VTOL Flight Envelopes and Stall characteristics

Hamdy SALLAM
Rotorcraft Flight Test Pilot

Your safety is our mission.

An Agency of the European Union

Agenda

- Objectives
- Applicable SC VTOL requirements
- Stall characteristics CS 23 vs SC VTOL
- Flight Envelopes in SC VTOL
- AC25-7D Envelope presentations
- VTOLs Flight Envelopes adaptation
- Conclusions
- Questions?

Objectives

- Identify where in the SC VTOL we refer to the Novel Concept of Flight Envelopes
- Provide EASA position on Stall Compliance Demonstration
- Provide EASA position on Flight Envelopes
- Identify some possible challenges when defining Flight Envelopes with VTOLs, and eVTOLs in particular

Applicable SC VTOL requirements Subpart A

VTOL.2000 Applicability and definitions

(5) ‘normal flight envelope’ means the flight envelope associated with routine operational and/or prescribed conditions;

(6) ‘operational flight envelope’ means the flight envelope associated with warning onset;

(7) ‘limit flight envelope’ means the flight envelope associated with aircraft design limits or protection limits;

Applicable SC VTOL requirements Subpart B

VTOL.2105 Performance data

(a) Unless otherwise prescribed, an aircraft must meet the performance requirements of this Subpart in:

(1) still air and standard atmospheric conditions at sea level for all aircraft; and

(2) ambient atmospheric conditions within the operational flight envelope for:

(i) reserved.

(ii) Category Enhanced.

VTOL.2110 Flight Envelopes

The applicant must determine the normal, operational and limit flight envelope for each flight configuration used in operations. The flight envelopes determination must account for the most adverse conditions for each flight configuration.

Applicable SC VTOL requirements Subpart B

VTOL.2115 Take-off performance

(a) The applicant must determine take-off performance accounting for:

(1) operational flight envelope;

(2) reserved; and

VTOL.2120 Climb requirements

The design must comply with minimum climb performance out of ground effect:

(a) in the normal flight envelope.

(b) for Category Enhanced:

(1) in the operational envelope;

(2) reserved.

(c) reserved.

VTOL.2125 Climb information

(a) The applicant must determine, as applicable, climb and/or descent performance:

(1) in the normal flight envelope;

(2) for Category Enhanced, in the operational envelope;

(3) reserved.

(b) The VTOL ceiling in and out of ground effect, if applicable, must be determined within the operational flight envelope.

Applicable SC VTOL requirements Subpart B

VTOL.2135 Controllability

(a) The aircraft must be controllable and manoeuvrable, without requiring exceptional piloting skills, alertness, or strength, within the operational flight envelope and must be controllable and manoeuvrable within the limit flight envelope:

(1) at all loading conditions for which certification is requested;

(2) during all phases of ground or flight operations;

(3) reserved;

(4) during configuration changes;

(5) in all degraded flight control system operating modes; and

(6) the applicant must demonstrate controllability in wind from zero to a wind limit appropriate for the aircraft type.

(b) Reserved.

(c) Reserved.

(d) It must be possible to make a smooth transition from one flight condition to another without danger of exceeding the limit flight envelope.

Applicable SC VTOL requirements Subpart B

VTOL.2145 Flying qualities

(a) Within its flight envelopes, the aircraft must show suitable stability and control feel, in all axes.

(b) Within its flight envelopes, no aircraft may exhibit any divergent stability characteristic, so as to require exceptional piloting skills, alertness, or strength or otherwise endanger the aircraft and its occupants.

VTOL.2150 Stall characteristics and stall warning

(a) If part of the lift is generated by a wing, the aircraft must have controllable stall characteristics in straight flight, turning flight, and accelerated turning flight with a clear and distinctive stall warning that provides sufficient margin to prevent inadvertent stalling.

VTOL.2160 Vibration

(a) Each part of the aircraft must be free from excessive vibration throughout the limit flight envelope.

(b) Reserved.

(c) Reserved.

(d) Reserved.

