EUROPEAN AVIATION SAFETY AGENCY
AGENCE EUROPÉENNE DE LA SÉCURITÉ AÉRIENNE
EUROPÄISCHE AGENTUR FUR FLUGSICHERHEIT

Additive Manufacturing (AM)

EASA Workshop

Machine Knowledge Transfer, and Training

June 28-29th 2018

Koeln

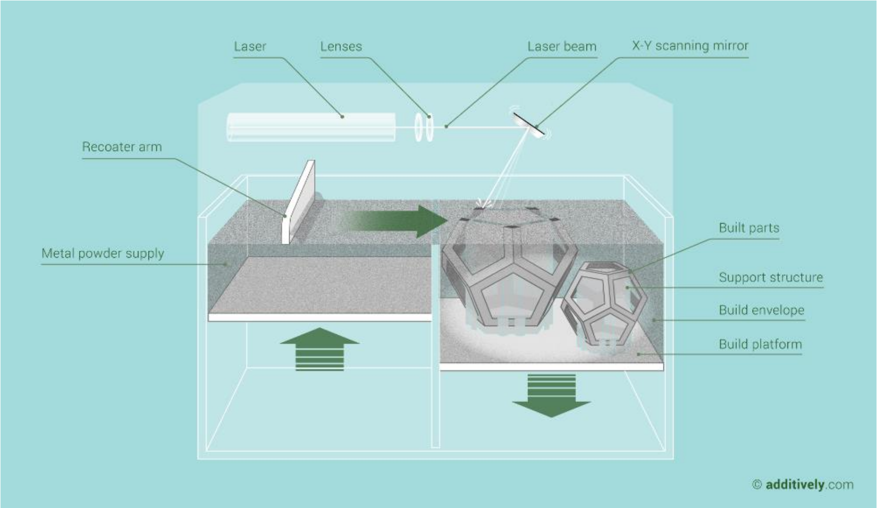
Dr. S.Waite
Senior Expert - Materials
Certification Directorate

Your safety is our mission.

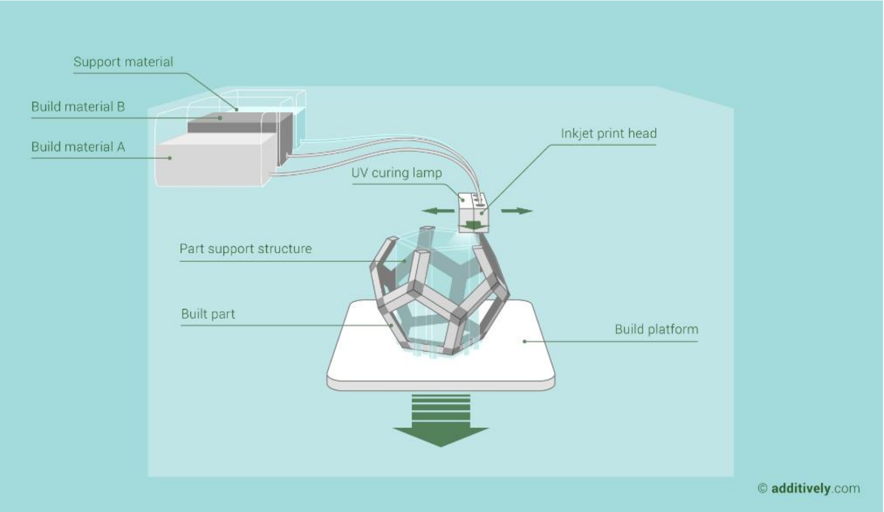
Additive Manufacturing – many methods, and definitions:

'... make objects...layer upon layer...'

Laser-melting



Photopolymer-jetting



- metallic/non-metallic
- single material, multi-material, + fillers,
- hybrid processes, e.g. icw convention methods

Illustrations courtesy of additively your access to 3D printing

- significant potential commercial benefits, e.g. rapid prototype evolution, reduced part count, weight reduction etc

AM – EASA Perspective (see support slides and EASA Workshop presentations and CM*)

- rapidly increasing number of materials, processes, and applications, i.e. baseline applications and repair
- potential safety considerations
  - 'engineering properties', e.g. anisotropic, new and competing damage modes
  - repeatability - many variables (materials, processes, products), etc
  - changes in relationship between design, production, continued airworthiness (CAW), more integrated than many typical metallic processes (some similarities wrt composites)
  - increasing process driven quality (relative to inspection)
  - pressure for utilisation in increasingly critical applications
  - **industry and regulator knowledge base and training**
    - are changes required in rules and/or guidance?

*EASA Workshop 2016: http://www.easa.europa.eu/system/files/dfu/WORKSHOP%20Additive%20Manufacturing%20-%20Presentations.zip

EASA Safety Conference 2016: https://www.easa.europa.eu/event-type/annual-safety-conference

EASA Workshop 2017: http://www.easa.europa.eu/newsroom-and-events/events/2017-easa-workshop-additive-manufacturing

EASA Certification Memo: https://www.easa.europa.eu/sites/default/files/dfu/EASA%20CM-S-008%20Additive%20Manufacturing.pdf

EASA - AM

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

➢ EC No 216/2008 annex
1.a. STRUCTURES AND MATERIALS … TO ENSURE INTEGRITY OF STRUCTURES, PROPULSION SYSTEM, SYSTEMS AND EQUIPMENT

Basic Regulation

(EC) No 216/2008

EU Parliament
EU Council

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.

➢**21A.31 MATERIALS AND PROCESSES… METHODS OF MANUFACTURE AND ASSEMBLY … PART OF TYPE DESIGN**

On the continuing airworthiness of aircraft and aeronautical products, parts and appliances, and on the approval of

GM 21.A.147(a) Changes to the approved production organisation – Significant changes
1 …to be approved by the competent authority include:
- significant changes to production capacity or methods…

EU Commission

•Binding

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

PART 21

Certification Specifications

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

PART 145 – Maintenance organisation approvals

PART 66 – Certifying staff

Part 147 – Training organisations requirements

EASA

•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
CS 25.613: Mechanical Strength Properties and Design Values Materials. (a) … design values based upon a statistical basis

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.**

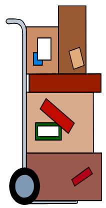
(b) Each **new aircraft fabrication method must be substantiated by a test programme**

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)*

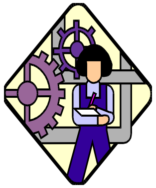
Material properties built into part, or repair…

Manufacturing Processes



Material Purchased

+



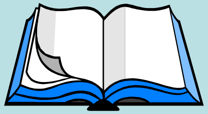
Internal Manufacturing Processes Controlled by site specific Process Documents

=

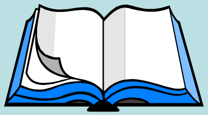
Production Certification (PC)

+ Material & Processing Standards

Material Specification

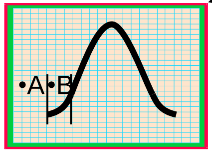


Process Specification



- close link between DOA, POA, and suppliers, mostly via specifications

Engineering Processes



Prediction of Material Behavior

(Design Values)

+

Prediction of Structural Behavior

(Design Analysis)

+

Verification & Certification Tests

=

Note: slide from a CMH-17 composite tutorial – similar for AM

AM ‘Engineering Properties’ are:

- defined by the ‘material and process’
- built directly into the part or repair

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

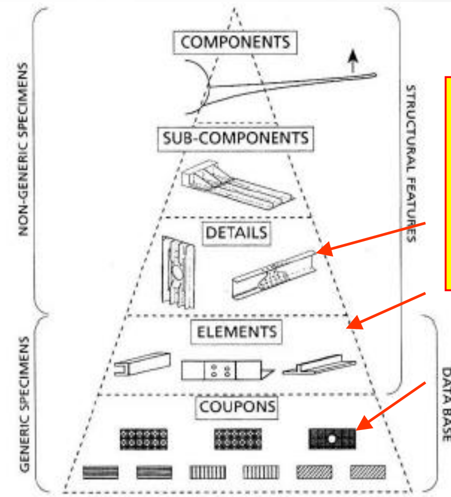
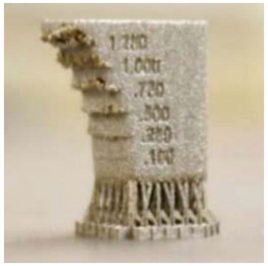


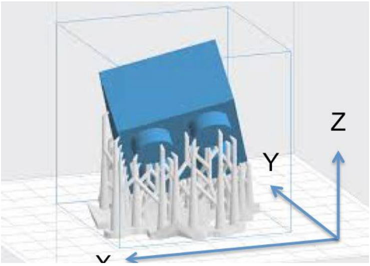
Figure 1 - Schematic diagram of building block tests for a fixed wing.

representative ‘engineering properties’ developed here?

e.g. AM, composites, bonded joints



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



e.g. support structure on the build platform

.... limited to specific machine serial number
... avoid using different materials in the same machine
until variability/equivalence is better understood

Additive Manufacturing: What is new to manufacturing regarding AM?

