EASA
European Aviation Safety Agency

Digital Transformation of Production –challenges and opportunities for industry and regulators

Moderator

Panellist

Matthew Mercy

Simon Waite

Neil Mantle

Panel 2

Jose Sanchez-Gomez

Yann Marchal

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EASA
European Aviation Safety Agency

Panel 2: Digital Transformation of Production – challenges and opportunities for industry and regulators

Bratislava

October 2016

S.Waite: Senior Expert – Materials – EASA Certification Directorate

M. Mercy: Project Certification Manager – Propulsion - EASA Certification Directorate

Jose Sanchez-Gomez -Executive Expert Composite Materials - Airbus Group

Yann Marchal - 3D Woven Composites Parts Centre of Excellence - Safran Aircraft Engines

Neil Mantle - Head of Additive Layer Manufacturing - Rolls-Royce plc

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EASA Annual Safety Conference: New Technologies & New Business models

Panel 2: Digital Transformation of Production – challenges and opportunities for industry and regulators

Technologies in production are changing the landscape of both design and manufacturing.

The aerospace industry is a global industry, using novel **materials and processes** and it is already a pioneer in many of these technologies.

What are the challenges and opportunities for both industry and regulators?

…current themes include… Composites and Additive Manufacturing (AM)

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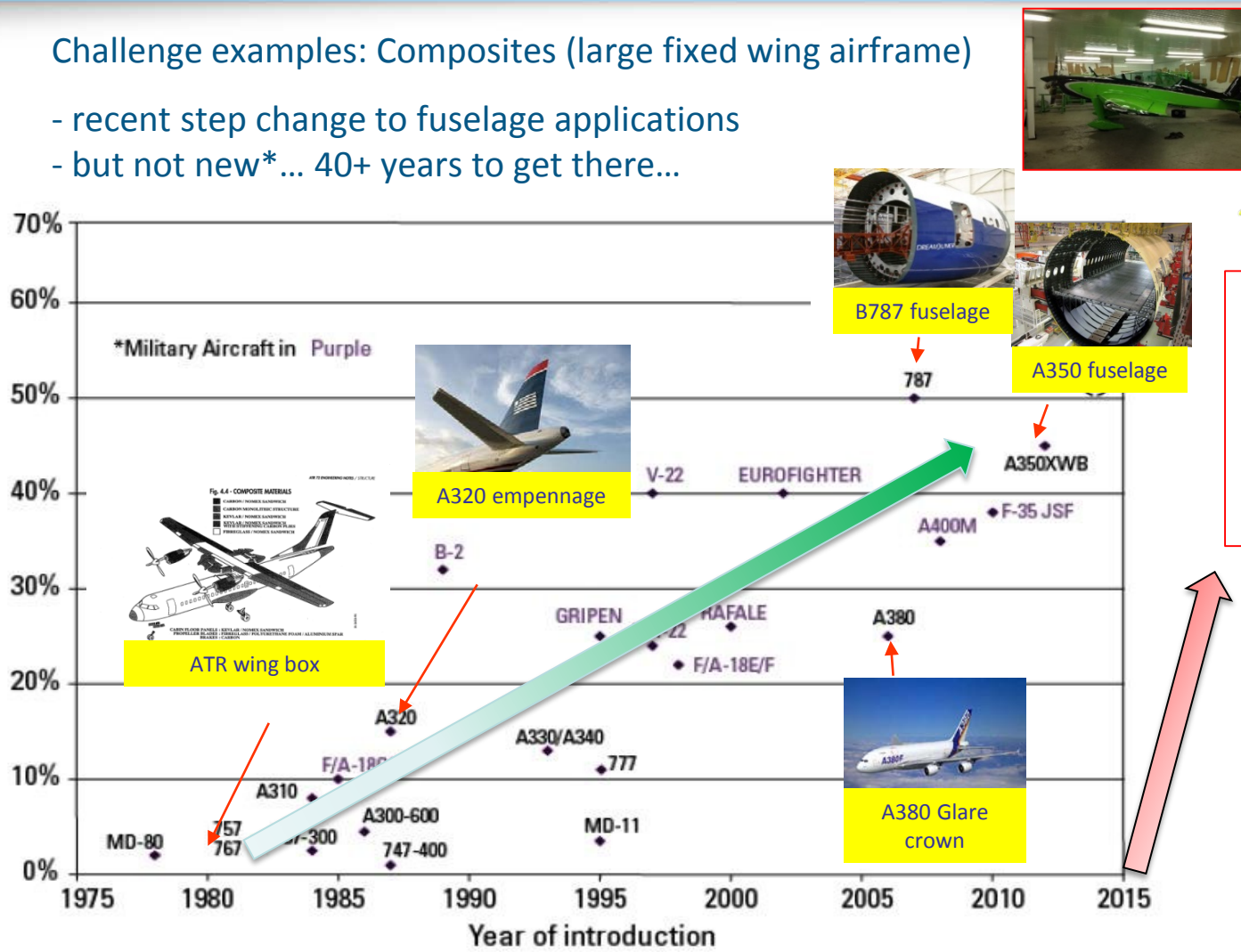
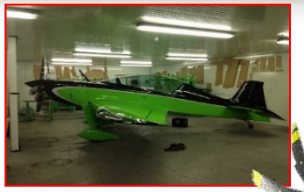
Challenge examples: Composites (large fixed wing airframe)

