EASA
European Aviation Safety Agency

Structural Aspects of Cabin Layouts and Antenna Installations

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Abbreviations

AMC	Acceptable Means of Compliance www.easa.europa.eu/the-agency/faqs/acceptable-means-compliance-amc-and-alternative-means-compliance-altmoc www.easa.europa.eu/system/files/dfu/EasyAccess2Part-21_Feb_2016.pdf
CFD	Computational Fluid Dynamics
CMH17	Composite Materials Handbook (www.cmh17.org)
CRI	Certification Review Item
CS	Certification Specifications (www.easa.europa.eu/document-library/certification-specifications)
CVE	Certification Verification Engineer (www.easa.europa.eu/faq/20110)
DOA	Design Organisation Approval (www.easa.europa.eu/easa-and-you/aircraft-products/design-organisations)
EASA CM	EASA Certification Memorandum (www.easa.europa.eu/document-library/public-consultations/certification-memoranda)
(E)TSO	(European) Technical Standard Order www.easa.europa.eu/the-agency/faqs/etso-authorisations, www.faa.gov/aircraft/air_cert/design_approvals/tso
FAA AC	Federal Aviation Administration Advisory Circulars (www.faa.gov/regulations_policies/advisory_circulars)
FAA IP	Federal Aviation Administration Issue Paper
GA & RA	General Aviation & Rotorcraft
GAMA	General Aviation Manufacturers Association (www.gama.aero/publications)
LA	Large Aeroplanes
M&P	Materials &Processes
MMPDS	Metallic Materials Properties Development and Standardization (www.mmpds.org), formerly MIL-HDBK-5
OEM	Original Equipment Manufacturer
STC	Supplemental Type Certificate (www.easa.europa.eu/document-library/type-certificates/supplemental-type-certificates)
(V)VIP	(Very) Very Important Person

Contents

Introduction

- Many STC's affect structural integrity of the aircraft
- For example, because of installation aspects (local attachment) or major changes to baseline airframe structure

- For this workshop, two very common types of STC's (with structural implications) will be addressed:
  - Cabin layouts (in particular (V)VIP configurations)
  - Antenna installations

- Focus will be on CS-25 aircraft, although some aspects apply to other aircraft/rotorcraft as well
- Not a full coverage of all structural aspects, but more "lessons learned"

Introduction

- Structures includes many subject areas:
  - Loads
  - Aeroelasticity (incl. Vibration & Buffeting)
  - Static Strength
  - Fatigue & Damage Tolerance
  - Materials & Processes
  - Crashworthiness
  - Decompression
  - Impact Conditions (bird strike, engine/wheel/tyre debris,…)

- Not always fully appreciated by DOA's (the term "CVE Structures" may have different meanings…)

Introduction

- Fourteen (14) Structures Experts within EASA:
  - Chief Expert:

  Richard Minter
  - Senior Experts:

  Laurent Pinsard (GA & RA), Simon Waite (M & P), Wim Doeland (LA)
  - Experts:

  George Zografos, Torsten Jaudas, Elena Garcia, Wolfgang Hoffmann, Dietmar Bloemen, Emmanuel Licheron, Aiko Duehne, Emily Lewis, Herdrice Hereson, Antonio Blanco

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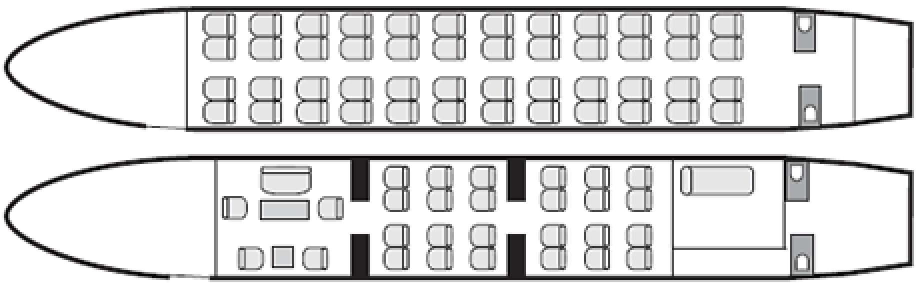
- Introduction
- Cabin layouts
  - Static strength substantiation
    - External loads
    - Allowable interface loads
    - Wear & tear factor (1.33)
    - Material design values
    - Test, or analysis supported by test
  - Installation of seat adapter plates
  - Compliance with decompression requirements
- Antenna installations

