AM lessons learnt and their effect on GKNs approach to certification of higher classification structures

2019 EASA-FAA Workshop on Additive Manufacturing

Jon Baxendale | 06/11/19

GKN AEROSPACE

Contents

GKN AM

GKN Aerospace Global Technology Centres

AM & Metallics
- Powder Bed (EBM /LPB)
- Advanced Metallics
- AM Integration (all)
- AM Material Science

UK
Bristol

Thermoset
- Dry Fibre
- Complex Concepts
- Anti-Ice Systems
- Industry 4 System

AM
- Freeform deposition LMD-w for Airframe

US
Oakridge

Metallics
- Metallic Forming
- Spinning
- Complex Ti machining
- Transparencies/ Coatings

Global Technology

Netherlands
Hoogeveen

Composites
- Thermoplastic Welding & AFP
- Thick walled / braided
- Complex Concepts
- Filament Winding

Integrated Systems
- Wiring & Sensors
- Complex Assemblies
- Industry 4 System

Sweden
Trollhatten

AM
- Freeform deposition LMD-w for Engines
- Bi-Metallic Welding & Automation
- Blown Powder AM

New Concepts
- Advanced Engine concepts
- Material technology
- Industry 4 System

Generic Research performed as part of a connected Ecosystem.

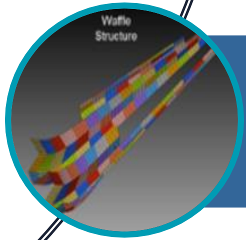
"Fail Fast & Learn"

Technology Demonstration in partnership with our customers.

"Excite the Market"

Application demonstration to prove process capability.

"Proving RFT Quality"



A learning space for people training & development.

"Technical Excellence"

Bristol - Global Technology Centre (GTC) Vision

10,000m^2 Technical Centre

- ATI funded Open Access Collaborative Centre
- Filton location
- Opens Q2 2020

Partners include;
Advanced Manufacturing Research Centre (AMRC), Additive Industries B.V., ANSYS UK Limited, ATS Applied Tech Systems Limited, Centre for Modelling & Simulation, Digital Catapult, KUKA Industries UK Limited, Manufacturing Technology Centre, Materialise UK Limited, National Composites Centre, PXL Realm, Thales UK Limited, University of Bath, University of Bristol and University of Sheffield.

GKN AM Bristol

GKN Aerospace – Additive Bristol Overview

GKN Additive Manufacturing Centre in Filton, Bristol (UK):

- 10 years R&T experience in Powder Bed
- Over 50 engineers, multi-functional team:
  - Material Scientists, Process Specialists, Design, Manufacturing Engineers
- Electron Beam Melting (EBM):
  - Ti64 material, military components flying today
  - Full industrialised solution, including powder recycling
- Laser Powder Bed (LPB):
  - Ti64 – Currently going through certification for topologically optimised civil components. A-Basis static allowables have been generated. TRL 6 scheduled for Early 2020.
  - In718 – High temperature capability at TRL5, now bringing H282 capability to the centre
- Polymer:
  - Rapid prototype capability, including tooling, jigs & fixtures to support production
- Direct Energy Deposition (DED):
  - Direct Energy Deposition capability in next 12 months

GKN AM AS9100 Approval

Certification achieved as a separate GKN business

Approved for Powder bed and down stream related activities

Lloyd's Register

Certificate of Approval

This is to certify that the Management System of:

GKN Aerospace Services Ltd

Trading As: GKN Aerospace Additive - Bristol

PO Box 500 Golf Course Lane Filton, Bristol, BS34 9AU, United Kingdom

has been approved by LRQA to the following standards:

AS 9100D (technically equivalent to EN 9100:2018 and JISQ 9100:2016)

This certification has been performed in accordance with the requirements of EN 9104-001:2013

Lloyd's Register Quality Assurance is accredited under the IAQG ICOP scheme

Certification Structure – Single Site

David Derrick - Area Operations Manager UK & Ireland

Issued by: Lloyd's Register Quality Assurance Limited

Issue date: 18 December 2018
Expiry date: 17 December 2021
Certificate identity number: 10159671

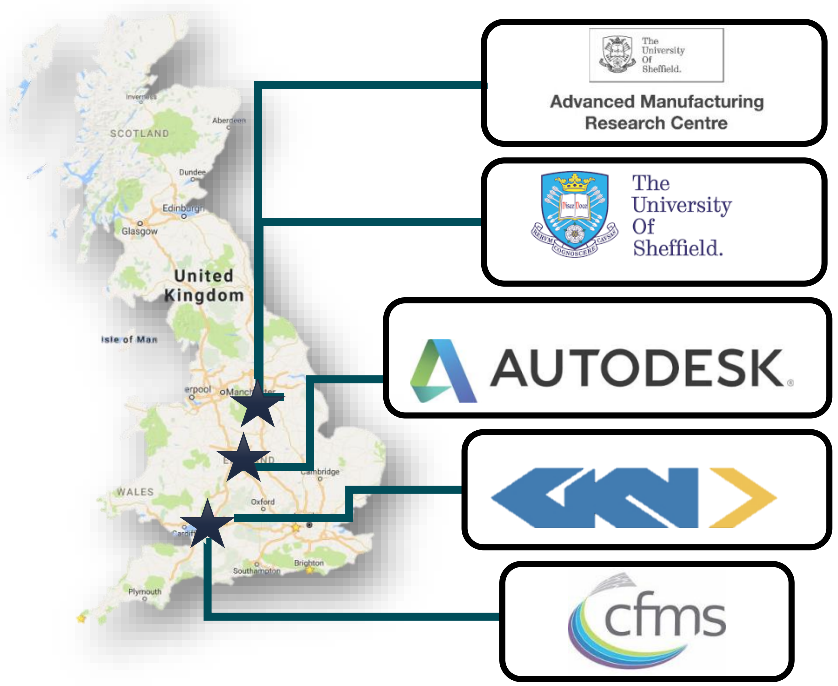
Original approval(s):
AS 9100 - 18 December 2018

Approval number(s): AS 9100 - 0078772

The scope of this approval is applicable to:
Production of additive manufactured metallic components for the aerospace industry and other complex fields, involving the following activities: powder bed additive manufacture, powder re-cycling and re-certification for internal operations and management of component finishing activities.