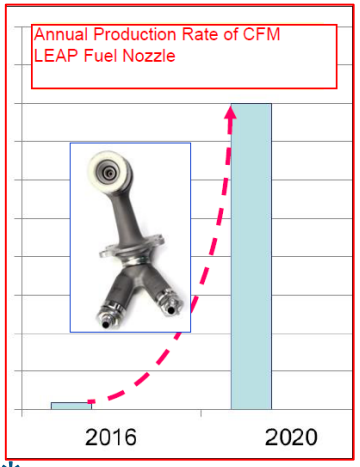
- recent step change to fuselage applications
- but not new*… 40+ years to get there…





Additive Manufacturing: rapid application

- ?? % weight
- criticality?



sandwich secondary structure - primary control surfaces – PSE monolithic structure

* systems – fuel nozzle.

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Digital Transformation of Production – challenges and opportunities for industry and regulators

Challenges:

technology and business models diverging…

- many **new 'materials and processes'** defining **'engineering properties'**
  - more **integrated technologies** - complex parts and repairs
  - increasing reliance upon **process control** relative to inspection
  - **new and competing damage modes** (some difficult to inspect/detect)

- **globalisation** - extensive **globally dispersed sub-contracting** within/between design, production, and maintenance activities

- **compressed timescales** – accelerated introduction into increasingly **critical applications**

- **appropriate staff knowledge base** - industry and regulators (training?)

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Agenda

Industry Presentations :

1. A350 Manufacturing Process at Illescas Plant Wing Lower Cover and Section 19
   Jose Sanchez-Gomez - Airbus Group - Executive Expert Composite Materials
2. LEAP composite fan blade technology: from early designs to certification
   Yann Marchal Safran Aircraft Engines – Expert in the 3D Woven Composites Parts Center of Excellence
3. Additive Layer Manufacturing
   Neil Mantle – Head of Additive Layer Manufacturing Rolls-Royce plc

EASA

1. Enabling Technology – An Agency Perspective

Panel summary/discussion (all – lead M. Mercy)

ESCAA
Dr. Jose Sanchez
Composite Central Tech. Authority

A350 Manufacturing Process WLC and S19

AIRBUS

Meet the Airbus family from 100 to 500+ seats

A320 Family

The market leader

A330 Family

The right aircraft, right now

A350 XWB

The Xtra that makes a difference

A380

Own the sky

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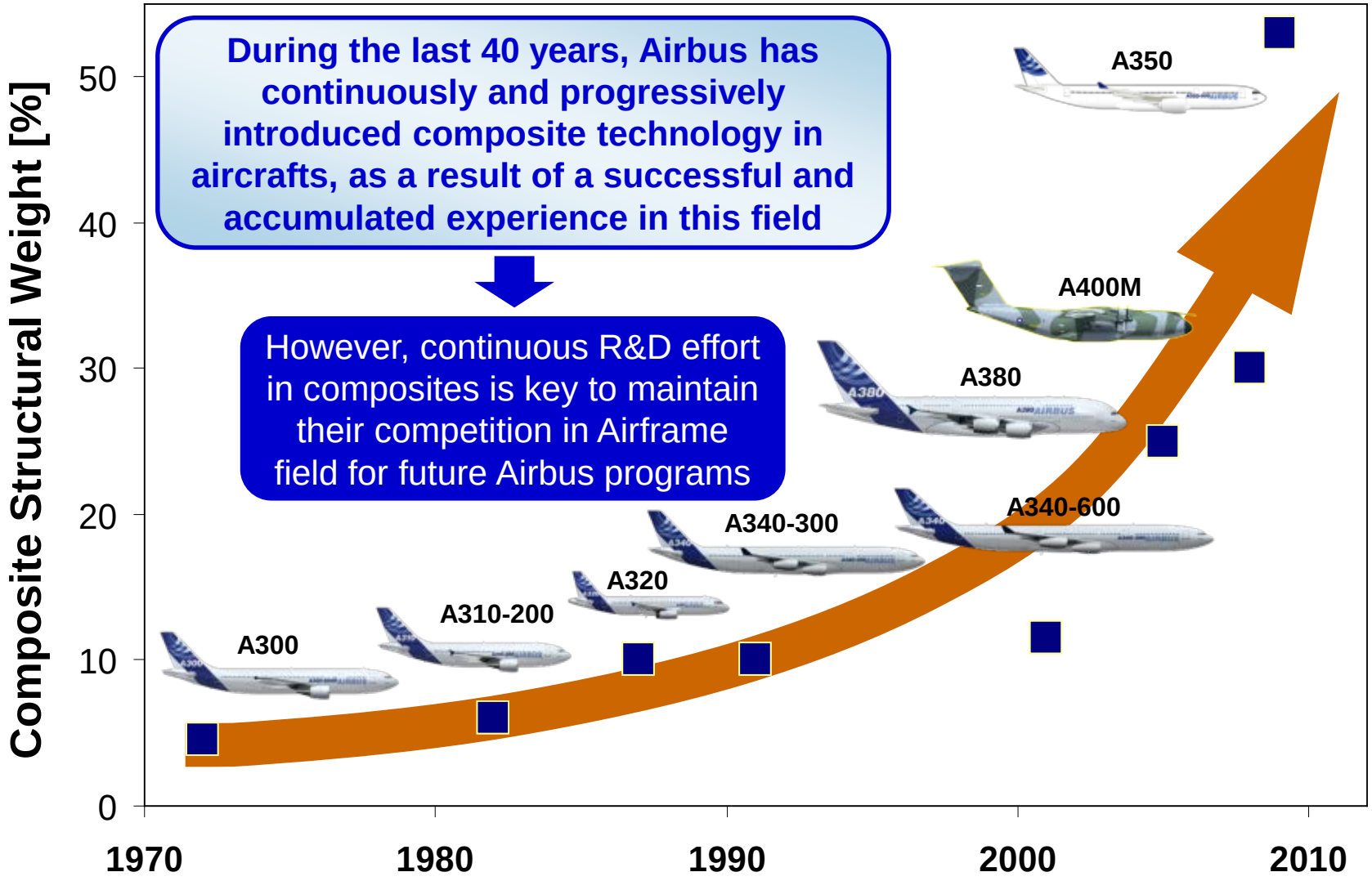
Composite use in Airbus A/C: a sustained increase