Applicable SC VTOL requirements Subpart C

VTOL.2200 Structural Design Envelope

The applicant must determine the structural design envelope, which describes the range and limits of aircraft design and operational parameters for which the applicant will show compliance with the requirements of this Subpart. The applicant must account for all aircraft design and operational parameters that affect structural loads, strength, durability, and aeroelasticity, including:

(a) structural design airspeeds to be considered when determining the corresponding manoeuvring and gust loads must:

(1) if part of the lift is generated by a wing, be sufficiently greater than the stalling speed of the aircraft to safeguard against loss of control in turbulent air, if applicable; and

(2) provide sufficient margin for the establishment of practical operational limiting airspeeds.

(b) flight load conditions to be expected in service;

(c) mass variations and distributions over the applicable mass and centre of gravity envelope, within the operating limitations;

(d) loads in response to all designed control inputs; and

(e) redistribution of loads if deflections under load would significantly change the distribution of external or internal loads.

The Structural Design Envelope defines the parameters that are used to define the Limit Flight Envelope.

Applicable SC VTOL requirements Subpart C

VTOL.2215 Flight load conditions

(a) Critical flight loads must be established for symmetrical and asymmetrical loading from all combinations of flight parameters and load factors at and within the boundaries of the manoeuvre and gust envelope:

(1) at each altitude within the operating limitations, where the effects of compressibility are taken into account when significant;

(2) at each mass from the design minimum mass to the design maximum mass; and

(3) at any practical but conservative distribution of disposable load within the operating limitations for each altitude and weight.

(b) Vibration and buffeting must not result in structural damage

(1) up to dive speed.

(2) within the limit flight envelope.

(c) Flight loads resulting from a likely failure of an aircraft system, component, or lift/thrust unit must be determined.

Flight Load Conditions VTOL.2115 (a) defines the limit manoeuvres that make up the Limit Flight Envelope.

Applicable SC VTOL requirements Subpart G

VTOL.2600 Flight crew compartment

(a) The flight crew compartment arrangement, including flight crew view, and its equipment must allow the flight crew to perform their duties within the flight envelopes of the aircraft, without excessive concentration, skill, alertness, or fatigue.

Stall characteristics CS 23 vs SC VTOL

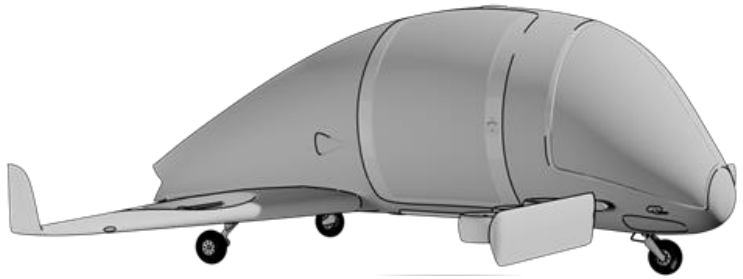
In CS-23 Amdt 5, 23.2110 is the “stall speed” requirement

If a CS23 aircraft can “stall” (which they all usually do), then 23.2150 applies

CS-23 Amdt 5 SUBPART B - Flight		(Ref ASTM F44 F3264-17 Standard Specification for Normal Category Aeroplanes Certification)	Remarks
23.2110	*Stall speed*	5.3 *Stall Speed:* F3179/F3179M-16 Standard Specification for Performance of Aeroplanes	
23.2150	*Stall characteristics, stall warning, and spins*	5.11 *Stall Characteristics, Stall Warning, and Spins:* F3180/F3180M-16 Standard Specification for Low-Speed Flight Characteristics of Aeroplanes	

Stall characteristics CS 23 vs SC VTOL

Stall is a “characteristic”, even if only in the Limit flight envelope



Stall is NOT possible (out of safety objective)

Determine the Stall Speed according to 23.2110, that refers to F3179M ASTM standard (which are mainly the Stall requirements of CS 23 amdt 4)