UKAS MANAGEMENT SYSTEMS 001

AIRLIFT & DAM Programme Overview



- 4 year collaborative R&D projects
- Funded by the Aerospace Technology institute (ATI)
- Bringing together partners with unique skillsets from industry, research and technology institutes, catapults and academia
- £32M across all partners over 4 years

AIRLIFT and DAM

AIRLIFT - Additive IndustRiaLIsation for Future Technology

A technology industrialisation programme which uses industry 4.0 and simulation competencies to develop LMD-w & powder bed

Industrialisation and large scale

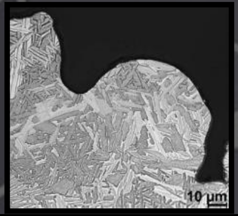
Digital twin for AM

LMD wire factory pilot line

DAM - Developing Design for Additive Manufacturing

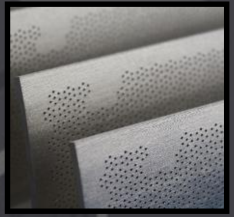
Develop the next generation of design tools, methods and people to exploit AM using a data driven material centric approach

Material Centric Design



Generative Design

Functional systems



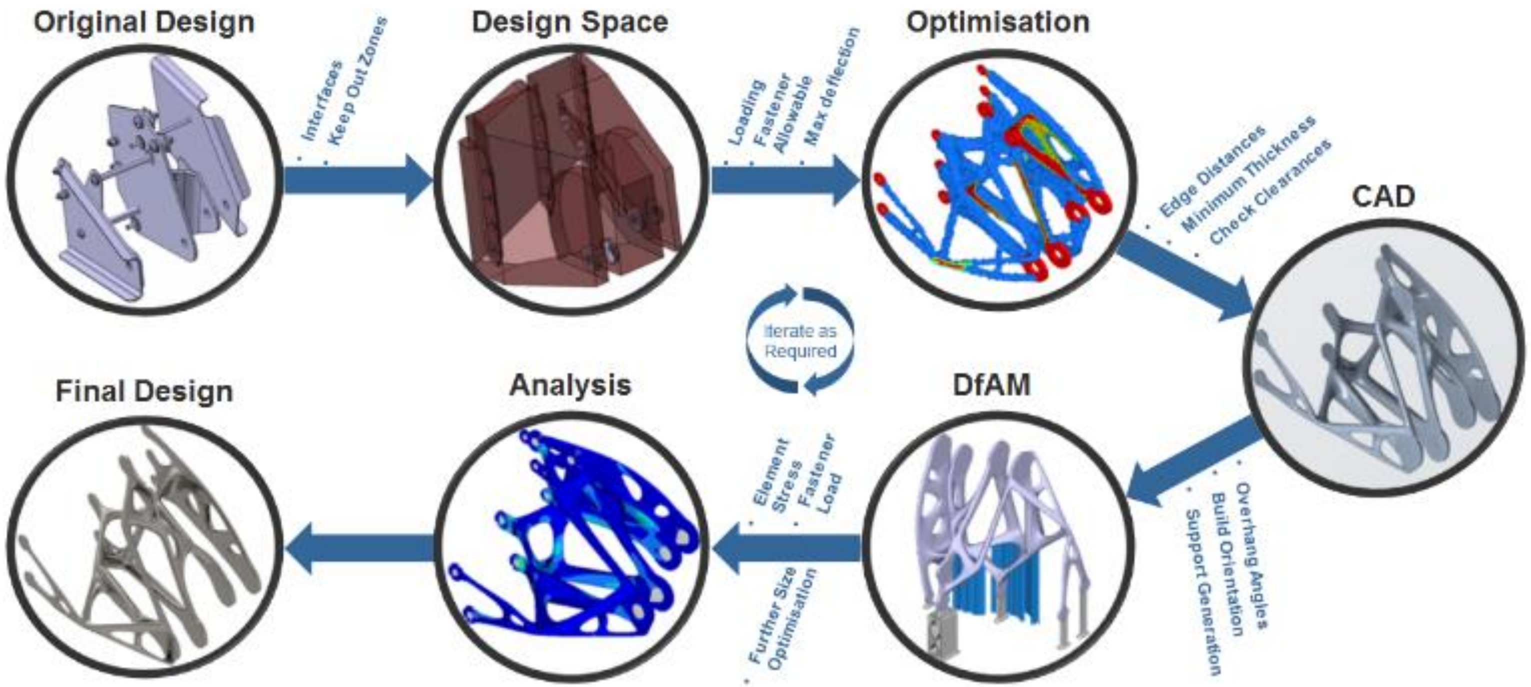
Case Studies

Flight Control Pulley Support (Consultancy)

Collaboration with aircraft manufacturer to redesign Pulley Support System.

