Funded by the Erasmus+ Programme of the European Union

Airworthiness & Type Certification

Airworthiness Issues

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Rome, 20 Sep. 2017

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- Structural Strenght & Material Qualification
- Primary Composite Structures
- Fatigue & Damage Tolerance
- Aging Aircraft
- Crashworthiness
- System Safety Assessment
- Systems Structures interaction
- Flammability & Fire Protection
- Lightining Protection

1. Structural Strenght & Materials Qualification

Structures Classifications

Source: Airbus

Primary Structure – Structure that carries flight, ground, crash or pressurization loads.

Fatigue Critical Structure (FCS) – Structure that is susceptible to fatigue cracking that could lead to a catastrophic failure of an aircraft.

Principal Structural Element (PSE) – Element of a primary structure subject to repeated loading conditions the failure of which could lead to a catastrophic condition

SUBPART C – STRENGTH REQUIREMENTS	
GENERAL	
CS XX.301	Loads
CS XX.303	Factor of safety
CS XX.305	Strength and deformation
CS XX.307	Proof of structure
EMERGENCY LANDING CONDITIONS	
CS XX.561	*General*
FATIGUE EVALUATION	
CS XX.571	Fatigue evaluation of flight structure
SUBPART D – DESIGN AND CONSTRUCTION	
GENERAL	
CS XX.603	Materials
CS XX.605	Fabrication methods
CS XX.609	Protection of structure
CS XX.610	Lightning and static electricity protection
CS XX.613	Material strength properties and design values
CS XX.629	Flutter

Limit Loads (LL) & Ultimate Loads (UL)

CS 25.301 Loads

(a) Strength requirements are specified in terms of **limit loads** (the maximum loads to be expected in service) and **ultimate loads** (limit loads multiplied by prescribed factors of safety). Unless otherwise provided, prescribed loads are limit loads. (…)

CS 25.303 Factor of safety

Unless otherwise specified, a factor of safety of 1·5 must be applied to the prescribed limit load

$$LL \times SF = UL$$

Structutal Strenght Req.s

CS 25.305 Strength and deformation

(a) The structure must be able to support limit loads without detrimental permanent deformation. At any load up to limit loads, the deformation may not interfere with safe operation.

(b) The structure must be able to support ultimate loads without failure for at least 3 seconds. (…)

CS 25.307 Proof of structure

(a) Compliance with the strength and deformation requirements of this Subpart must be shown for each critical loading condition.

Structural analysis may be used only if the structure conforms to that for which experience has shown this method to be reliable.

In other cases, substantiating tests must be made to load levels that are sufficient to verify structural behaviour up to loads specified in CS 25.305.

(…)

- **Req. XX.301**

  LL = Maximum loads expected during operations

  UL = LL x Safety Factor (SF)

- **Req. XX.303**

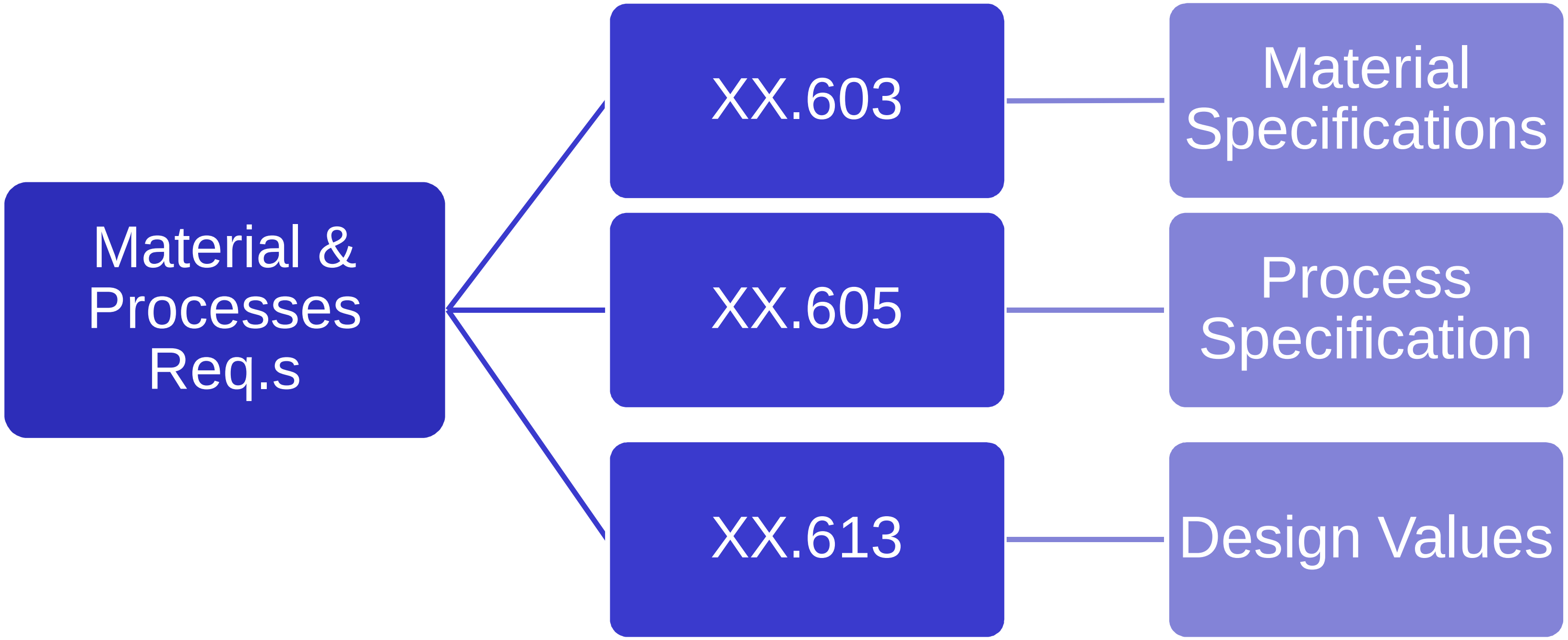
  SF **= 1.5** unless othewise stated

- **Req. XX.305**

  The structures must withstand LL without detrimental permanent deformations and must sustain UL without failure for at least 3 seconds

- **Req. XX.307**

  Req. XX.305 must be verified in all the anticipated operating and environmental conditions


Material &
Processes
Req.s
XX.603
XX.605
XX.613
Material
Specifications
Process
Specification
Design Values

CS 25.603 Materials

The suitability and durability of materials used for parts, the failure of which could adversely affect safety, must –

(a) Be established on the basis of experience or tests

(b) **Conform to approved specifications**, that ensure their having the strength and other properties assumed in the design data

(c) Take into account the effects of **environmental conditions**, such as temperature
and humidity, expected in service.

CS 25.605 Fabrication methods

(a) The methods of fabrication used must produce a **consistently sound structure**.

If a fabrication process (such as gluing, spot welding, or heat treating) requires close control to reach this objective, **the process must be performed under an approved process specification**.

(b) Each new aircraft fabrication method must be substantiated by a **test programme**.

“Consistently” = Able to be reproduced with the same strenght characteristics

“Sound” = Good, Sufficenlty robust

CS 25.613 Material strength properties and Material Design Values

(a) Material strength properties must be based on **enough tests** of **material meeting approved specifications** to establish design values on a statistical basis.

(b) Material design values must be chosen to minimise the probability of structural failures due to **material variability**. (…) compliance must be shown by selecting material design values which assure material strength with the following probability:

A-Basis

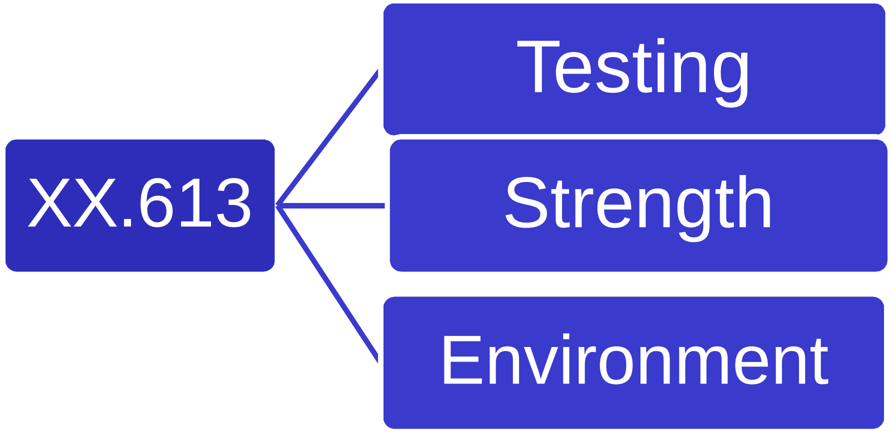
(1) Where applied loads are eventually distributed through a **single member** within an assembly, the failure of which would result in loss of structural integrity of the component, **99% probability with 95% confidence**.

B-Basis

(2) For **redundant structure**, in which the failure of individual elements would result in applied loads being safely distributed to other load carrying members, **90% probability with 95% confidence**.

(c) The effects of **environmental conditions**, such as temperature and moisture, on material design values used in an essential component or structure must be considered where these effects are significant within the aeroplane operating envelope.

MATERIAL QUALIFICATION



- **Material Design Values.** Material strength properties **established based on the regulatory requirements**. Account for the effects on the operational environment in which the materials operate. Generally Design Values are statistically determined based on enough data that, when used for design, the probability of the structural failure due to material variability will be minimized. **Design values are a subset of the aircraft's type design**

- **Material Allowables –** Material strength properties that have been **statistically derived** from **data obtained from tests of materials purchased and processed per acceptable specifications**. Unlike material design values, material allowables **may or may not account for the operational environment.** Temperature and moisture corrections factors may be applied to the material allowables derived from room temperature tests (for economic reasons) to account for the expected environment to form material design values used in aircraft design

Allowables Statistical Basis

«A-Basis» vs «B-Basis»

- **X** = mechanical characteristic (e.g. ultimate tensile strenght) = random variable with a probability density **f(x) not completly known** (estimated from a finite data sample)

- X_p = p-th quantile of X, i.e. $\mathbf{P(X > X_p) = p}$

  p = 0.99 for A-Basis

  p = 0.90 for B-Basis

- Because f(x) is not completely known then X_p is a random variable as well.