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A350 Manufacturing Process at Illescas Plant - WLC

Wing Lower Cover

Tooling Preparation → Lay up *(AFP / ATL)* → Vacuum Bagging → Autoclave Curing → Debagging

Stringer process steps

Flat layup *(AFP)* → Cutting → Forming (Press) → Loading on curing tools → Stringer placement on skin → Vacuum Bagging

Tooling Preparation → Loading on curing tools

Final operations

Autoclave Curing → Trimming → Root joint shims → NDI → Man hole gaskets. → Dimens. Inspect. → Painting → Sub-assy Operations → Delivery

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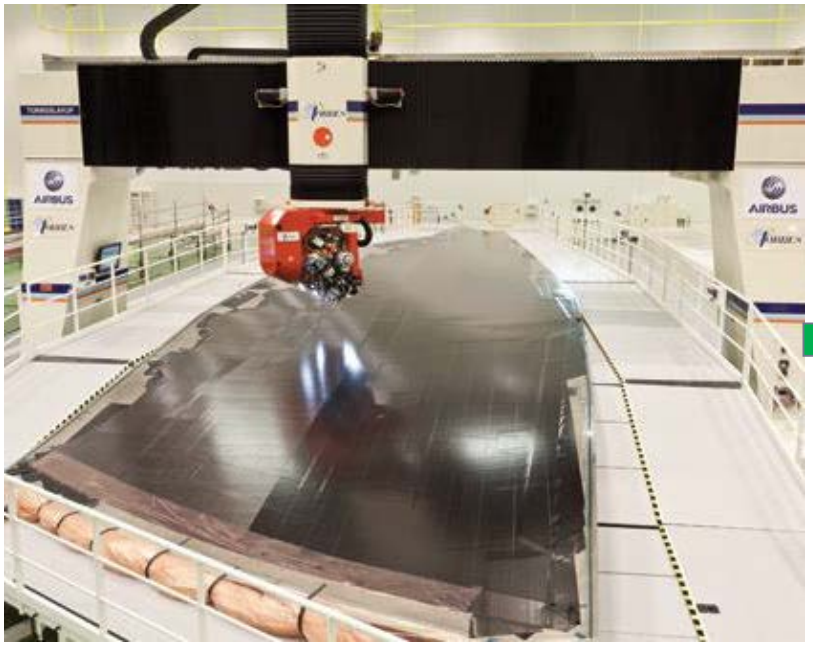
A350 Manufacturing Process at Illescas Plant - WLC

Lay-up

Standard Process
Automated Tape Layup (ATL)



New Process
Automated Fiber Placement (AFP)

- ✓ Reduction of material scrap
- ✓ Improvement of productivity rate

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A350 WLC Manufacturing Process

- ✓ Before implementation of the FP manufacturing process in a real part, robust development of the process, including manufacturing tolerances has been performed
- ✓ As last step First part qualification (FPQ) have been performed determining defectology and correlation with NDT results
- ✓ Typical defectology produced due to this new process and its influence in the structural test pyramid have been considered during structural testing

