Structures SC VTOL MOC

Interaction Systems and Structures; Design Loads; Component loads, Structural Durability; Aeroelasticity; Protection of Structure; Materials and Processes; Special Factors of Safety

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Your safety is our mission.

Structures MOC-VTOL

- General
- Interaction system & structure
- Flight loads conditions
- Component loads
- Ground & water loads
- Structural durability
- Aeroelasticity
- Protection of Structure
- Materials and Processes
- Special Factors of Safety

General

- → Basic vs Enhanced
- → Different configuration and flight modes (flight loads, aeroelasticity)
- → Flight control system (flight loads, interaction of system and structure)
- → SC VTOL 2250 (c) Design (Enhanced): No single failure catastrophic

VTOL.2205 Interaction of systems and structures

System failure:

- → flight control systems (FBW),
- → autopilots,
- → stability augmentation systems,
- → load alleviation
- → flutter control
- → Fuel/Energy management …

VTOL.2205 Interaction of systems and structures

→ MOC under progress based on CS 25 Appendix K

CS 25 Appendix K
structure whose failure could prevent continued safe flight and landing

ADAPTED

MOC VTOL.2205
any structure the loading of which may be changed by failure(s) of the system

→ Scenarios to consider:

System fully operable	**System in failure condition**		**Failure indication**	**Dispatch with known failure conditions**
	At time of occurrence	**Continuation of the flight**		
Nominal condition	Static Strength(1) Residual Strength Vibrations Flutter (if failure causes velocity increase)	Static Strength(1) Residual Strength Vibrations Flutter(1) Fatigue & Damage Tolerance	Detectability	Limitations may be established

(1) For determination of **Safety Factor** and **Flutter Speed**, the probability will be consistent with the safety objective defined in SC VTOL for Category Enhanced and Category Basic (no. passengers)

MOC VTOL.2510 Equipment, systems, and installations

Table 1: Safety Objectives

	Maximum Passenger Seating Configuration	Failure Condition Classifications			
		Minor	Major	Hazardous	Catastrophic
		Allowable Qualitative Probability			
		Probable	Remote	Extremely Remote	Extremely Improbable
		Allowable Quantitative Probability (Note C and D) Development Assurance Level			
Category Enhanced	-	$\leq 10^{-3}$ FDAL D (see Note B)	$\leq 10^{-5}$ FDAL C	$\leq 10^{-7}$ FDAL B	$\leq 10^{-9}$ FDAL A
Category Basic	7 to 9 passengers (Basic 3)	$\leq 10^{-3}$ FDAL D (see Note B)	$\leq 10^{-5}$ FDAL C	$\leq 10^{-7}$ FDAL B	$\leq 10^{-9}$ FDAL A
	2 to 6 passengers (Basic 2)	$\leq 10^{-3}$ FDAL D (see Note B)	$\leq 10^{-5}$ FDAL C	$\leq 10^{-7}$ FDAL C (see Note A)	$\leq 10^{-8}$ FDAL B (see Note A)
	0 to 1 passenger (Basic 1)	$\leq 10^{-3}$ FDAL D (see Note B)	$\leq 10^{-5}$ FDAL C	$\leq 10^{-6}$ FDAL C (see Note A)	$\leq 10^{-7}$ FDAL C (see Note A)

[Quantitative safety objectives are expressed per flight hour]

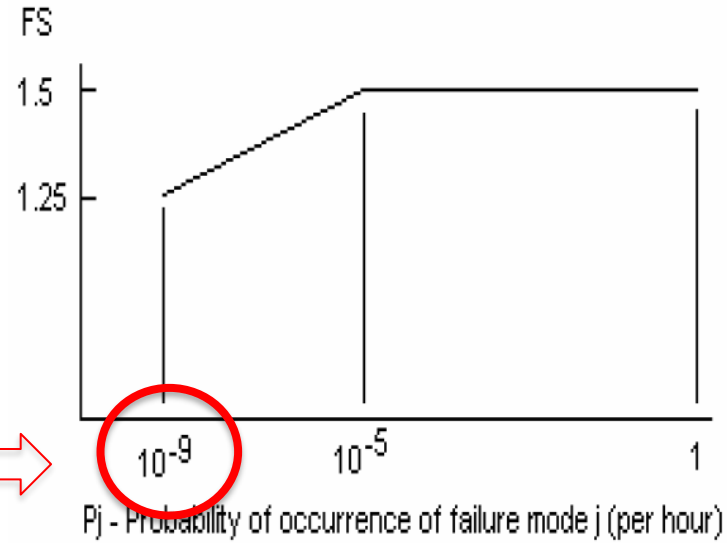
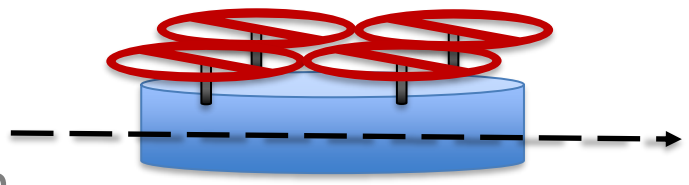


