

# Handling Qualities Certification Criteria and Means of Compliance for eVTOLs

**Hamdy Sallam**

Rotorcraft and VTOL flight test pilot, EASA

**Mitch Soth**

Policy and Standards flight test engineer, FAA

**Ross Schaller**

Policy and Standards flight test engineer, FAA



# Statement of the scope of this presentation

EASA and the FAA are harmonizing the certification criteria and applicable means of compliance (MoCs) for eVTOLs in several technical domains.

This presentation would like to share the status of the harmonization effort for the requirements and MoCs that address handling qualities.

The material presented is still under development, and may change in the future when the authorities will publish, according to their internal procedures, the official material.

# Agenda

EASA and FAA approach to eVTOL certification

HQs requirements for EASA SC VTOL and FAA

Definitions

Handling Qualities

Handling Qualities levels

Target Handling Qualities levels

New Proposed updated table

Questions



# EASA and FAA approach to Certification

EASA has published SC VTOL that is intended to be used as Cert. Basis for all eVTOL designs

FAA uses 21.17b, G-1 for each eVTOL applicant

While the process is different, the intent and technical requirements are being harmonized

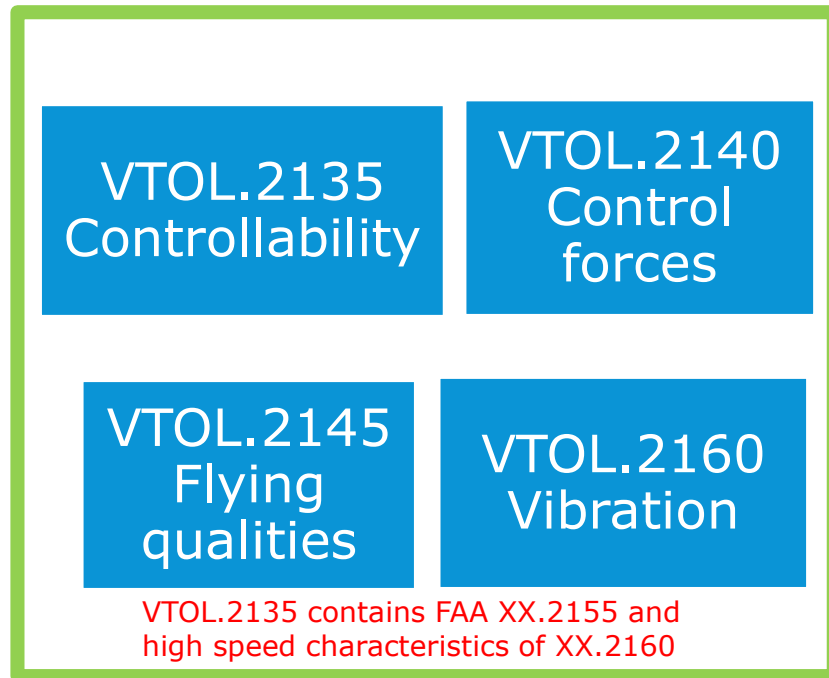
There is also an ongoing effort to harmonize the Means of Compliance (MoC), both at Authority level, and at Industry level

It is a “bookkeeping effort” to link the technical requirements to the certification requirements and applicable MoCs