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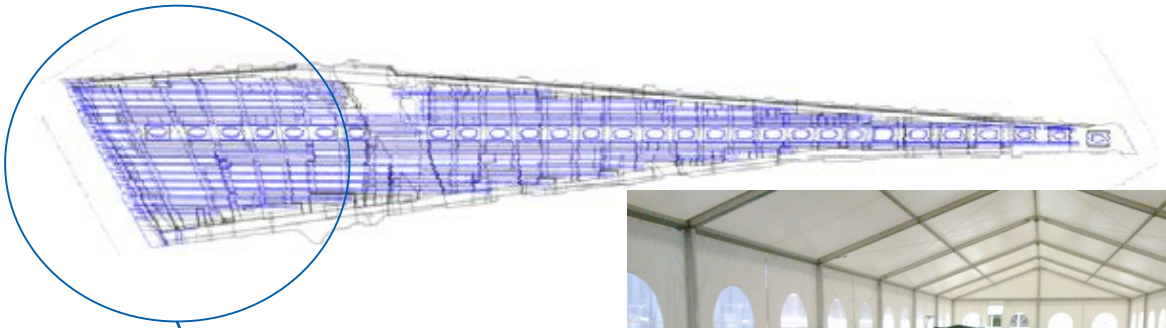
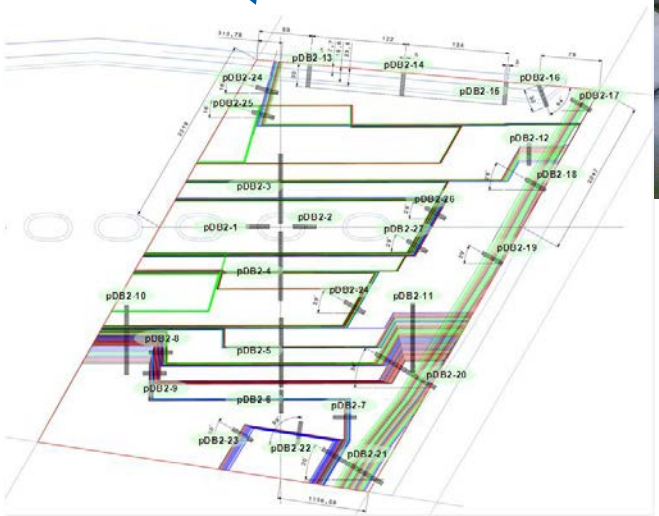
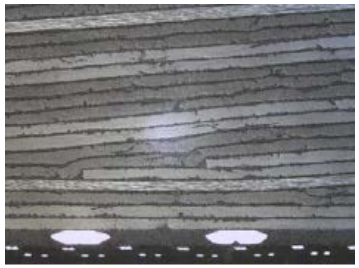
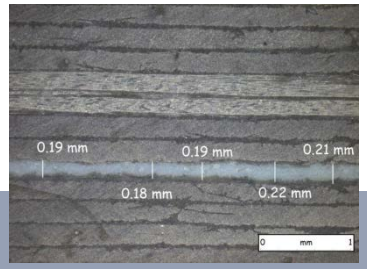
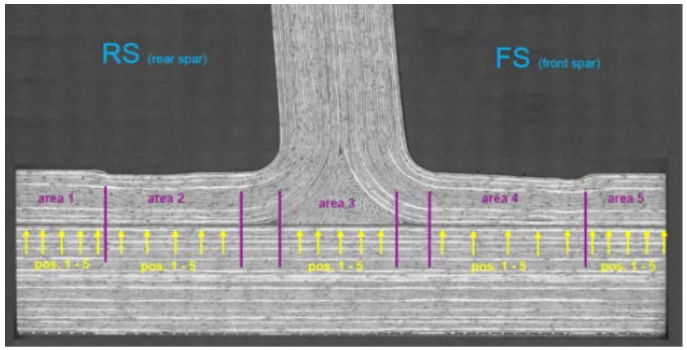
A350 Manufacturing Process at Illescas Plant – WLC FPQ