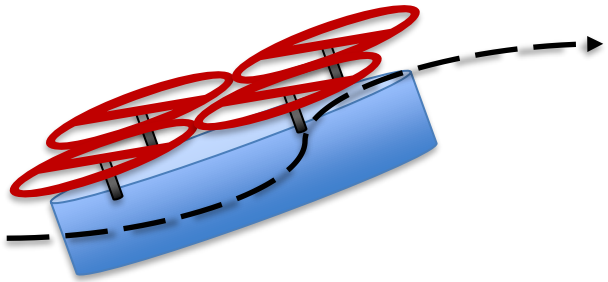
Figure 1
Factor of safety at the time of occurrence

VTOL.2215(a) Flight Load Conditions

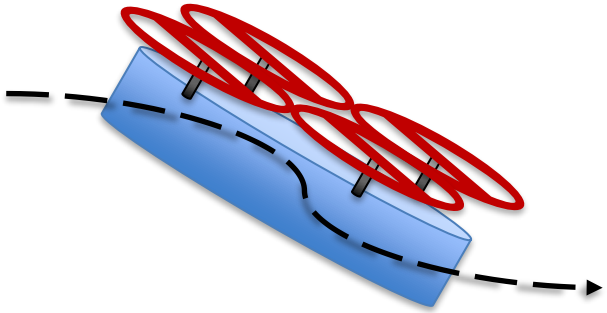
- → Proposed MoC published 25 May 2020
- → 19 comments currently under review and MoC under revision



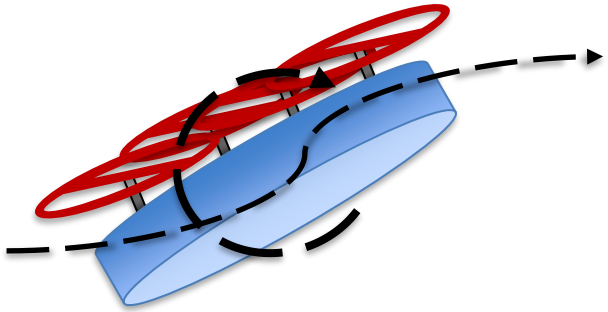
1g Symmetric Flight



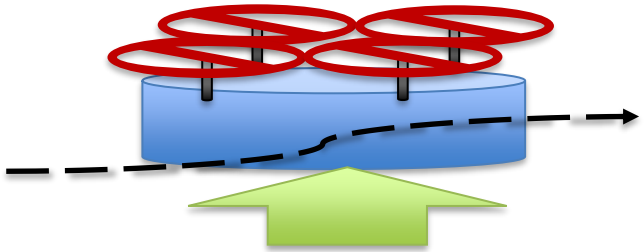
Symmetrical pull-up and recovery
Max positive load factor
Max associated pitch accelerations



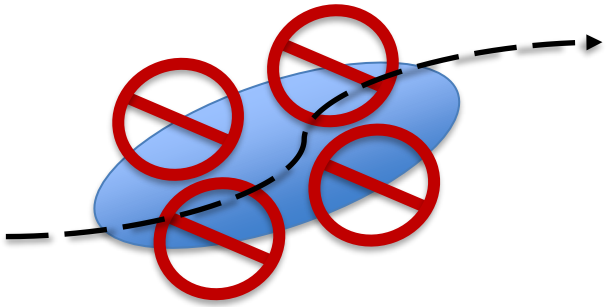
Symmetrical pushover and recovery
Max negative load factor
Max associated pitch accelerations