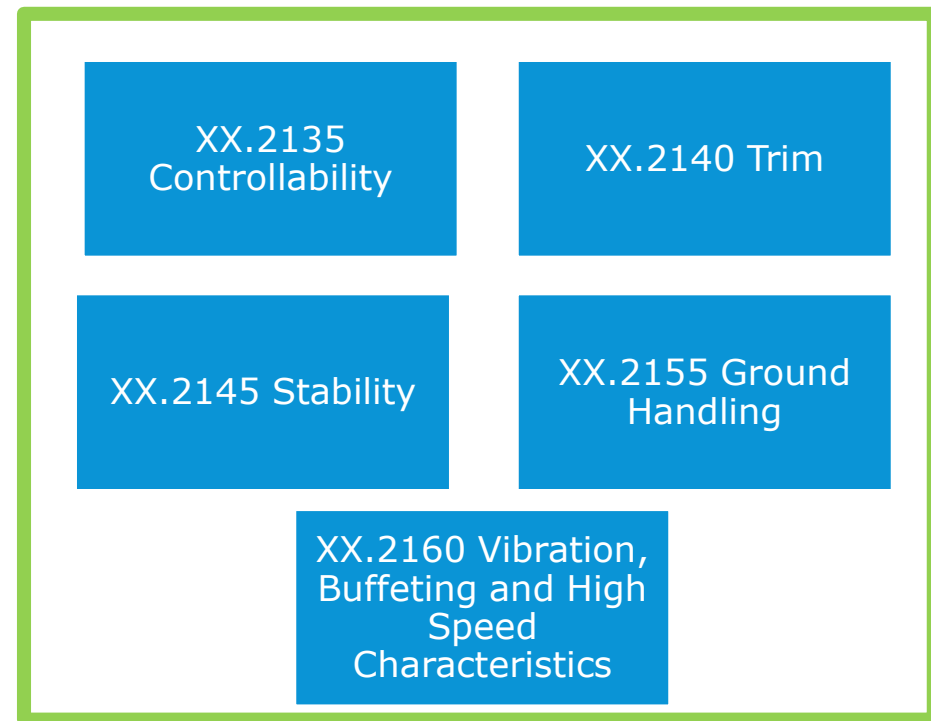


# HQs Requirements for EASA SC VTOL and FAA

## EASA



## FAA



# Definitions

## Stability

Is a characteristic of an aircraft to retain a given flight condition:

Can be Positive, Negative or Neutral

**Static stability** - the initial tendency of an aircraft to return to or depart from its trim condition following a disturbance.

**Dynamic stability** – the longer-term tendency of an aircraft to return to or depart from its trim condition following a disturbance.

# Definitions

## Manoeuvrability

Is the ability of an aircraft to change its flight condition

Manoeuvrability = Control Margin + Control Response

Control Response = Control Power + Quickness

Control power (open loop max capability, e.g. deg/sec for rate command)

Quickness (closed loop rate for moderate amplitude attitudes).

Is a "performance" measure of aircraft.

Control margin - The amount remaining of aircraft response by a given effector's displacement before being saturated.



## Definitions

# Inceptor characteristics (IC)

To include the deadband, force gradients, stick jump, and ergonomics.

They are inherently linked to the determination of Stability and Controllability

They can hide or exaggerate Handling Qualities deficiencies





# Definitions

## Flying Qualities

The characteristics of an aircraft resulting from the combination of the platform's inherent and augmented stability and manoeuvrability.

It is also the Open Loop Response of the aircraft

# Definitions

## Controllability

A measure of the response of an aircraft ("performance") relative to the pilot's flight control inputs.

The characteristic of an aircraft derived from the combination of Flying Qualities and the nature of the flight controls/inceptors.



# Definitions

## Task/Mission

Task - the actual work assigned to a pilot to be performed in completion of, or as representative of, a designated flight segment.

Mission - All operational requirements the pilot/vehicle combination must be able to accomplish if the intended use of the aircraft is to be fulfilled

# Definitions

## Aircraft cues

The visual/haptic/motion/instrument references the pilot uses to fly the manoeuvre and self evaluate his/her precision during a handling task

The internal & external visual references that the pilot uses to fly the aircraft

# Definitions

## Handling Qualities

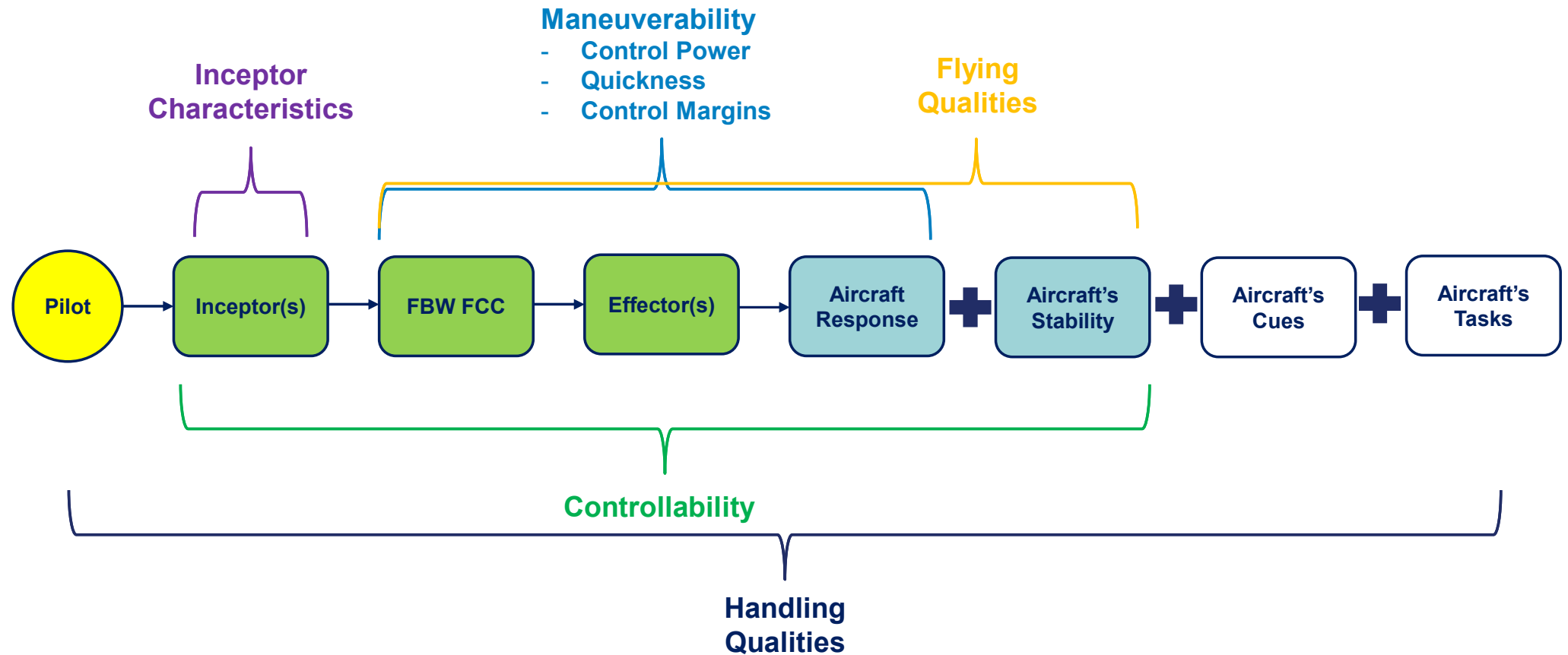
From Cooper-Harper "Those qualities or characteristics of an aircraft that govern the ease and precision with which a pilot is able to perform the tasks required in support of an aircraft role."