Cabin layouts - general

- Cabin layouts (changes):
  - Can vary from replacing some galleys or re-arranging business/premium/economy class areas using existing (approved) seats, to complete refurbishments like (V)VIP installations



- From a Structures point of view, the following items/subjects are highlighted in this workshop:
  - Static strength substantiation
  - Installation of seat adapter plates
  - Compliance with decompression requirements

Cabin layouts - static strength

- Static Strength substantiation:
  - External loads
  - Allowable interface loads
  - Wear & tear factor (1.33)
  - Material design values
  - Test, or analysis supported by test
- This applies to:
  - Item of mass to be installed (seat, lavatory,…)
  - Supporting structure (bulkheads, floor,…) – interface loads and structure itself
- For example, when installing new seats: seat may be OK, interface loads may be OK, but could be too heavy for floor structure (running load lb/in, floor loading lb/in^2)

Cabin layouts - static strength

- Main external loads to be considered:
  - Emergency landing loads (CS 25.561)
  - Flight (manoeuvre, gust) loads (CS 25.301 to CS 25.427)
  - Ground loads (CS 25.471 to CS 25.519)
  - Pressure (decompression) loads (CS 25.365)
- Emergency landing loads may not cover all of the above load conditions
  - For example, maximum up/down (vertical (z-)direction) g-loads may be resulting from gust or ground load conditions
  - Not easy to determine without OEM support / data
- Always check whether existing approvals (STC's, (E)TSO's) cover the applicable aircraft loads)

Cabin layouts - static strength

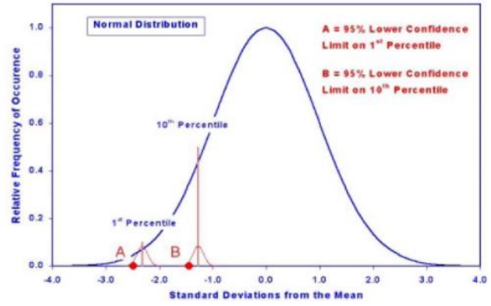
- Allowable interface loads:
  - Best to obtain and to use OEM data
  - With an existing (approved) installation where the relevant parameters are known (weight, loads, ….), one could derive (“reverse engineering”) allowable interface loads, and show that the new installation stays within those limits
  - Care must be taken however with this “reverse engineering” approach – examples exist of erroneous data being generated (wrong assumptions, superseded OEM data,…)

Cabin layouts - static strength

- Wear & tear factor (1.33):
  - Contained in CS 25.561(c): "….The local attachment for these items should be designed to withstand 1.33 times the specified loads if these items are subject to severe wear and tear through frequent removal… "
  - Leads to questions: which items are subject to this 1.33 factor and what means frequently removed?
  - Refer to EASA CM S-002 for further details:
    - Factor applies to quick change interior items (both pax and freighter configurations)
    - Frequency greater than typical seat movements (e.g. dividers and partitions)
    - For items of mass > 0.45 kg (1 lb) (or > 0.15 kg (0.33 lb) if attached to a seat), and for safety equipment mounting
  - For dual latches (e.g. trolley restraints in galleys): factor need not be applied if one latch is shown to be able to take ultimate load (ref. FAA AC 25-17A)

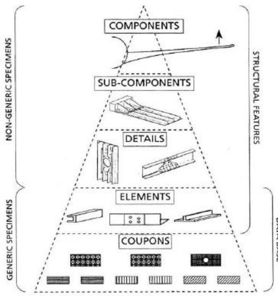
Cabin layouts - static strength

- Material design values
  - As per CS 25.613(b), for redundant (multi-load path) structure, design values must be established which assure strength with 90% probability and 95% confidence (“B-Basis ” or “T90” per MMPDS / CMH-17)
  - For single load path structure, 99% probability and 95% confidence applies (“A-Basis ” or “T99” per MMPDS / CMH-17)
  - Applies not only to airframe structure, but also to interior equipment items (including seats), including joints and bonded inserts
  - Use of mean (average) values, or S-Basis allowable, is therefore not permitted
    - Except as per AMC 25.613: source, application and service experience



Cabin layouts - static strength

- Test, or analysis supported by test:
  - How to substantiate the strength of the installed items, like galleys, lavatories,….
  - One particular useful reference is GAMA Publication No. 13
  - Mentions three basic compliance philosophies:
    - Similarity
    - Analysis, supported by (subcomponent) tests
    - Full-scale tests (with material and process variability “overload” factor)
  - Each approach has its own benefits and drawbacks, including:
    - Similarity claim needs to properly address (compare) all relevant critical design parameters
    - Analysis needs to be validated, and subcomponent test data base needs to be established
    - Full-scale tests can be complicated and expensive, and time-consuming



