European Union Aviation Safety Agency

Developing composite (and other advanced manufactured) product certification – a regulator's perspective

ICCM23 Belfast

(note: based upon presentation given at Airbus Modelling and Simulation Workshop May 2023)

Rapidly evolving:

- use of Modelling and Simulation (M&S)
- understanding & development of the 'test and analysis' pyramid

S. Waite: EASA Senior Expert – Materials

Certification Directorate

Modelling and Simulation

Modelling and Simulation (M&S):

'…the use of a (conceptual, mathematical or numerical) model as a basis for simulation by computational means of physical phenomena. Modelling is the act of constructing a model; simulation is the execution of a model to obtain analytical results'

Reminder: Industry 'expectation' is to replace much testing by analysis… regulators require certification by '**test**', or '**analysis supported by test**'

M&S* developing rapidly:

- in conjunction with many other overlapping technologies and concepts,
  e.g. AI**, ML, Digital Twins, Big Data, SHM etc

- in conjunction with many evolving 'Materials, Processes, and Advanced Manufacturing***' technologies

- at micro, macro, 'Material'**, 'Engineering Property', and 'Aircraft' levels

*EASA CM-S-014 Modelling and Simulation – CS25 Structural Certification Specifications
https://www.easa.europa.eu/en/proposed-cm-s-014-modelling-simulation-consultation

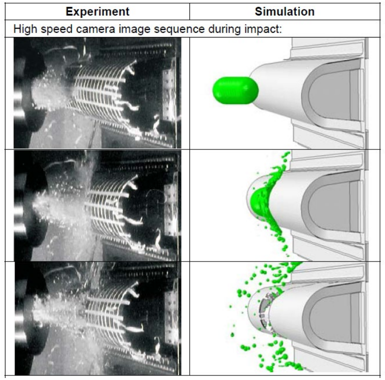
**Example: EASA Artificial Intelligence concept paper (proposed Issue 2)
https://www.easa.europa.eu/en/newsroom-and-events/news/easa-artificial-intelligence-concept-paper-proposed-issue-2-open

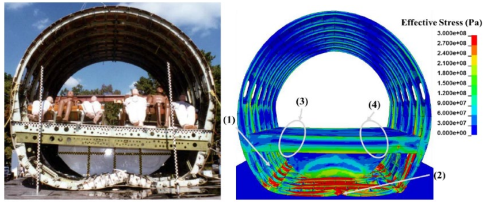
***Example: EASA-FAA Additive Manufacturing Event 2021, M&S Mini-Workshop
https://www.easa.europa.eu/en/newsroom-and-events/events/easa-faa-industry-regulator-am-event-0

Modelling and Simulation

Main Structures subjects where M&S is applied for certification:

- → Static strength
- → Impact conditions
  - → Crashworthiness including Ditching
  - → Bird strike
  - → Dynamic seat certification
  - → Fuel system crash resistance
  - → Uncontained engine failures
  - → Wheel & tyre debris
- → Loads and aeroelasticity / vibration & buffeting
- → Thermal (heat transfer) analysis*
- → Engine failure conditions
- → Fatigue & damage tolerance





(a) Post-impact picture of section drop experiment
(b) Section drop test simulation result

"'Certification by Analysis', or Modelling & Simulation" W. Doeland
Workshop on Modelling & Simulation, Koeln, 29/30 August 2019
https://www.easa.europa.eu/newsroom-and-events/events/workshop-dynamic-modeling-and-simulation

Different types of M&S techniques for Structures:

- → Finite (Element, Difference, Volume) Methods
  - → Computational Solid or Structural Mechanics (CSM)
  - → Computational Fluid Dynamics (CFD)
- → Static and dynamic, linear and non-linear
- → Implicit and explicit analysis
- → Eulerian, Lagrangian, Arbitrary Lagrangian-Eulerian (ALE), Combined Eulerian-Lagrangian (CEL), Smoothed Particle Hydrodynamics (SPH)

What is the 'best', or at least '**adequate**' technique for your application… and why?

*Note: Including composite production/cure simulation - not discussed in this presentation

Modelling and Simulation

Main 'Attention Items' for M&S:

- *Verification*
- *Validation*
- *Errors & Uncertainties*
- *Extrapolation*
- *Documentation*
- *Experience*

'Attention Items'

not new…but increasingly challenging …many new 'precise', but not necessarily 'accurate' modelling tools

…need to be better understood and standardised, from the terminology onwards

necessary for optimised test/analysis pyramids and 'smarter testing'

"'Certification by Analysis', or Modelling & Simulation" W. Doeland
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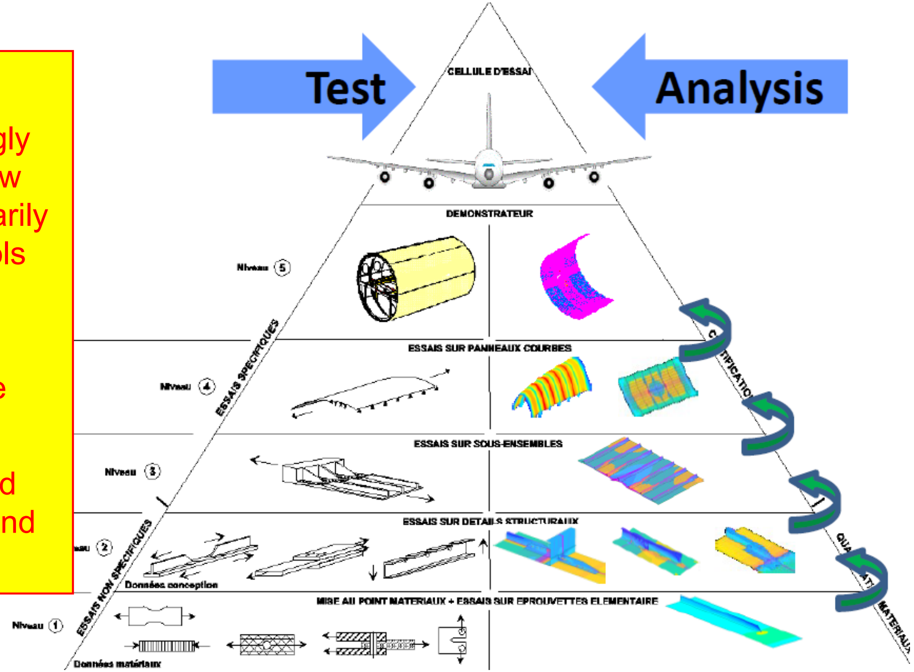