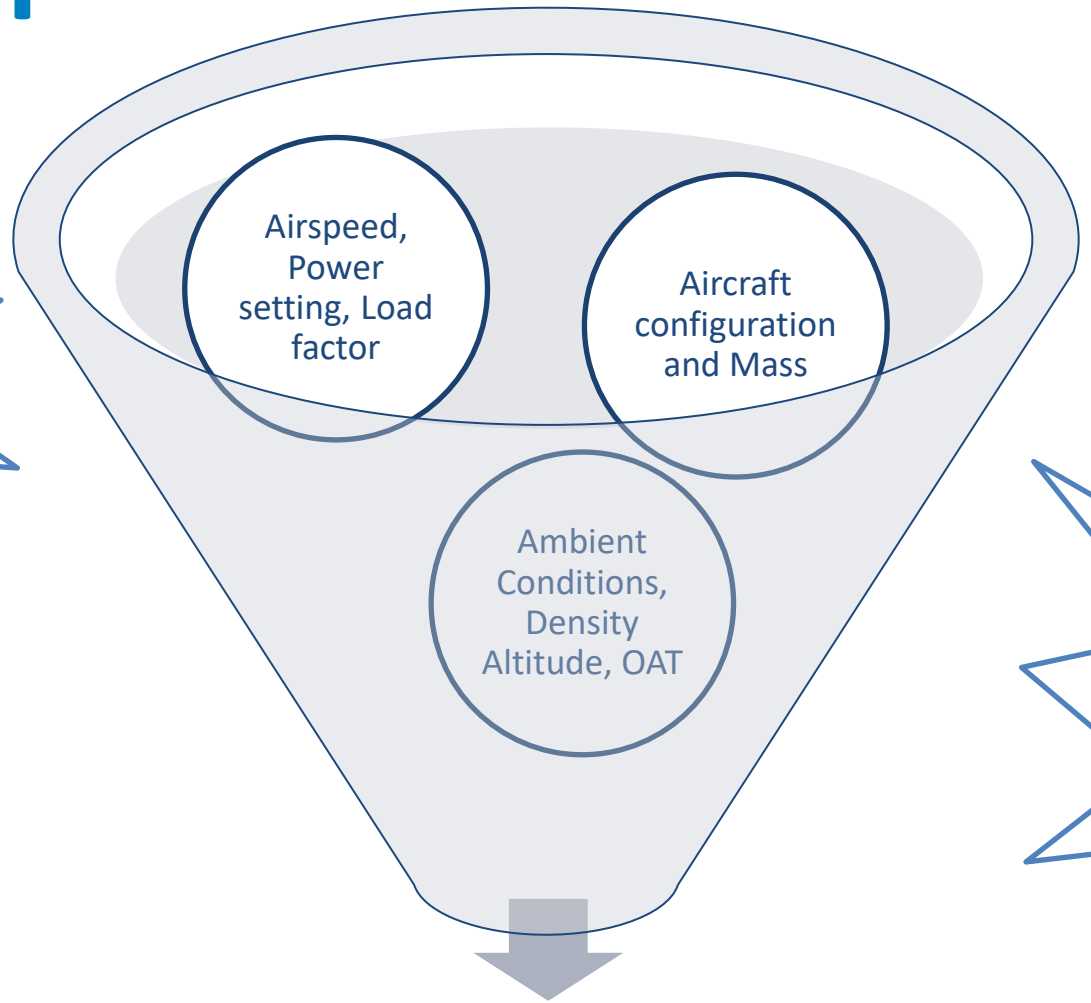
Show compliance to VTOL.2110 Flight Envelopes and provide evidence Stall is outside of LFE

Determine the Stall characteristics, Stall Warning, and Spins, according to 23.2150, that refers to F3180 “Low Speed Flight Characteristics”

VTOL.2150 applies only to recovery from controlled flight departure, if and when applicable