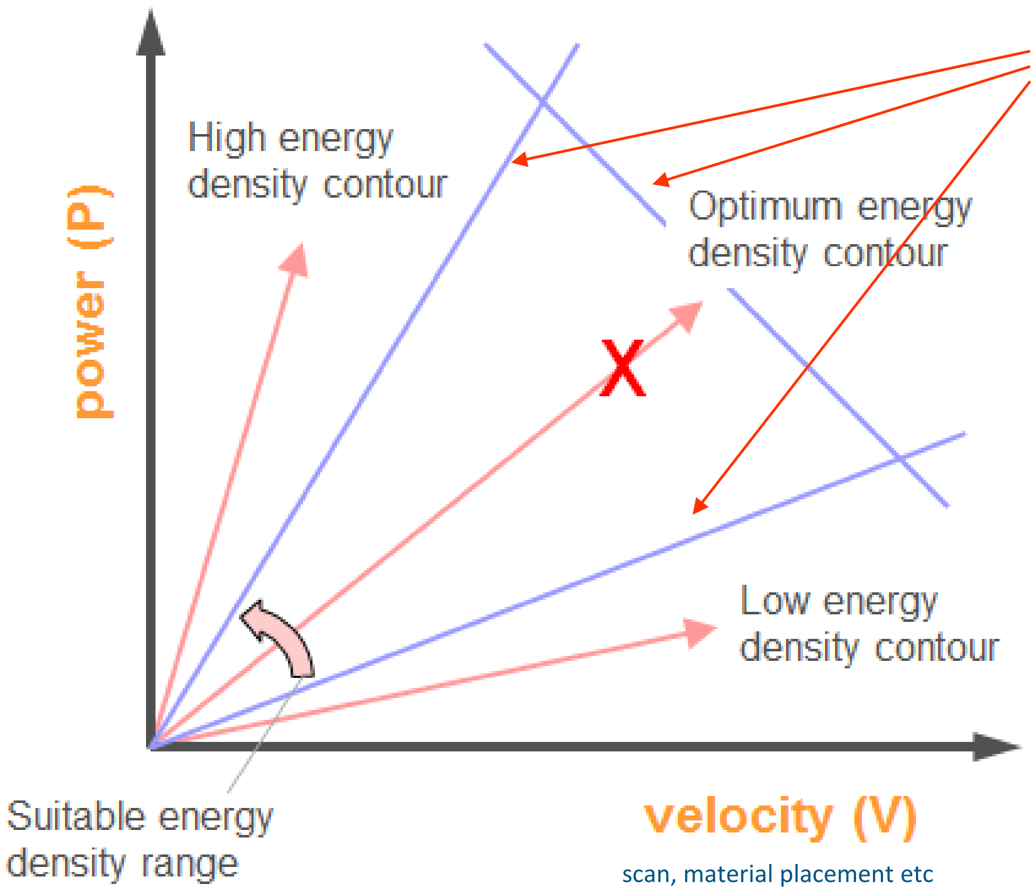
raw materials	e.g. handling, transport, storage, preparation etc	many existing standards and practices apply
build process	e.g. preparation, processing, process monitoring etc	many (TCH) methods... few existing standards
post build processing	e.g. removal from equipment, heat treatment, machining etc	many existing standards and practices apply
inspection & testing	e.g. chemical, physical, NDI, visual etc	many existing standards and practices apply

access to complex part surfaces?

Develop and maintain Design Allowables?

- Many materials and processes…

What needs to be understood? P-V diagrams etc:



Metallic/non-metallic and many processes generalisations:

Boundary definitions:

- Key parameter definition?
- Competing defect/damage modes?
- Statistical credentials (A, B-Basis etc)?
- Sensitivity (% change in 'engineering properties' wrt boundaries and key parameters?)

- 100+ control parameters
20, 30, 40….'key parameters'?

- is the importance and level of training a function of these points?

What is a ‘key parameter/characteristic*?

- large ‘engineering property’ change relative to a parameter range (relative to machine operation tolerances/capabilities?)?

- defect/damage mode change relative to a parameter range (relative to machine operation tolerances/capabilities?)?

Many materials and processes…
How do we regulate this…

e.g. does a static part remain a static part if produced using AM?

* ‘key characteristic’ used in SAE

Writing guidance for the many materials and processes will be a **resource challenge**…

Guidance documents… EASA priorities and resources:

Example AM challenge - Guidance (what is the appropriate level of detail)?

- FAA *Memorandum AIR100-16-130-GM18 'Engineering Considerations for Powder Bed Fusion (PBF) Additively Manufactured Parts'

…addresses one method, PBF, which refers to (but does not address in detail) *'100 control parameters… '**

many variables – materials, process, configurations…
Who is going to do this for each material and process…? What level of detail?

- *need to standardise strategy to identify **key parameters and manage sensitivity**?*
- *failure modes wrt hazard analysis?*
- *other mitigating factors?… e.g. batch mixing in multi-load path structure etc*

* one of a number of useful developing FAA AM documents

EASA Certification:

It will be important for the **regulators to understand the machine technologies and that appropriate knowledge is being transferred between the TCHs, machine producers, and other sub-contractors, such that the TCHs and STCHs have full and appropriate knowledge to demonstrate to the regulators full control and responsibility for their products, including maintenance considerations**.

AM relative to The Regulations – EASA priorities and resources:

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

e.g. AM within scope of LOI (NPA 2015-03)

21.B.100 Level of Involvement

….(b) The Agency shall establish its **level of involvement** at the level of compliance demonstration items, or groups thereof, following a **safety and environmental risk assessment, taking into account** but not limited to:

1. the **novel or unusual features** of the certification project, including operational, organisational and knowledge management aspects;

2. the **criticality of the design or technology** and the related safety and environmental risks, including those identified on similar designs; and…

AM relative to The Regulations – EASA priorities and resources:

EASA CM–S-008 Issue 01: Additive Manufacturing:

- simple message to industry… share intent early with EASA in order to support integration within existing regulatory framework

EASA Risk Matrix (RM) elements:

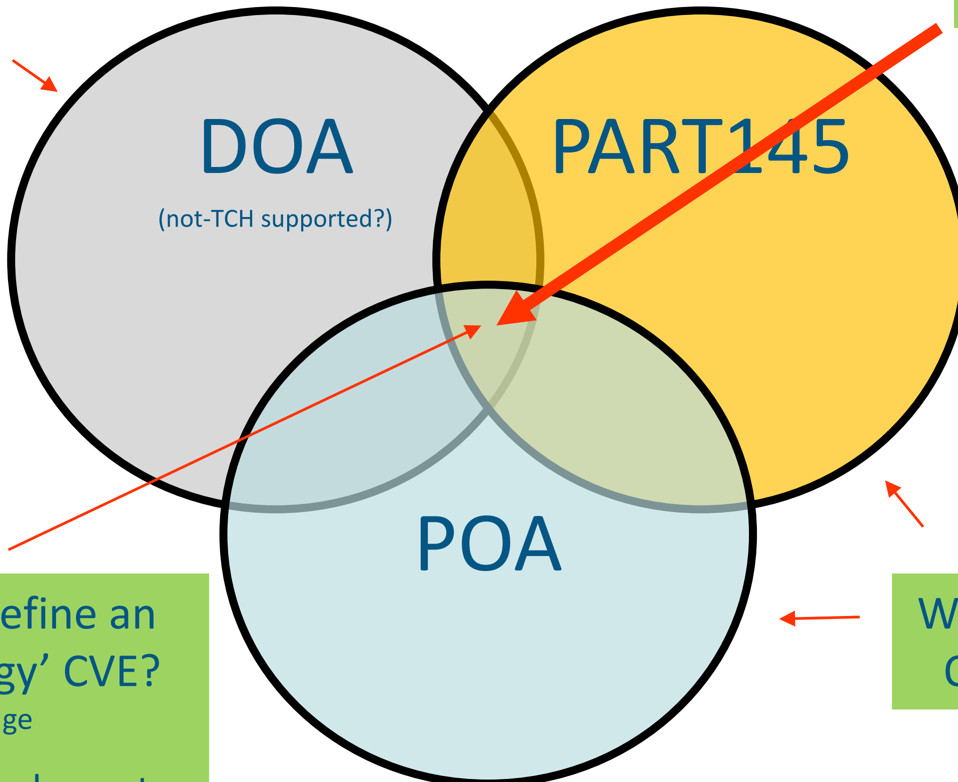
- Scope, definition, and associated AM terminology not standardised
- Current RULES ineffective (Low risk… existing rules are high level and generic)
- Current GUIDANCE ineffective (Low risk… however some additional supporting guidance is expected to be necessary)
- Design Certification - Engineering Properties
- DOA related
- POA related
- Repairs and Maintenance
- DOA/POA/Maintenance and Cert interfaces
- EASA DESIGN CERT interface with EASA DOA, POA, Maintenance
    - DOA - POA interface
    - DOA - Maintenance interface
    - POA - Maintenance interface
    - EASA - Industry interface
- Bogus Parts/Non-Compliant parts

- common to RM elements:
- Knowledge transfer
- Training
- Workforce awareness

Knowledge Transfer – What needs to be transferred to whom in order to support defining appropriate training?:

- The AM Machine…

What does an AM Design Engineer need to understand about the machine and its operation wrt design allowables/values?