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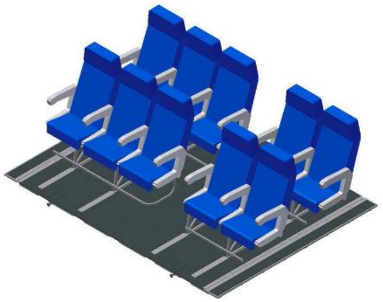
- Antenna installations

Cabin layouts – seat adapter plates

- For some configurations (cabin layouts), seat pattern does not fit with existing seat rail / track layout
  - Design solution could be to install seat adapter plates – also known as pallets or plinths
  - FAA AC 25.562-1B characterizes a plinth as an adapter used to attach a single seat to the floor, and gives an example of a pallet as an adapter used to attach multiple rows of seats
  - However, this does not adequately cover all cases / installations – additional guidance in EASA Generic CRI
  - FAA issued Policy Statement PS-ANM100-000129 (plus attachment) in May 2000, but is different from EASA Generic CRI – additional compliance effort may be required for EASA



Cabin layouts – seat adapter plates

- Safety objective: seat adapter plate should not introduce weak link in the chain of passenger – seat - floor (structure)

- Key issue: where is the critical interface? Can seat adapter plate be considered as part of floor or as part of seat?
  - if part of floor ("pallet"): seat needs to comply with dynamic requirements of CS 25.562 (typically covered by ETSO), and combination of seat and seat adapter plate needs to comply with static requirements of CS 25.561
  - if part of seat ("plinth"): combination of seat and seat adapter plate needs to comply with both static requirements of CS 25.561 <u>and</u> dynamic requirements of CS 25.562
    - Re-testing seat and seat adapter plate (to meet CS 25.562) required

Cabin layouts – seat adapter plates

- EASA Generic CRI:
  - Offers 3 options for applicants:
    - (1) Classify seat adapter plate as plinth
    - (2) Classify seat adapter plate as pallet due to its size
    - (3) Classify seat adapter plate as integral part of floor, based on 3 methods of compliance:
      - (1) Design review showing the new floor design for seat installation uses the same or equivalent design principle as the original floor provided in the Type Design
      - (2) Design review showing the level of integration of the plate to the floor, including the redundancy and strength of the attachments are acceptable to the Agency based on the experience of the applicant and the Agency with similar designs
      - (3) Analysis supported by test should be performed accounting for floor deformation and the stiffness of the seat combined with the 16g seat test measured peak dynamic load applied statically.
  - Option 3, method 2 (similarity) and method 3 (new designs) are most common approaches

Contents

Cabin layouts - decompression

- Text of CS 25.365(e), as introduced by JAR-25 Change 14 (same as FAR 25 Amendment 71/72):

CS 25.365 Pressurised compartment loads

(e) Any structure, component or part, inside or outside a pressurised compartment, the failure of which could interfere with continued safe flight and landing, must be designed to withstand the effects of a sudden release of pressure through an opening in any compartment at any operating altitude resulting from each of the following conditions:

(1) The penetration of the compartment by a portion of an engine following an engine disintegration.

(2) Any opening in any pressurised compartment up to the size H_o in square feet; however, small compartments may be combined with an adjacent pressurised compartment and both considered as a single compartment for openings that cannot reasonably be expected to be confined to the small compartment. The size H_o must be computed by the following formula:

$$H_o = PA_s$$

where,

H_o = maximum opening in square feet, need not exceed 20 square feet.