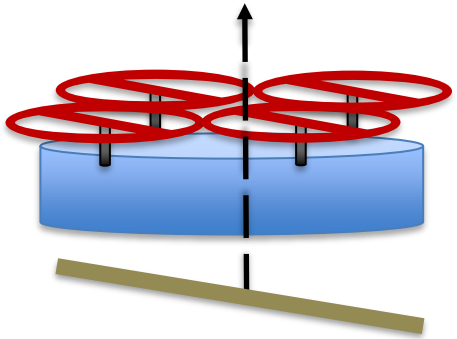
Rolling Flight Conditions
2/3 max positive load factor
Max associated pitch and roll accelerations



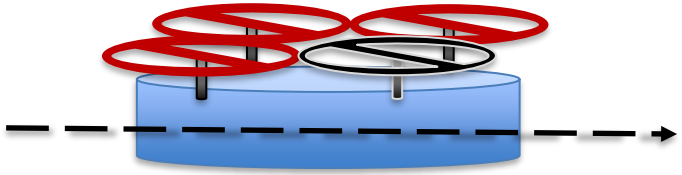
Gusts
Vertical and horizontal



Yawing Conditions
Max associated yaw acceleration
Max transient sideslip angles

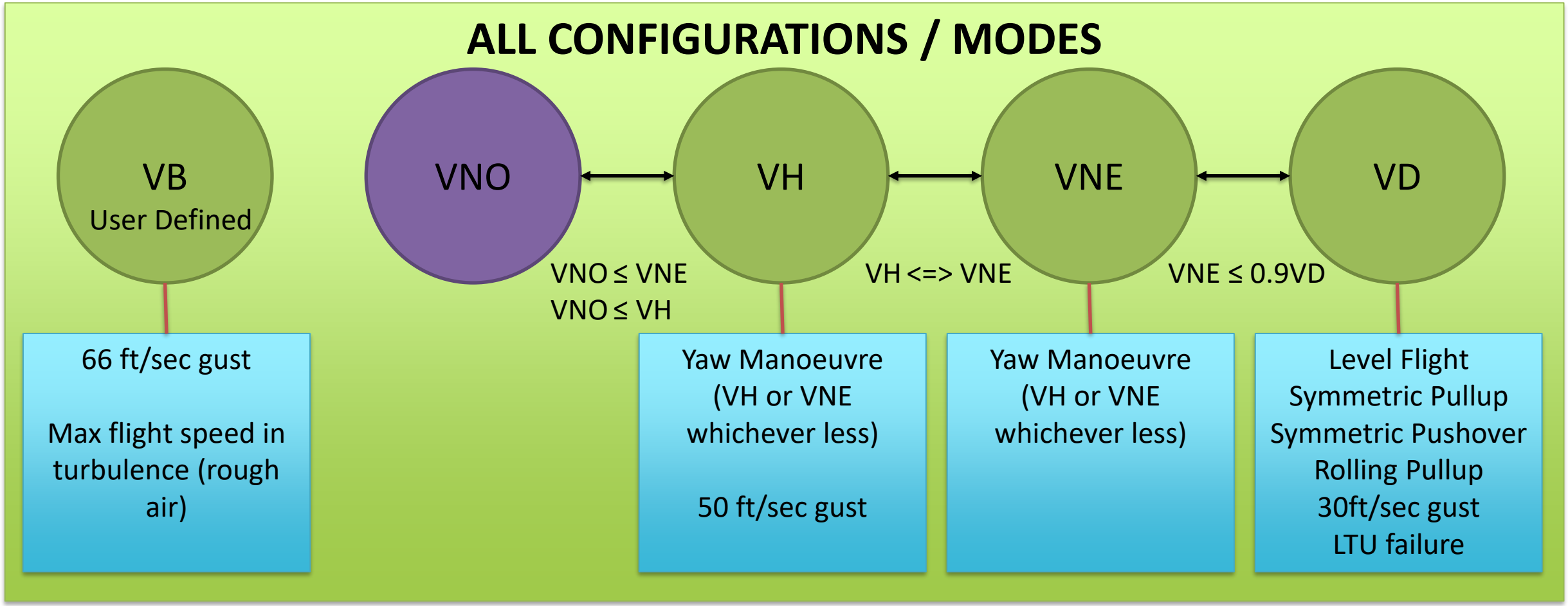


Vertical TO
Max slope



Unsymmetrical loads due to lift/thrust unit failure (failure case)