Ref. Verification and Validation of Models and Analyses: a must for the aeronautical industry, Jean-François Imbert, October 2012

Verification: the process of determining that a computational model accurately represents the underlying mathematical model and its solution ("Are the equations being solved correctly?")

Validation: the process of determining the degree to which a model is an accurate representation of the real world from the perspective of the intended uses of the model ("Are the correct equations being solved?")

Modelling and Simulation - Materials

'Engineering Properties' are:

- significantly defined by the 'material <u>and</u> processes' during consolidation in the final complex configuration

Where are the 'engineering properties' developed in the pyramid?

What are the appropriate simulation input data and appropriate statistical methods?

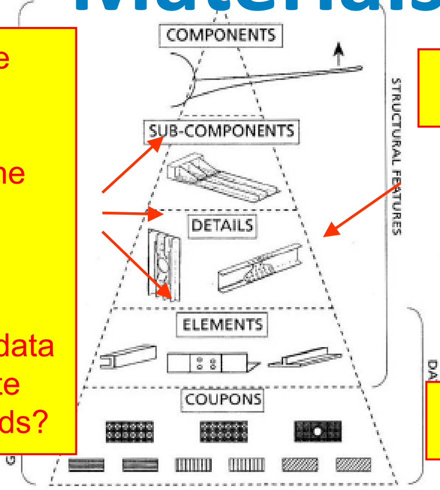


Figure 1 - Schematic diagram of building block tests for a fixed wing.

CS2x.305, 2x.307

????

CS2x.603, 2x.605, 2x.613

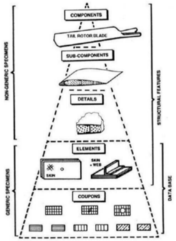
a 'challenge':

- 'complex parts' – base pyramid coupon data may not represent the complex part properties (although stable simple base pyramid data is essential…otherwise, how can the higher pyramid work be trusted?)

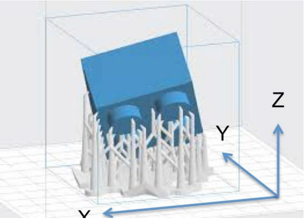
- 'sensitive processes' – a major challenge if completing production activities in a more challenging maintenance environment

e.g. AM, composites, bonded joints, advanced alloys

Note: Many pyramid definitions possible, (including inverted)



e.g. no access to free edges – fatigue issue?



e.g. support structure on the build platform

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Materials and the Regulations

Existing Regulatory Framework (moving toward **performance based regulations**)

- EC No 216/2008 annex
  1.a.**Structures and materials**: the **integrity of the structure must be ensured throughout, and sufficiently beyond, the operational envelope for the aircraft, including its propulsion system**, and **maintained for the operational life of the aircraft.**
  1.c.3. Systems and equipment…

Basic Regulation

EC 2018/1139

EU Parliament
EU Council

Binding

- **21A.31 Type design …** shall consist of:
  - 2. Information on **materials and processes** and on **methods of manufacture and assembly** of the product necessary to ensure the conformity of the product

Implementing rules

Regulation No 1702/2003

For the airworthiness and environmental certification of aircraft and related products, parts and appliances, as well as for the certification of design and production organisations.

U Commission

21.A.147(a) Changes to the approved production organisation
GM 21.A.147(a) – Significant changes
1 …to be approved by the competent authority include:
 - significant changes to production capacity or methods…
Note: See EASA-CM-S-008 for details regarding AM

Acceptable Means of Compliance (AMC) and Guidance Material (GM) for PART21

Certification Specificati (CS)

Airworthiness Codes e.g. CS 23, 25, 27, 29 e

PART 145 – Maintenance organisation approvals

PART 66 – Certifying staff

Part 147 – Training organisations requirements

Non-Binding

- **Certification Specifications: Limited 'Material and Process', e.g.**
  CS 25.603: Materials… 'suitability and durability … based upon experience/test… conform to specifications… consider environment… references AMC 20-29 'Composite Aircraft Structure'
  CS 25.613: Mechanical Strength Properties and Design Values Materials. (a) ... design values based upon a statistical basis

EASA – Regulatory Framework and Change

1/ EASA priorities and resources:

EASA Level of Involvement (LoI): PART21.100: (Opinion 07/2016 + NPA 2017-20, due Autumn 2019, now published)

- **priority is safety… ’do not reduce the existing level of safety’**
- **prioritise activities with respect to <u>novelty, criticality, complexity</u>**

Proportionate Means of Compliance expected

New materials, processes, configurations, analytical tools etc

EASA move towards ‘Performance’ Based Regulations’ (PBR), i.e. less prescriptive

e.g. CS23 ‘General Aviation…’ amdt.4 to amdt.5

- **flexibility benefit for industry technology progress… and potential safety benefits…**

  ….but need for a ‘level playing field’ remains (new organisations?)
- **standardisation organisations and shared industry databases becoming increasingly important**

Not only materials databases, but shared analytical method/tool databases?