Flight Envelopes in SC VTOL

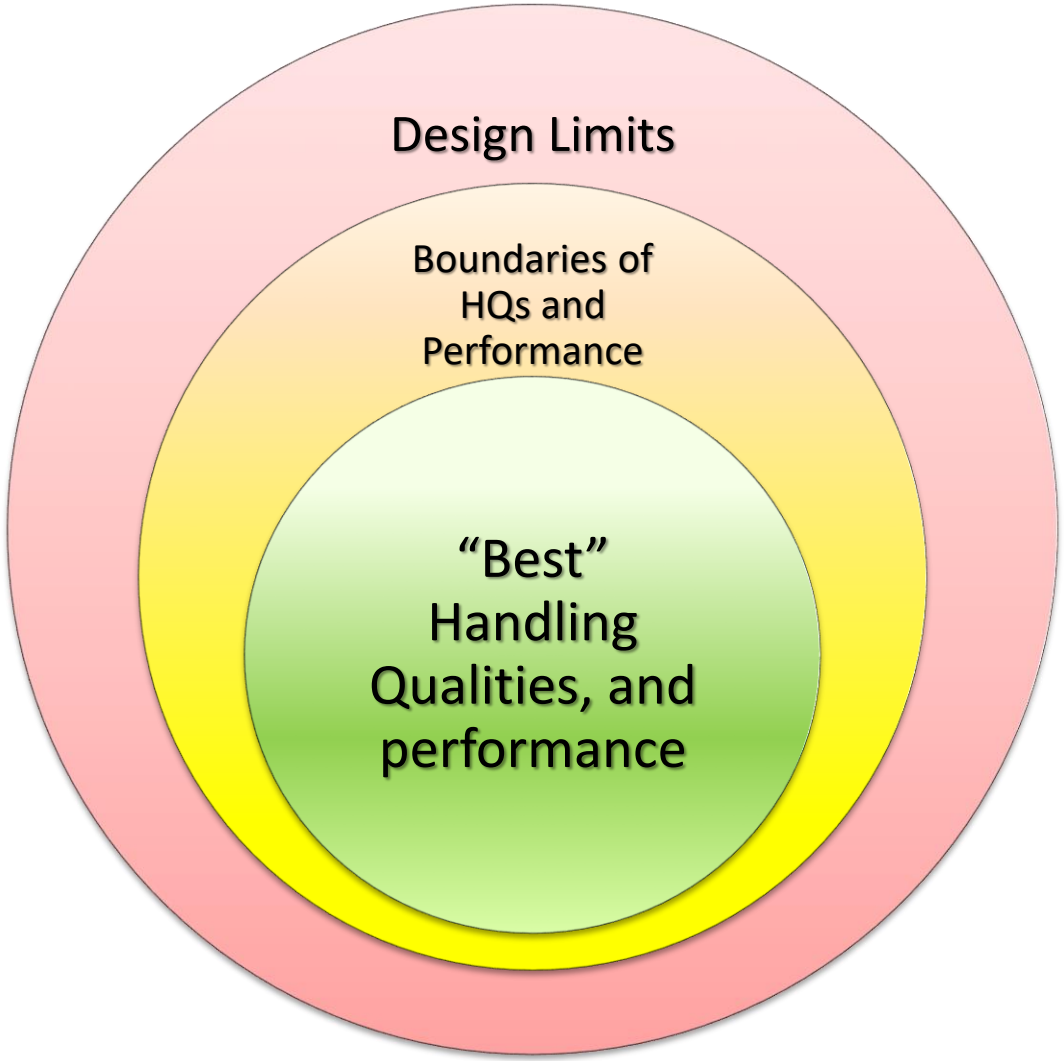
Parameters according to MoC to VTOL.2200