- $\mathbf{x_{amm}}$ ("Allowable") = lower bound of unilateral confidence interval at **95% confidence level** (sufficently low value of the p-th quantile) namely

$$\mathbf{P(X_p > x_{amm}) = 0.95}$$

$$P(X_p > x_{amm}) = \gamma = 0.95$$

$$P(X > X_p) = p = \begin{cases} 0.99 & Base\,A \\ 0.9 & Base\,B \end{cases}$$

$$A - Basis\ value = \overline{x} - (K_A) \cdot s$$

$$B - Basis\ value = \overline{x} - (K_B) \cdot s$$

Source: Rice R.C., Goode R.J., Bakuckas J.G., Thompson S.R., Development of MMPDS Handbook Aircraft Design Allowables, *7th Joint DOD/FAA/NASA Conference on Aging Aircraft, September 8-11, 2003, New Orleans, LA*

2. Primary Composite Structures

- Material Properties & Fabrication Methods
- Static Strenght
- Fatigue & Damage Tolerance
- Aeroelastic instabilities
- Crashworthiness
- Flammability & Fire Protection
- Lightning Protection
- Continued Airworthiness (e.g. Repair Issues)

IMPORTANT ASPECTS

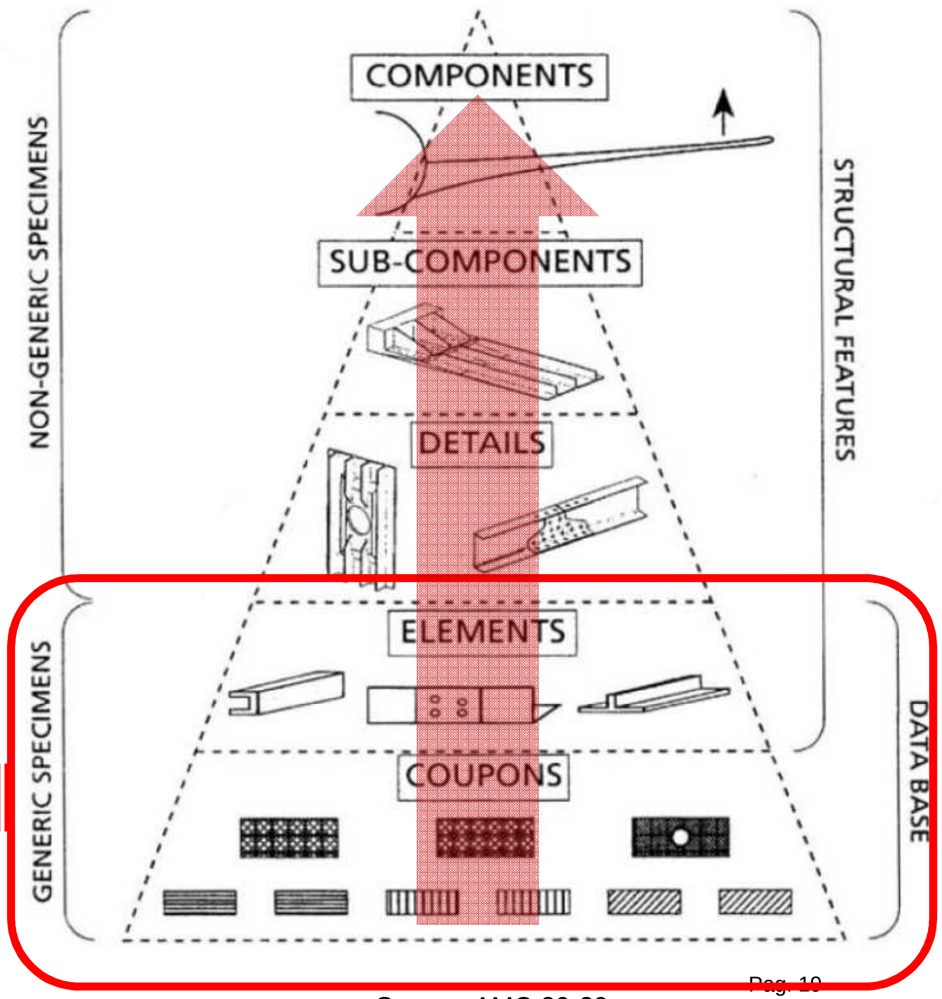
Means of Compliance
AMC 20-29/AC 20-107B → CMH-17 COMPOSITE MATERIALS HANDBOOK

- **Environment**
  - Temperature
  - Humidity
  - Contaminant Fluids
- **Fatigue Degradation**
- **Manufacturing Defects & Artificial Damages**
  - Production
  - Operation
  - Maintenance

BUILDING BLOCK

- Risk reduction **Incremental** approach
- Testing on elements of **increasing complexity**
- Final **full-scale** test or
  (HTW or RTW + overload factors)
- **Subcomponent test + analysis supported by test evidence at lover level**

Data Base

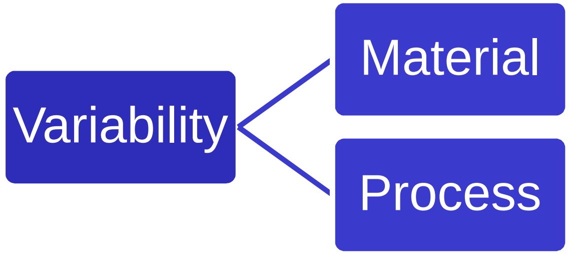


Source: AMC 20-29

RTD = Room Temperature Dry

The following must be defined ….

- Material specification
- Process specification
- Material Properties



….to assure:

- Design values reliability
- Material reproducibility

[WARNING]

EASA does not certify materials and processes *however* materials and processes specifications are part of the Type Design subject to type-certification

(AMC 20-29)

Source: DOT-FAA-03-19

3. Fatigue & Damage Tolerance

SAFE – LIFE

FAIL – SAFE

DAMAGE TOLERANCE

Safe-Life (replacement time) determination

- The probability of a chatastrophic failure due to fatigue must be extremely remote within the component replacement time
- No detectable damage is allowed to come up before the replacement time
- The usage spectrum must be representative of the real usage (HF, GAG, S/S, …)
- **Load spectrum = usage spectrum + cyclic loads**
- Mean S-N curves derived from constant amplitude fatigue test
- Working (reduced) S-N curves take into account fatigue scatter
- **Miner's Rule** (Cumulative Damage) is applied to work out the life

At the end of its safe-life the part must be replaced

i	CONDITION	% OF TIME	numero di cicli (ni)
1	ON GROUND	3,5	
2	APPROACH	5	
3	SPOT-TURN	1	
4	LANDING	1,5	
5	AUTOROTATION	1	
6	TAKE-OFF	1,5	
7	DESCENT	1,5	
8	CLIMB	3	
9	LEVEL FLIGHT	56,5	
10	PULL-UP	0,22	
11	HOVERING	10	
12	TRANSITION	4,52	
13	TURNS	8	
14	SPECIAL TURNS	0,76	
15	LATERAL FILGHT	2	
	TOT (FLIGHT HOURS)	**100**	

Measured Loads (Flight Load Survey)

Component Strength (S/N Curve)

Usage (Flight Spectrum)

$\sum_i \frac{n_i}{N_i}$

Miner's Rule

Life Determination

Source: AC 27-1B Chg 2 MG 11.

$$d = \sum \frac{n_i}{N_i}$$

$$Life = \frac{100FH}{d}$$

Some weakness

- Usage spectrum not always fully representative of the real operational use
- The effect of load sequence is not taken into account
- The effect of the nominal stress below the fatigue limit is not considered
- Load survey variability
- Miner Hypotesis (total damage = 1) not always verified (D = 0.5 – 2)

DT scope

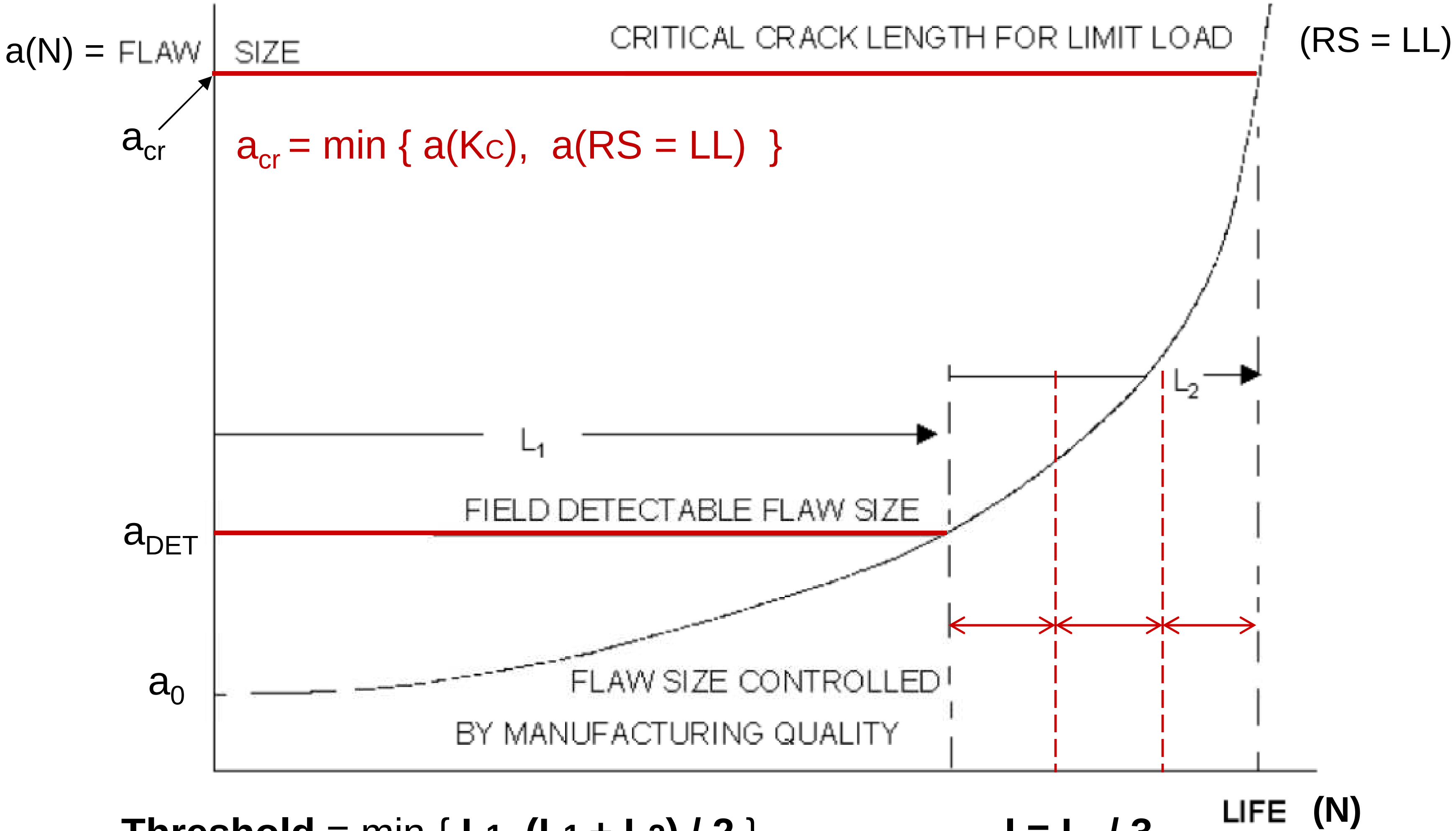
1) To determine by analysis or test the propagation of a damage/defect in a structural component subjcted to **static and/or cyclic loads**