Design Airspeeds (2200) and Flight Cases (2215(a))



All critical speeds and configurations should be considered for each flight manoeuvre, up to the aircraft maximum defined: VD(s), VH(s) or VNE(s)

Other Design Load Conditions: Status

→ VTOL.2220 Ground and Water Loads

- Ground conditions:
  - ✓ Proposed MoC published 25 May 2020
  - 3 comments under review
- Water conditions:
  - ✓ Proposed MoC ready for public consultation with Phase 2 MoC
  - ✓ See Presentation Ditching, Emergency Flotation and Limited Overwater Operation

→ VTOL.2225 Component Loading Conditions

- Currently being drafted

Structural Durability 2240

- Objectives
- Selection of structures
- Structural failure rate 2240d & 2250(c)
- Fatigue Spectrum
- Procedures for compliance with SC VTOL. 2240 (a) for composites, metallic
  a) Basic
  b) Enhanced

Structural Durability 2240 (a) & (b)

Objectives:

For Enhanced & Basic VTOL 2240 (a):

Do all necessary evaluation & actions (inspection, procedures) "*to prevent structural failures due strength degradation, which could result in serious or fatal injuries, or extended periods of operation with reduced safety margins.*"

For Enhanced only VTOL 2240 (b):

Detection of structural damages before failure (Damage Tolerance)

Structural Durability 2240

Selection of structures:

PSE definition (CS) not applicable to VTOL:

Principal Structural Elements (PSE) are structural elements that contribute significantly to the carrying of flight or ground loads and the fatigue failure of which could result in catastrophic failure of the rotorcraft

- → Single Load Path catastrophic should be prevented per design / configuration (MOC VTOL 2250 (c))
- → Structural parts simply static loaded catastrophic compensating provision (MOC. VTOL 2250 (c) (b))
- → Rotating machinery parts no catastrophic (MOC VTOL 2240 (d))

VTOL 2240 compliance applicable to any structural part susceptible to fatigue and fatigue originated from damages-flaws(*) including primary load path, control system, landing gear, engine mount…

VTOL SSE → Selected Structural Elements

(*) for composite Basic and Enhanced category and metallic enhanced category.

Structural Durability 2240

Failures & classification

VTOL	Requirement	Applicability
VTOL.2240 (a) & (b)	Structural Durability	*any part susceptible to fatigue and fatigue originated from damage flaw …*
VTOL.2240 (d)	High energy fragment	*rotating parts (blade, fragments…)*
VTOL.2250 (c)	Design and construction principal	*no single failure catastrophic*