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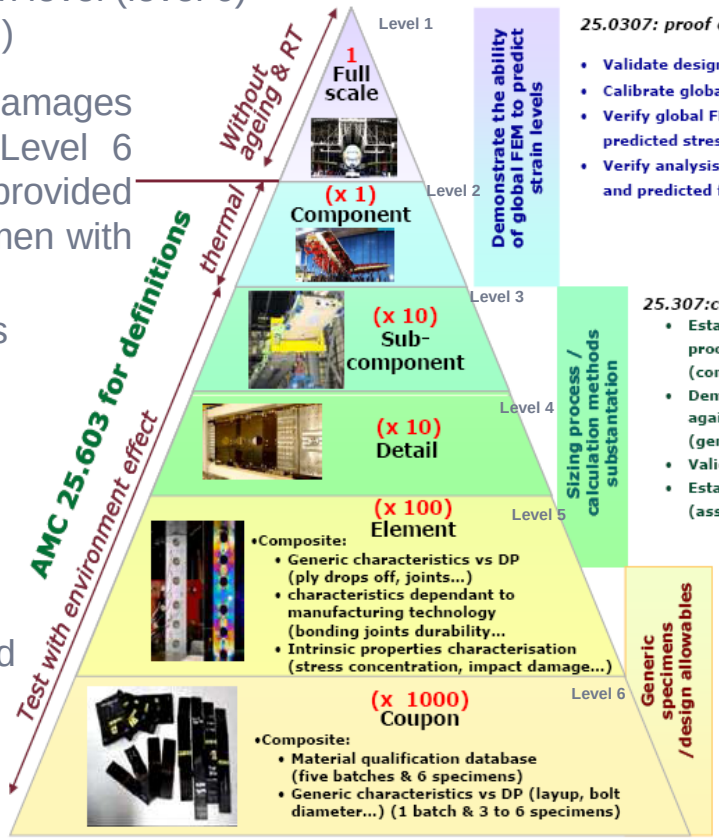
A350 Manufacturing Process at Illescas Plant – Structural tests validation

- ✓ A test pyramid approach has been followed for validation of the structure provided with typical manufacturing defects and damages due to impacts
- ✓ The test pyramid going from tests at coupon level (level 6) to full scale test at component level (level 2)
- ✓ The number of specimens and number of damages varies depends on the specimen size. Level 6 corresponds to hundred of specimens provided with one damage and level 2 is one specimen with hundred of damages
- ✓ Level 5 and 6 are used to obtain allowables for different configurations (lay up & thickness), different design details (stringers, skin panels, stiffened panels, holed panels, etc), in different temperature and humidity conditions
- ✓ Level 4 to 2 are used for design validation purposes. The specimens are manufactured following same manufacturing process and includes artificial damages to simulate porosities, delaminations, scratches or disbondings. Additionally, damages due to impacts are included.



Demonstrate the ability of global FEM to predict strain levels

25.0307: proof of structure (max strain level)

- Validate design & assembly concepts
- Calibrate global FEM
- Verify global FEM predicted stress/strain distribution
- Verify analysis methods and predicted failure modes

Sizing process / calculation methods substantation

25.307:consolidation of methods applicability

- Establish analysis methods and computing process from generic up to specific features (combined effects)
- Demonstrate accuracy of the methods against predicted failure mode (generic single characteristics)
- Validate EKDF applicabilty
- Establish manufacturing process capabilities (assembly/parts vs inspection methods)

Generic specimens /design allowables

25.603-605-613

- Establish strain characteristics with defined failure modes
- Define statistical basis due to material / technology variability (A&B values)
- Establish EKDF per characteristic
- Establish standards specification (materials / manufacturing)

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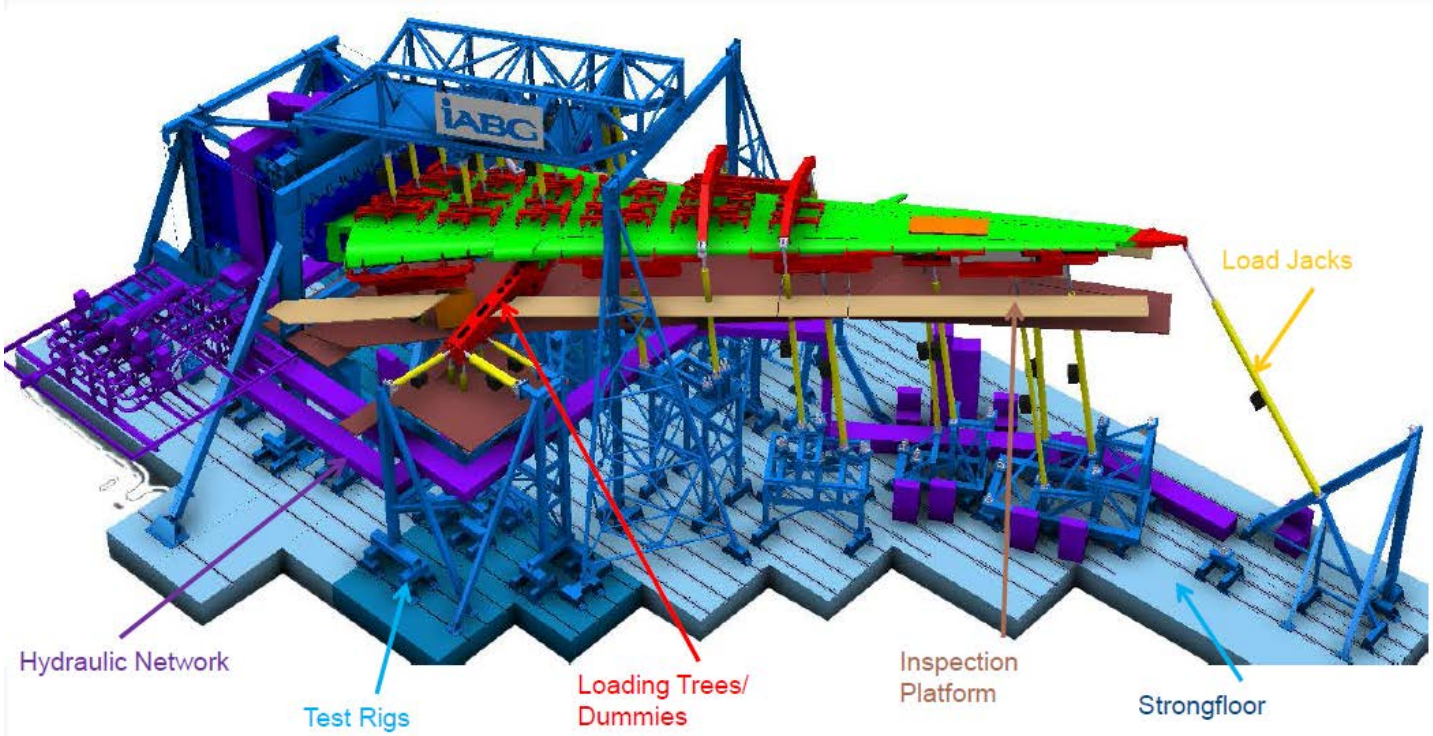
A350 Manufacturing Process at Illescas Plant – Structural tests validation – Wing Level 2 - EW