Benefits

- Ground up AM design optimised for loads and design space
- 33% weight saving
- 38 parts into 1
- 20% cost saving

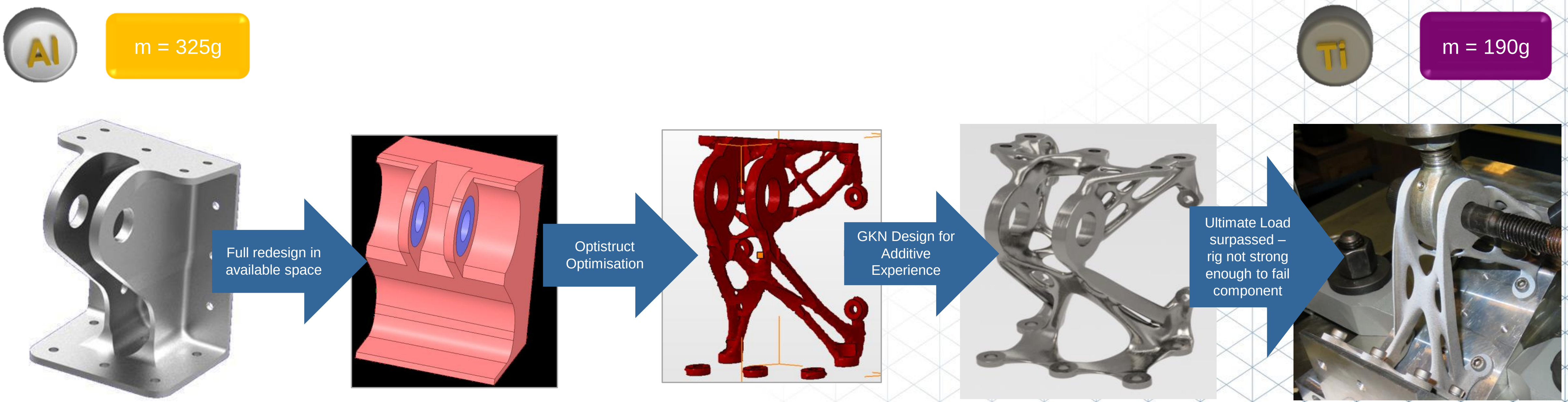


Hinge Bracket (Demonstrator)

GKN initiative to demonstrate the benefits of topology optimised structures using AM processes by the R&T team.

Benefits:

- Significantly reduce mass through topology optimisation (~40%)
- Used the additional strength provided by Ti material to significantly change the design
- Design bounded by Strength & Displacement requirements
- Component exceeded test rig safety limit – could not be broken

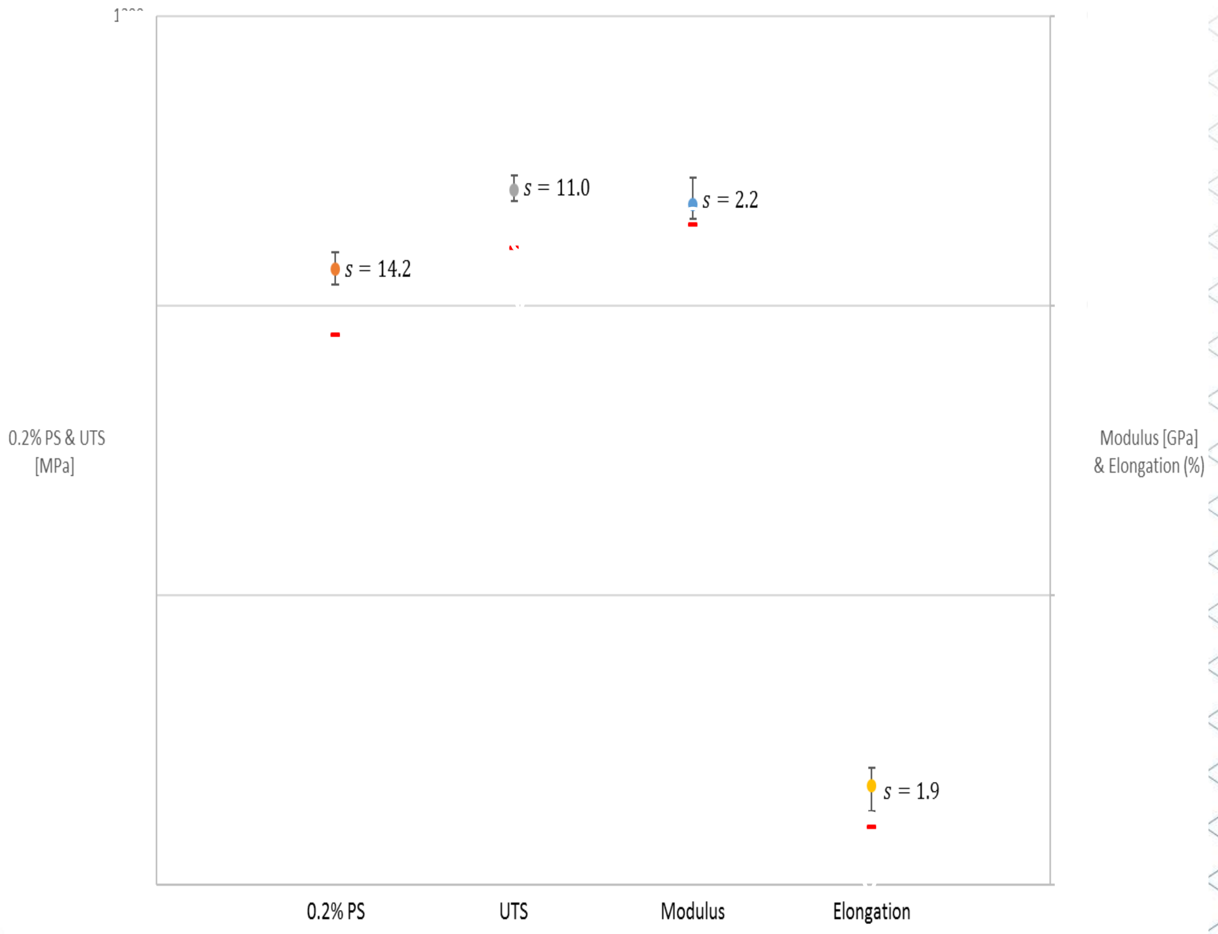


Catcher Bracket (Demonstrator)

Collaboration with customer to demonstrate use of EBM on high classification part.