EASA – Regulatory Framework and Change

1/ EASA priorities and resources:

PBR: ‘Proportionate Means of Compliance’ expected with respect to ‘Criticality’

e.g. ASTM F3572-2023 ‘Standard Practices for Additive Manufacturing – General Principles – Part Classifications for Additive Manufactured Parts Used in Aviation’

Classification	Consequence of Failure	General Description
A	High	Part the failure of which can directly affect continued safe flight and landing Part the failure of which can result in serious or fatal injury to passenger or cabin crews or maintenance personnel Part the failure of which can result in excessive load for the flight crew
B	Medium	Part the failure of which can indirectly affect continued safe flight and landing Part the failure of which can result in injury to passenger or cabin crews or maintenance personnel Part the failure of which can result in a significant increase in workload for the flight crew
C	Low	Part the failure of which has no affect on continued safe flight and landing Part the failure of which has no affect on passengers and cabin crews Part the failure of which can result in a slight reduction in operational/functional capabilities Part the failure of which can result in a slight increase in workload for the flight crew
D	Negligible or No Effect	Part not covered above Part the failure of which would pose no risk of damage to other equipment or personnel Part not affecting operational/functional capabilities

Note: Various definitions of criticality/safety classification exist across products. However,

- these can be mapped to this table
- not intended to change existing ‘criticality’ processes
- link to proportionate MoCs?
- NOT NEW, but AM offers potentially more competing damage modes and safety outcomes

EASA

Materials and the Regulations

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**; (see AMC No°1 to CS 25.603(a));

(b) conform to **approved specifications** that ensure their having the strength and **other properties assumed in the design data** (see AMC 25.603(b)); and

(c) take into account the effects of environmental conditions, e.g. temperature and humidity, expected in service.

Note: AMC amended at amdt 27 to better address Advanced Manufacturing when '…*the design of complex part configurations for which the characteristics of the materials are defined close to completion of the part production*'

Note: EASA intent to generalise AMC 25.603, 25.605, and 25.613 to be applicable to all products, possibly via generic guidance, e.g. AMC 20-XX (TBD)?

Materials and the Regulations

CS 25.605: Fabrication Methods

(a) The fabrication methods used (i.e. **the manufacturing and assembly methods, including consideration of the materials and material processes**) must produce the strength and other properties necessary to ensure a **consistently safe part**. If a fabrication method includes processes that require close control to reach this objective, then those processes must be performed under representative approved fabrication process specifications, **supported by appropriately approved material specifications (including considering the raw/feedstock/unfinished material specifications) with appropriate controls for the design data.**

(b) Each **new fabrication method must be substantiated by a test programme that is representative of the application**

Note: Amended at amdt 27 to better address Advanced Manufacturing when '…*the design of complex part configurations for which the characteristics of the materials are defined close to completion of the part production*'

Materials and the Regulations

CS 25.571: Damage Tolerance & Fatigue Evaluation of Structure

(a) General. An evaluation of the strength, detail design, and fabrication must show that catastrophic failure due to fatigue, manufacturing defects, environmental deterioration, or accidental damage will avoided throughout the operational life of the aeroplane…

(3)…..inspections or <u>other procedures</u> must be established as necessary to prevent catastrophic failure, and must be included in the Airworthiness Limitations Section of the Instructions for Continued Airworthiness required by CS 25.1529'

Note: competing damage modes (some difficult to detect) and competing failure sequences…
… a simulation/prediction 'challenge'
Note: a model tuned to a test result is not a prediction!

Materials and the Regulations

Note: Certification benefits from predicted ‘tests to failure’ somewhere (above coupon level) …provides some confidence regarding definition of where the ‘edge of the cliff’ is… load, mode, location

Established

- limited ‘engineering data’/generic strain data/broader limited model validation/verification

- ‘engineering judgement’?
    - test config definitions and numbers?
- probably less statistically credible (‘small data set’ stats?)
- some representative engineering data

- statistically credible, e.g. lamina/laminate A and B basis data
- possibly some representative design data, e.g. open hole/closed hole

Developing

(complex/optimised configs, anisotropy etc)

- limited ‘engineering data’/generic strain data/broader limited model validation/verification
- **possible partial mitigation – test more load cases?**

- **proposed fewer tests**
- more ‘engineering judgement’?
    - test config definitions?
    - test numbers?
- select correct/optimal test cases

- less representative data, e.g. VARTM part

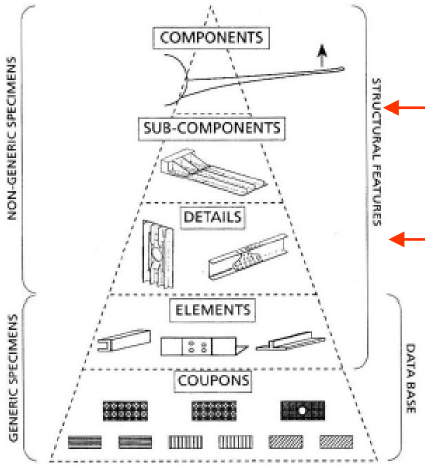

Figure 1 - Schematic diagram of building block tests for a fixed wing.

Statistics and Representative Testing for Certification

EASA

Materials and the Regulations

How much testing is required to achieve an 'acceptable' level of safety?

CS 25.307: Proof of Structure

(a) Compliance with the strength and deformation requirements … 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

(d) When static or dynamic tests are used to show compliance with the requirements of CS 25.305 (b) …appropriate material correction factors must be applied to the test results, unless the structure… being tested has features such that a number of elements contribute to the total strength of the structure and the failure of one element results in the redistribution of the load through alternate load paths.

Materials and the Regulations

How much testing is required to achieve an ‘acceptable’ level of safety?