Aspects considered when defining defects and impact locations were :

- Geometrical features
- High Strain regions
- Critical sizing load case
- Design Failure modes and RFs

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A350 Manufacturing Process at Illescas Plant – Section 19

Section 19

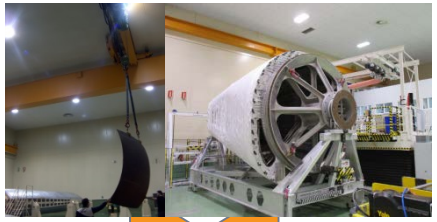
Stringer Flat ATL & NC Cutting

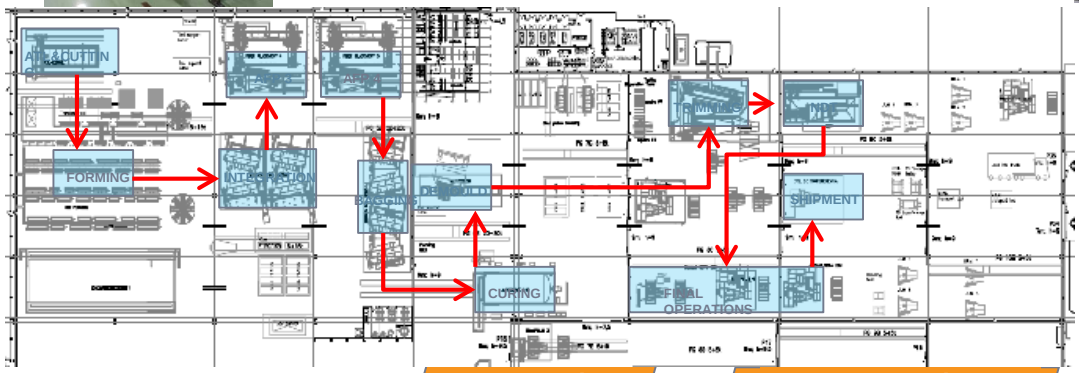
Stringer Press Forming & Omega Set up

Stringer Integration into mandrel

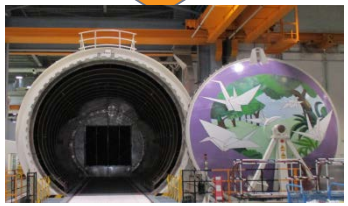
Skin FP Lay Up

Caul plate positioning& Bagging





Autoclave Cocuring



Shipment tool

Final Operations

Automatic NDT inspection

Automatic trimming, drilling and measurement

Demoulding

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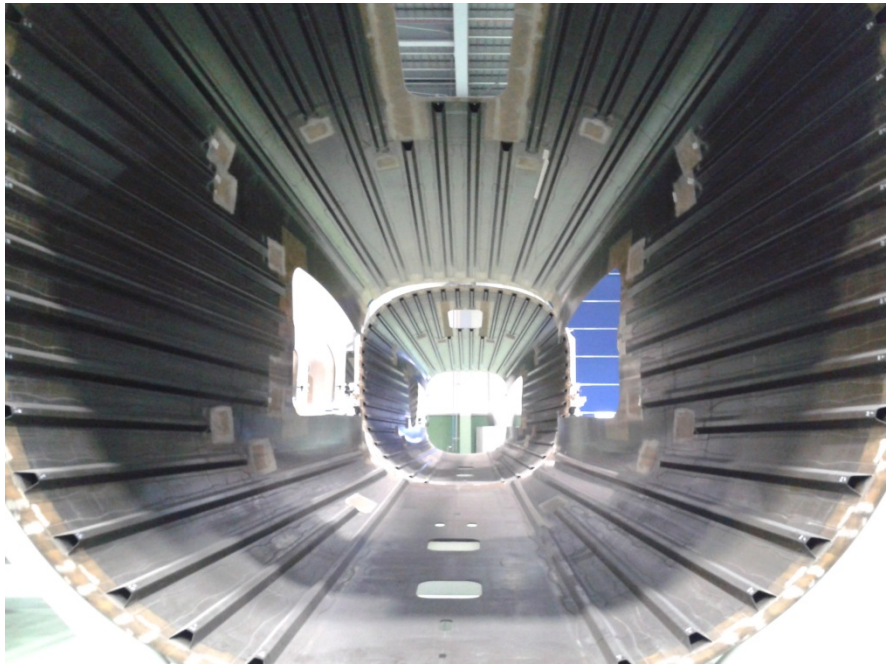
A350 Manufacturing Process at Illescas Plant – Section 19

Section 19



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A350 Manufacturing Process – Conclusions

- ✓ Percentage of Composite Materials on Airbus aircrafts structures has increased during the last 40 years continuously and progressively as a results of a successful and accumulated experience in this field.

- ✓ As an example, in the last Airbus A350 aircraft, 53% of the structure is made in Composite. Fuselage sections and Wing skins are made in Composite.