Are identified with the pilot in the loop assessing the combination of Flying Qualities, Inceptor characteristics, and the required compensation in an environment during a specified task.

Closed loop response of aircraft

To assess Handling Qualities the pilot flies an assigned task in a specified environment (with aircraft cues and levels of atmospheric disturbances). Therefore, the Handling Qualities experienced in a task are the summation of Flying Qualities + Inceptors ( $FQ + Inc. = \text{controllability}$ ) of the aircraft in specified environmental conditions.

# Handling Qualities



# Handling Qualities Levels definitions

Handling Qualities Rating (HQR)	Description	Cooper Harper Rating Scale (CHR)
Satisfactory (SAT)	Handling Qualities allow achievement of <b>desired performance criteria without exceptional piloting skills and with no or <u>minimal pilot compensation</u></b> .	1-3
Adequate (ADQ)	Handling Qualities allow achievement of <b>desired performance criteria</b> or <b>adequate performance criteria</b> without exceptional piloting skills and <b><u>with moderate to extensive pilot compensation</u></b> .	4-6
Controllable (CON)	Handling Qualities DO NOT allow achievement of adequate performance criteria WITHOUT exceptional piloting skills. Allows however <b>continued safe flight and landing, without exceptional piloting skills</b> , after a transient condition or reconfiguration to retain control, if necessary.	7-9



# Handling Qualities Levels definitions

The “precision performance” should be achieved without “Exceptional piloting skills”. The “level of compensation” is always referred to the “average pilot”, or a pilot without “exceptional piloting skills”.

It is important to highlight that the boundary between SAT and ADQ may be based on whether “desired” performance is achieved with either “Minimal” or “Moderate” pilot compensation. A CHR 4 may still be acceptable, as long as the issue driving the compensation is correctly identified and is considered not to be a safety issue.

The definition of CON considers also HQs following a Failure condition. Continued Safe Flight Landing (CSFL) is still guaranteed with 7-9, however the HQ degradation is such that it needs to be in line with the probability of the failure occurrence.

Transients during atmospheric disturbance (AD) and failure conditions (FC) are not considered in the pilot in the loop definition of HQs. Even CON considers the evaluation performed after the transient has occurred and the pilot is back in the loop.



# Target Handling Qualities Levels – current EASA MoC

Phase of flight: CRUISE (Example)									
FltC  $X_{FE} * X_{FC} * X_{AD}$	Atmospheric Disturbance (AD)								
	Light			Moderate			Severe		
	Flight Envelope (FE)								
Failure Condition (FC)	NFE	OFE	LFE	NFE	OFE	LFE	NFE	OFE	LFE
Nominal Condition	SAT	SAT	CON	SAT	SAT	CON <small>NOTE 1</small>	SAT	ADQ <small>NOTE 1</small>	CON <small>NOTE 1</small>
Probable up to Remote Failure Conditions:	SAT	ADQ	CON	SAT	ADQ <small>NOTE 1</small>	CON <small>NOTE 1</small>	ADQ	CON <small>NOTE 1</small>	CON <small>NOTE 1</small>
Extremely Remote Failure Conditions:	ADQ	ADQ	CON	ADQ	CON <small>NOTE 1</small>	NOTE 2	CON	NOTE 2	NOTE 2