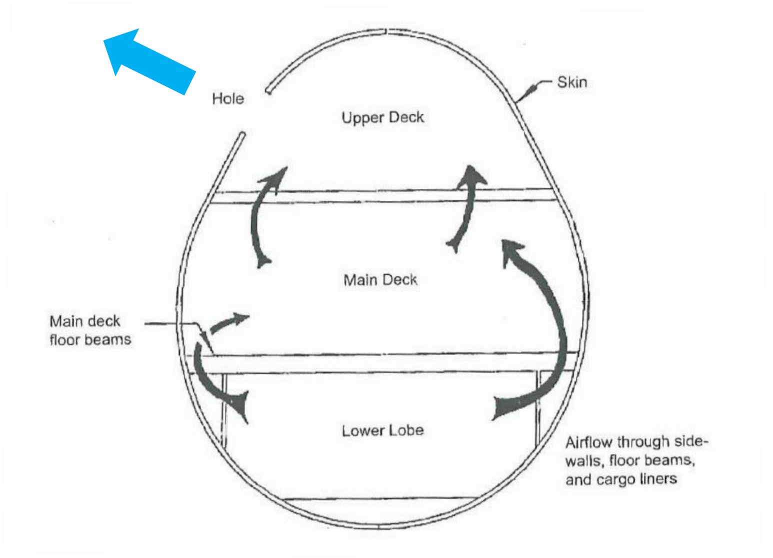
$$P = \frac{A_s}{6240} + \cdot 024$$

A_s = maximum cross sectional area of the pressurised shell normal to the longitudinal axis, in square feet; and

(3) The maximum opening caused by aeroplane or equipment failures not shown to be extremely improbable. (See AMC 25.365 (e).)

Cabin layouts - decompression

- Basics of decompression (example case):
  - Opening (hole) assumed to occur in pressure vessel
  - Cabin air escapes (outboard flow) from upper deck into ambient environment
  - Creates flow of cabin air from other compartments (main deck, lower lobe), but this flow “lags behind” the outboard flow due to obstructions , creating pressure differential over the floors, partitions, etc.



Cabin layouts - decompression

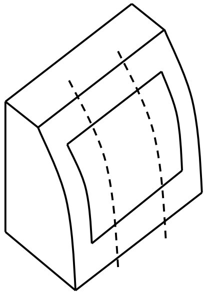
- Discussions with applicants seeking approval of (V)VIP conversions highlighted the need for a definition of “small” compartments in CS 25.365(e)(2)
- Also, interpretation of CS/FAR 25.365(g) raised some questions, in relation to collapse/failure of certain boundary elements (partitions, walls, ceilings,…):

> (g) Bulkheads, floors, and partitions in pressurised compartments for occupants must be designed to withstand conditions specified in sub-paragraph (e) of this paragraph. In addition, reasonable design precautions must be taken to minimise the probability of parts becoming detached and injuring occupants while in their seats.

- To clarify the acceptable means of compliance, an EASA Generic CRI has been defined

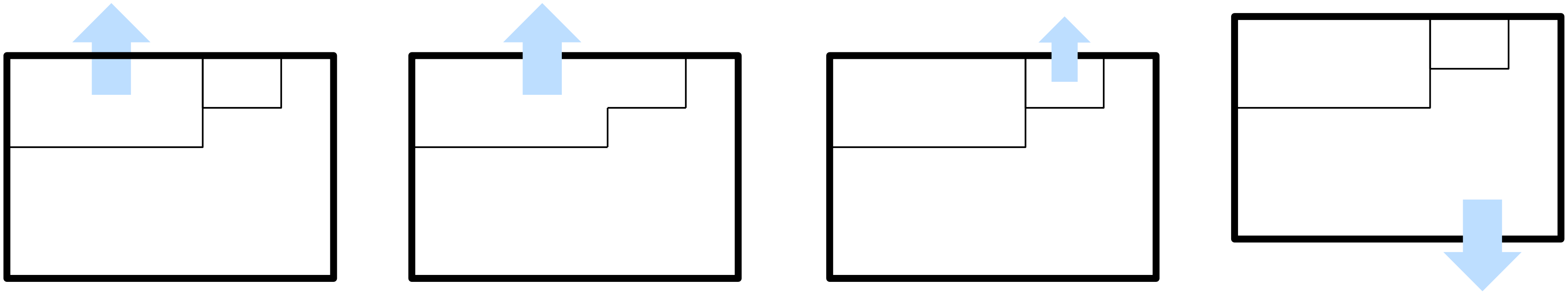
Cabin layouts - decompression

- To distinguish between “small” and “large” compartments, the following criterion is recommended in the EASA Generic CRI:
  - The opening resulting from CS 25.365(e)(2) should be considered as a rectangle
  - So a 20 square feet opening (the maximum in accordance with CS 25.365(e)(2)) would become a rectangle of approximately 4.5 by 4.5 feet, or 54 by 54 inches
  - Assuming a typical frame pitch of 20 inches, and assuming that the opening can be confined by the next frame on either side, this would mean that “small” compartments (for an aircraft where a 20 square feet opening size needs to be considered) would be those compartments that have a width of three frame bays or less



Cabin layouts - decompression

- For “large” compartments, consider opening in the compartment as defined by CS 25.365(e)
- For “small” compartments:
  - When combined with an adjacent compartment, consider opening defined by CS 25.365(e)(2) in the combination of compartments
  - Consider skin bay opening (ref. CS 25.365(e)(3)) in “small” compartment (not combined with adjacent compartment)