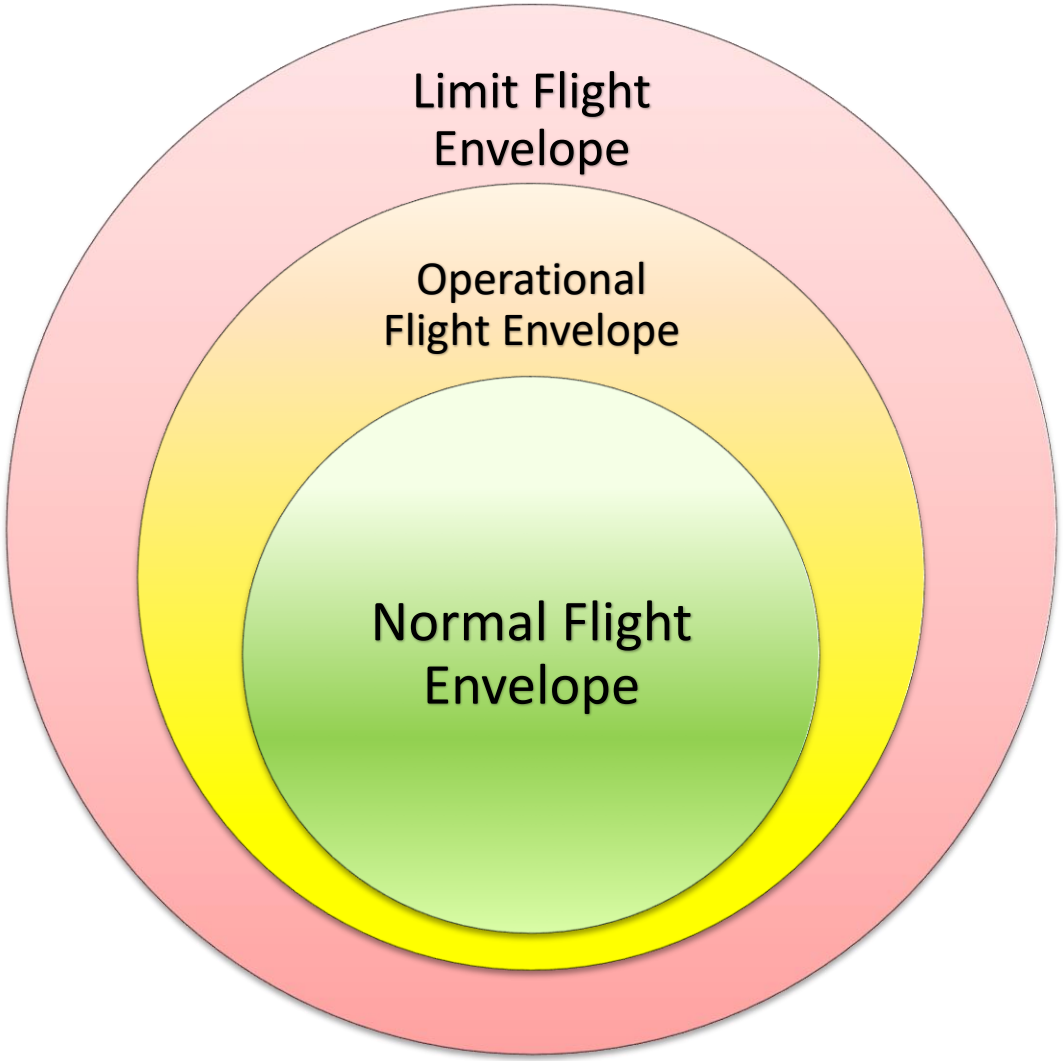


Limit Flight Envelope

Combination of parameters according to MoC to VTOL.2215

Flight Envelopes in SC VTOL