AMC 25.307: Proof of Structure… structure must:

(a) … support limit loads without detrimental permanent deformation, and:

(b) … support ultimate loads without failure

Compliance can be shown by **analysis supported by… test evidence, …or by test only**

Conservative assumptions may be considered in assessing whether or not an analysis may be accepted without test substantiation

… application of **Finite Element Method or engineering formulas** to complex structures …**considered reliable only when validated by full scale tests** (ground and/or flight tests). Experience relevant to the product in the utilisation of such methods should be considered.

Materials and the Regulations

AMC 25.307: Proof of Structure…

5 CLASSIFICATION OF STRUCTURE

(a) New Structure, Similar New Structure, Derivative/Similar Structure

(b) Justifications…for classifications (other than New Structure)

(i) …accuracy/conservatism of the analytical methods, and

(ii) … comparison with previously tested structure. Considerations include,

- external loads (bending moment, shear, torque , etc.);
- internal loads (strains, stresses, etc.);
- design concepts … details, geometry, structural arrangements, load paths ;
- materials ;
- test experience (load levels achieved, lessons learned);
- deflections ;
- deformations ;
- extent of extrapolation from test stress levels.

When is 'extrapolation' acceptable?

Materials and the Regulations

AMC 25.307: Proof of Structure…

6 NEED AND EXTENT OF TESTING

…following factors should be considered in deciding the need for and the extent of testing including the load levels to be achieved:

(a) …classification of the structure (as above);
(b) …consequence of failure… in terms of the overall integrity of the aeroplane;
(c) …consequence of failure of interior items of mass and supporting structure to the safety of the occupants.

Relevant service experience may be included in this evaluation.

Materials and the Regulations

- How are these issues managed safely, at the moment (certification v design)?
  - change not to reduce the existing ‘acceptable’ level of safety (‘equivalence’ expected)

Existing ‘accepted’ level of safety based upon:

- experience
- reaction to incidents and accidents
- R&D
- ‘engineering judgement’
- regulations existing at the time of certification
- Type Certificate Holder (TCH) in-house design practices
- other design criteria (ref. CMH-17 Vol.3 Chpt 7 ‘Composite Design’)

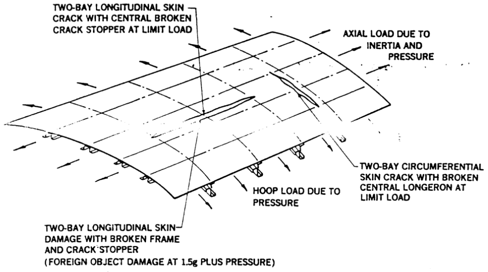

FIGURE 2. FUSELAGE DAMAGE TOLERANCE SIZES FOR STRUCTURAL DESIGN

e.g. Design for Redundant Structures …Tom Swift. For conventional metals, a cracked frame and 2 cracked frame bay skins

Design (and test) for certification using ‘robust’ design concepts to address uncertainties e.g. maintenance philosophies… damage detection, Residual Strength capability, including M&S capabilities etc

applies to baseline structures, **modifications, and repairs**

Composite Simulation

Summary - Modelling and Simulation challenges:

- Modelling & Simulation plays an important role in the life cycle of an aircraft, from conceptual design to retirement from service
- Software tools are becoming more advanced, more capable, more widespread….and more difficult to comprehend /assess
- Trend is to perform more analysis and less testing
- Requires more attention to issues such as verification & validation aspects, errors and uncertainty quantification, extrapolation/similarity, experience and record keeping
- Overall lack of guidance material – more standardization is needed, as much as possible (Structures CM-S-014 proposed as starting point for EASA standardization – initially physics based model approach… ML to follow?)
- Need to identify best practices & develop guidance material to facilitate application of M&S (level playing field) and streamline certification process

"'Certification by Analysis', or Modelling & Simulation" W. Doeland
Workshop on Modelling & Simulation, Koeln, 29/30 August 2019

Composite Simulation

Summary - Composites Challenges and Modelling & Simulation:

- need to address M&S issues in conjunction with the evolving test and analysis pyramid strategies, evolving Advanced Materials technologies, and other developing integrated technologies
  - increasingly complex simulation tools for ‘optimised’ designs (more reduced margins?)
    (increasingly complex and optimised materials, processes, fabrication methods, and configurations – anisotropy, competing failure modes etc – need to predict failure mode, load, and location)
  - industry intent to increasingly replace test with analysis
    (appropriate test link to (and between) micro, macro, material properties, engineering properties, aircraft level performance to be better understood and standardised)
  - increasingly complex supply chains
    (subcontractors within, and between design, manufacture, and in-service functions… potential for interface issues and ‘knowledge gaps’)

Regulator challenge: to address a potentially divergent situation,
if certification is to be by ‘test’, or ‘analysis supported by test’

EASA

Composite Simulation

Questions?

Composite Simulation

Support Slides?

Modelling and Simulation

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- → Static strength
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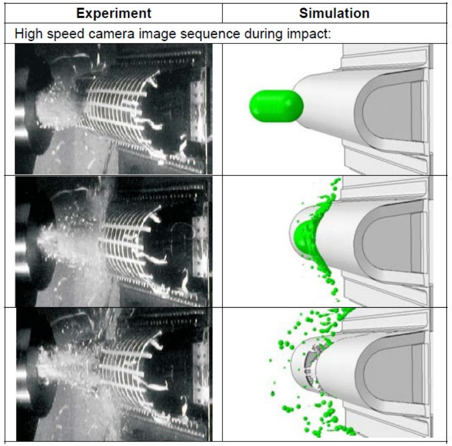