2) To define an **inspection program** to find the damage with high probability before it reaches its critical size

- Step 1 – damage propagation speed **$da/dn = f(\Delta K)$** including ΔK threshold and critical value
- Step 2 – initial damage size ($\mathbf{a_0}$) and detectable damage size ($\mathbf{a_{DET}}$)
- Step 3 – Residual Strenght (RS) and critical defect size $\mathbf{a_{CR}}$
- Step 4 – Inspection interval

Source: FAA, Damage Tolerance *Analysis for Antenna Installation on Pressurised Transport Airplanes*, Chicago Certification Office

Damage Tolerance Data



Threshold = min { **L1**, **(L1 + L2) / 2** }

I = L_2 / 3

5. Aging Aircraft

Structural Integrity

AMC 20-20

With the increased use, longer operational lives and experience from in-service aircraft, there is a need for a programme to ensure a high level of structural integrity for all aircraft

Continuing Aircraft Integrity Program

- **WFD**
  - MED
  - MSD
- **SSID** (DT data)
- SB Review
- CPCP
- FCS Repair Review

DSG ≤ LOV

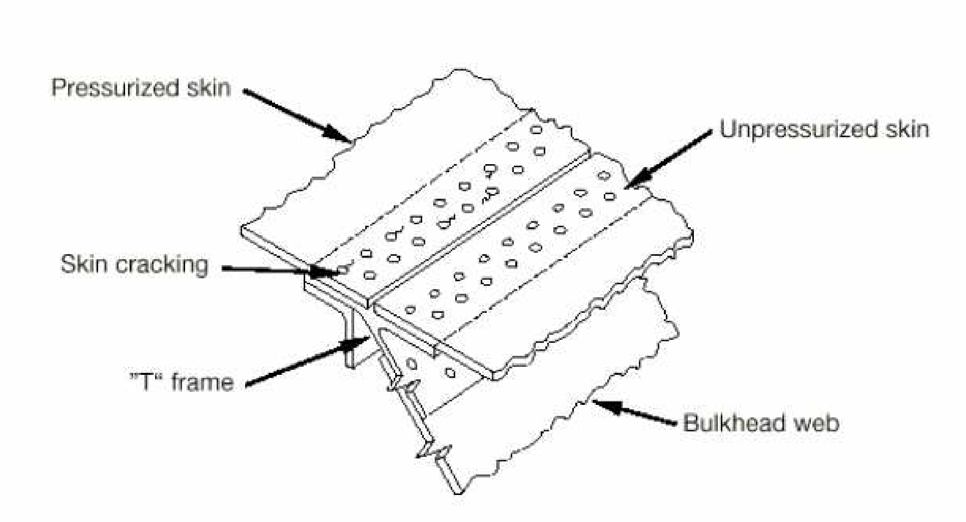
Programme	Affected Structure*	Implementation
CPCP	All Primary Structure	½ DSG
SSID	PSEs as defined in CS25.571	½ DSG
SB-Review	SBs that address a potentially unsafe structural condition	¾ DSG
REGs and RAPs	Repairs to fatigue critical structure (FCS).	¾ DSG
WFD	Prmary structure susceptible to WFD	1 DSG

Limit of validity (LOV) = period of time for which it has been shown (based on fatigue test evidence) that the established inspections and replacement times are sufficient to allow safe operation and to preclude WFD. The LOV and associated actions should be incorporated in the ALS

Widedspread Fatige Damage (WFD)

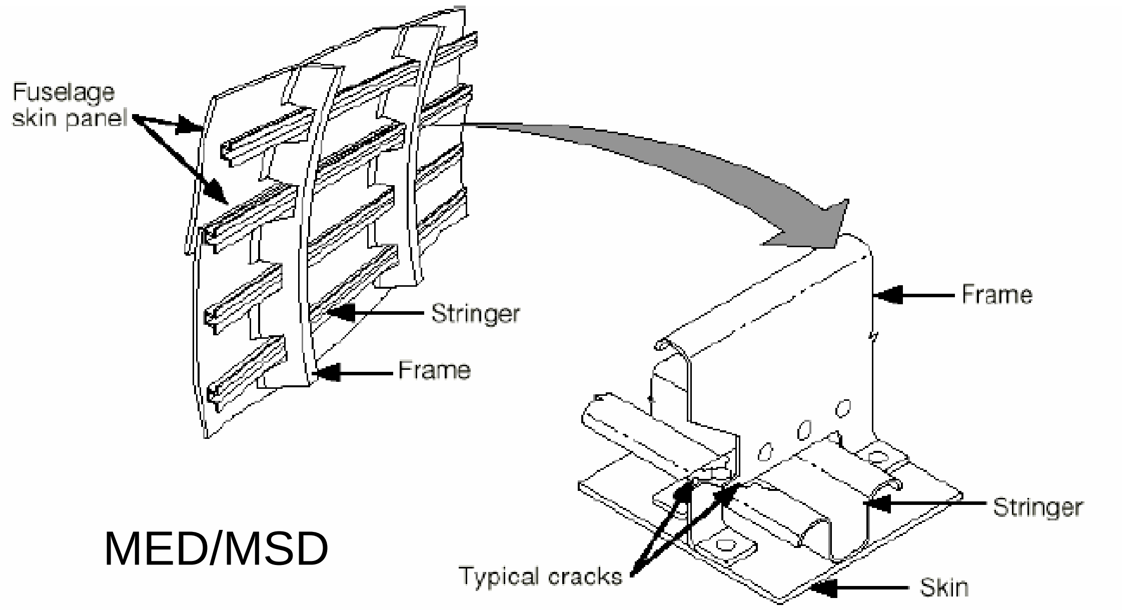
AMC 20-20

- The likelihood of the occurrence of fatigue damage in an aircraft's structure increases with aircraft usage
- The design process generally establishes a design service goal (DSG) in terms of flight cycles/hours for the airframe
- It is expected that **any cracking that occurs on an aircraft operated up to the DSG will occur in isolation** (i.e. local cracking), originating from a single source, such as a random manufacturing flaw (e.g. a mis-drilled fastener hole) or a localised design detail
- It is considered unlikely that cracks from manufacturing flaws or localised design issues will interact strongly as they grow
- With extended usage, **uniformly loaded structure** may develop cracks in adjacent fastener holes, or in adjacent similar structural details. The **development of cracks at multiple locations** (both MSD and MED) may also result in strong interactions that can affect subsequent crack growth, in which case the predictions for local cracking would no longer apply.



Ex. **skin joint**. Load transfer occurs. Simultaneous cracking at many fasteners along a common rivet line may reduce the residual strength of the joint below required levels before the cracks are detectable under the maintenance programme established at time of certification.

MSD



MED/MSD

Source : EASA AMC 20-20

LOV=Limit Of Validity
ISP = Initial Inspection Point
SMP = Structure Modification Point