Benefits:

- Demonstrated use of EBM on Q20+ was suitable to manufacture thick wall Ti64 components.
- Distortion compensation implemented to minimise amount of ‘stock-on’ material required.
- Post machining of AM Ti64 components methodology demonstrated.
- All customer requirements met.
- Identified that customer requirement for NDT was a key blocker for progressing the project.



Saab Low Criticality Components (Flying Parts)

GKN collaboration with Saab to integrate AM technology within Gripen E and TX Trainer platforms. Parts manufactured on Arcam A2XX machine.

Benefits:

- Demonstration of component cost saving
- 11 different components fabricated using AM
- Certification of low criticality components
- In-production thin-walled EBM parts

Pilatus Nacelle Access Panel Hinges (Certification due 2019)

GKN collaboration with Pilatus to replace traditionally manufactured parts with LPB topologically optimised parts. Parts manufactured on EOS M290 machine.

Benefits:

- Demonstration of component weight and cost saving for customer
- 4 different components redesigned to be topologically optimised and fabricated using AM
- **Generation of static (tensile and bearing) A and B basis values for geometries of 2mm thickness**
- Certification of class 3 components with EASA

The following work packages were created for the project;

1. Design Support
2. Material Specifications
3. Build Process Specifications
4. Material Allowables Generation
5. Component and Assembly Level Testing
6. FAI and Entry into Service

Pilatus Nacelle Access Panel Hinges (Certification due 2019)
1. Design Support

The customer supplied GKN with existing non AM designs and some initial AM concepts they had generated at the outset of the project.

GKN provided AM expertise to modify the concepts to ensure that the designs were able to be manufactured, this consisted of the following stages;

- AM concept design review and providing initial feedback
- Design iteration
- Support structure design and nesting concepts
- Performing build simulations
- Manufacturing trial components
- Preliminary component testing conducted by the customer
- Final drawing/model release

Extant Designs

AM Designs

A key to success was the customers willingness to accept GKN feedback and modify designs accordingly.

Pilatus Nacelle Access Panel Hinges (Certification due 2019)
2. Material Specifications and 3. Build Process Specifications

EASA CM Additive Manufacturing No.: CM-S-008 Iss 01

It is essential that design values used for AM materials reflect not only the variability of the constituent materials as purchased by the suppliers, but also the variability introduced by the manufacturing process used to fabricate production parts. AM variability is to be shown to be controlled through material specifications in combination with process controls defined in process specifications, including post processing operations. As required by 21.A.31, these specifications (for both, material and process) as well as the method(s) of manufacture, shall be introduced in the type design under the design approval applicant or holder responsibility.

Design Organisation Approval Holders as well as ADOA are advised to involve the Agency at the earliest opportunity during the development and implementation of AM.

Production Organisation Approval holders are advised to inform their respective competent authorities at the earliest opportunity before the implementation of AM processes.

The customer holds DOA and POA for the parts but are not experts in AM. Therefore part of the SoW required GKN to provide material and process specifications that they could use to show compliance to EASA.

GKN have generated and provided powder material specifications and LPB process specifications which have now been embedded into the customers specifications.

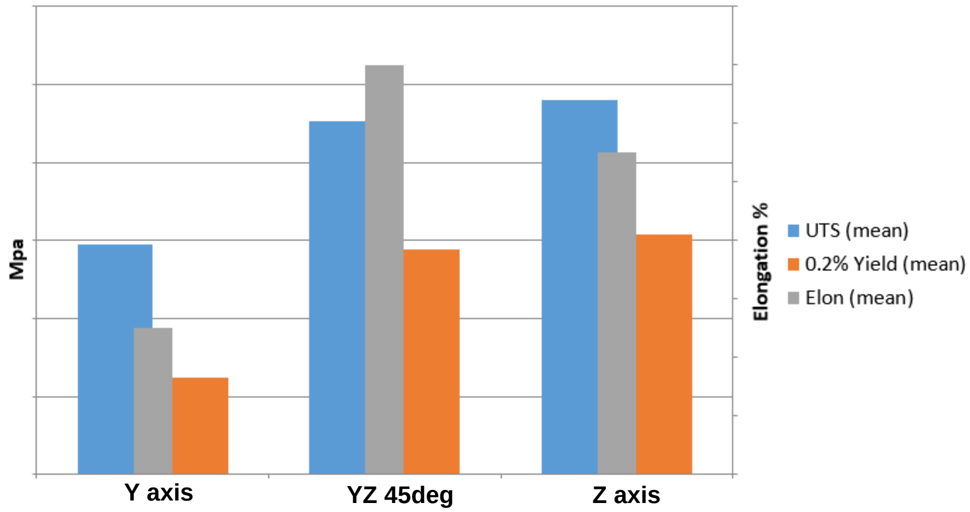
Pilatus Nacelle Access Panel Hinges (Certification due 2019)
2. Material Specifications and 3. Build Process Specifications