Large TCH needs and organisation process different to MRO!

Does EASA need to define an 'Integrated Technology' CVE?
…Materials, POA, DOA knowledge

What does EASA need to know to fairly regulate the industry?

What does an AM Machine Operator need to know?

Existing regulation does not help at any useful detailed level… example composites

Note: Existing Part 66 'Certifying Staff' … very limited wrt Composites:

PART 66 'Certifying Staff': 66.A.45 Type/task training and ratings

'6.3 Aircraft Materials — Composite and Non-Metallic
6.3.1 Composite and non-metallic other than wood and fabric'

no further information!

Issue recognised:

- EASA intent to add some/all of SAE AIR 5719 'Teaching Points for an Awareness Class on Critical Issues in Composite Maintenance and Repair'' to PART 66
- supported by various 'airworthiness' training activities (on-line and hands-on)

Is an AM equivalent to AIR 5719 appropriate?

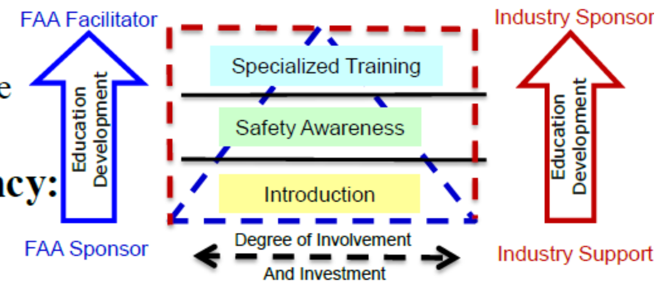
Knowledge Transfer – What needs to be transferred to whom in order to support appropriate training?:

Is this an appropriate support model for AM? If not, why not?

Composite Educational Initiatives

FAA AVS Composite Training

- **FAA composite training strategy established** [Sept., 2009]
  - Courses to support airframe structural engineering, manufacturing, and maintenance functional disciplines



Incl. three levels of competency:

I) Introduction (common to all functional disciplines)
Self-study intro content for composite basics/terminology
CMH-17 Tutorial for composite certification & compliance [Aug, 2008]

II) Safety Awareness (courses for each functional discipline)
Skills needed for FAA workforce supporting composite applications (including industry focal involved in safety and certification oversight)

III) Specific Skills Building (most courses developed by the industry)
Specialized skills needed in the industry & some FAA experts
Currently dominated by industry on-the-job training/mentoring

e.g. Level II:
Composite Engineering (CSET)
Composite Manufacturing (CMfgT)
Composite Maintenance (CMT)

Composite Structural Engineering Technology
Module 1.0: Introduction

Click Here for Optional Slides

Federal Aviation Administration

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This Workshop: Machine Producer/Knowledge Transfer/Training

- Invited attendees - 3 groups (based upon different knowledge/different needs):

- Group 1: Machine Manufacturers
- Group 2: TCHs
- Group 3: Operator/MRO/POA/non-TCH DOA & Standardisation bodies

- closed group discussion and open cross group discussions:

- possible themes suggested in the invitation (repeated in support slides)

- deliberately not constrained to a matrix question/feedback format in order to allow easier identification of any issues. However, one constraint is to address the **key question**:

/Q/ What knowledge* does each group believe that it needs from the other groups (including the regulators) in order to function more efficiently and better meet its (safety) objectives?

* themes, level of detail etc, also see invitation and support slides

Maybe we will identify some common knowledge transfer priorities…

Recent related activities:

PRI: Bodies of knowledge:

- *Process Operator/Technician*
- *Process Planner*
- *Process Owner*

FAA Workshop 2017:

http://www.tc.faa.gov/its/worldpac/techrpt/tc18-3.pdf

SAE ('operator training' – Norway April 2018)

This Workshop: Machine Producer/Knowledge Transfer/Training

EASA
European Aviation Safety Agency

EASA AM Machine Producer –

- Knowledge Transfer - Training Meeting

Cologne, 28-29 June 2018

AGENDA

DAY 1, 28/06/2018, Jugendherberge Köln-Deutz (Siegesstr. 5, D-50679 Köln)

TIME	MEETING ROOM	TITLE, SPEAKER
12:30 H – 13:00 H	LOBBY, RECEPTION DESK	REGISTRATION
I. ALL-HANDS MEETING: INITIAL GROUP PRESENTATIONS (20 MIN PER GROUP)		
13:00 H – 15:00 H	Wolgograd	**Introductory Words** EASA
		Group 2 presentation (Chair: Mr Jeffrey CONNER, GE Aviation) TCHs
		Sub-group 3a presentation (Chairs: Mr Simon MÜLLER, Lufthansa Technik & Mr Wayne THOMAS, Air New Zealand) Operator/MRO/POA/ non-TCH DOA
		Sub-group 3b presentation (Chair: Ms Rachael ANDRULONIS, NIAR) Standardisation Bodies
		Group 1 presentation (Chair: Mr Richard GRYLLS, SLM Solutions Group AG) Machine Producers
15:00 H – 15:30 H	CANTEEN ROOM (SEPARATE, ON THE LEFT)	NETWORKING BREAK
II. GROUPS MEETINGS		
15:30 H – 17:30 H	Turku	Group 1
	Indianapolis	Group 2
	Tunis	Group 3 (a&b)
17:30 H		CLOSING OF 1ST DAY

This Workshop: Machine Producer/Knowledge Transfer/Training

EASA AM Machine Producer –

- Knowledge Transfer - Training Meeting

Cologne, 28-29 June 2018

10:00 H – 10:30 H	TURKU/ INDIANOPOLIS/ TUNIS	NETWORKING BREAK
	[..continue] II. GROUPS MEETINGS	
10:30 H – 12:30 H	Turku	Group 1
	Indianapolis	Group 2
	Tunis	Group 3 (a&b)
12:30 H – 13:30 H	CANTEEN ROOM (SEPARATE, ON THE LEFT)	LUNCH BREAK
	III. ALL-HANDS MEETING: CONCLUSIONS (20 MIN PER GROUP)	
13:30 H – 14:30 H	Wolgograd	**Group 1 presentation (Chair: Mr Richard GRYLLS, SLM Solutions Group AG)** Machine Producers
		Group 2 presentation (Chair: Mr Jeffrey CONNER, GE Aviation) TCHs
		Sub-group 3a presentation (Chairs: Mr Simon MÜLLER, Lufthansa Technik & Mr Wayne THOMAS, Air New Zealand) Operator/MRO/POA/ non-TCH DOA
		Sub-group 3b presentation (Chair: Ms Rachael ANDRULONIS, NIAR) Standardisation Bodies
14:30 H – 15:00 H	CANTEEN ROOM (SEPARATE, ON THE LEFT)	NETWORKING BREAK
15:00 H – 16:30 H		IV. DISCUSSION
17:00 H		CLOSING

Group 1

GROUP 1: Machine Producer Chair: Richard GRYLLS, SLM Solutions Group AG (richard.grylls@slm-solutions.us)					
First name	**Family Name**	**Job Title**	**Organisation**	**TCH, machine producer, regulator, standardisation body etc**	**E-mail address**
Niccoló	GIANNELLI	Aerospace Application and Account Manager EMEA	Stratasys	machine producer	Niccolo.Giannelli@stratasys.com
Rachael	Brandt	Associate Application Engineer Manufacturing SBU.	Stratasys	machine producer	Rachael.Brandt@stratasys.com
Vinu Chaprayil	VIJAYAN	Business Development Manager – Aerospace	EOS GmbH	machine producer	vinu.vijayan@eos.info
Lucas	FUCHS	Business development manager - turbo machinery	EOS GmbH	machine producer	Lukas.Fuchs@eos.info
Jonathan	ORTNER		Concept Laser	machine producer	jonathan.ortner@ge.com
Matthieu	PETELET	Industrialization Expert Aerospace	ARCAM EBM	machine producer	Matthieu.Petelet@ge.com
Andreas	SOLBACH	Application Engineer Aerospace	SLM Solutions Group AG	machine producer	Andreas.Solbach@slm-solutions.com
Richard	GRYLLS	Technical Director SLM Solutions NA	SLM Solutions Group AG	machine producer	richard.grylls@slm-solutions.us
Simon	MERKT-SCHIPPERS	Industry Manager Additive Manufacturing for	Trumpf Laser und Systemtechnik GmbH	machine producer	simon.merkt@de.trumpf.com
Julia	MOLL	Application Engineer Aerospace / Energy	Trumpf Laser und Systemtechnik GmbH	machine producer	Julia.Moll@de.trumpf.com
Jono	MUNDAY	Customer Projects Manager	Renishaw PLC	machine producer	Jono.munday@renishaw.com
Mark	VAES	CTO	Additive Industries b.v.	machine producer	m.vaes@additiveindustries.com
Harry	KLEIJNEN		Additive Industries b.v.	machine producer	h.kleijnen@additiveindustries.com