MED/MSD
coaleshence

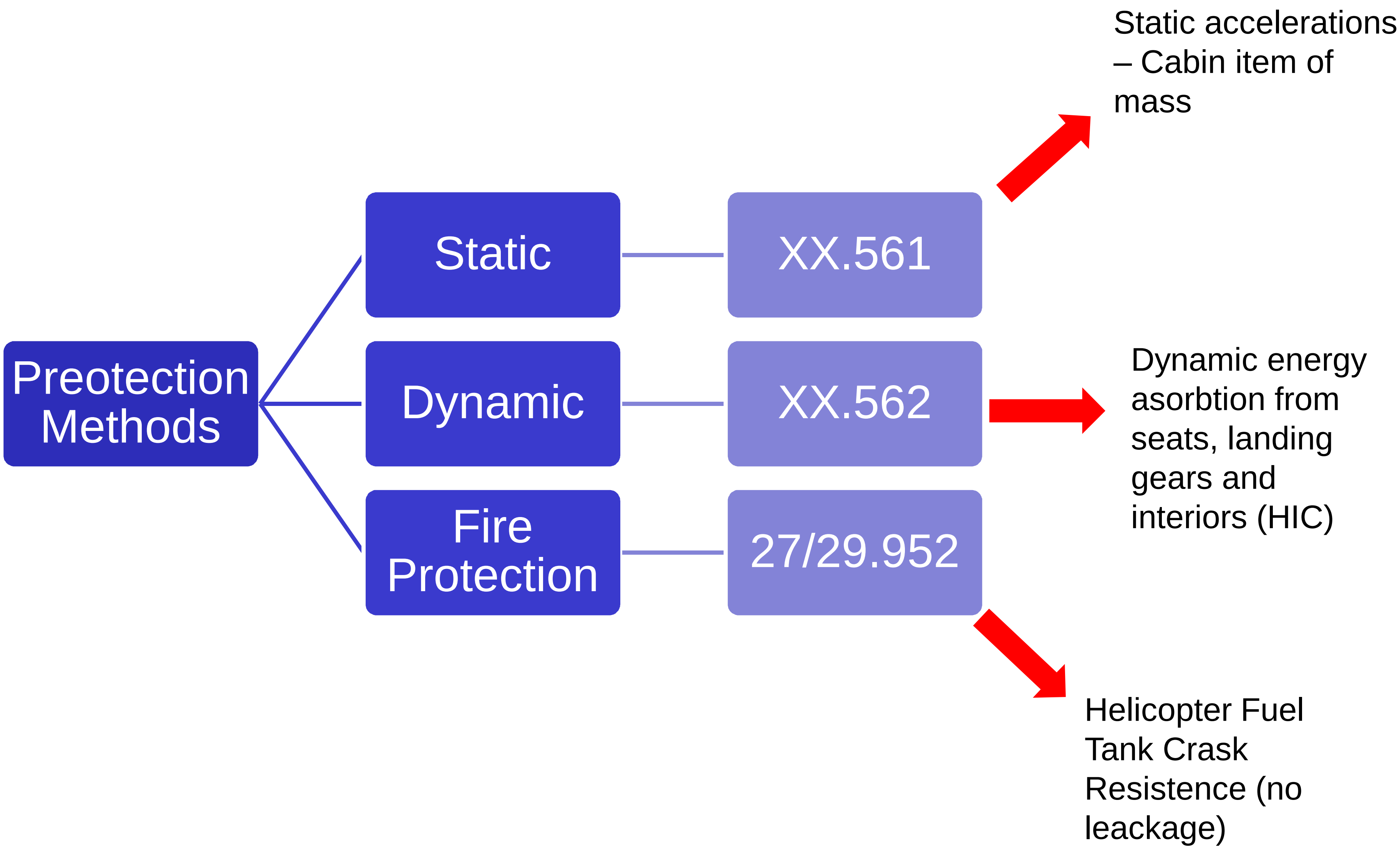
Inspection Start Point (ISP) = Point in time when special inspections start due to a specific probability of having MSD/MED. It is determined by a statistical analysis of crack initiation based on fatigue testing, teardown, or service experience of similar structural details. The ISP is equivalent to a lower bound value with a specific probability in the statistical distribution of cracking events.

Structural Modification Point (SMP) = Point reduced from the WFD average behaviour (i.e., lower bound). Operation up to SMP provides equivalent protection to that of a two-lifetime fatigue test. No aircraft should be operated beyond the SMP without modification or part replacement. The SMP can be determined by dividing the WFD Average Behaviour by a factor of 2 if there are viable inspections, or by a factor of 3 if inspections are not viable.

Source : EASA AMC 20-20

6. Crashworthiness

Aircraft passive protection



Birdstrike

CS 25.631 Bird strike damage

The aeroplane must be designed to assure capability of continued safe flight and landing of the aeroplane after impact with a 4 lb bird when the velocity of the aeroplane (relative to the bird along the aeroplane's flight path) is equal to VC at sea-level or 0·85 VC at 2438 m (8000 ft), whichever is the more critical.(…)

Landing Gear Drop Test

CS 29.473 Ground loading conditions and Assumptions

(b) Unless otherwise prescribed, for each specified landing condition, the rotorcraft must be designed for a limit load factor of not less than the limit inertia load factor substantiated under CS 29.725.

CS 29.723 Shock absorption tests

The landing inertia load factor and the reserve energy absorption capacity of the landing gear must be substantiated by the tests prescribed in CS 29.725 and 29.727, respectively.

These tests must be conducted on the complete rotorcraft or on units consisting of wheel, tyre, and shock absorber in their proper relation.

7. Hazard Analysis & Safety Assessment of Aircraft Systems

Risk = Probability * Consequences

>> SAFETY BARRIES

INTEGRITY LEVEL >>

Source : ASCOS / Internet

HAZARD Concept

- An Hazard is a risky situation i.e. a "situation" (= set of elements and circumstances) that could lead to an unwanted harm effect for people or goods

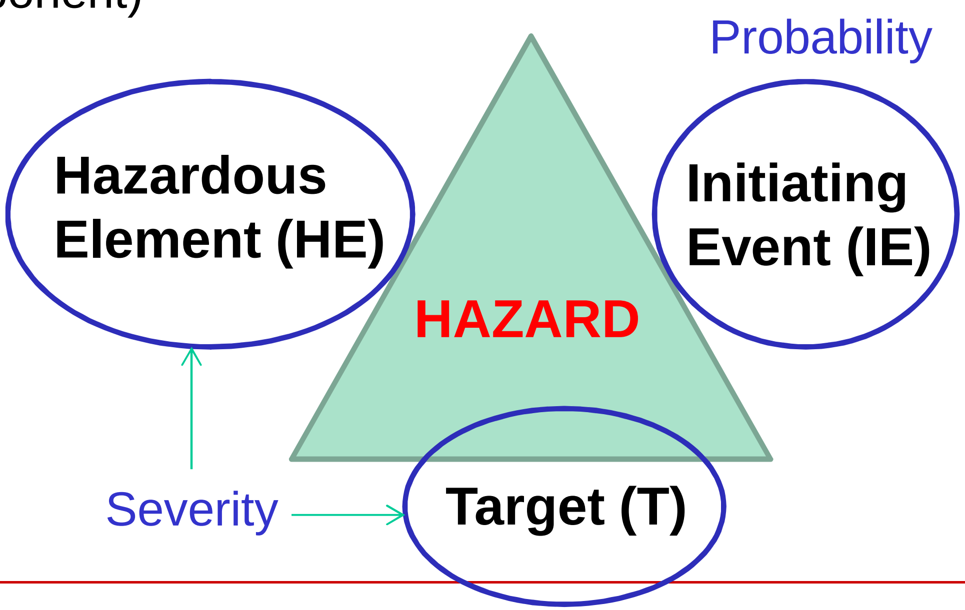
"a state or a set of conditions, internal or external to a system, that has the **potential** to cause harm." (NASA NPR 8715.3C)

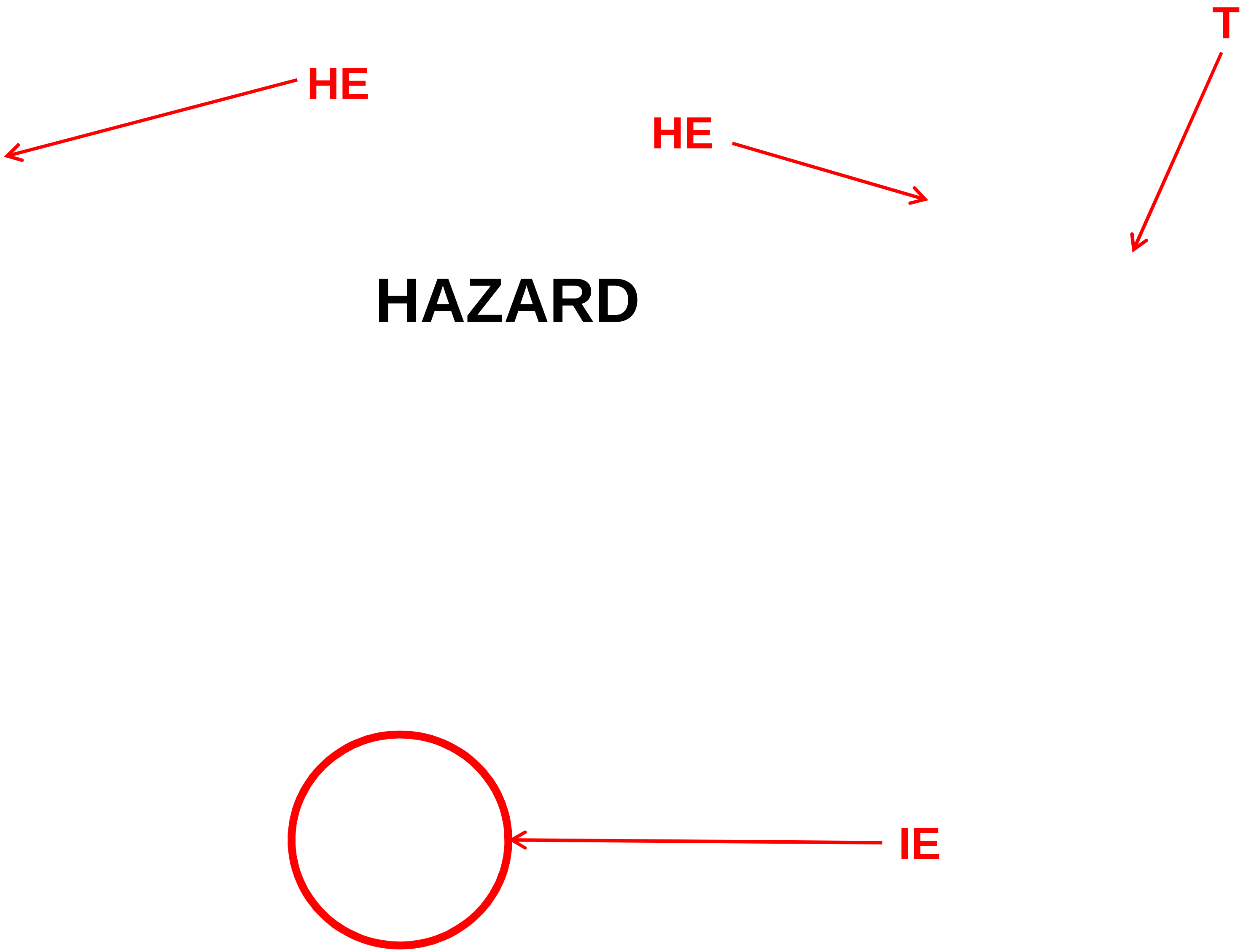
- Hazard Triangle (Hazard Component)

HE –The basic hazardous resource creating the impetus for the hazard, such as a hazardous energy source.