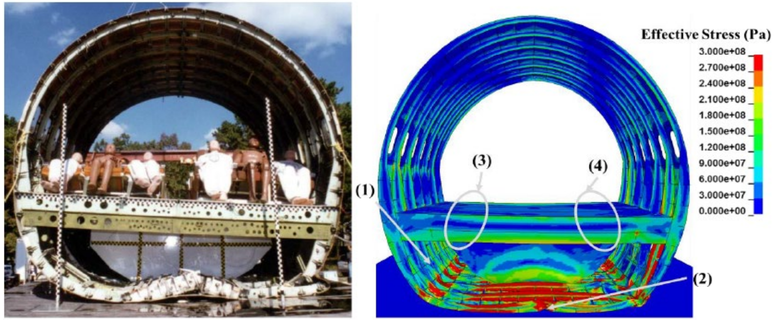

(a) Post-impact picture of section drop experiment

(b) Section drop test simulation result

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EASA

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Modelling and Simulation

Different types of M&S techniques for Structures:

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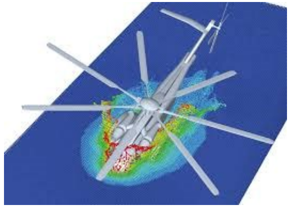
  - → Computational Fluid Dynamics (CFD)
- → Static and dynamic, linear and non-linear
- → Implicit and explicit analysis
- → Eulerian, Lagrangian, Arbitrary Lagrangian-Eulerian (ALE), Combined Eulerian-Lagrangian (CEL), Smoothed Particle Hydrodynamics (SPH)

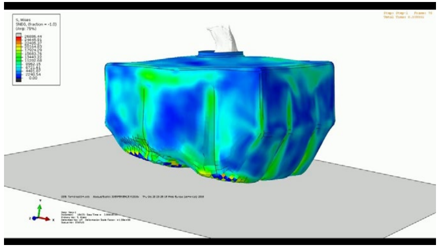
Many rapidly evolving techniques

- developing knowledge gaps?
- what does a user need to know/demonstrate for certification (including user competence)?
- what does a regulator need to know to support 'Performance Based Regulation' …certification effort being proportionate to criticality?
- What is useful at the application 'engineering property' level?

What is the 'best', or at least '**adequate**' technique for your application… and why?

"'Certification by Analysis', or Modelling & Simulation" W. Doeland Workshop on Modelling & Simulation, Koeln, 29/30 August 2019





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Modelling and Simulation

EASA CM-S-014 – broader evolving M&S guidance (not only M&P)…

‘benchmark’ and framework for certification discussion

Notification of a Proposal to issue a Certification Memorandum

much of this CM is relevant to other products

Modelling & Simulation – CS-25 Structural Certification Specifications

EASA Proposed CM No.: CM-S-014 Issue 01 issued 14 July 2020

Regulatory requirement(s): CS 25.301, CS 25.305(e), CS 25.307, CS 25.362, CS 25.561, CS 25.562, CS 25.563, CS 25.571, CS 25.603, CS 25.629, CS 25.631, CS 25.723, CS 25.734, CS 25.775(b), CS 25.865, CS 25.903(d), CS 25.963(e), 21.A.245, 21.A.55

https://www.easa.europa.eu/en/proposed-cm-s-014-modelling-simulation-consultation

Modelling and Simulation

EASA CM-S-014

Table of Content

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EASA

Modelling and Simulation - Materials

Modelling and Simulation considerations (at all levels):

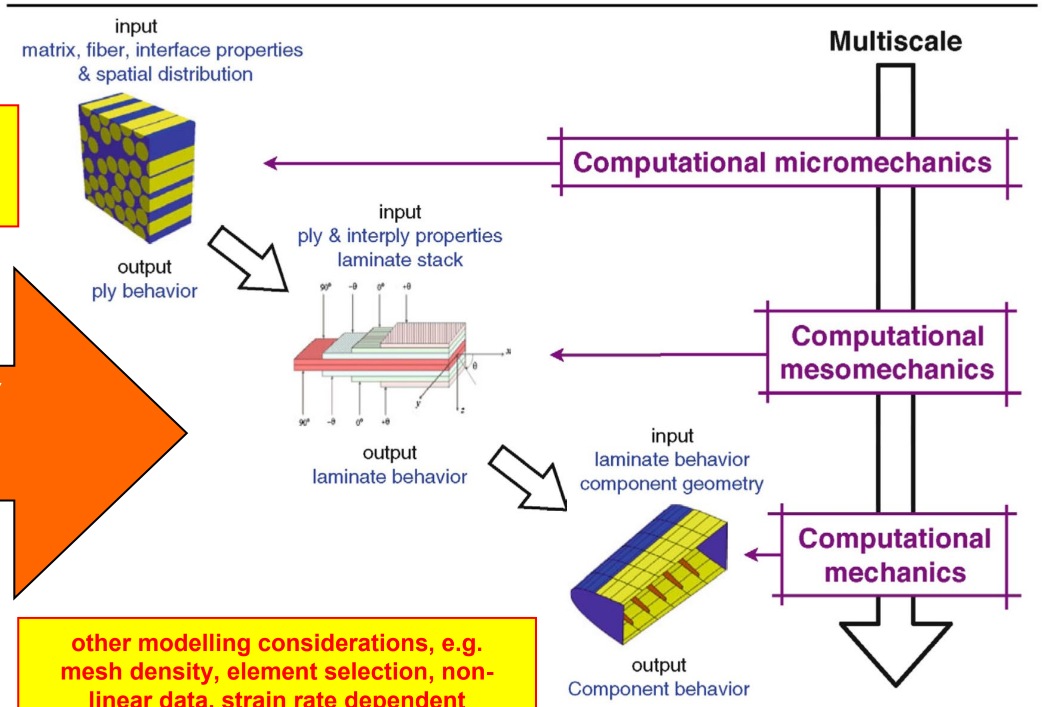
Main 'Attention Items' for M&S:

- *Verification*
- *Validation*
- *Errors & Uncertainties*
- *Extrapolation*
- *Documentation*
- *Experience*

Representative?