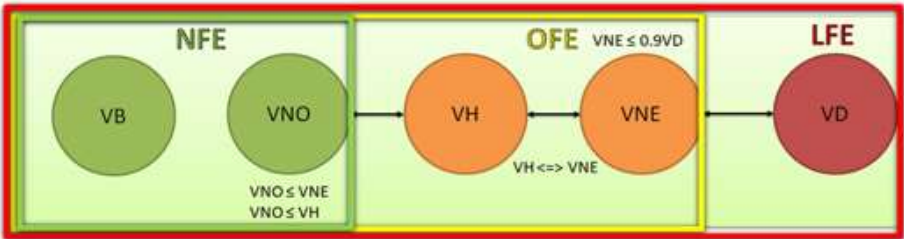
NOTE 1: This is considered to be a transient condition, and it is expected that better HQR will be achieved when the AD level is decreased. Likewise it should be demonstrated that better HQRs are achieved in the more favourable Flight Envelopes: such transition should be relatively quick and without requiring exceptional piloting skills.

NOTE 2: This FC is shaded in red as it could possibly have a related probability lower than Extremely Improbable, and should not be considered. If the FC probability is greater than Extremely Improbable, then the minimum HQR should be CON.

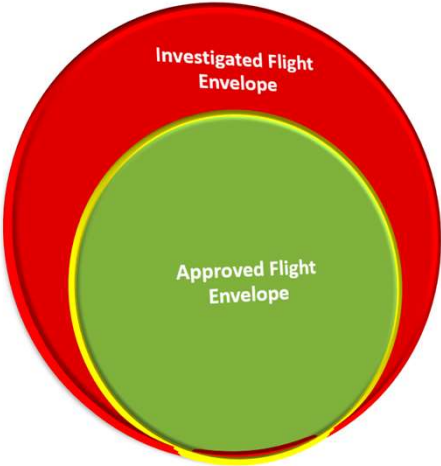
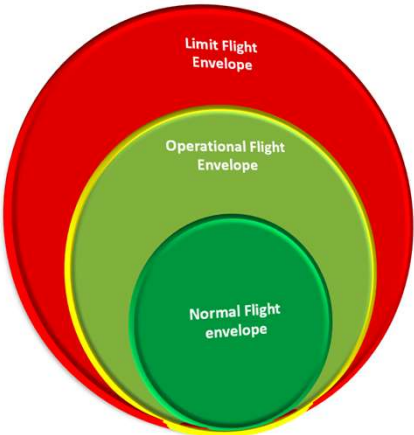
Current

# Target Handling Qualities Levels - Flight Envelope Definitions

## EASA



## FAA



- Key:**
- NFE:** Normal Flight Envelope
  - OFE:** Operational Flight Envelope
  - LFE:** Limit Flight Envelope
  - $V_B$ :** turbulence penetration speed
  - $V_{NO}$ :** maximum structural cruising
  - $V_{NE}$ :** never-exceed speed
  - $V_H$ :** maximum speed in level flight with maximum continuous power
  - $V_D$ :** Design diving speed



# Target Handling Qualities Levels - Atmospheric Disturbance

The levels of AD, and probability associated with encountering each level has not reached any acceptable consensus so far.

Some proposals have been made by applicants, but they miss the operational data.

The AD levels light and moderate have been merged, and the probabilities have been removed.

# Target Handling Qualities Levels - Failure conditions

The failure conditions that need to be considered are those that affect the pilot in the loop handling of the eVTOL.

Transients, and the effect of transients, are out of scope of the HQs evaluation. They are considered in the system safety analysis.

The level of HQs degradation (ADQ and CON) needs to be consistent with the probability and safety objective.

# New Proposed updated table

NEW  
Proposal!!

FLIGHT CONDITION	Atmospheric Disturbance (AD)			
	Light Moderate		Severe	
	Flight Envelope (FE)			
Failure Condition effect on HQs (FC)	NFE/OFE or Approved Envelope	LFE or Investigated Envelope	NFE/OFE or Approved Envelope	LFE or Investigated Envelope
Nominal Condition to Minor	SAT	CON NOTE 2	ADQ NOTE 1	CON NOTE 1 NOTE 2
Major to Hazardous	ADQ		CON NOTE 1	

NOTE 1: This ~~is considered to be~~ a transient condition, and it is expected that better HQR will be achieved when the AD level is decreased.

NOTE 2: It should be demonstrated that better HQRs are achieved in the more favourable Flight Envelopes: such transition should be relatively quick and without requiring exceptional piloting skills.

# Target Handling Qualities Levels – future activities

The terminology, test setups, test techniques, and desired and adequate criteria for each task element are being harmonized with the goal of having a common database of HQ tools between the authorities.

Flight Test Maneuvers (FTMs) ~ Handling Quality Task Elements (HQTEs)

Specific Flights (SPFs) ~ Flying Quality Assessments (FQAs)

# Questions?



Your safety is our mission.