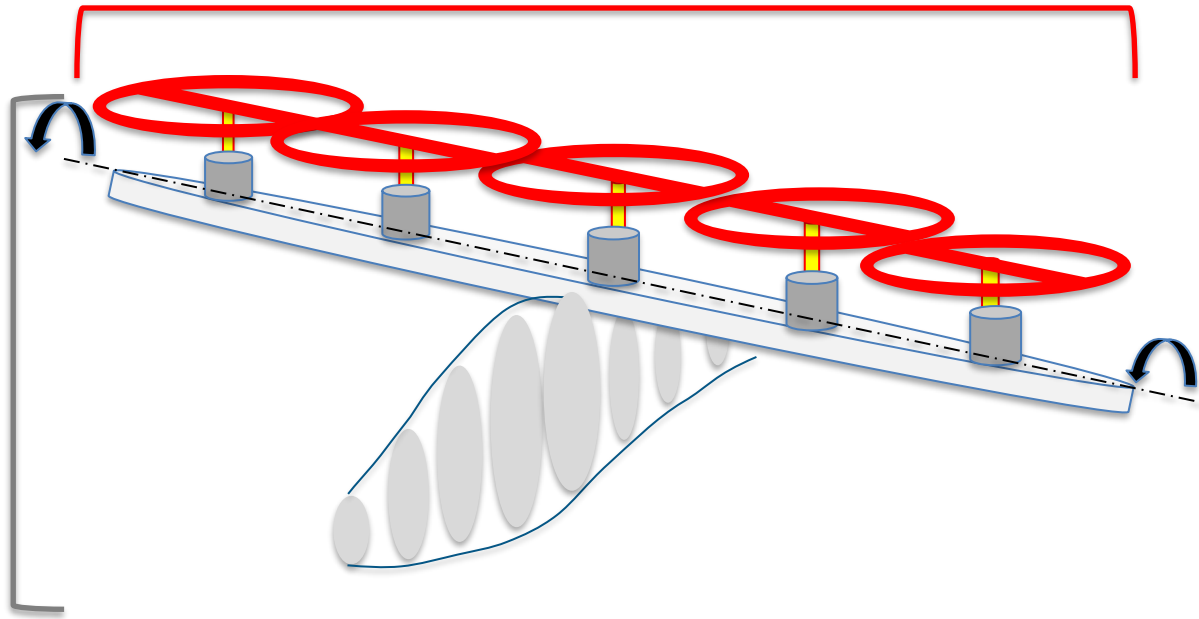
Structural Durability 2240

Failures & classification

lift/thrust unit or rotating-machinery:
no catastrophic effect per design. MOC VTOL.2240(d) & 2250 (c)

Simply loaded "static" elements:

1) Single failure no catastrophic (MOC VTOL.2250 (a)(4)) or when impracticable:
2) Catastrophic extremely improbable with compensating elements (MOC.VTOL.2250 (a)(5)(ii) & (b))