AC25-7D envelopes presentation

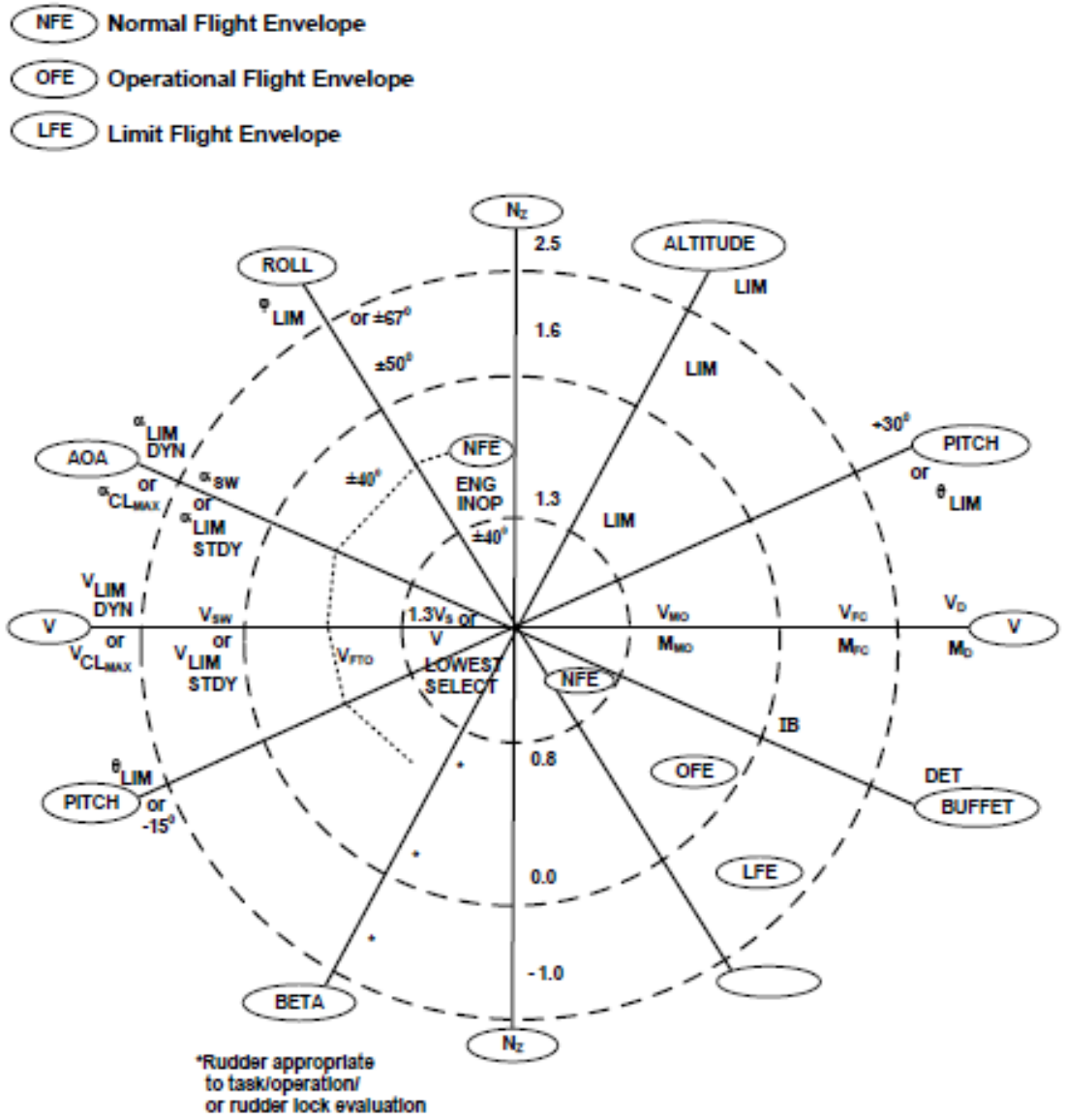
Graphs taken from AC25-7D Appendix E “Handling Qualities Rating Method”