Correct failure modes?

'Attention Items'
to be considered
at all levels



other modelling considerations, e.g. mesh density, element selection, non-linear data, strain rate dependent properties, hour glassing,

…other AC 20-146 issues etc?

W. Doeland Notes 21/10/19

"'Certification by Analysis', or Modelling & Simulation" W. Doeland
Workshop on Modelling & Simulation, Koeln, 29/30 August 2019

Materials and the Regulations

CS 25.613: Mechanical Strength Properties and Design Values Materials

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

…. and C and D-basis for Additive Manufacturing

‘statistical data’ - a significant challenge if the ‘engineering properties’ are developed in expensive higher pyramid fabrication processes/components
- when is the use of Baysian statistics appropriate?

Materials and the Regulations

AMC 25.307: Proof of Structure…

7 CERTIFICATION APPROACHES

(a) Analysis, supported by new strength testing of the structure to limit and ultimate load. (typically for **New Structure**)

Substantiation of the strength/deformation up to limit/ultimate loads normally requires testing of sub-components, full scale components or full scale tests of assembled components (such as a nearly complete airframe)

Sufficient limit load test conditions should be performed to verify deformation requirements of CS 25.305(a) and to provide validation of internal load distribution and analysis predictions for all critical loading conditions.

…

Materials and the Regulations

AMC 25.307: Proof of Structure…

7 CERTIFICATION APPROACHES

(a) Analysis, supported by new strength testing of the structure to limit and ultimate load. continued…

How many tests? Anisotropy? Competing failure modes?

…ultimate load tests often result in significant permanent deformation, choices will have to be made with respect to the load conditions applied… usually based on the number of test specimens available, the analytical static strength margins of safety of the structure and the range of supporting detail or sub-component tests. An envelope approach may be taken, where a combination of different load cases is applied, each one critical for a different section of the structure

These … tests may be supported by detail and sub-component tests that verify the design allowables (tension, shear, compression) of the structure and often provide some degree of validation for ultimate strength.

Materials and the Regulations

AMC 25.307: Proof of Structure…

7 CERTIFICATION APPROACHES

(b) *Analysis validated by previous test evidence and supported with additional limited testing.*

(typically for **Similar New Structure**)

The extent of additional limited testing (number of specimens, load levels, etc.) will depend upon the degree of change, relative to para 5(b)(i) and (ii). For example, if the changes to an existing design and analysis necessitate extensive changes to an existing test-validated finite element model (e.g. different rib spacing) additional testing may be needed. Previous test evidence can be relied upon whenever practical.

These … tests may be supported by detail and sub-component tests that verify the design allowables (tension, shear, compression) of the structure and often provide some degree of validation for ultimate strength.

Materials and the Regulations

AMC 25.307: Proof of Structure…

7 CERTIFICATION APPROACHES

(c) *Analysis, supported by previous test evidence* (typically for **Derivative/ Similar Structure.**

… demonstrate how previous static test evidence validates the analysis and supports showing compliance for the structure under investigation,… considering paras 5(b)(i) and (ii) For example, if the changes to the existing design and **test-validated analysis are evaluated to assure they are relatively minor and the effects of the changes are well understood, … further testing may not be necessary**, e.g. a weight increase results in higher loads …. corresponding increase in some of the element thickness and fastener sizes, and materials and geometry (overall configuration, spacing of structural members, etc.) remain generally the same, the revised analysis could be considered reliable based on the previous validation.

Materials and the Regulations

AMC 25.307: Proof of Structure…

7 CERTIFICATION APPROACHES

(d) ***Test only***.

Sometimes no reliable analytical method exists, and testing must be used to show compliance …or it may be elected to show compliance solely by tests even if there are acceptable analytical methods. … In such cases, the **test load conditions should be selected to assure all critical design loads** are encompassed.

How many tests? Anisotropy? Competing failure modes?

… for single load path structure which carries flight loads (including pressurisation loads), the test loads must be increased to account for variability in material properties, as required by CS 25.307(d). In lieu of a rational analysis, for metallic materials, a factor of 1.15 applied to the limit and ultimate flight loads may be used. If the structure has multiple load paths, no material correction factor is required.

Note: More complex structure may require more load cases:

e.g. established (and limited!) single load path test strategies (max up-down wing bending?) may not be adequate for multi-load path wing structure in General Aviation

EASA – Regulatory Framework and Change

EASA priorities and resources…

2/ EASA Certification Re-organisational Structure – Certification Directorate Roadmap 2020

- reorganised to facilitate and support technological innovation

(e.g. UAS, VTOL, Hydrogen, Electric and Hybrid propulsion)

3/ EASA – R&D Strategy:

- EASA Basic Regulation 2018/1139, Article 86.1… **assist the Member States** and the **Commission** in **identifying key research themes** in the field of civil aviation

See support slides for R&D examples

EASA – Regulatory Framework and Change

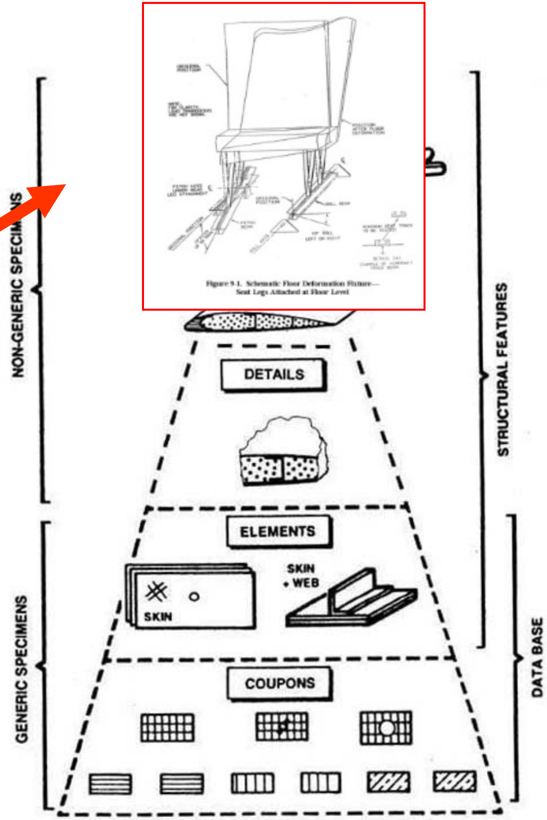
Certification – Simulation Example – Composite Seats