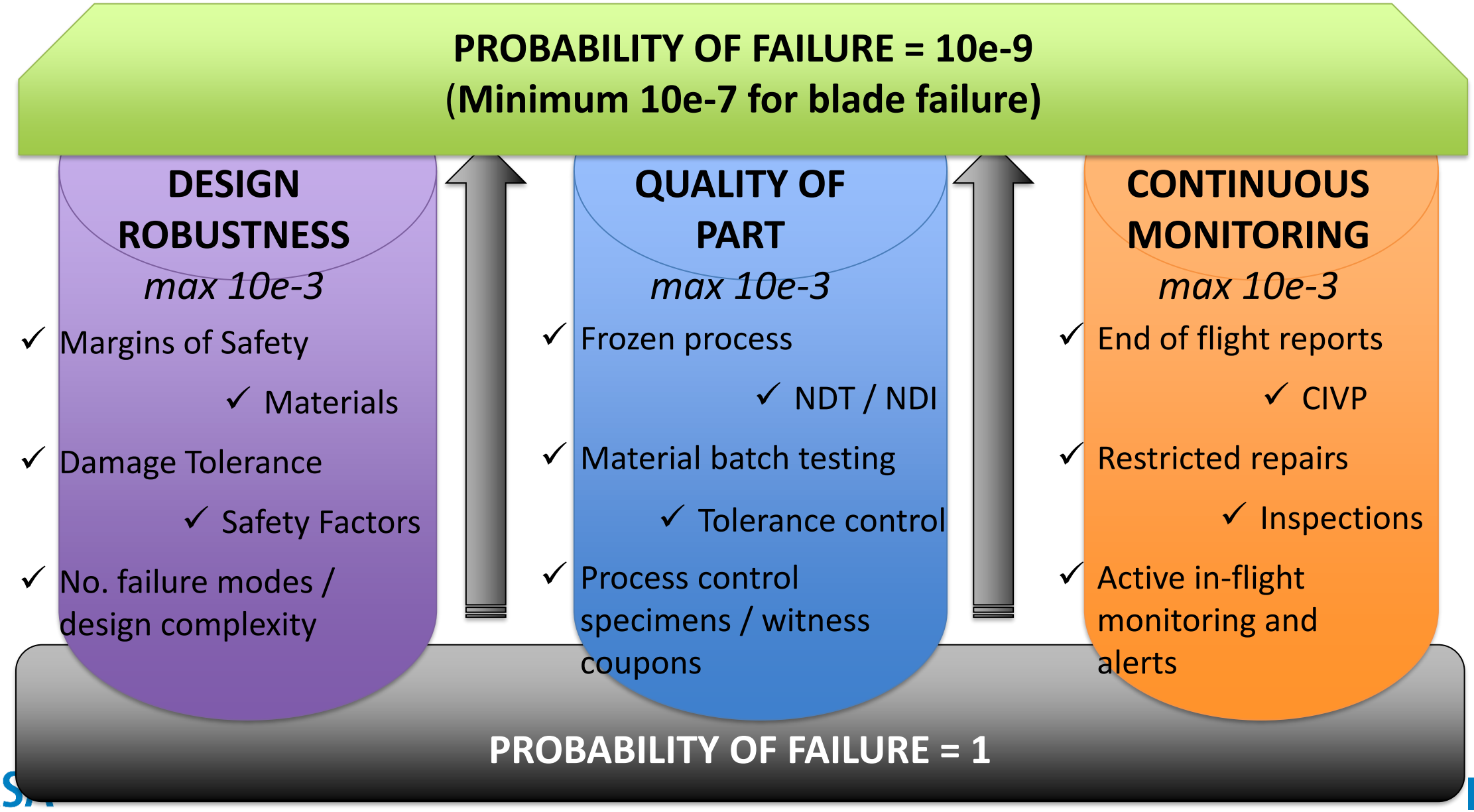
Structural Durability 2240

Structural Failure Rate

- → SCOPE of Structural Failure Rate:
  - → SC-VTOL 2240(d): Blade Failure Rate for cascading failures (Enhanced Category).
  - → SC-VTOL 2250(c): Single part not catastrophic failure: Compensating Provisions to demonstrate extremely improbable (MOC VTOL 2250 (b))
- → Structural Failure Rate:
  - → Very challenging to define quantitatively
  - → Framework to develop probability qualitatively (EASA VTOL.MOC phase 2)
  - → Supported by a EUROCAE Standard

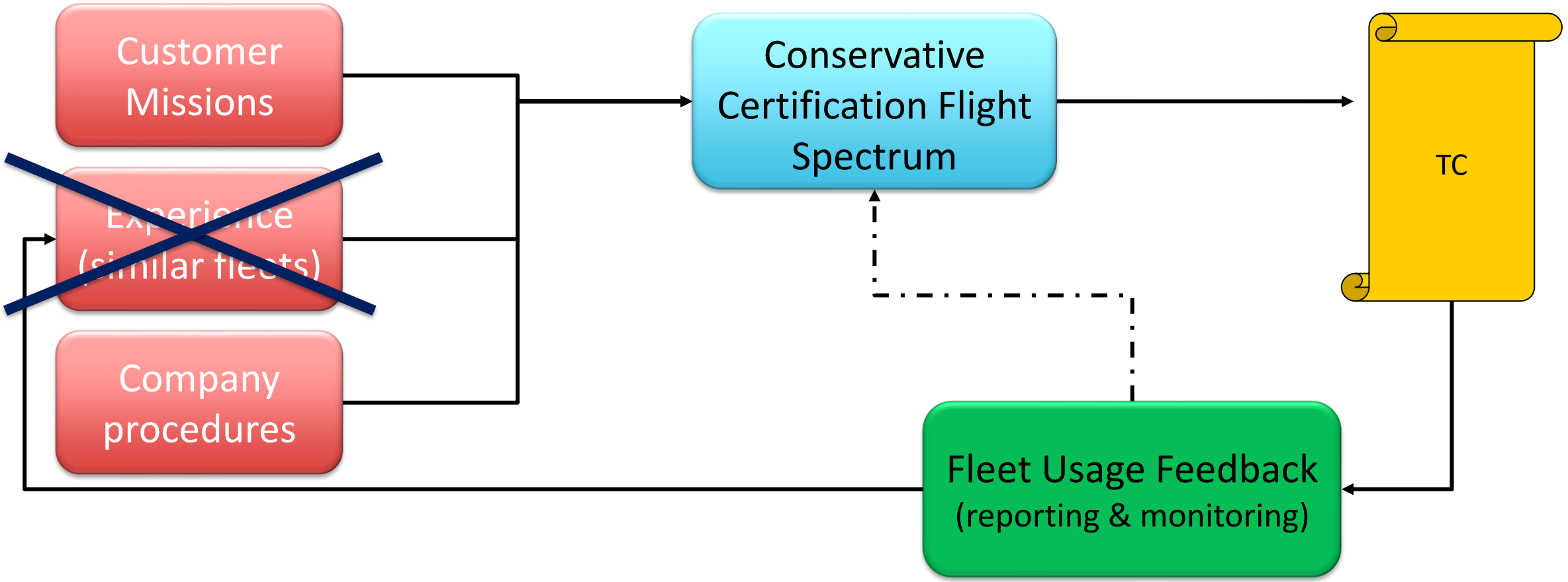
Structural Failure Rate

EASA VTOL.MOC to provide framework



Structural Durability 2240

Fatigue spectrum



Validity of the Certification Assumptions: (EASA CM-S-007 Continued Integrity Verification Programme & usage monitoring.)