- ✓ To improve process reliability, substitution of manual operations by automated processes is key next step. R&D is focused on these developments to use automated robust processes and be able to rationalize PCS and NDT inspections. For example, development of new automated surface treatments for structural bonding application.

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AIRCRAFT ENGINES

LEAP COMPOSITE FAN BLADE TECHNOLOGY

FROM EARLY DESIGNS TO CERTIFICATION

—

October 25th 2016

EASA Safety Conference

Yann Marchal
Safran Aircraft Engines

SAFRAN

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1

DESCRIPTION OF THE TECHNOLOGY

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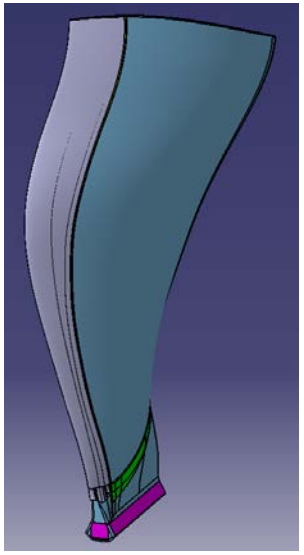
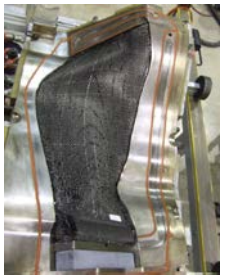
LEAP FAN Blade Technology

	LEAP-1A/C
General Parameters	
Diameter	78
Type of fiber reinforcement	3D woven
Fiber	IM7
Resin system	PR520
Leading Edge	Ti64
Erosion Protection	
Pressure side	Polyurethan film + paint
Suction side	PU paint
Wear protection	Post bonded Low friction wear material
Highlights	
Prime reliable	flowpath
Life	> 100 000 cycles
Life certification	Test
Allowables	A-Basis
Endurance limit	5.10^8 HCF



From an optimized weave pattern made for damage tolerance…

…Through a robust and automated weave process…



…And Resin Transfer Molding toolings made for high manufacturing rates…

…To a high performance, low weight, incredibly durable fan blade

Titanium

-50%

Weight

Composite

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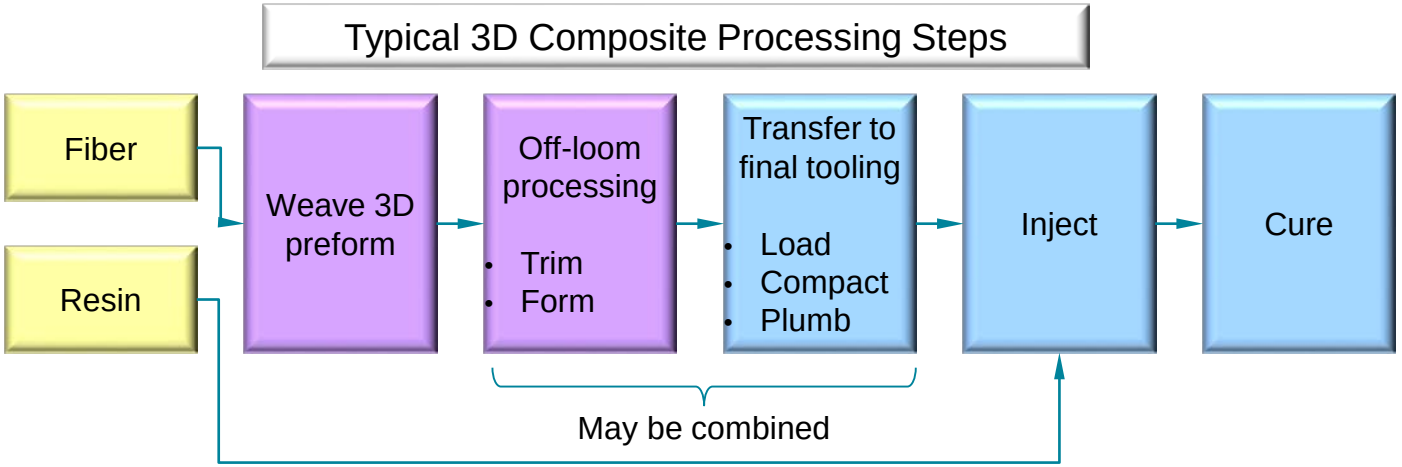
Fully Controlled Manufacturing