Seat design driven by dynamic requirements
Although not PSE etc, seats are pax. critical and systemic failure is to be avoided:

Metallic Seat Experience – 'Acceptable' Level of Safety provided by:

- ETSO (Engineering Technical Standard Order) + SAE stds (little/no discussion regarding M&P etc)
- very limited high pyramid X-Y-Z axis static and dynamic testing (little/no mid pyramid testing due to Boundary Condition challenges)
- generally good in-service experience
- isotropic material
- typically detectable damage modes

* 25.561, 25.562



Composite Simulation

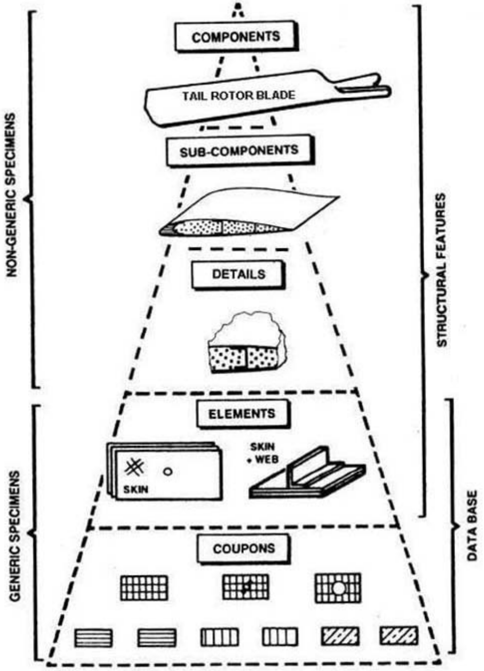
Example – Composite Seats

Composite Primary Load Path Experience – none/very limited

(some seat back and pan experience): Is the existing metallic approach appropriate?

- ETSO (Engineering Technical Standard Order) + SAE stds (little/no discussion regarding M&P, DT etc)
- very limited high pyramid X-Y-Z axis static and dynamic testing (little/no mid pyramid testing due to Boundary Condition challenges)
- no in-service experience
- anisotropic material
- material/engineering properties dependent upon M&P control
- competing damage modes – some potentially difficult to detect
- material/engineering properties potentially strain rate sensitive

EASA raised Certification Review Item (CRI) to be issued with ETSO in order address the delta by reference to AMC 20-29 'Composite Aircraft Structure'



Ensure existing 'acceptable' level of safety is maintained:
- What is appropriate simulation for composite seats?
- What test article configurations and test numbers are required?

Composite Simulation

Example – Composite Seats – Simulation challenges

Static and Dynamic Performance of damaged structures:
Current practice (SAE ARP 6337) expects consideration of static testing of damaged seat structures in order to demonstrate some structural robustness. However, seats are designed to function to meet dynamic requirements.

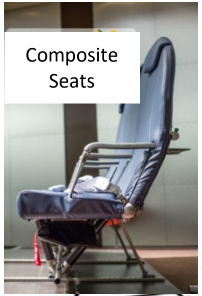
/Q/ What are the relative static (Residual Strength) and dynamic performances of composite seat structures when subjected to a range of similar damage states and what simulation, and supporting test substantiation, would be necessary to demonstrate this, see developing work*?

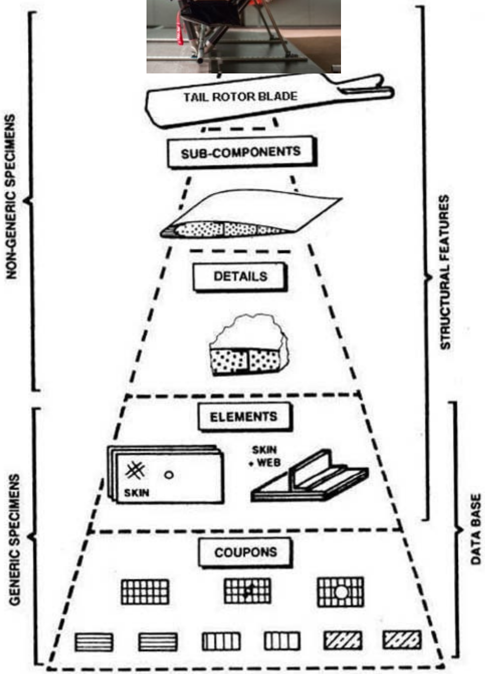
/Q/ Should dynamic tests include damages? If so, when does damage relieve, rather than compromise, the structure? Can simulation meaningfully demonstrate this?

Seat Families (AC 20-146A Methodology for Dynamic Seat Certification by Analysis for Use in Parts 23, 25, 27, and 29 Airplanes and Rotorcraft)**:**

/Q/ Although already a challenge for metallic seat structures, when/how can simulation be trusted to define composite 'seat family' performance and better optimise the test/analysis matrix (Smarter Testing)?