Two graphs are shown, one for “flaps up” and one for “flaps down” configuration

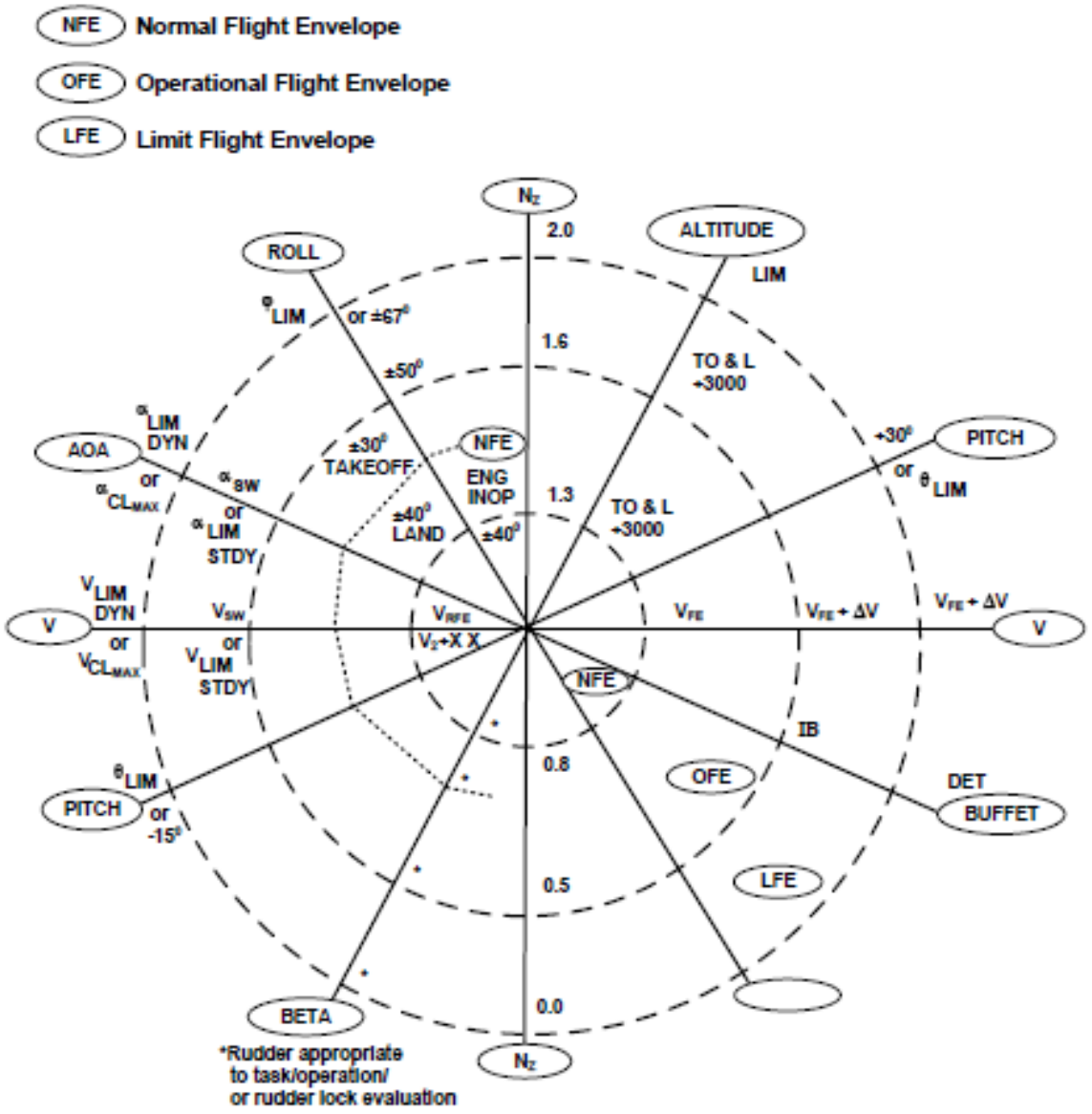
Could be a method to build on, keeping in consideration what ambient parameters affect the FE, and VTOL characteristic speeds