IE –The trigger(s) or initiator event(s) that would cause the hazard to occur. The IM would cause the actualization or transformation of the hazard from a dormant state to an active mishap state.

T –This is the person or thing that is vulnerable to injury and/or damage, and it describes the severity of the mishap event. This is the mishap outcome and the expected consequential damage or loss.





Source : IAASS Space Safety Course, Turin 2015

The 1309 requirement

CS 25.1309 Equipment, systems and installations

The requirements of this paragraph, except as identified below, are applicable, in addition to specific design requirements of CS-25, to any equipment or system as installed in the aeroplane.

Although this paragraph does not apply to the performance and flight characteristic requirements of Subpart B and the structural requirements of Subparts C and D, it does apply to any system on which compliance with any of those requirements is dependent.
(…)

(a) The aeroplane equipment and systems must be designed and installed so that:

(1) Those required for type certification or by operating rules, or whose improper functioning would reduce safety, perform as intended under the aeroplane operating and environmental conditions.

(2) Other equipment and systems are not a source of danger in themselves and do not adversely affect the proper functioning of those covered by sub-paragraph (a)(1) of this paragraph.

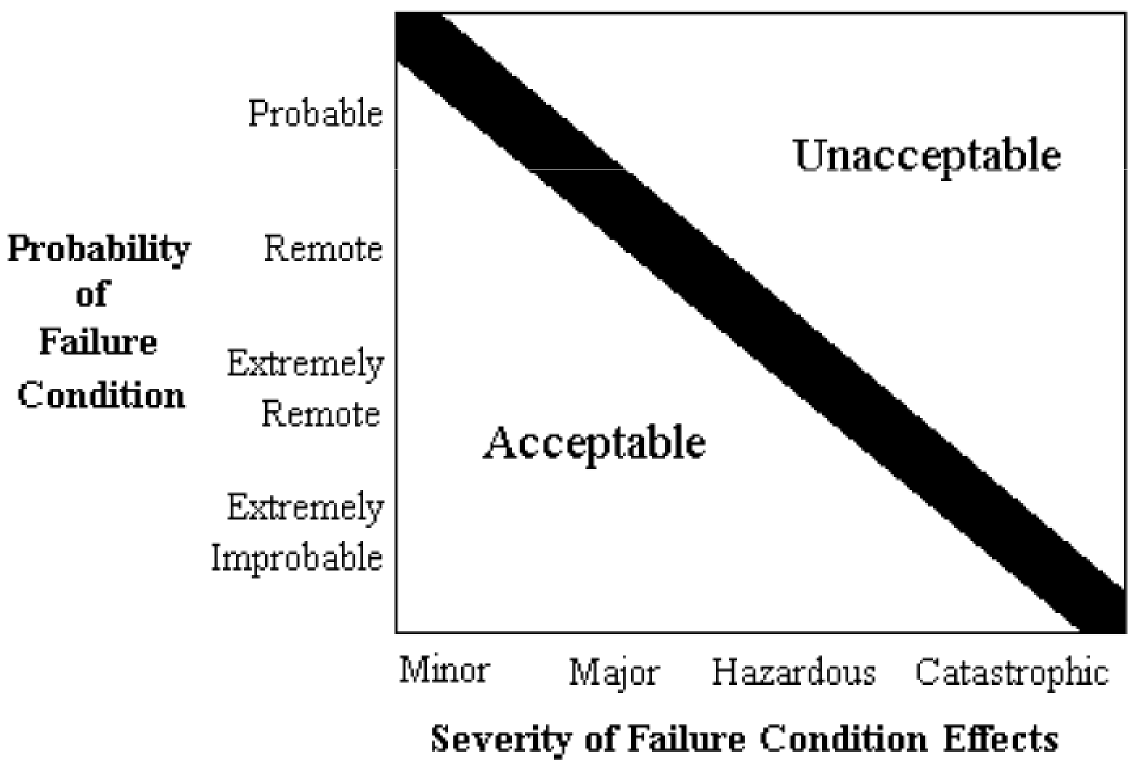
(b) The aeroplane systems and associated components, considered separately and in relation to other systems, must be designed so that –

(1) Any catastrophic failure condition
(i) is extremely improbable; and
(ii) does not result from a single failure; and

(2) Any hazardous failure condition is extremely remote; and

(3) Any major failure condition is remote.

(…)



Classification of Failure Conditions

(Effect SEVERITY)

- **No Safety Effect** – FC that would **not affect** the operational capability of the aeroplane or increase crew workload

- **Minor** – FC which **would not significantly reduce aeroplane safety**, and which involve crew actions that are well within their capabilities. Minor FC may include, i.e, a slight reduction in safety margins or functional capabilities, a slight increase in crew workload, such as routine flight plan changes, or some physical discomfort to passengers or cabin crew.

- **Major** – FC which would reduce the capability of the aeroplane or the ability of the crew to cope with adverse operating conditions to the extent that there would be, i.e., a **significant reduction in safety margins or functional capabilities**, a **significant increase in crew workload** or in conditions impairing crew efficiency, or discomfort to the flight crew, or physical distress to passengers or cabin crew, **possibly including injuries**

FC = Failure Condition

- **Hazardous** – FC, which would reduce the capability of the aeroplane or the ability of the crew to cope with adverse operating, conditions to the extent that there would be:

  (i) A **large reduction in safety margins or functional capabilities**

  (ii) Physical distress or **excessive workload** such that the flight crew cannot be relied upon to perform their tasks accurately or completely; or

  (iii) **Serious or fatal injury to a relatively small number of the occupants** other than the flight crew.

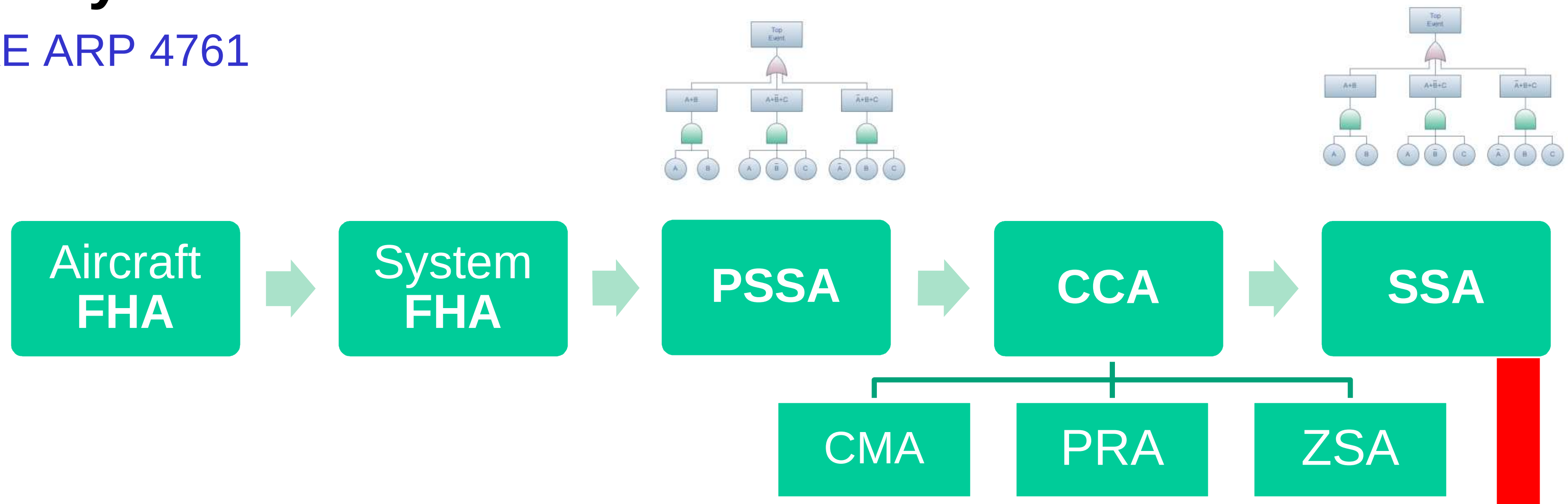
- **Catastrophic** – **FC which would result in multiple fatalities, usually with the loss of the aeroplane**

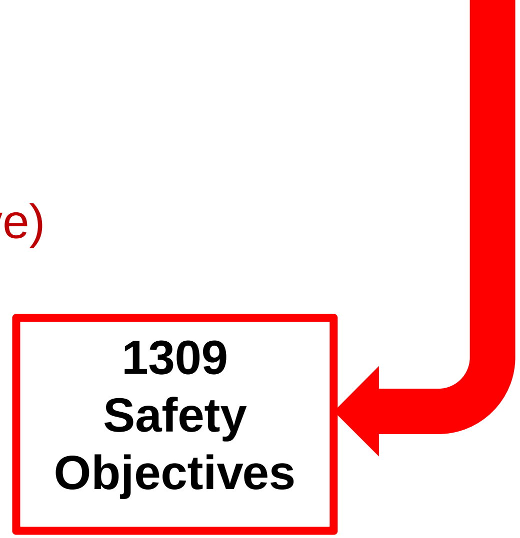
FC = Failure Condition

Probabilistic Terminology	Qualitative Description	Safety Target (p = Prob. / FH)
PROBABLE	FC anticipated to occur one or more times during the entire operational life of each aeroplane	**p > 1E-5**
REMOTE	FC unlikely to occur to each aeroplane during its total life, but which may occur several times when considering the total operational life of a number of aeroplanes of the type.	**1E-7 < p ≤ 1E-5**
EXTREMELY REMOTE	FC not anticipated to occur to each aeroplane during its total life but which may occur a few times when considering the total operational life of all aeroplanes of the type.	**1E-9 < p ≤ 1E-7**
EXTREMELY IMPORBABLE	FC so unlikely that they are not anticipated to occur during the entire operational life of all aeroplanes of one type.	**p ≤ 1E-9**