Group 2

GROUP 2: TCH Chair: Jeffrey CONNER, GE Aviation (jeff.conner@ge.com)				
First name	**Family Name**	**Job Title**	**Organisation**	**TCH, machine producer, regulator, standardisation body etc**
Holger	LOGES	Manufacturing Technologies Development Engineer	Airbus	TCH
Philippe	EMILE	Additive Manufacturing Expert	Airbus	TCH
Neil	MANTLE	Head of Centre of Competence – Additive Layer Manufacturing	Rolls-Royce	TCH
Jeffrey	CONNER	Chief Consulting Engineer – Fielded Product Integrity	GE Aviation	TCH
Mark	SHAW	Qualifications & Certification Leader	GE Aviation	TCH
Anne	THÉNAISIE		SAFRAN AIRCRAFT ENGINES	TCH
Yann	DANIS	Safran HE additive manufacturing expert	SAFRAN HELICOPTER ENGINES	TCH
Bruno	MACQUAIRE	Head of R&T Additive Manufacturing plateform	Safran	TCH
Dominique	BOUVIER		SAFRAN HELICOPTER ENGINES	TCH
**MR Bouvier will attend only on 29 June*				
Sophie	FERRENDIER	Vehicle Airworthiness Expert	AIRBUS Helicopters	TCH

Group 3a

Sub-group 3a: MRO/Operator/POA/non-TCH DOA Sub-group chair: Simon MÜLLER, Lufthansa Technik AG (simon.mueller@lht.dlh.de) & Wayne THOMAS, Air New Zealand (wayne.thomas@airnz.co.nz)				
First name	**Family Name**	**Job Title**	**Organisation**	**TCH, machine producer, regulator, standardisation body etc**
Wayne	THOMAS	3D Printing and Advanced Manufacturing Project Manager	Air New Zealand	Operator
Joseph	CHONG	Vice President, Aircraft Engineering	ST Engineering Aerospace Ltd.	DOA
Wen Ming	TAN	Assistant Principal Engineer, Aircraft Engineering	ST Engineering Aerospace Ltd.	DOA
Guo Ying	ZHENG		ST Engineering Aerospace Ltd.	DOA
Simon	FEICKS	Project Manager Additive Manufacturing	Lufthansa Technik AG	DOA
Simon	MÜLLER	Additive Manufacturing Engineer	Lufthansa Technik AG	DOA
Clemens	MIASKOWSKI		Lufthansa Technik AG	DOA
Geert	APPELTANS	Quality Manager Polymers	Materialise NV	Industries
Jörn	WERITZ	Quality Manager Metals	Materialize GmbH	Industries
Éric	BAUSTERT	R&T Manager	Volume-e	Industries
Utkarsha	ANKALKHOPE	Senior Research Engineer, National Centre for Additive Manufacturing	MTC UK	Industry Support
Martin	DURY	Training Operations Manager, Training Services	MTC(AMTC) UK	Industry Support
Thorsten	WESENDRUP		Premium AEROTEC GmbH	Industries

Group 3b

First name	Family Name	Job Title	Organisation	TCH, machine producer, regulator, standardisation body etc
Hannah	GODREY	General Manager, PRI Europe and Professional Development Manager	Performance Review Institute (PRI) Europe	Standardisation body
Ian	SIMPSON	Nadcap Program Manager - Welding	Performance Review Institute (PRI) Europe	Standardisation body
Sara	GOBBI	Director of European Affairs	ASTM International	Standardisation body
Rachael	ANDRULONIS	Senior Research Engineer	National Institute for Aviation Research, Wichita State University (NIAR)	Standardisation body

Questions?

Support Slides

Possible knowledge transfer themes might include (see invitation):

- Who are the key functionaries, e.g. machine operator, CVE, design staff, production staff, training staff, etc. and where does the technical knowledge exist,
  - what background knowledge do they need (theory/practical)
  - what do they need to know?
- what timescales are expected for training of each functionary?

- Knowledge base for CVEs (and/or other key staff members) addressing AM? (EASA understands that knowledge relating to materials, POA, DOA, systems etc may all be necessary to appropriately address the integrated link between design, production, and maintenance)

- Machine producer interface with industry (from the TCH, machine manufacturer, MRO, or other sub-contractor basis)
  - what does the TCH/STCH need to know from the machine producer to clearly demonstrate control and responsibility for the product
  - how does this change in the maintenance environment

Possible knowledge transfer themes might include (see invitation):

- Understanding/training relating to machine issues
  - Maintenance practices and impact upon key variables/sensitivities (how are key variables/sensitives identified)
  - Calibration practices
  - Software management
  - Cyber security issues

- Training strategy
  - How was the training strategy developed in your organisation?
  - Initial strategy – lessons learned?
  - Current training strategy – lessons learned?
  - Future training strategy and the planned link between the machine manufacturer, the DOA, and the POA or PART145 organisation

- Development of a common industry lead training strategy?

Possible knowledge transfer themes might include (see invitation):

- Development of a common industry lead training strategy?
- Is there a need for a high level training ‘teaching points’ guideline, similar to SAE AIR 5719 as used for composites ?
- Is there a need to adopt a training strategy similar to composites, e.g. level 1,2, and 3 etc (no need to reinvent the wheel etc)
- How can standardization bodies support the above activities?

EASA – AM WG Subject Contacts

EASA AM Strategy - current activities:

- EASA AM WG – subject contacts (as identified in CM*):

- Shared responsibilities via subject contacts
- Co-ordinated through EASA AM WG, e.g. internal meetings etc

- Cert. Directorate (Chief Expert - Airframe)	R. Minter – richard.minter@easa.Europa.eu
- Structures	S. Waite (AM WG chair) – simon.waite@easa.europ.eu
	W. Hoffmann - wolfgang.hoffmann@easa.europa.eu
- Propulsion	M. Mercy - matthew.mercy@easa.europa.eu
	O. Kastanis - omiros.kastanis@easa.europa.eu
- Systems	**M. Weiler - michael.weiler@easa.europa.eu**
- Cabin Safety	T. Ohnimus - thomas.ohnimus@easa.europa.eu
- DOA	A. Enache - alexandru.enache@easa.europa.eu
	O. Tribout - olivier.tribout@easa.europa.eu
- POA	D. Lamothe - dominique.lamothe@easa.europa.eu
	S. Pernet - samuel.pernet@easa.europa.eu
- Maintenance	R. Tajas - rosa.tajes@easa.europa.eu
- ETSO	TBD

* changes in progress since CM published – new subject contacts 'red text'

EASA AM Strategy - current activities:

- EASA AM WG:

- Risk and Mitigation Matrix
- Workshops (first meeting - September 2016)
- Regular communication with other regulators

Certification Memo: **EASA CM–S-008 Issue 01: Additive Manufacturing***

Requirements: CS X.571, CS X.603, CS X.605, CS X.613, CS-E 70, CS-E 100 (a), CS-P 170, CS-P 240, CS-APU 60, GM 21.A.91, 21.A.101, 21.A.133, 21.A.433, GM 21.A.435, 21.A.437, 21.A.447, 21.A.805, AMC 145.A.42(c)

Purpose/Scope: …provide guidance regarding regulator expectations relating to the usage of AM technologies in products (Aircraft, Rotorcraft and Propulsion) subject to EASA Type Certification

simple 'early engagement' message…

EASA Certification Policy and Guidance for DOA and POA Holders

- is a change of material or/and process iaw GM 21A.91
- in repair, repair design would normally be classified Major, applicants are advised to consult EASA when introducing AM in repairs, including cases where they hold a privilege for repair approval.

not intended to make everything Major…
'case by case' approach…

*https://www.easa.europa.eu/system/files/dfu/EASA%20CM-S-008%20Additive%20Manufacturing.pdf

CM: EASA Certification Policy and Guidance for DOA and POA Holders

- Design Organisation Approval Holders are advised to involve the Agency at the earliest opportunity during the development and implementation of AM. ....AM will be subject to increased oversight by the agency and that specific audits will be scheduled to examine the introduction and use of AM within the scope of the design organisation audit cycle. ... audits may take place concurrently with the review of AM applications rather than post approval.

- Production Organisation Approval holders are advised to inform their respective competent authorities at the earliest opportunity before the implementation of AM processes. ...implementation of a new AM process by a POA holder is a change which may be identified as a significant change in accordance with Part 21.A.147 + GM

simple 'early engagement' message...

PART145s typically have no access to TCH hazard analysis, damage modes, criticality etc – which AM might change

EASA - AM

potential need for more guidance regarding expectations proportional to criticality recognised

CM: Maintenance/Operators: Existing DOA, POA, PART145 regulations apply…

PART 145.A.42 Acceptance of components:

'…organisation may fabricate a restricted range of parts to be used in the course of undergoing work within its own facilities… procedures are identified in the exposition.'