- Guidance taken from many sources in generating this documentation including AMS, ASTM, NASA, FAA job aid, NADCAP plus internally from GKNs R&T team.
- The following list of powder and build process specifications have been provided to the customer or are referenced within their specifications;
  - SPEC TS 101 Titanium Powder for Powder Bed Fusion Additive Manufacturing
  - SPEC PS 102 Ti-6Al-4V Powder intended for Laser Powder Bed Additive Manufacturing
  - SPEC MS 102 Ti-6Al-4V Powder for Laser Powder Bed Additive Manufacturing
  - SPEC TS 201 Process Technical Specification for Powder Bed Fusion
  - SPEC MS 202 Process Manufacturing Specification for the Production of Ti-6Al-4V Parts Using the EOS M290

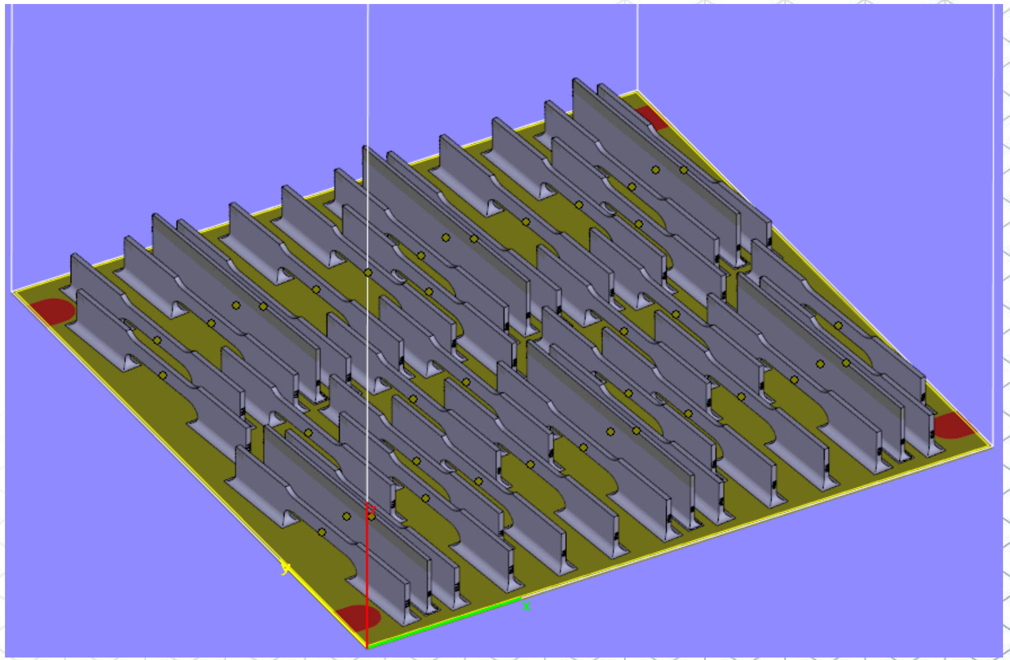
Pilatus Nacelle Access Panel Hinges (Certification due 2019)
4. Material Allowables Generation

Allowables generated (tensile & bearing only) used conservative approach, from reviewing R&T data at TRL 4 the following had been determined;

- As deposited coupon properties worse than machined
- Thin coupon properties worse than thick for as deposited coupons
- Coupon tensile strength properties in XY plane worse than other orientations for as deposited coupons



Test campaign with large number of coupons that statistically reflect manufacturing variation in production (i.e. powder, surface effect, build quality, etc.)



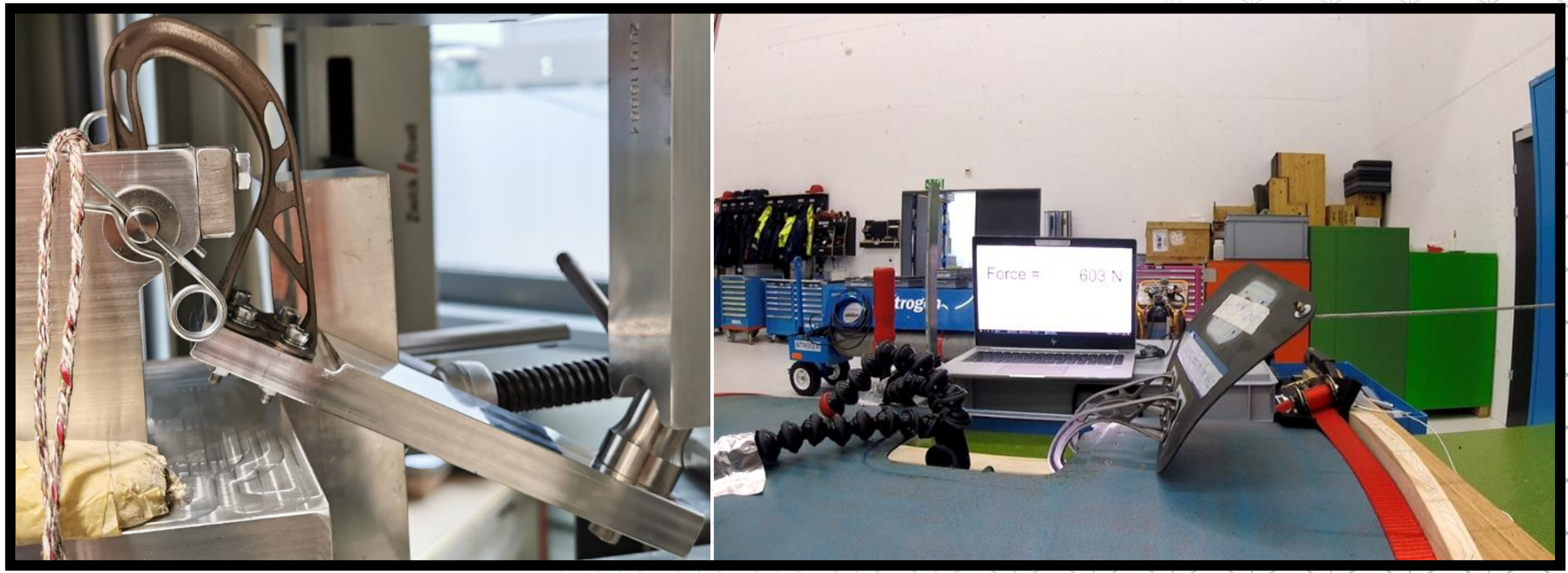
Pilatus Nacelle Access Panel Hinges (Certification due 2019)
4. Material Allowables Generation