Consider the variable FEs depending on the State of Charge of the batteries. Re-consider the way FE are presented and/or displayed to the crew.

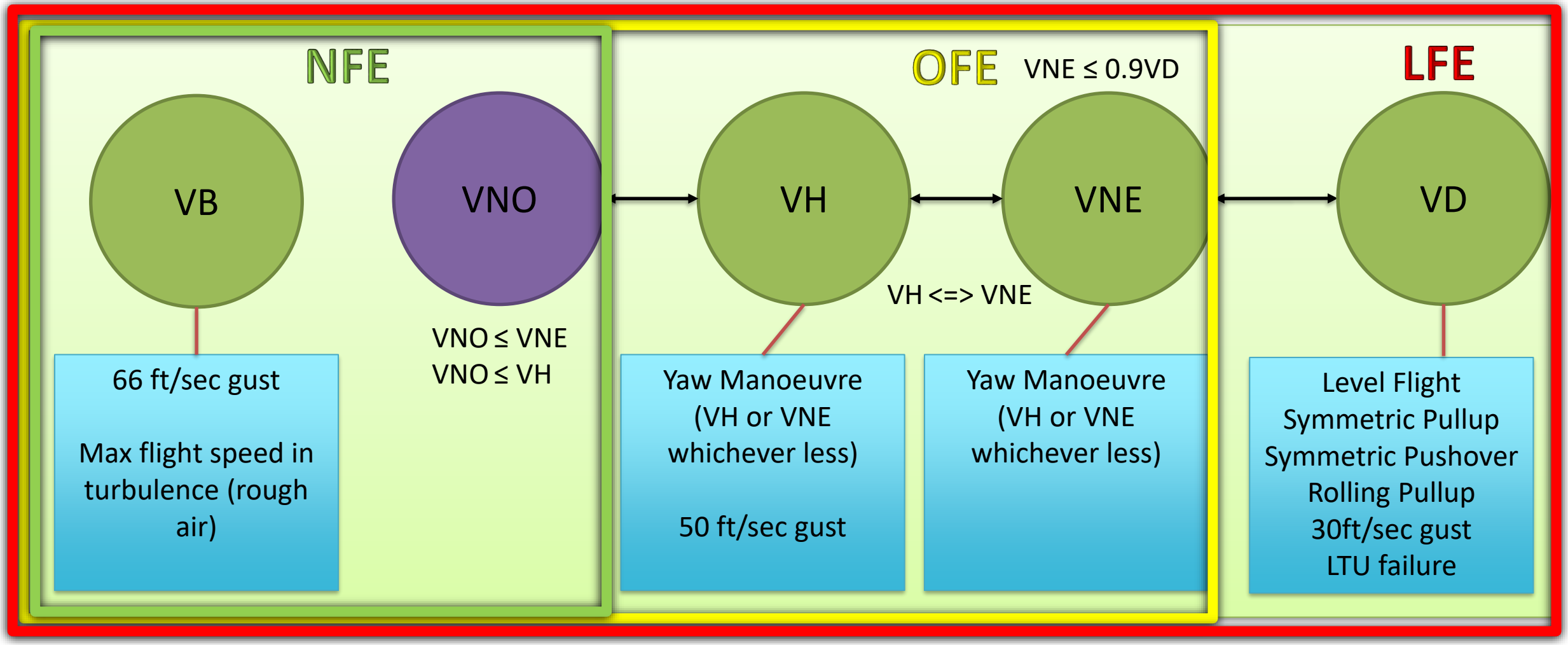
Envelope presentation – Flaps Up FE



Envelope presentation – Flaps Down FE

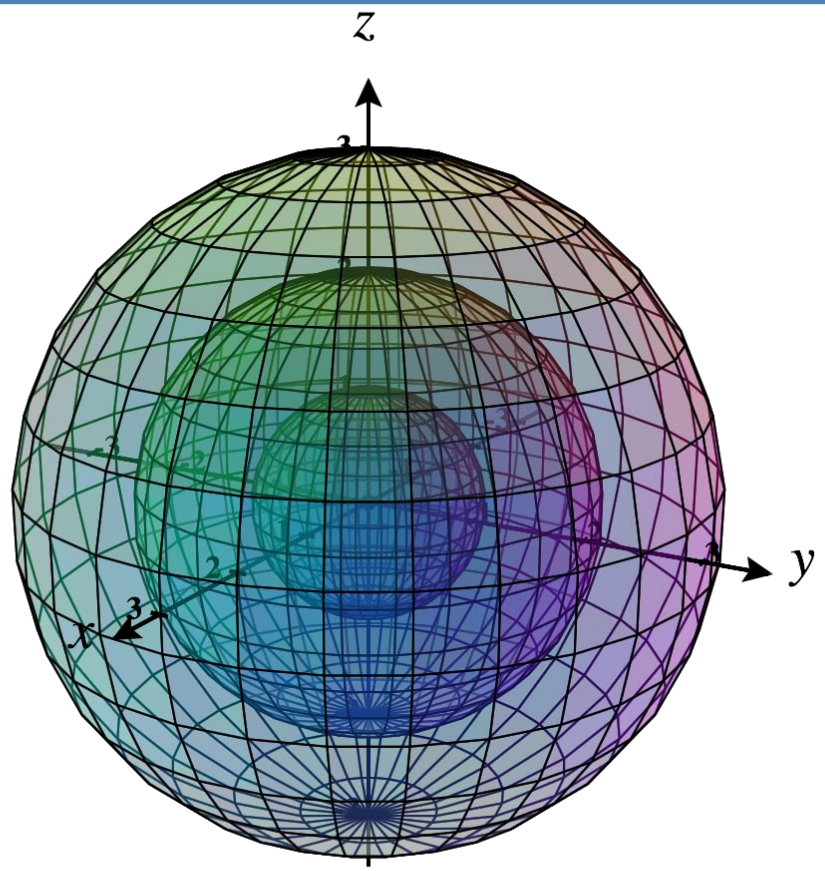


VTOLs Flight Envelopes adaptation



VTOLs Flight Envelopes adaptation

The FE will change with the different energy levels and different configurations?



Conclusions

The Stall Characteristics, if an aircraft can stall, are expected to be demonstrated with the AMCs of CS 23, with the applicable adaptations to electric energy lift/thrust systems and advanced flight control systems

Flight envelopes touches many parts of the SC VTOL, it is a topic that covers almost all Subparts

EASA is presenting the principles of flight envelopes and it is up to Industry to propose possible means to show compliance to the applicable requirements. An EUROCAE standard on this topic would be welcomed.

Flight Envelopes might vary with the remaining energy level or State of Charge (SoC), and different configuration. The way they are presented/displayed should be reconsidered

EASA
European Union Aviation Safety Agency

Thank you for your attention

Feel free to submit your questions on our live event platform.....

easa.europa.eu/connect

Your safety is our mission.

An Agency of the European Union