircraft, and/or to enable the crew to keep their situational awareness in terms of external obstacles and traffic. Moreover, depending on the external visibility (weather and illumination), the visual external view available to the crew can prevent physiological incidents such as spatial disorientation. The available external cues have therefore been considered when mandating any instrument as a required minimum.

2.4 FLIGHT CONTROL LAW RESPONSE TYPES

The applicant should identify the flight control laws (FCL) response type for their aircraft in each stage of flight. The response types could be the result of aerodynamic surface displacement and/or the use of LTUs. For the minimum flight instruments identified, it is irrelevant which are the means used to create the aircraft rates or attitudes when controlling the aircraft trajectory. However, the specific characteristics and dynamics of the indications of these minimum flight instruments may vary based on the type of flight control law response and the integration of aerodynamic surfaces (which will have minimum and maximum excursions) and LTU interaction, required to produce the commanded rates/attitudes/translation.

The control law response Types defined in ADS-33E-PRF (reference 2) were used as a starting point. These are listed in TABLE 2-1 and explained in the subsequent paragraphs. However, the applicant can determine which FCL comes closest to the implemented design and specify the minimum instruments accordingly.

TABLE 2-1: TYPICAL FCL RESPONSE TYPES AS DEFINED IN ADS-33E-PR

FCL	Definition
RATE	Rate response
RCDH	(Yaw) Rate Command Direction (Heading) Hold
RCHH	(Vertical) Rate Command Height (Altitude) Hold
ACAH	Attitude Command Attitude Hold
RCAH	Rate Command Attitude Hold
PH	Position Hold
TRC	Translational Rate Command

NOTE: *In the paragraphs below, control modes are presented in an order from a low level of automation (controller loops) to higher levels of automation.*

2.4.1 RATE (Rate response)

A response type that controls a rate-of-change around a different body axis that is directly proportional to the magnitude of the control input of the pilot. In accordance with ADS-33, it also constitutes a response type that fails to meet any of the other response types that are presented below.

2.4.2 RCDH (Rate Command Direction (Heading) Hold)

Typically implemented for the yaw axis, RCDH is a response type that controls the angular yaw rate in direct proportion to the magnitude of the control input of the pilot. The heading hold element ensures that when the pilot releases the control input to zero, yaw rate reduces to zero and the FCL will maintain the heading achieved at that time.

2.4.3 RCAH (Rate Command Attitude Hold)

The rate command is equivalent to yaw in RCDH but implemented for the pitch/roll body frame axes. The rate of change commanded by the pilot is therefore the inertial angular rates in the body frame, and not the rate of change of attitude. The attitude hold element (maintained with respect to an earth-fixed inertial frame) ensures that when the pilot releases the control input to zero, pitch and/or roll rate reduces to zero and the FCL will maintain the pitch angle or roll angle achieved at that time. Whenever a disturbance changes the attitude of the aircraft the controller will return to the saved attitude.

2.4.4 RCHH (Rate Command Height (Altitude) Hold)

Typically implemented for the vertical axis. A response type that controls translational rate that is directly proportional to the magnitude of the control input of the pilot. In other words, the pilot directly controls the vertical speed using stick position. If the pilot releases the control input to zero, the translational rate will reduce to zero and hence the aircraft will remain at its current height/altitude.

2.4.5 ACAH (Attitude Command Attitude Hold)

Typically implemented for pitch and roll axis. A response type that controls the absolute attitude angle (around pitch and roll) directly proportional of the magnitude of the control input of the pilot.

2.4.6 TRC (Translational Rate Command)

TRC is the more generic counterpart of RCHH, typically implemented for the horizontal position of the aircraft. It is a response type that controls the translational rate of aircraft

movement over the ground in direct proportion to the magnitude of control input of the pilot. In other words, the pilot directly controls the speed of the aircraft (and hence position over the ground) in the respective x and y direction using stick position. If the pilot releases the control input to zero, the translational rate will reduce to zero and hence remain in its current position. TRC is usually implemented with alignment to the aircraft's heading, so that for example, a right control inceptor results in a velocity vector to the right from the pilot's perspective.

2.4.7

PH (Position Hold)

PH ensures that when the pilot releases the control input to zero, the FCL will maintain the aircraft's position achieved at that time, despite possible external disturbances.

CHAPTER 3

MINIMUM PRIMARY FLIGHT INSTRUMENT REQUIREMENTS

3.1 GENERAL

This chapter presents those minimum information that must be measured and displayed, as required to control the flight trajectory of the aircraft, without considering information associated with the means of propulsion. Flight instruments should provide accurate attitude, airspeed and altitude indications, and any other information that a pilot may require to maintain situational awareness, avoid spatial disorientation, execute recovery from any unusual attitudes, and arrest a higher-than-normal pitch, roll or yaw rate that may be encountered. In visual conditions, external cues may be sufficient for certain indications, for example in determining the aircraft attitude to control the aircraft trajectory and avoid spatial disorientation.

The following instruments are considered to be the primary flight instruments:

- i. Attitude (pitch and roll) indicator.
- ii. Airspeed indicator.
- iii. Altitude indicator.
- iv. Rate of Turn indicator.
- v. Direction indicator.
- vi. Vertical Velocity (Rate-of-climb) indicator.
- vii. Velocity Vector indicator.

Only certain indications may be required to be present (the minimum), depending on the visual conditions, and on the flight control laws implemented in the VTOL. The tables below present a quick reference summary of those minimum indications for each set of flight control laws. TABLE 3-1 presents those indications that shall be implemented to enable flight in good visual conditions (i.e. day-VFR). And TABLE 3-2 presents those indications that shall be implemented to enable flight in marginal visibility or in the complete absence of external visual cues (special/night VFR and IFR).

TABLE 3-1: MANDATORY FLIGHT INDICATIONS IN GOOD VISIBILITY (DAY VFR)

	RATE	RATE + RCDH + RCHH	ACAH + RCDH	ACAH + RCDH + RCHH	ACAH + RCDH + RCHH + PH	TRC + RCDH + RCHH + PH
Attitude (Pitch & Roll)			✓	✓	✓	
Airspeed	✓	✓	✓	✓	✓	✓
Altitude	✓	✓	✓	✓	✓	✓
Rate of Turn						
Direction	✓	✓	✓	✓	✓	✓
Vertical Velocity	✓	✓	✓	✓	✓	✓
Velocity Vector					✓	✓