'All necessary data to fabricate the part …approved by the competent authority, TC holder, or Part-21 design organisation approval holder, or supplemental STC holder;'

'Para.7. Examples of fabrication under the scope of an Part-145…:

a) Fabrication of bushes, sleeves and shims… b) …secondary structural elements and skin panels… etc

All the above fabricated parts, should be in accordance with data provided in overhaul or repair manuals, modification schemes and service bulletins, drawings or otherwise approved by the competent authority. Note: It is not acceptable to fabricate any item to pattern unless an engineering drawing of the item is produced which includes any necessary fabrication processes and which is acceptable to the competent authority.'

Certification Memo (lessons learned):

- **working well with large TCHs**, e.g. Airbus, Rolls Royce, Safran (see 2016 Workshop Slides)
  - evolution towards more critical applications in progress

e.g. DRAFT AMS 7003 – agree upon 'Significant Process Characteristics' SPCs

- need strategy to **better identify and understand 'key parameters'**, e.g. machine parameters, statistical strategy, enable shared databases (e.g. SAE AM-P, NIAR work) etc

- some **challenges** to be addressed regarding **optimisation of evolving use in maintenance/operator environment**
  - less critical interior part applications….
    - strength, fire, failure modes (sharp edges preventing evacuation, fatigue), statistics etc

- rapid technology integration…
  - **knowledge base/training for industry/regulators is likely to be a challenge**

New!
Support
CM

EASA – NAA activities: NAA Materials Network (NAAMN)*

- improve communication/standardisation between NAA and EASA regarding broader 'material and process' issues

NAAMN – Terms of Reference:

To identify, and address as necessary, common **Materials and Process** (metallic, non-metallic, ceramic, Additive Manufacturing (AM) etc) issues with **potential safety implications** from an **European NAA perspective**.

To consider all aspects of Materials and Processes in the context of all activities, including design, supply, production, and maintenance.

To consider Materials and Processes issues ranging from detailed technical issues (airframe, propulsion, systems, cabin safety, maintenance etc) through to organisational and regulatory structural issues, including certification, material qualification, complex part substantiation, training, standardisation, R&D, and rulemaking.

* see support slide for current membership (all European NAAs invited, currently 11 NAAs)

Conclusions – 2017 (see 2016 presentation): AM is rapidly evolving:

- EASA does not approve materials or processes, but accepts them as part of a project - provided that they are shown to be validated, applicable, and repeatable

- Technology, and technology application, changes must not reduce the existing 'acceptable' level of safety

- EASA AM Working Group in place to review and assess risk, and risk mitigation, and to work with other regulators and industry (CM) to help ensure safe integration of the evolving technologies into aviation

- EASA AM CM in place

CM approach seems to work

- additional NAA communication path established to support process (NAAMN)

Conclusions: AM is rapidly evolving:

Rules: limited/possibly no rule change expected by EASA…

Guidance: some guidance development expected (level of content/detail unclear), a function of:

- criticality of applications
- identification of any common underlying philosophy development* associated with maturing technologies e.g. icw international standards bodies etc, e.g. SAE, ASTM.
- would an AM equivalent to AMC 20-29 'Composite Structures' potentially useful?

R&D: EASA increasingly working with EU funded projects

Workforce knowledge base and training (industry and regulators)

– likely to be a limiting factor in this rapidly developing technology

* it is understood that IP will not be shared. However, applicants are required to meet the requirements, e.g. show stable process, repeatable 'engineering properties' etc

Questions?

Support Slides

EASA - AM

- 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…

…gulatory Framework (moving towards **performance based regulations**)

Basic Regulation

(EC) No 216/2008

EU Parliament
EU Council

…ing 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.

- **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

EU Commission

GM 21.A.147(a) Changes to the approved production organisation – Significant changes
1 …to be approved by the competent authority include:
- significant changes to production capacity or methods…

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

PART 21

Certification Specifications

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

PART 145 – Maintenance organisation approvals

PART 66 – Certifying staff

Part 147 – Training organisations requirements

EASA

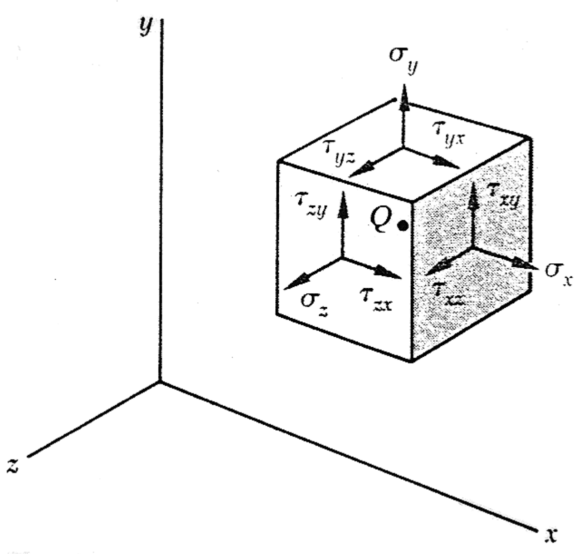
•Binding

•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
CS 25.613: Mechanical Strength Properties and Design Values Materials. (a) … design values based upon a statistical basis

'Engineering Properties'*: '… historically, many materials used in aviation are isotropic

- properties similar in all directions of load application, e.g. mechanical, thermal etc (+ similar/limited damage modes)



Isotropic: similar strength in X,Y, and Z directions

Anisotropic: different strengths in X and/or Y and/or Z directions

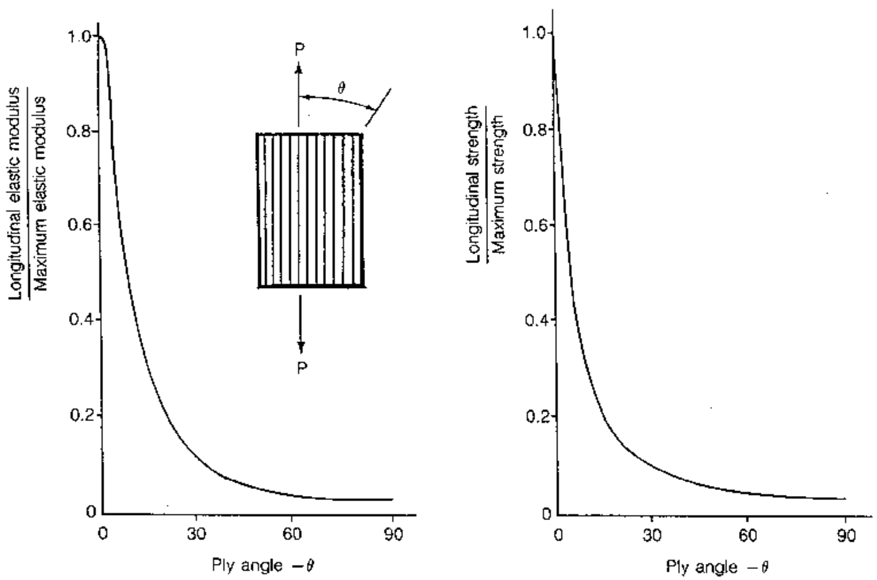
* 'engineering properties', e.g. strength + stiffness (local and global buckling) which define the structure performance

intentional or unintentional!

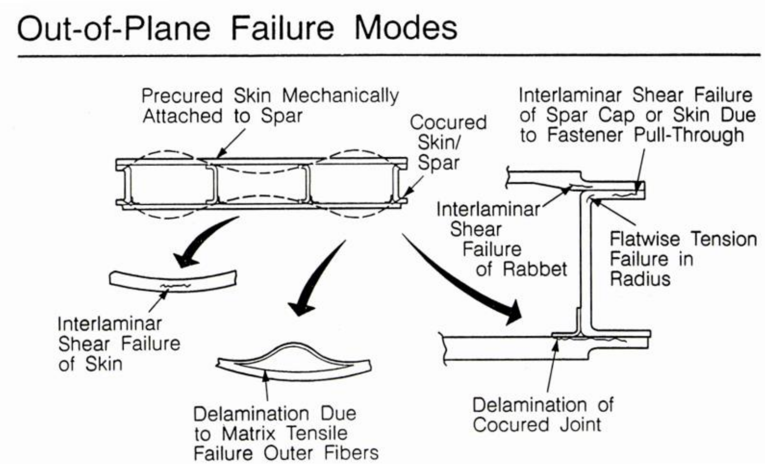
‘Engineering Properties’: ‘... make objects…layer upon layer…’

- initially assume AM potentially <u>anisotropic</u> – properties change with direction of load application (+ competing damage modes)

Anisotropy: Significant strength/stiffness reduction with orientation relative to load



Strength/Stiffness v Ply Angle
(non-dimensionalised)



Anisotropy: potentially difficult to predict:

- **failure loads**
- **damage modes**
- **damage locations**
- **damage sequence**

Identification and control of key process steps essential… look for substantiated tolerance sensitivity data

Example AM challenge…*

CS 25.613: Mechanical Strength Properties and Design Values Materials

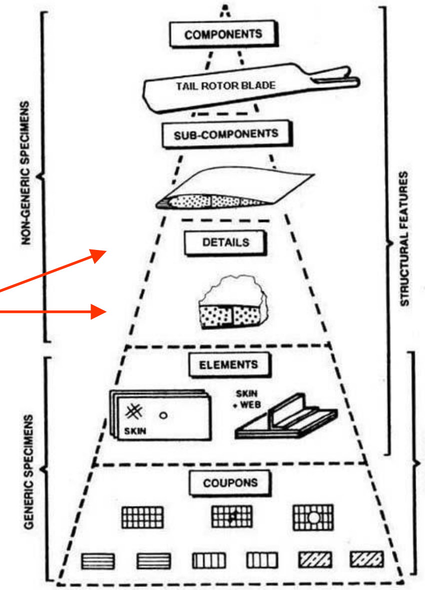
How do we statistically manage inaccessible free edges in complex laser melt parts?