Safety Assessment Process

SAE ARP 4761



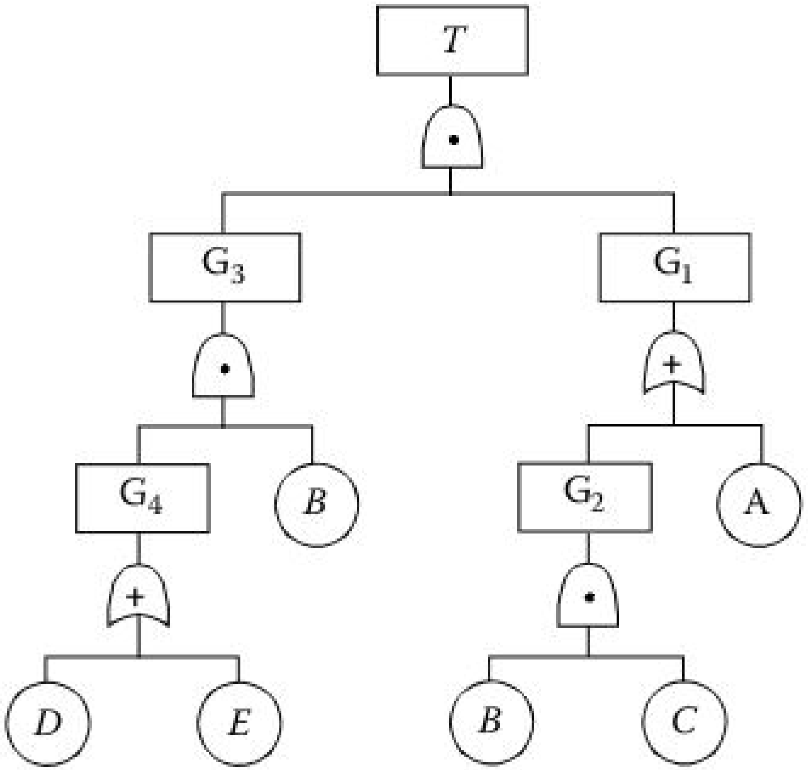


FHA – Functional Hazard Analysis
PSSA – Prelimiary Sistem Safety Analysis (qualitative)
CCA – Common Cause Analyis
SSA – System Safety Analiysis (quantitative)
CMA – Common Mode Analysis
PRA – Particular Risk Analyis
ZSA – Zonal Safety Analysis

Functional Hazard Assessment (FHA)

Fault Tree Analysis (FTA)

- System fault propagation analysis (for indipendent basic events)
- It is carried out for each FC HAZ o CAT identified in the FHA
- **PSSA** → Qualitative FTA
  - Single Point of Failure identication
  - Redoundancy assessment
- **SSA** → Quantitative FTA quantitativa
  - Safety objectives numerical verification



Boolean Algebra

T=G3*G1
G3=G4*B
G1=G2+A
G4=D+B
G2=B+C

→ T=((D+B)*B)*((B+C)+A) =
=BD+BE+BCD+BCE+BAD+BAE

Minimal Cut Set (Kj) = Set of basic elements (Xi) whose failure is a necessary and sufficient condition for a system failure to occur (Top Event T)

T = K1 + K2 + … Kn where Ki = X1*X2*…*Xi*…

P(T) = P(K1+…+Kn) = … (by using the Inclusion-Exclusion Theorem)

8. Systems-Structures interaction

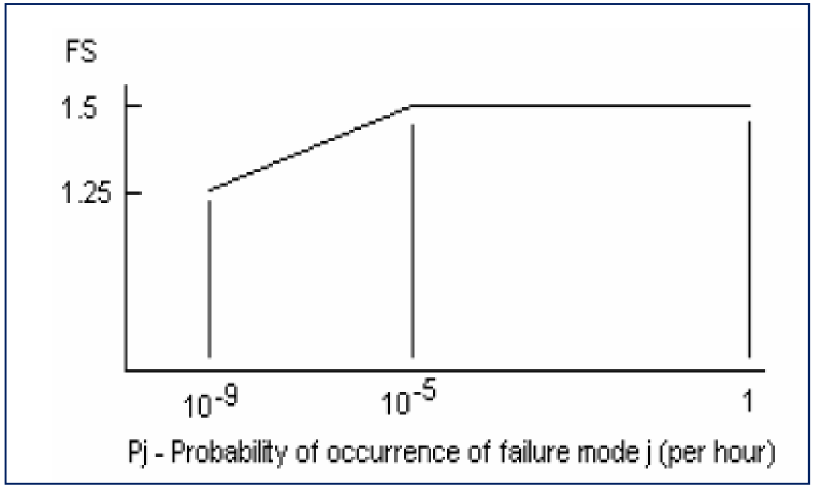
CS 25.302 Interaction of systems and structures

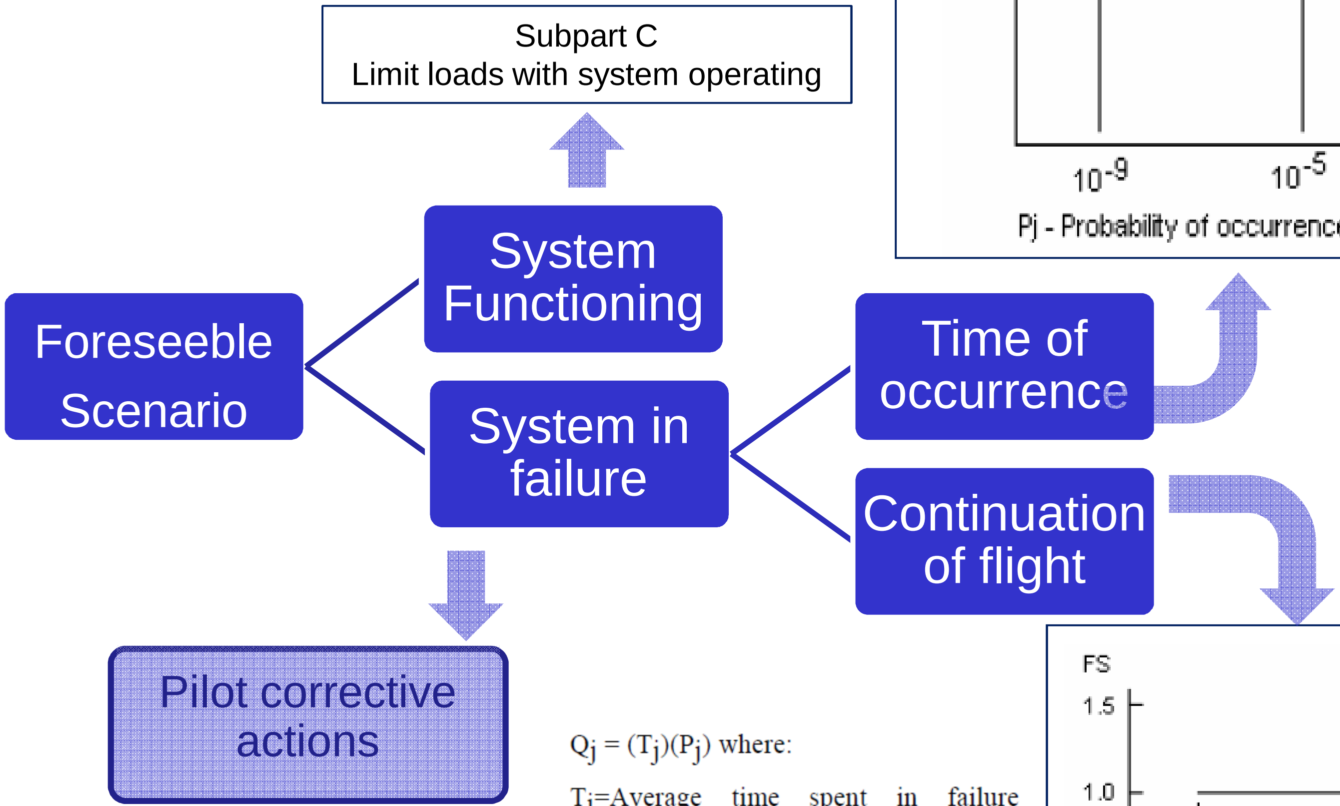
For aeroplanes equipped with systems that affect structural performance, either directly or as a result of a failure or malfunction, the influence of these systems and their failure conditions must be taken into account when showing compliance with the requirements of Subparts C and D. (…)

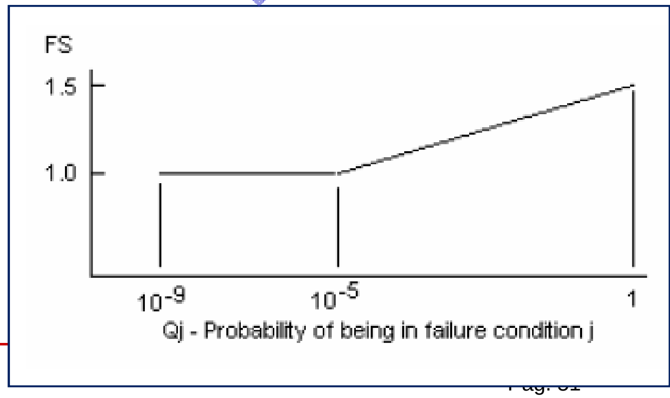
- Consider all failures not **“extremely improbable”** that could affect structure performances in the flowing situations
  - Normal condition
  - Time of occurrence
  - Continuation of flight
- The loads in the above conditions must be evaluated and a Factor of Safety dependent on the “**probability of being in failure condition”** or on the **“failure rate”** must be applied

- **Probability terminology** and **Safety Objectives** same of CS 25.1309

CS 25 Appendix K







$Q_j = (T_j)(P_j)$ where:

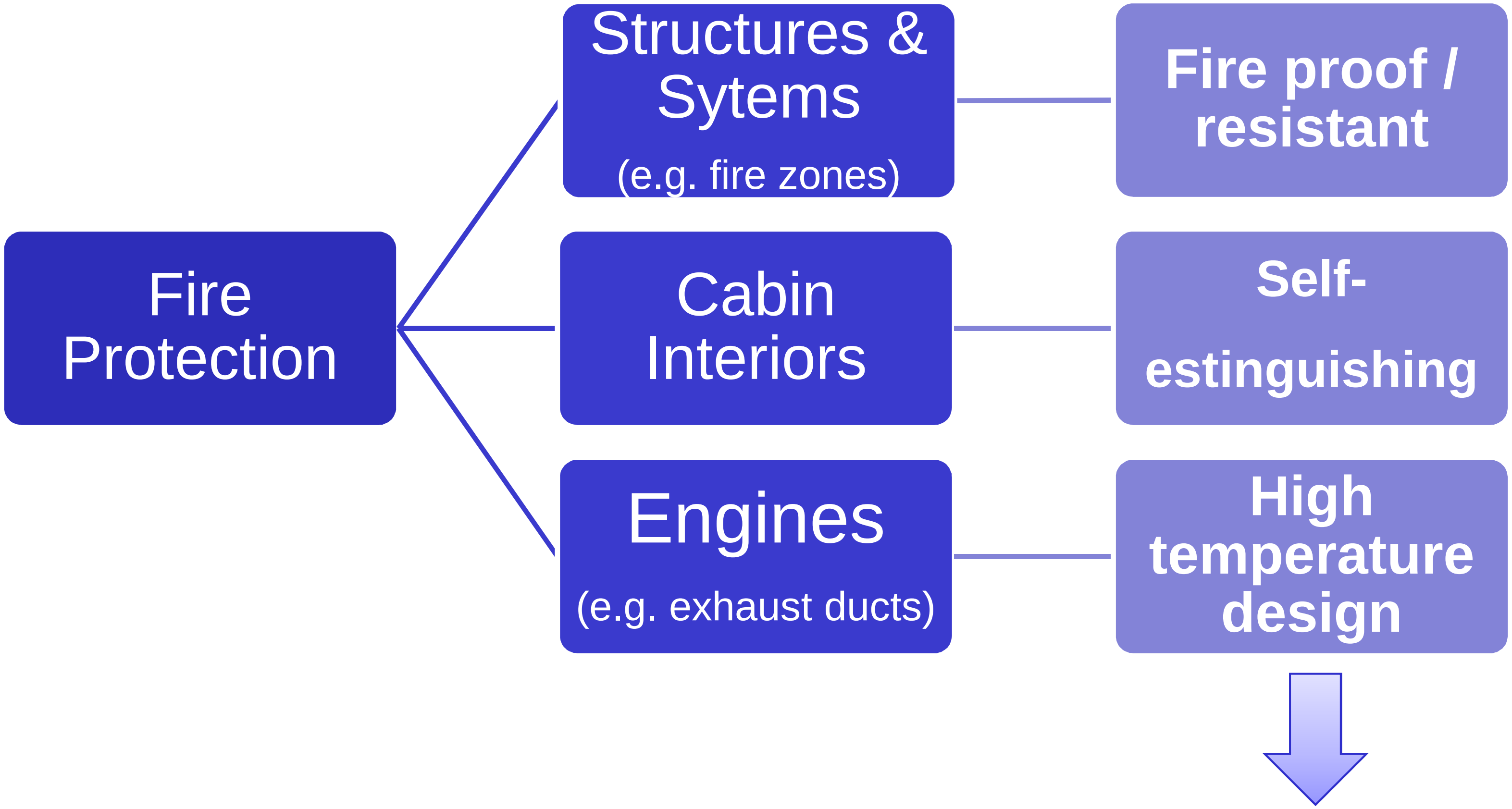
T_j=Average time spent in failure condition j (in hours)

P_j=Probability of occurrence of failure mode j (per hour)

Source : CS-25 Appendix K

Sapienza Università di Roma

9. Fire Protection



no degradation of the component during its life under normal/anomalous thermal conditions

Fire proof (15 min.) / Fire resistant (5 min.) materials

FAA AC 20-135

- The component is requested to protect other parts of the aircraft or its function from the effects of an on-board fire

- To be verified by test –
  - No flame penetration
  - No re-ignition on cold side
  - Residual strength

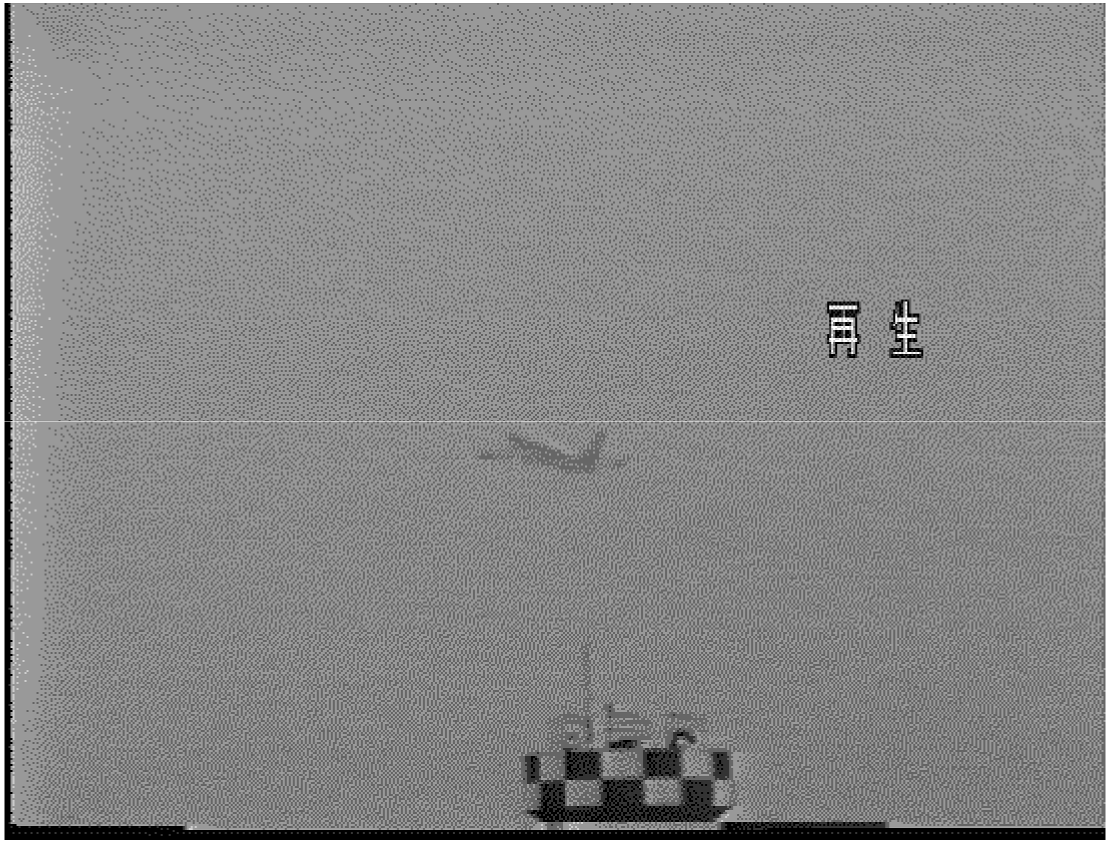
Flammability features cabin interiors

(cushions, moquette, etc.)

CS 25.853 (Compartment Interiors) & CS 25.855 (Cargo/Baggage Compartment) & Appendix F

- Self-estinguishing features to be demonstrated by test –
  - Once burner flame is interrupted, fire must die out
  - Extension of burn within certain limits
  - (No toxic emissions)

10. Ligthning Protection



Source : Internet

- **Req. CS 25.581** (large a/c)

  (a) The **aeroplane must be protected against catastrophic effects from lightning**

  (b) **For metallic components**, compliance with sub-paragraph (a) may be shown by –

    (1) **Bonding** the components properly to the airframe; or

    (2) Designing the components so that a **strike will not endanger the aeroplane**.

  (c) **For non-metallic components**, compliance with sub-paragraph (a) may be shown by –

    (1) Designing the components to **minimise the effect of a strike**; or

    (2) Incorporating acceptable means of **diverting the resulting electrical current** so as not to endanger the aeroplane.

- **Direct effects must be avoided either by minimizing the strile effect or diverting electical current** (by assuring sufficient electical conductivity)

- **Design details for structure metallization**
  - Metallic layers — type, thickness, material
  - Electrical Bonding: — where, how large? how many?
  - Joints — Good tight electrical contact for avoiding sparks and assuring continuity
  - Dissimilar materials — galvanic corrosion
  - Mechanical bonding (adhesives) — dielectics vs conductives

Zone 1A:

First return stroke zone - low expectation of hang on

Zone 1B:

First return stroke zone - high expectation of hang on

Zone 1C:

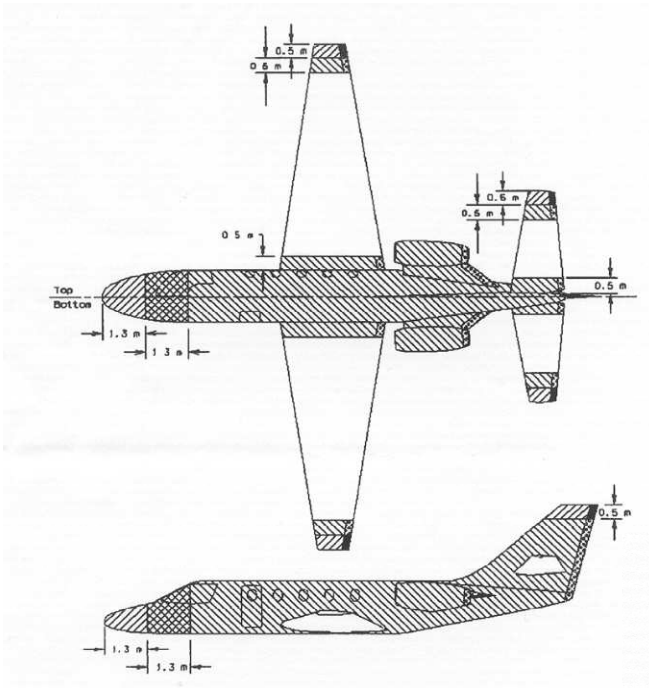
First return stroke zone of reduced amplitude - low expectation of hang on

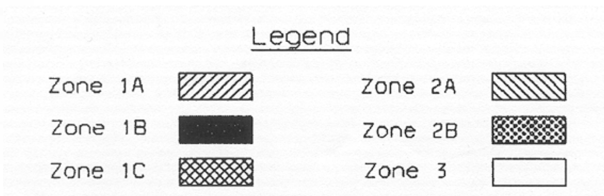
Zone 2A:

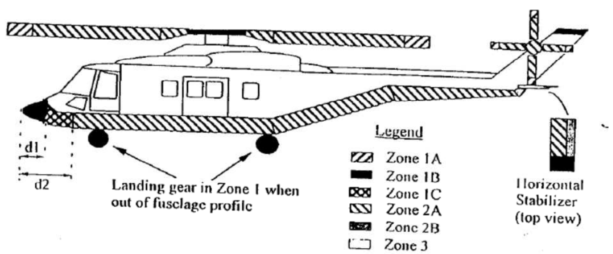
Swept stroke zone - low expectation of hang on

Zone 2B:

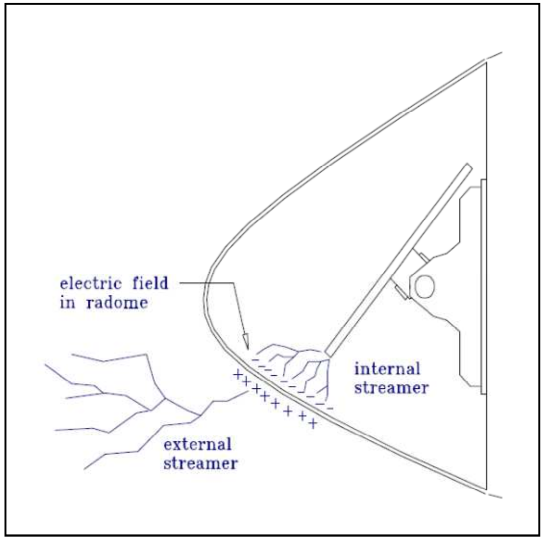
Swept stroke zone - high expectation of hang on







Zoning modification



Fonte: DOT/FAA/AR-04/13

Current component levels for testing (EUROCAE ED-84)

A Initial strike

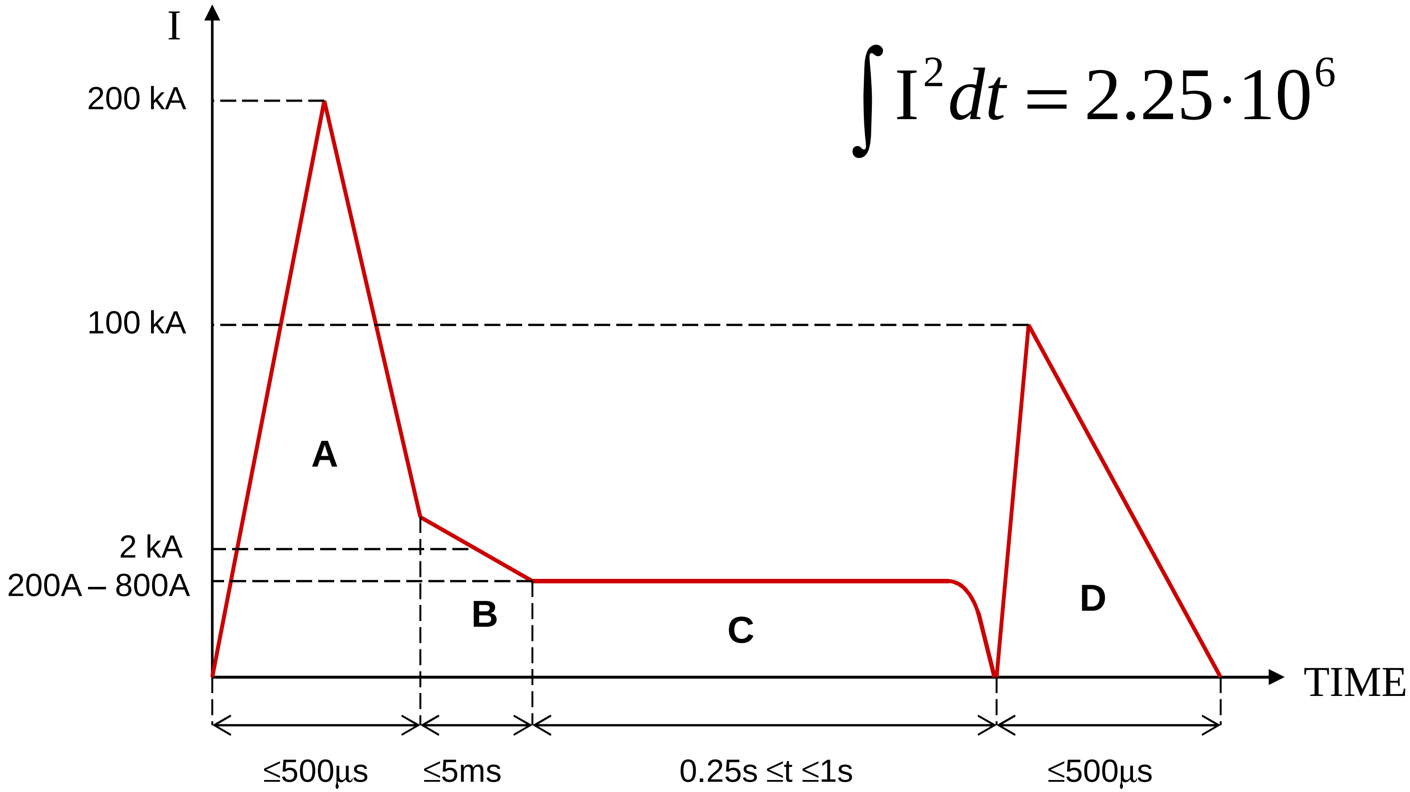
B Intermediate current

C Continuing current

D Re-strike

→ **ACTION INTEGRAL** [A^2s] = [J/Ω] enengy dissipated per ohm of resistance (basically **A+D**)

$$\int I^2 dt = 2.25 \cdot 10^6 \quad A^2 s$$



- **Direct effects**
  - On the attaching point

    Thermal Effects

    - Joule Heating $Q = RI^2 \Delta T$
    - Arc radiation
    - Direct energy transfer from the arc attaching point to the sourroundings

    Transient mechanical forces

    - Acustic effects
    - Magnetic forces (inuctions / magnetic pressure)
    - Material explosion due to vaporization and rapid gas expantion

  - On the conducting zones away from the attaching point
    - Joule Heating
    - Magnetic forces (inuctions / magnetic pressure)

- **Heating** → Mechanical properties degradation

$$\Delta T = \propto 1 / S^2$$

ΔT = temperature increase
S = bonding section
γ = Resisrivity [Ohm*m]
ρ = Material density
c = Specific Heat

Tufting

- Non protected CFRP panel – Zone 1A strike

Unpainted

Painted

- Protected CFRP panel ECF (Cu, t = 0.7 mm)

Zone 1A

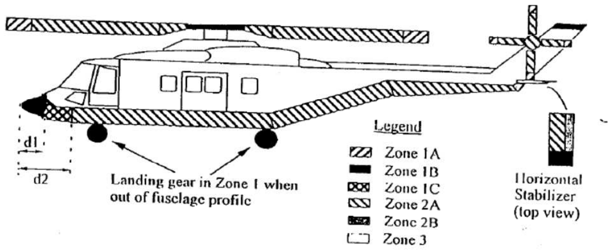
Zone 2A

Source: AGATE-WP3.1-031027-043

Certification Approach

(SAE ARP 5577 "Aircraft Lightning Direct Effect Certification")

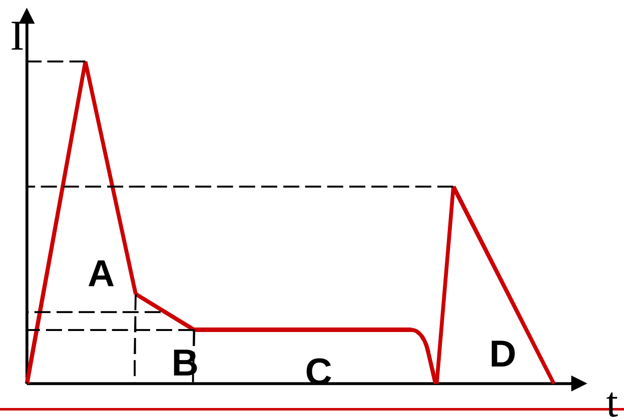
- Determine the lightning strike zones for aircraft



- Establish the lightning environment associated with the zones

  ✓ Waweform

  ✓ Lightning current components



- Perform a safety classification

  - ✓ Detailed list of aircraft structure, systems and components whose lightning related failure or malfunction could contribute to or lead to catastrophic effects

- Make a Lightning Hazard Assessment

  - ✓ Damage Tolerance analysis to identify lightning direct effect and their potential hazard in each items identified in the safety classification

  - ✓ Consider the ability of the aircraft structure, systems and components to safely tolerate direct lightning attachment, conduction of lightning current and magnetic forces as appropriate for zones whithin which a structure, systems or components is located.

  - ✓ A design review should identify aircraft structure and components that clearly require additional protection

- Design protection in accordance with acceptance criteria

  - ✓ Completion of the protection design to meet acceptance criteria resulting from hazard assessment

  - ✓ **E.g.**
    - Maximum allowable damage
    - Maximun size of hole allowed in metallic skin
    - Maximum extent of delamination allowed in composite skin

  - ✓ **N.B.**
    - Rupture of composite materials because of rapid expansion of gasses whithin them is not allowed
    - Consequential damage to the aircraft structure or components as a results of lightning damage elsewere on the aircraft is not allowed

- Verfiy compliance

  - ✓ By Similarity
  - ✓ By Test
  - ✓ By Analysis

  - ✓ **N.B.**

    Fonte: AGATE-WP3.1-031027-043

    – Analysis is not often pratical for direct effects….

    – Analysis is applied to establish ability of structure and components to conduct currents without damages based on consideration of adequate crosssectional area and material conductivities

- Determine and implement corrective mesures

  - ✓ If compliance verification is not achived **review the design**

  - ✓ Make a **new complaiance demonstration**

Thank you
for your attention

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