Tensile				
	YTS (MPa)		UTS (MPa)	
A-basis	817		904	
B-basis	846		930	
Bearing				
	e/D= 1.5		e/D= 2.0	
	YBS (MPa)	UBS (MPa)	YBS (MPa)	UBS (MPa)
A-basis	1305	1510	1513	1876
B-basis	1351	1553	1566	1930

Pilatus Nacelle Access Panel Hinges (Certification due 2019)
5. Component and Assembly Level Testing and 6. FAI and EIS

- The customer submitted a Qualification Test Plan to EASA very early on in the project.
- Manufacture of parts for component and assembly level testing has been completed and test reports are in the process of being generated.
- Certification from EASA is currently forecast by the end of 2019. FAI will be completed in 2020 and Entry into Service will follow.

Manufactured Parts

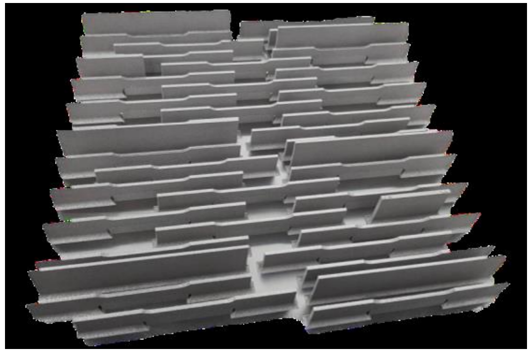


Component & Assembly Testing
Courtesy of Pilatus Aircraft Ltd

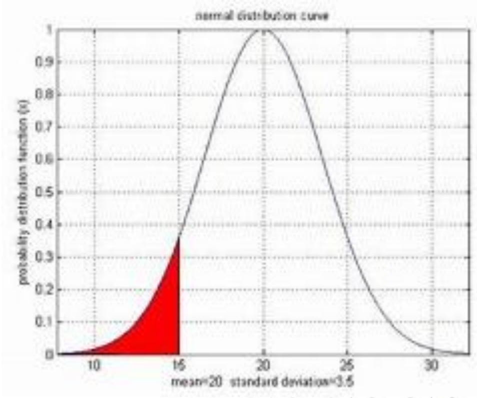
Pilatus Nacelle Access Panel Hinges (Certification due 2019)

Material & Process Specifications

Material & Process Qualification

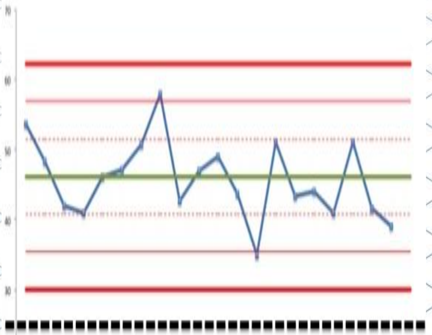


Static Test Campaign



Calculation of allowables and release of drawings

Component and Assy testing



Use of SPC

LCL ≠ material allowable

Lessons Learnt

- Parts need to be designed and nested considerate of all follow on processes.
- Having one build complete does not guarantee future builds will do likewise.
- Use of simulation helps but does not currently guarantee ‘right first time’.
- Elimination of powder contamination is difficult.
- Challenges in the supply chain, predominantly two causes;
  - Companies with vast aerospace experience but AM is new to them (Tooling, Machining, Surface Finishing, Inspection).
  - Companies with vast AM experience but material manufacture in aerospace is new to them (Machine OEMs).

Route to certification of higher class structures

Additive Bristol certification approaches

Initial approach (Part Based)

EQUIVALENCE PART BASED CERTIFICATION USING S BASIS ALLOWABLES

- Compare AM vs Cast Material… Or wrought!
- Demonstrate Large Reserve Factor vs Existing Dataset
- Reduces benefit of AM Material Potential
- Certification may only be valid for builds in which S basis coupons were co-produced.
- Empirical Certification – Aggressive Schedule

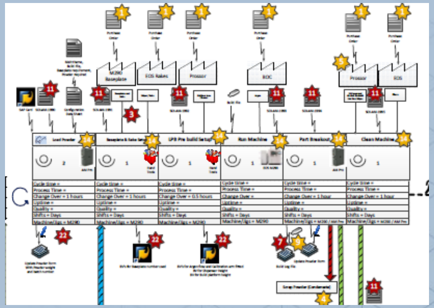
Current approach (Process Based but with extensive part testing)

PROCESS / PART BASED CERTIFICATION USING A BASIS ALLOWABLES

- Frozen material and process specifications required.
- Design & analyse parts using allowables generated for AM material. Perform part testing to validate use of allowables
- Certification only valid for parts using frozen nest.
- Medium schedule

Future approach (Process Based)