- free edge coupons produced in parallel with parts

- coupons produced from part cut-up

- use higher pyramid component testing (small data set statistics?)

Free Edge – fatigue issue?



AMC 20-29 Figure 2 - Schematic diagram of building block tests for a tail rotor blade

Non-TCH DOA unlikely to have this information… e.g. acceptable free edge details etc

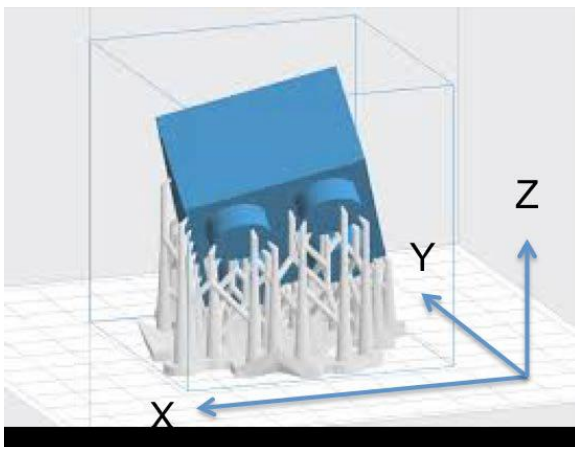
** similarities to how castings are addressed in CS25.621 'Castings Factors'?*

Identification and control of key process steps essential… look for substantiated tolerance sensitivity data

Example AM challenge…

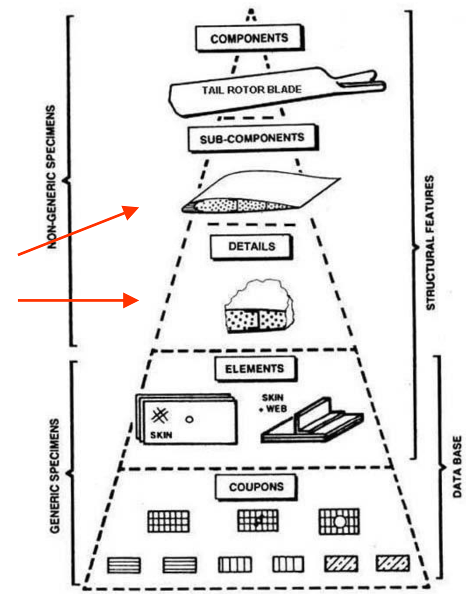
CS 25.613: Mechanical Strength Properties and Design Values Materials

How do we statistically manage complex supported parts?*



PBF part (blue) and Support Structure (white) on the Build Platform

Unsupported "roof"



AMC 20-29 Figure 2 - Schematic diagram of building block tests for a tail rotor blade

* *support provides physical support and/or thermal management*

EASA AM: Strategy:

1 - Understand the technology / process / product and its actual, planned or potential uses.

2 - Identify potential safety / environmental risks.

3 - Define and implement means to mitigate risks working closely with industry and NAAs.

4 - Monitor evolution of technology / product / process and effectiveness of mitigation.

5 - Review and revise implementation of strategy as necessary.

CM:

EASA Certification Policy and Guidance for DOA and POA Holders

applicants to demonstrate:

- complies with appropriate CS's
- suitable for intended use
- source materials purchased to spec
- produce consistent product to process spec
- statistically significant design values wrt <u>defined facilities/equipment</u>
- control of equipment/process

Risk and Mitigations Matrix:

Preliminary (initial) areas of risk list (under EASA AM WG review/development*):

Scope and definition of AM not standardised
New materials
Many process parameters to control (see Appendix)
Anisotropic properties of finished part
Variation in the types of AM equipment / processes and lack of standardization
Limited understanding of acceptable ranges of variation for key manufacturing parameters
Limited understanding of key failure mechanisms
Transfer from small scale manufacture to high levels of production
Lack of broad industry databases / allowables (each implementation is unique)
Development of capable NDI methods
Repairs
Current rules: Note: ARAC Composite and Metallics group also has to consider new technology in F&DT recommendations)
Insufficient guidance (Likely)
POA related
DOA related
DOA and POA link
Certification related
Higher risk of bogus parts

* including identification of existing mitigations and the need for new additional actions

NAA Materials Network (NAAMN): Current Members

Organisation	Focal First Name	Focal Family Name	Focal Function within NAA	e-mail address
CAA-NL	Bart	Abbes	Aircraft Structures Specialist	bart.abbes@ilent.nl
CAA-CZ	Tomaz	Franc	Specialist - Aircraft Design Section	franc@caa.cz
CAA-CH	Andreas	Boss	Inspector	Andreas.boss@bazl.admin.ch
LBA 1	Dietmar	Goldschmidt		dietmar.goldschmidt@lba.de
LBA 2	Karen	Mueller	National Standardisation Coordinator (NSC) Luftfahrt-Bundesamt	Karen.Mueller@LBA.DE
CAA-SI	Bostjan	Palcic	Airworthiness Inspector	bostjan.palcic@caa.si
CAA-RO	Alexandru George	Musat	Airworthiness Inspector	alexandru.musat@caa.ro
ECAA-EE	Margus	Keerman	Senior Inspector Airworthiness	margus.keerman@ecaa.ee
Austro Control	Flrian	Glatzl	Airworthiness and Certification Surveyor	Florian.Glatzl@austrocontrol.at
Trafi (Finland)	Jyrki	Laitila	Head of Unit, Airworthiness	jyrki.laitila@trafi.fi
CAA- Poland - Institute of Aviation	Małgorzata (Margaret)	Zalewska	Composites Testing Laboratory Manager in the Institute of Aviation	malgorzata.zalewska@ilot.edu.pl
CAA-UK	Ted	Blacklay	Airworthiness Survey - Subject Matter Expert for Materials, Special Processes and NDT	ted.blacklay@caa.co.uk

Standardisation of Certification Requirements Applicable to AM

- limited material specific specific rules/guidance
  (although significant to design and throughout CSs)

- governing rule is CS 2x.603:

CS 25.603: Materials (For Composite Materials see AMC 20-29*)

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

- *be based upon experience/test*
- *conform to specifications (meeting design data)*
- *consider environmental effect (temperature, moisture etc)*

*AMC 20-29 - harmonised with FAA AC20-107B

CS- E – different words, similar intent as CS 2x-603, 605

CS-E 70 Materials and Manufacturing Methods (See AMC E 70)

(a) The suitability and durability of materials used in the Engine must be established on the basis of experience or tests. The assumed design values of properties of materials must be suitably related to the minimum properties stated in the material specification.

(b) Manufacturing methods and processes must be such as to produce sound structure and mechanisms which retain the original mechanical properties under reasonable service conditions.

CS- E – different words, similar intent as CS 2x-613 (statistical credibility - safe-life - metal assumption)

CS-E 515 Engine Critical Parts

…the factors used to account for scatter should be justified. In order to utilise this approach the test should be designed to be representative of the critical engine conditions in terms of the temperature and stress at the specific features…

…test data should be reduced statistically in order to express the results in terms of minimum LCF capability (1/1000 or alternately -3 sigma). The fatigue life should be determined as a minimum life to initiation of a fatigue crack, defined typically as a crack length of 0.75mm.

CS25.571: ***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, corrosion, or accidental damage, will be avoided throughout the operational life of the aeroplane...'

Environmental Damage - ED

Accidental Damage - AD

Historically: metal/fatigue/corrosion focused

Existing CS25 Structures Regulations of particular interest and potential relevance include:

CS 25.571: Damage Tolerance and Fatigue Evaluation of Structure:

'(3)…..inspections or other procedures 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'

Does not need to be visual,
Note: 80-90% of inspections are visual
ref. also CS25.611

Does not need to be an 'inspection'

Notes:

1/ EASA does not approve inspection standards, but accepts them as part of a process, project etc - provided that they are shown to be validated, applicable, and repeatable

2/ technology and technology application changes must not reduce the existing 'acceptable level of safety'

AM - Maintenance/Operating Environment:

Example AM challenge – existing requirements/awareness***…*

PART 145.A.42 Acceptance of components:

'…organisation may fabricate a restricted range of parts to be used in the course of undergoing work within its own facilities provided procedures are identified in the exposition.'