- In addition, consider opening defined by CS 25.365(e) remotely from “small” and “large” compartments

Cabin layouts - decompression

- Some “large” compartments have been found to be problematic
  - For example, those “large” compartments with small volumes and/or small (narrow) dimensions (like corridors)
- For these compartments, guidance on collapse/failure of boundary elements (partitions, walls, ceilings) is provided
  - For reasons of continued safe flight and landing, and for occupant protection, every reasonable and practicable design effort should be taken to design partitions, walls, etc. to withstand the resulting pressure differentials
    - Collapse of floor not allowed
  - This includes strengthening of structural elements (such as partitions, walls and ceiling panels), or providing additional venting, or relocation of interior walls (partitions)
  - In some (very limited) cases, only under certain conditions (see next slide), collapse/failure of such elements may be allowed

Cabin layouts - decompression

- These conditions are:
  - Strengthening, additional venting, etc. is shown not to be practicable
  - Continued safe flight and landing is preserved
    - E.g. no collapse of floors
  - Compartment is not provisioned with safety belts and not likely to be occupied by the same person for a significant period of time
    - Includes lavatories & corridors, but excludes crew rest, bedrooms, etc.
  - Minimize probability of debris becoming detached and injuring occupants
    - E.g. use of lanyards
  - No collapse/failure when considering an opening size equal to a skin bay
    - OEM lavatories already installed presently excluded
  - Clear identification of these cases and explicit agreement from EASA

Cabin layouts - decompression

- Generic CRI has been applied successfully in the last couple of years, in particular to (V)VIP configurations
- However, there is room for improvement, especially for “large” compartments with small volumes and/or small (narrow) dimensions (like corridors)

- Discussions with FAA, Airbus and Boeing are on-going which may result in a further update of the Generic CRI
- For the time being, Generic CRI is applied in its current form

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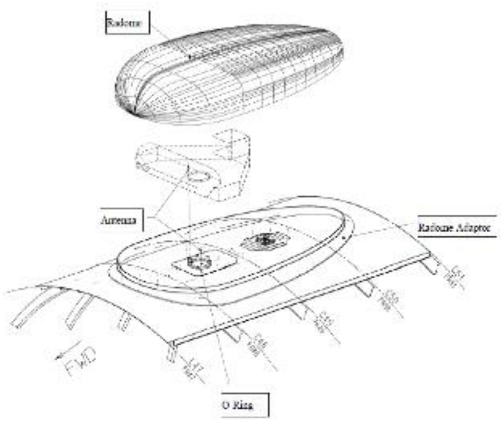
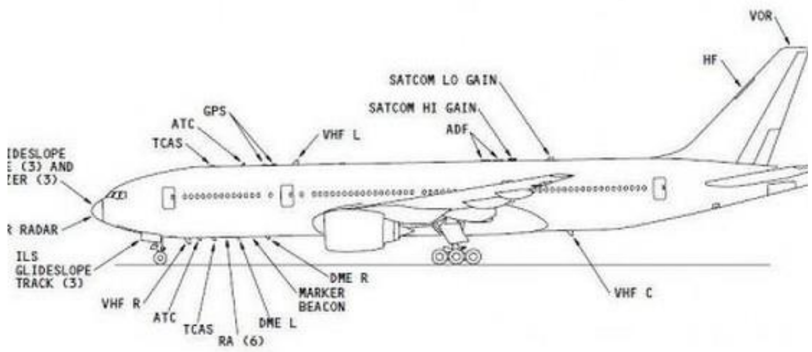
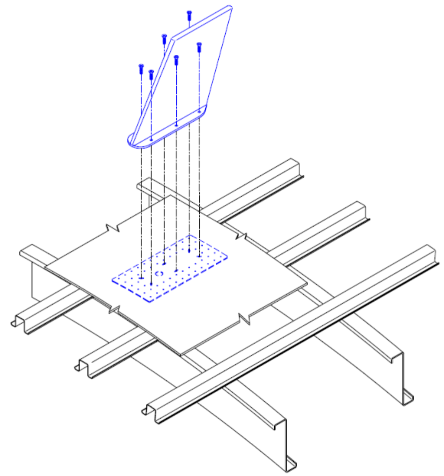
Antenna installations







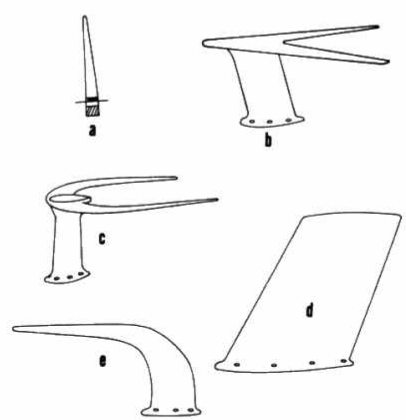


FIGURE 3.4.—Typical rigid antennas.