Structural Durability 2240

Fatigue spectrum

- → VTOL usage (e.g shuttle) should be well defined
- → Distribution between different configuration and flight mode (AC 27 MG11 example of usage spectrum that could be adjusted to VTOL)

Structural Durability 2240

Approach for fatigue & Damage tolerance

- For Category Basic, the procedures developed for compliance with SC VTOL.2240(a) *must develop and implement inspections or other procedures to prevent structural failures due to foreseeable causes of strength degradation, which could result in serious or fatal injuries, or extended periods of operation with reduced safety margins.*

Fatigue evaluation :

- Metallic CS 27.571 FATIGUE EVALUATION OF FLIGHT STRUCTURE
- Composite CS 27.573 DAMAGE TOLERANCE AND FATIGUE EVALUATION OF COMPOSITE ROTORCRAFT STRUCTURES
- Including associated AMC material

Structural Durability 2240

Approach for fatigue & Damage tolerance

For Category Enhanced, the procedures developed for compliance with SC VTOL.2240(a) *must be capable of detecting structural damage before the damage could result in structural failure*.

Damage tolerance approach :

- → Metallic CS 29.571 FATIGUE TOLERANCE EVALUATION OF METALLIC STRUCTURE
- → Composite CS 27.573 DAMAGE TOLERANCE AND FATIGUE EVALUATION OF COMPOSITE ROTORCRAFT STRUCTURES
- → Including associated AMC material

Structural Durability 2240

Approach for fatigue & Damage tolerance

Rotorcraft Structures Workshop Day 1 session 3 presentation

https://www.easa.europa.eu/newsroom-and-events/events/rotorcraft-structures-workshop-2019

Structural Durability 2240

Conclusions

- → Selection of structure: No PSE / Any structural part susceptible to fatigue → SSE
- → Establishment of the Spectrum different configuration and flight modes
- → Qualitative Structural failure rate to support compliance with VTOL 2240 (d) & 2250(c)
- → MOC VTOL 2240 (a) & (b) for Enhanced: adapted AC 29.571 & 573 approach
- → Conventional Means of Compliance Moc 2, 4 and 6 remains applicable

Aeroelasticity VTOL.2245

(a) The aircraft must be free from flutter, control reversal, and divergence:

(1) at all speeds within and sufficiently beyond the structural design envelope;

(2) for any configuration and condition of operation;

(3) accounting for critical degrees of freedom; and

(4) accounting for any critical failures or malfunctions.

(b) The applicants' design must account for tolerances for all quantities that affect flutter.

Aeroelasticity 2245

Approach: combination of AC 29.629 and AC 23.629 conditions

AC 29.629A Flutter and divergence

The aeroelastic evaluation of the rotorcraft should include an investigation of the significant elastic, inertia and aerodynamic forces on all aerodynamic surfaces (including rotor blades) and their supporting structure. The forces associated with the rotations and displacements of the plane of the rotors should be considered.

Aeroelasticity 2245

AC 29.629 b. Procedures

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(1) It should be shown by analysis that the rotorcraft is free from flutter and divergence (unstable structural distortion due to aerodynamic loading) under any condition of operation including:

i. Airspeeds up to 1.2 VD
ii. Lift Thrust Unit rotational speed range
iii. The critical combinations of weight, CG position, load factor and altitude.

Note: All parameters to be adapted to each configuration and flight mode as appropriate

Aeroelasticity 2245

CS 23 & AMC 23.629A Flutter and divergence

Report #45 not valid

Whirl Mode for multiple Lift Thrust Units.

Damage tolerance (VTOL 2240) for flutter evaluation

Interaction of systems and structures

Others

→ **VTOL.2255** Protection of Structure

→ **VTOL.2260** Materials and Processes

→ **VTOL.2265** Special Factors of Safety

Existing CS 25, 27, 29, ACs and EASA CMs are applicable for these topics

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

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An Agency of the European Union