AMC 145.A.42 Acceptance of components:

'All necessary data to fabricate the part should be approved either by the competent authority or the type certificate (TC) holder or Part-21 design organisation approval holder, or supplemental type certificate (STC) holder;'

* *AM similarities wrt composites*

** *applies to industry and regulators*

AM - Maintenance/Operating Environment:

*Example AM challenge – existing requirements/awareness***

PART 145.A.42 Acceptance of components:

‘7. Examples of fabrication under the scope of an Part-145 approval can include but are not limited to the following:

a) Fabrication of bushes, sleeves and shims.

b) Fabrication of secondary structural elements and skin panels.

c) Fabrication of control cables.

d) Fabrication of flexible and rigid pipes.

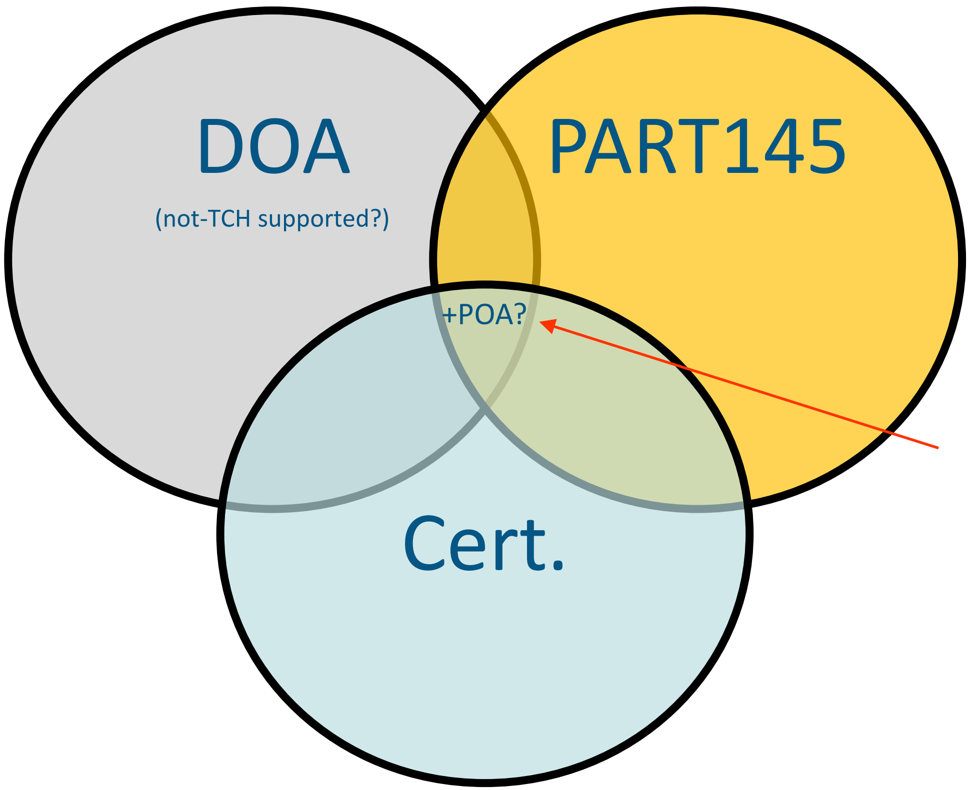
e) Fabrication of electrical cable looms and assemblies.

f) Formed or machined sheet metal panels for repairs.

changed material:
changed damage mode/debris?
- consider downstream critical part consequences…

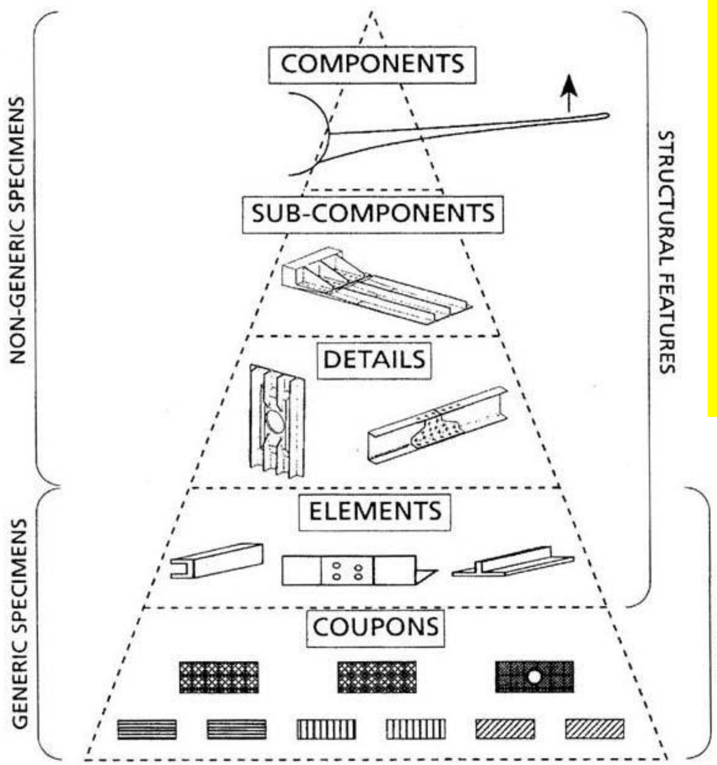
All the above fabricated parts, should be in accordance with data provided in overhaul or repair manuals, modification schemes and service bulletins, drawings or otherwise approved by the competent authority. Note: It is not acceptable to fabricate any item to pattern unless an engineering drawing of the item is produced which includes any necessary fabrication processes and which is acceptable to the competent authority.’

AM - Maintenance/Operating Environment:



Existing rules:
- POA?
- Improve links between EASA and NAAs

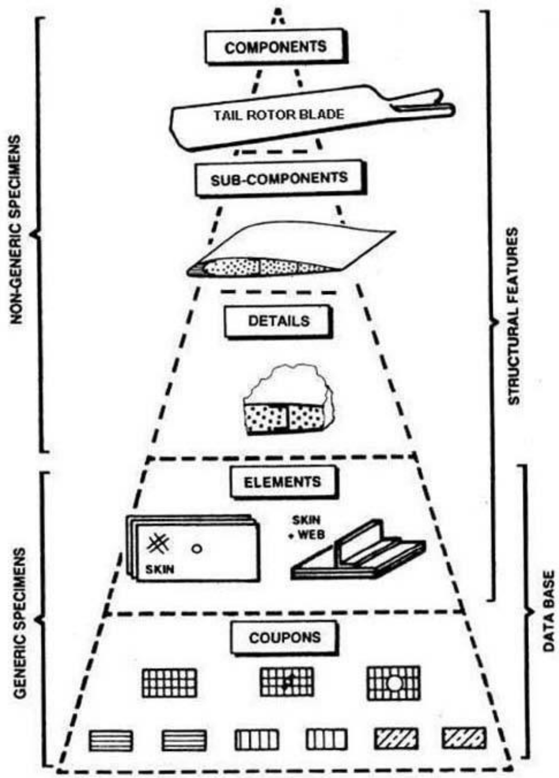
Substantiation: Test/Analysis Pyramid (Building Block)?



AMC 20-29 Figure 1 - Schematic diagram of building block tests for a fixed wing.

Static and F&DT substantiation in mid-upper test/analysis pyramid

- typically, representative Boundary Conditions are essential



AMC 20-29 Figure 2 - Schematic diagram of building block tests for a tail rotor blade

Design Philosophy: robust design concept, e.g. Large Damage Capability (LDC)

- to be similar to established metallic structure <u>except</u>:
  - potentially different/more competing damage modes,
  - some damage modes not so readily detected

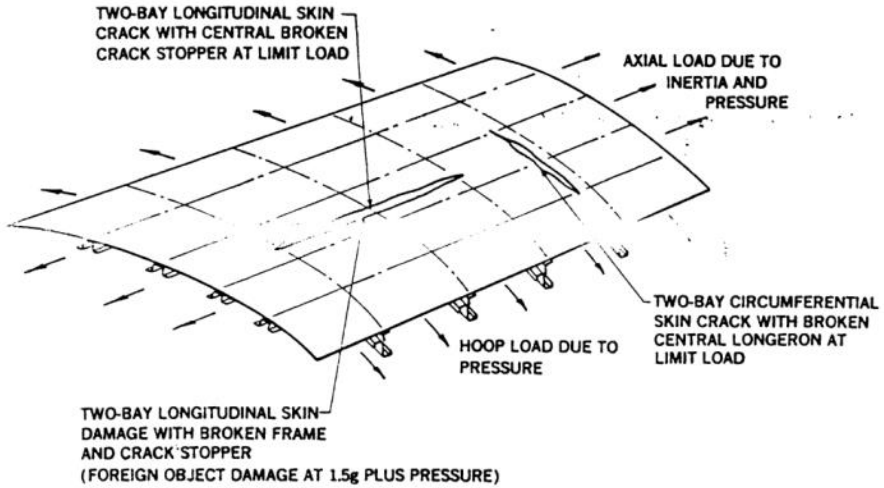


FIGURE 2. FUSELAGE DAMAGE TOLERANCE SIZES FOR STRUCTURAL DESIGN

Metal Design - Design for Redundant Structures' - T. Swift

- additional consideration may be required for technologies which change design concepts