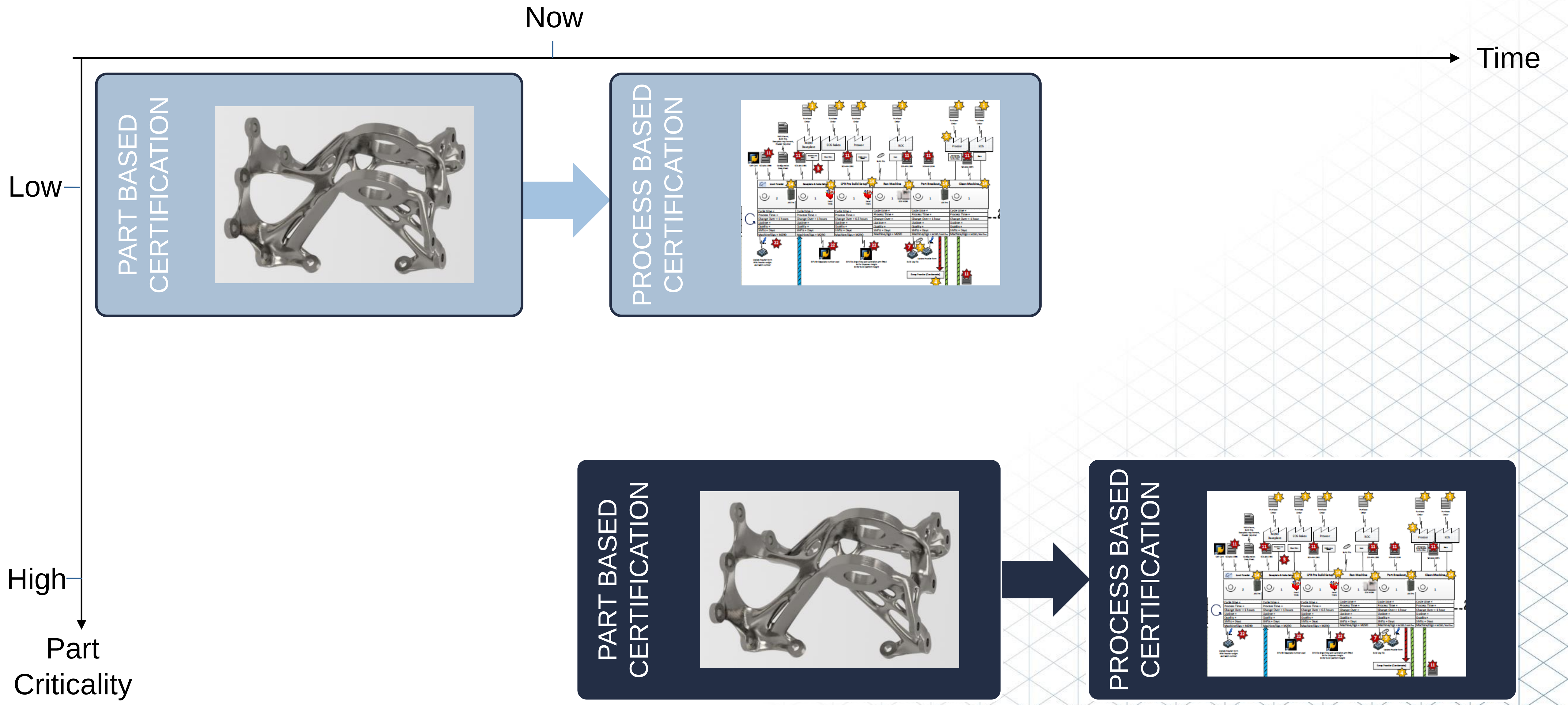
PROCESS BASED CERTIFICATION



- Frozen material and process specifications required.
- Population specific process parameters
- Certification valid for parts conforming to defined characteristics
- Longer timescale

Evolution of Approach to Certification

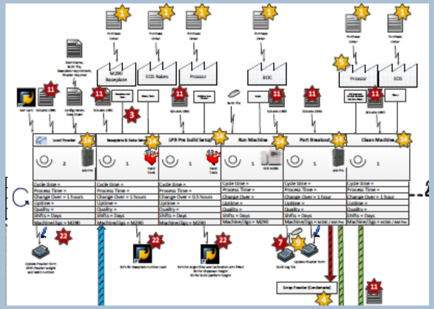
Certification approach evolution



Challenges associated with evolution (part to process)