Recent increase in STC applications for large antenna installations

Antenna installations

- In September 2014, EASA organized a workshop on STC Structural Substantiation, including antenna installations
  - https://www.easa.europa.eu/newsroom-and-events/events/stc-structural-substantiation-workshop-antenna-installation-damage

- During this workshop, the following main items related to antenna installations were addressed:
  - General installation aspects
  - Static strength substantiation
  - Fatigue & Damage Tolerance substantiation
  - Large Antenna installations ("small" versus "large")

- Interested parties are encouraged to read the proceedings of this workshop

Antenna installations

- Regulatory framework:
  - Currently, EASA has defined two Generic CRI's for large antenna installations on CS-25 aircraft:
    - "Structural certification criteria for large antenna installations"
    - "Vibration & buffeting compliance criteria for large external antenna installations"
  - Both CRI's are based on FAA Generic IP's, with similar (but not identical) content

- Last year, FAA published a draft Policy Statement (PS-ANM-25-17, "Structural Certification Criteria for Antennas, Radomes, and Other External Modifications") for public comment
  - Final version is being defined

- EASA is working on a CM (mostly focusing on CS-25), to be published for public comment towards the end of 2016

Antenna installations

- Generic CRI on structural certification criteria:
  - Means of Compliance
  - Provides guidance on most relevant applicable structural requirements:
    - CS 25.23, 25.301, 25.305, 25.365, 25.571, 25.581, 25.603, 25.605, 25.609, 25.613, 25.629, 25.631, 25.841, 25.901, 25.1419, 25.1529, and Appendix H

Antenna installations

- Generic CRI on vibration & buffeting compliance criteria:
  - Equivalent Safety Finding
  - Published by EASA for public comment (comment period closed 2 May 2016)
  - Applicant to show that original vibration & buffeting compliance demonstration remains valid
    - If not, flight testing up to Vdf/Mdf would be necessary
    - Evaluation through suitable combination of:
      - Similarity
      - CFD analysis
      - Vibration analysis
      - Flight testing up to Vmo/Mmo
    - Typically, compliance is based on combination of CFD analysis and flight testing up to Vmo/Mmo

Antenna installations

- Main compliance issues encountered when applying these two Generic CRI's:
  - Lack of OEM data / support, in particular in static strength and fatigue & damage tolerance substantiation of modified airframe structure
    - For example, installations on a composite fuselage rely upon more product specific data, much of which is proprietary, often requiring OEM data / support
  - Some example approaches taken by STC applicants for installations on a metallic fuselage:
    - Develop and validate FEM model of fuselage barrel, apply conservative external loads
    - Conservative critical crack length (e.g. between two fasteners)

Antenna installations

- Main compliance issues encountered (continued):
  - Validation of CFD analysis, for aerodynamic loads and vibration & buffeting compliance
    - Experience and proficiency of personnel involved
    - Comparison of flow field characteristics with (flight test, wind tunnel) data from a similar configuration up to Vdf/Mdf
    - If no significant flow field phenomena exist, comparison of another configuration that exhibits these phenomena

Antenna installations

- Main compliance issues encountered (continued):
  - Bird strike substantiation:
    - Determination whether bird can impact installation
      - All phases of flight (climb-out, cruise, descent and approach), from sea level to 20.000(*) feet, at the full range of certified design weights, CG limits, and the airspeeds defined in CS 25.631 (Vc, or 0.85 Vc at 8.000 ft), should be considered.
      - Probabilistic arguments (for example the likelihood of impact based on consideration of frontal area, flight phase, aircraft speed and altitude) are not acceptable to EASA
    - Test vs. analysis
      - Ref. CS 25.631: “Compliance may be shown by analysis only when based on tests carried out on sufficiently representative structures of similar design”
      - Tests may be expensive and have long lead time due to unavailability of test facilities
      - Validation, verification and extrapolation of explicit FE analysis is a tedious and complicated process

(*) under investigation

Q & A

Any questions…….?

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Thank you for your attention

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