Design philosophy changes:

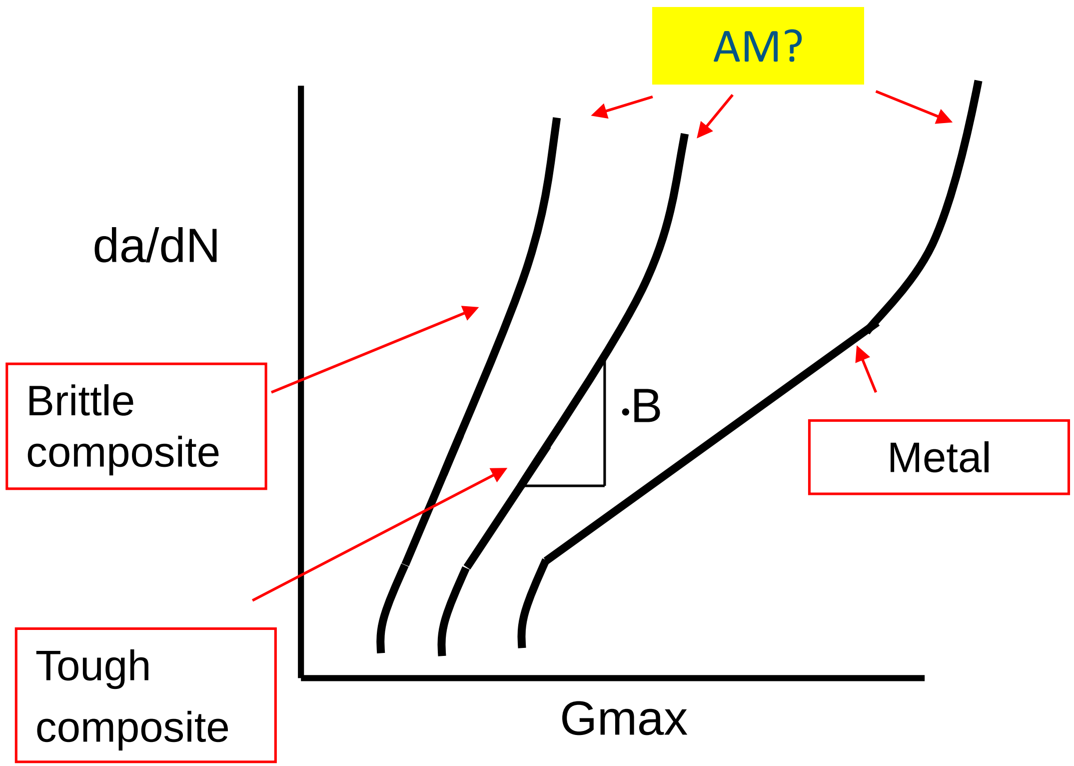
Do not reduce the existing Level of Safety

- show ‘equivalence’ to existing technologies
- result of: experience, R&D, ‘engineering judgement’, reaction to incidents and accidents, and regulations existing at the time of certification, Type Certificate Holder in-house design practice

Maintain robust ‘aircraft level’ design concept

- address all identified threats, e.g. manufacture, in-service
- similar to established metallic structure, e.g. T. Swift philosophy etc
- local damage may be different, but structural level failure may be driven by the similar failure mode, e.g. buckling

Damage – Inspection and Damage Tolerance:



$$\frac{da}{dN} = AG^{B} \qquad G \propto P^{2}$$

$$\Rightarrow \frac{da}{dN} \propto P^{2B}$$

Material	B
Steel	1.6
Aluminium	2.2
Carbon/Thermoplastic	6.1
Carbon/Epoxy	12.2

Solution :- ensure that when damage is present, G is below a threshold value for crack growth

AM – potential for a broad range of Fatigue and Damage Tolerance philosophies
- safe life, flaw tolerant safe life, fail-safe, damage tolerant?

Composite Safety Issues

AMC 20-29 - Composites:

3. APPLICABILITY

This AMC provides Acceptable Means of Compliance with the provisions of CS-23, CS-25, CS- 27 and CS-29. Many of the concepts included in this AMC may also be applicable in part or in full to other CSs. However, when using this AMC as an Acceptable Means of Compliance for these other CSs, appropriate engineering judgement should be exercised and early agreement with the Agency sought.

This AMC applies to: applicants for a type-certificate, restricted type-certificate or supplemental type-certificate; certificate/approval holders; parts manufacturers; material suppliers; and maintenance and repair organisations.

– similar for AM

Standardisation of Certification Requirements for Composites

Composite Certification - existing rules and guidance

EASA AMC 20-29/FAA AC20-107B – 'COMPOSITE AIRFRAME STRUCTURE'

CONTENTS (expanded 12 to 36 pages, new sections – red)

1984 document

applicable to PMC composite fan blade

1. PURPOSE
2. CANCELLATION
3. TO WHOM THIS AMC APPLIES
4. RELATED REGULATIONS AND GUIDANCE
5. GENERAL
6. **MATERIAL AND FABRICATION DEVELOPMENT**
7. PROOF OF STRUCTURE – STATIC
8. **PROOF OF STRUCTURE – FATIGUE AND DAMAGE TOLERANCE**
9. PROOF OF STRUCTURE – FLUTTER
10. CONTINUED AIRWORTHINESS
11. ADDITIONAL CONSIDERATIONS (crashworthiness, fire/flammability, lightning)

APPENDIX 1 Requirement Table

APPENDIX 2 Definitions

APPENDIX 3 Material Change

– similar for AM

Composite Safety Issues

Safety Management System

Standardisation of Certification Requirements for Composites:

AMC 20-29 includes clear linkage between design requirements and many material, production, and continued airworthiness related requirements…

Regulations:	CS23	CS25	CS27*	CS29*
Material and Fabrication	603 613 619	603 613 619	603 613 619	603 613 619
Proof of Structure – Static	305 307(a)	305 307(a)	305 307(a)	305 307(a)
Proof of Structure – F&DT	573**	571	573	573
Proof of Structure – Flight	629	629	629	629
Additional Considerations				
Impact Dynamics	561	561	561	561

Works for CS-P CS-E

table continues with other requirements linked to flammability, lightning strike, production specifications, continued airworthiness etc.

* Rotorcraft
** Many similar code numbers, but some differences in content

– similar for AM

Production Organisation Approval PART 21, Sub. G:

21.A.147 Changes to the approved production organisation

(a) ….each change to the approved production organisation … significant to the showing of conformity or to the airworthiness … particularly changes to the quality system, shall be approved by the competent authority

GM 21.A.147(a) Changes to the approved production organisation – Significant changes

1 Changes to be approved by the competent authority include:

- significant changes to production capacity or methods…
- changes in the production or quality systems …important impact on the conformity/airworthiness of each product, part or appliance.

2 …ensure that changes do not result in non-compliance … competent authority and approval holder to establish a relationship … will permit the necessary evaluation work to be conducted before the implementation of a change

Conclusions: AM is rapidly evolving:

Rules: limited/possibly no rule change expected by EASA…

Guidance: some guidance change expected (level of content/detail unclear), a function of:

- criticality of applications
- identification of any common underlying philosophy development* associated with maturing technologies e.g. icw international standards bodies etc, e.g. SAE, ASTM.
- would an AM equivalent to AMC 20-29 ‘Composite Structures’ potentially useful?

R&D: EASA increasingly working with EU funded projects

Workforce knowledge base and training: Need

* it is understood that IP will not be shared. However, applicants are required to meet the requirements, e.g. show stable process, repeatable ‘engineering properties’ etc

Conclusions:

POA/DOA/Maintenance:

- need to increase awareness of closer relationship between design, production, continued airworthiness (CAW), more integrated than many typical metallic processes (some similarities wrt composites)
- need to increase awareness of existing rules, particularly at interfaces between design, production, and maintenance, e.g. link between non-TCH DOA, PART 145 (AMC 145.A.42 para.7), and the need for TCH data for extensive repair and ‘replacement’ (also similarities wrt composites)

R&D:

EASA strategy to work with EU funded projects and industry to ensure regulatory resource is efficiently focused upon maturing methods and applications

- Test/analysis pyramid statistical credibility issue within scope of next EU FP - TBD

EASA AM Workshop

June 2018

CLOSE

Next EASA AM Workshop
… 2019 date TBD

Thank you for your interest and support

Particular thanks to: The Presenters

and

Lily Kamburova and Erika Amrhein for organising the agenda and managing this Workshop