PART BASED CERTIFICATION

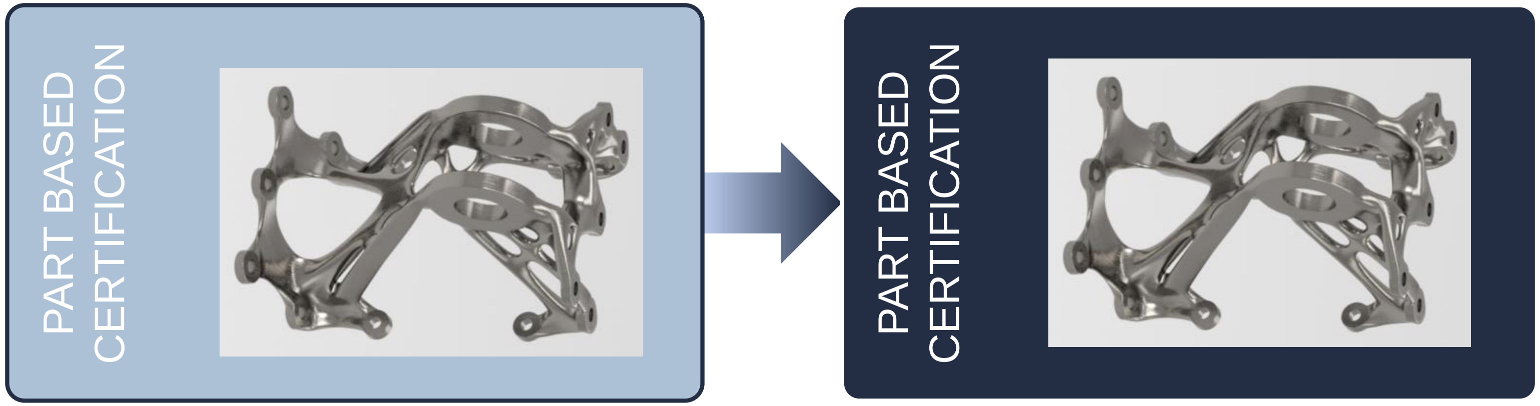
PROCESS BASED CERTIFICATION



Demonstrate equivalence between coupons and all parts manufactured using that process.
Potential to resolve by;

- Use of in situ monitoring methods
- Simulation of microstructure and defects
- Generation of kdf’s

Challenges associated with evolution (low to high criticality)

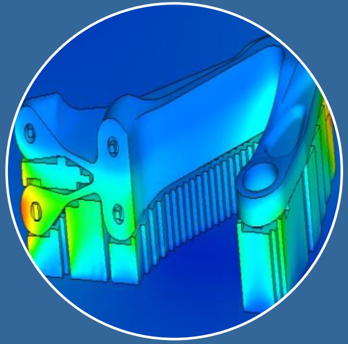


Many activities required across multiple topics including;

- Raw Material
- Design methods
- Machine OEMs
- Manufacturing
- NDT
- Destructive Testing

Challenges to certify higher classification structures

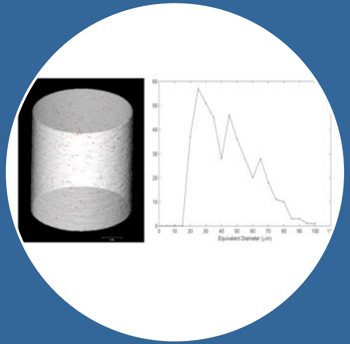
Raw Material



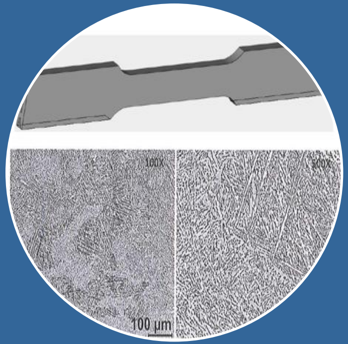
Design

Machine OEM

Manufacturing



NDT



DT

Raw Material
- Eliminating contamination in powder is difficult.
- How clean is clean?
- Inspection methods for contamination.
- Methods for influencing raw material properties

Design
- Microstructure simulation.
- Defect/anomaly distributions and frequencies to be obtained (through simulation and/or test)
- Lifing methodologies

Machine OEM
- Maintenance.
- Calibration.
- Obsolescence.
- Software revisions.

Manufacturing
- Seeding of defects.
- Specifications and KPV limit expansion.
- Robust production methods need developing.

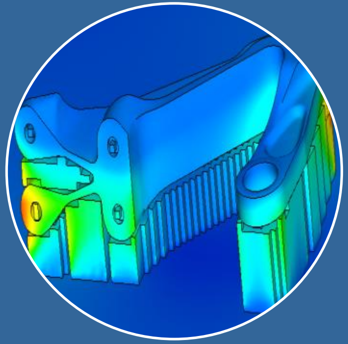
NDT
- Existing methods may not be applicable to AM. POD for methods req'd
- CT scanning is expensive
- In situ monitoring needs to become a capable and acceptable means of inspection.

DT
- Fatigue, fracture toughness) including effect of defects/anomalies
- MMPDS being updated to include new volume covering AM

Work being done by GKN to solve these challenges (DAM)

Raw Material

- Work on-going to develop robust methods for contamination control and powder inspection.



Design

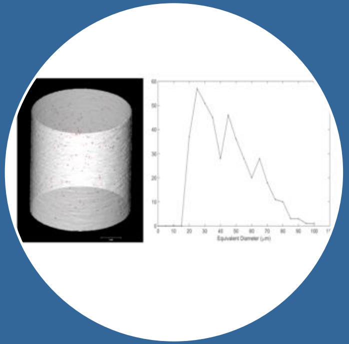
- Feasibility studies of simulation and modelling tools for microstructure formation.
- Influence of surface roughness on materials properties.
- Structural simulation of defects.

Machine OEM

- Driving OEMs to become compliant to standards (e.g. AMS 7003).
- Methodologies to be developed to resolve obsolescence and software updates.

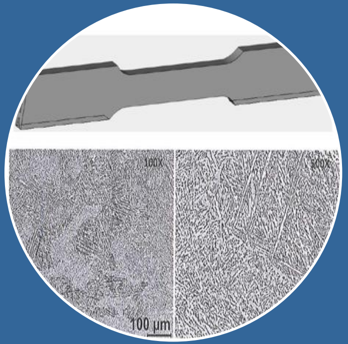
Manufacturing

- Understand microstructure formation rules.
- Propose methods to control the microstructure.
- Advanced PBF Support Structures.
- Post-Processing Enablers.
- Build review methods being developed



NDT

- Evaluate off the shelf solutions for in situ defect detection and monitoring
- Substantiation of in situ defect detection using 'traditional' methods



DT

- Low-cost and Small coupon testing (SPT)
- Probabilistic framework for AM

Thanks for listening

Any questions?

Jon Baxendale (Assistant Chief Engineer)
+441173176516
jonathan.baxendale@gknaerospace.com