* 'Effects of Defects in Composite Materials at Elevated Strain Rates', JAMS, April 20 2023



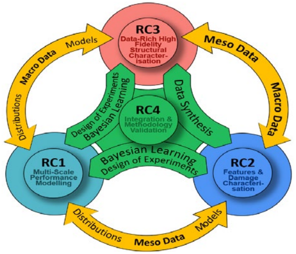


Composite Simulation

R&D: Modelling and Simulation: Example (EPSRC):

CerTest – Certification for Design: Reshaping the Testing Pyramid

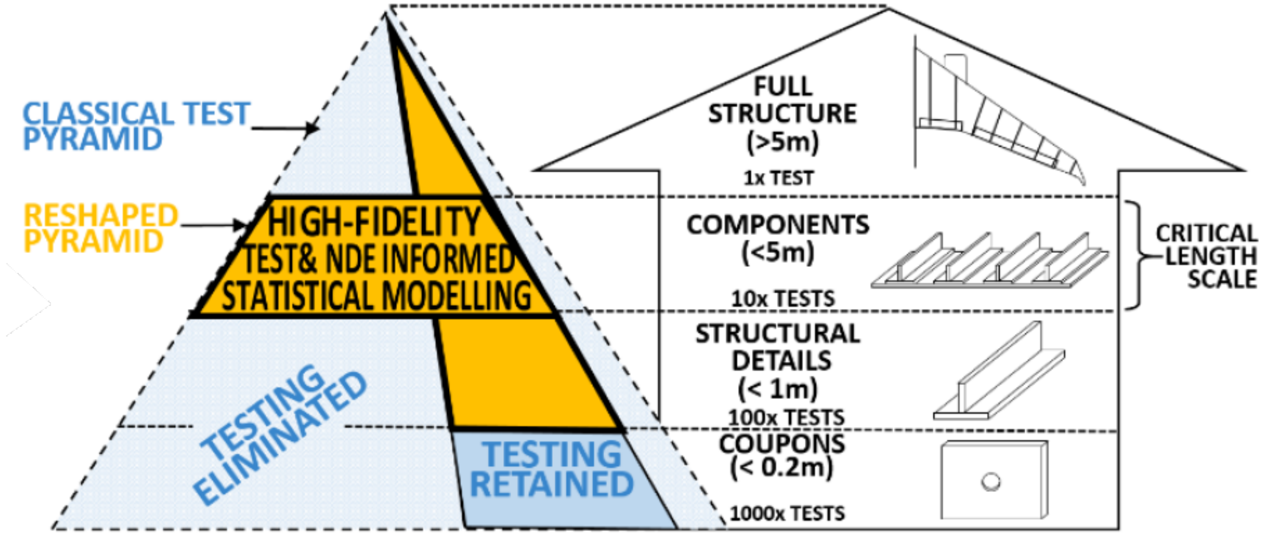
‘Certification for Design: Reshaping the Testing Pyramid’ (CerTest) – Objective: *‘…research will result in a new approach for integrated high-fidelity structural testing and multi-scale statistical modelling through Design of Experiments (DoE) and Bayesian Learning. The efficient exploitation and optimisation of advanced composite aero-structures is fundamentally prohibited by current test, simulation and certification approaches, and CerTest seeks to break this impasse by holistically addressing the challenges that are preventing step-changes in future engineering design by reshaping the ‘Testing Pyramid…’* https://www.composites-certest.com/



Composite Simulation

R&D: Modelling and Simulation: Example (EPSRC):

CerTest – Certification for Design: Reshaping the Testing Pyramid



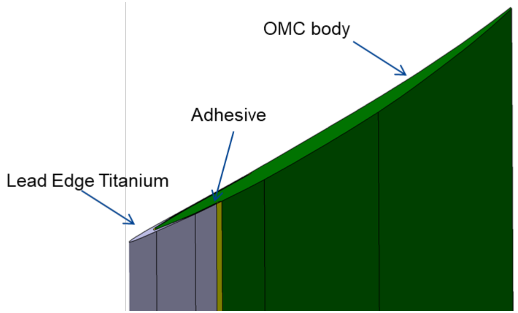
Composite Simulation

R&D: Modelling and Simulation: Example (EPSRC):

‘Manufacturing, Overhaul, Repair for Prognosis Health Overreach’ (*MORPHO*)’

Objective: ‘…proposes to embed printed and fiber-optical sensors in aircraft engine fan blades, thus providing them with cognitive capabilities already while they are manufactured. The parallel development of a digital/hybrid twin models will drastically improve the blades' Life Cycle Management (LCM). Particular focus lies on the efficient, profitable and environmental-friendly manufacturing, maintenance, and recycling of these next-generation smart engine fan blades.’

https://cordis.europa.eu/project/id/101006854



Composite Simulation

R&D: Modelling and Simulation: Example (CleanSky Horizon 2020):

Digital method for imprOved Manufacturing of next generation MultIfuNctIOnal airframe parts'' (DOMMINIO)

Objective: '…*Innovative multifunctional thermoplastic filaments will be efibre-based piezoresistive strain sensors employed to incorporate novel continuous CNT in the laminate, to enable reversible joining (using magnetic NPs) and increase the structural integrity (using continuous CF) of the 3D-printed reinforcements. Flexible automation of ATL and FFF manufacturing processes will be enabled by the development of new laser-scanning and smart nozzle systems, the simulation of ATL plies consolidation and interlaminar delamination in FFF and the development of novel air-coupled ultrasound quality monitoring systems. Besides, advanced modelling will support the selection of right process window parameters and the optimal production planning strategy, ensuring the quality of the final component. In addition, physics- and data-driven models (Digital Twin) will provide real-time data-driven fault detection capabilities supporting the implementation of new methodologies for SHM&M of multifunctional airframe parts.*'

https://cordis.europa.eu/project/id/101007022

Modelling and Simulation

Reminder:

Precise: clear and accurate (oed)

Accurate: correct and true <u>in every detail</u> (oed)