Raw material

Primarily positioning fiber

Primarily processing resin



- Composite fiber volume fraction is directly controlled by the preform design (weaving program)
- All fiber positioning is done in the dry state for 3D composites
- Introduction of resin is controlled in the plant

Composite part is manufactured entirely from raw elements and are processed within the plants to deliver a final product.

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Over 10 Years of Development for 3D Woven Technology

Start early discussion with EASA to prepare certification path jointly

Nov 2005

Feb / March
Jun / Oct
2006

May
Sep / Oct
2007

Sep 2008

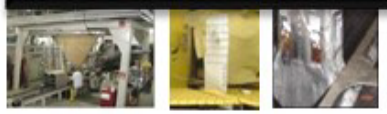
Apr 2009

Fev 2011

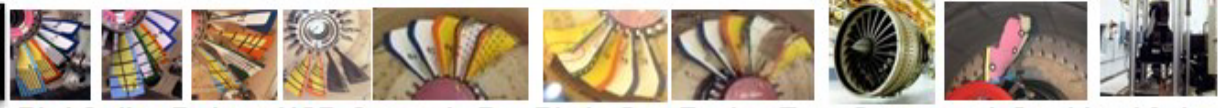
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011

Nov 2012
Start of Certification process

Technology screening



Large Engine



Bird Strike, Fatigue HCF, Strength, Fan Blade Out, Engine Test, Overspeed, Combined fatigue

Sub-Component Tests

LEAP Scale

Component Tests

Engine Tests

A robust and extensive maturation plan

LEAP

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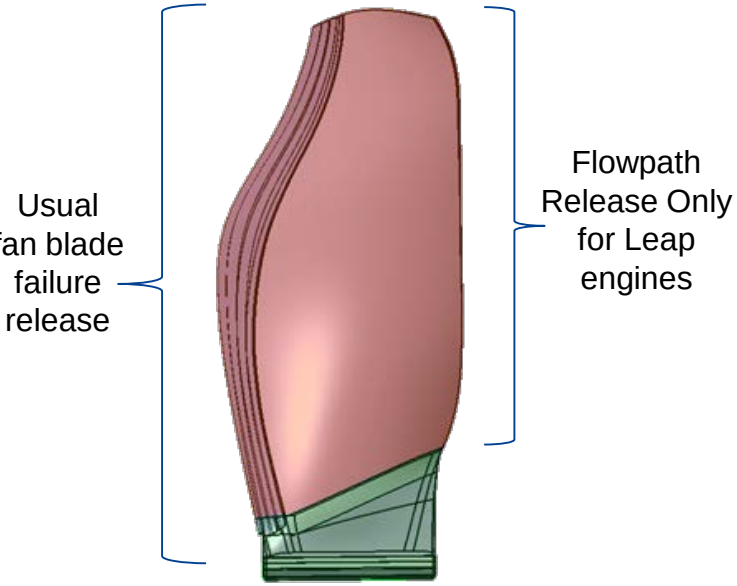
Joint Work with EASA to Adapt Regulation to the Capability of the Technology



Cyclic Life Demonstration by Test

Goal :

> Use enhanced damage tolerance and fatigue properties to reduce amount of material that could be released during Blade-Out event.
➔ Weight savings for the engines and aircraft

Special Condition dedicated to demonstrate the same level of safety:

> FBO test with fan blade failure at the inner annulus flow path line.
> Demo 2X load capability for fan blade retention system.
> Establish cyclic life operating limitation above 100 000 cycles (Demonstration by test)
> Substantiate hazardous engine effects for the blade retention system will be extremely improbable (< 10-9 per engine flight hour)
> Substantiate that lightning strike will not cause damage to the fan blades that would prevent continued safe operation of the affected engine.
> Account for the effects of in-service deterioration, manufacturing variation, minimum material properties and environmental effects.
> Fleet leader program.

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2

INTEGRATION OF PROCESS INTO DESIGN

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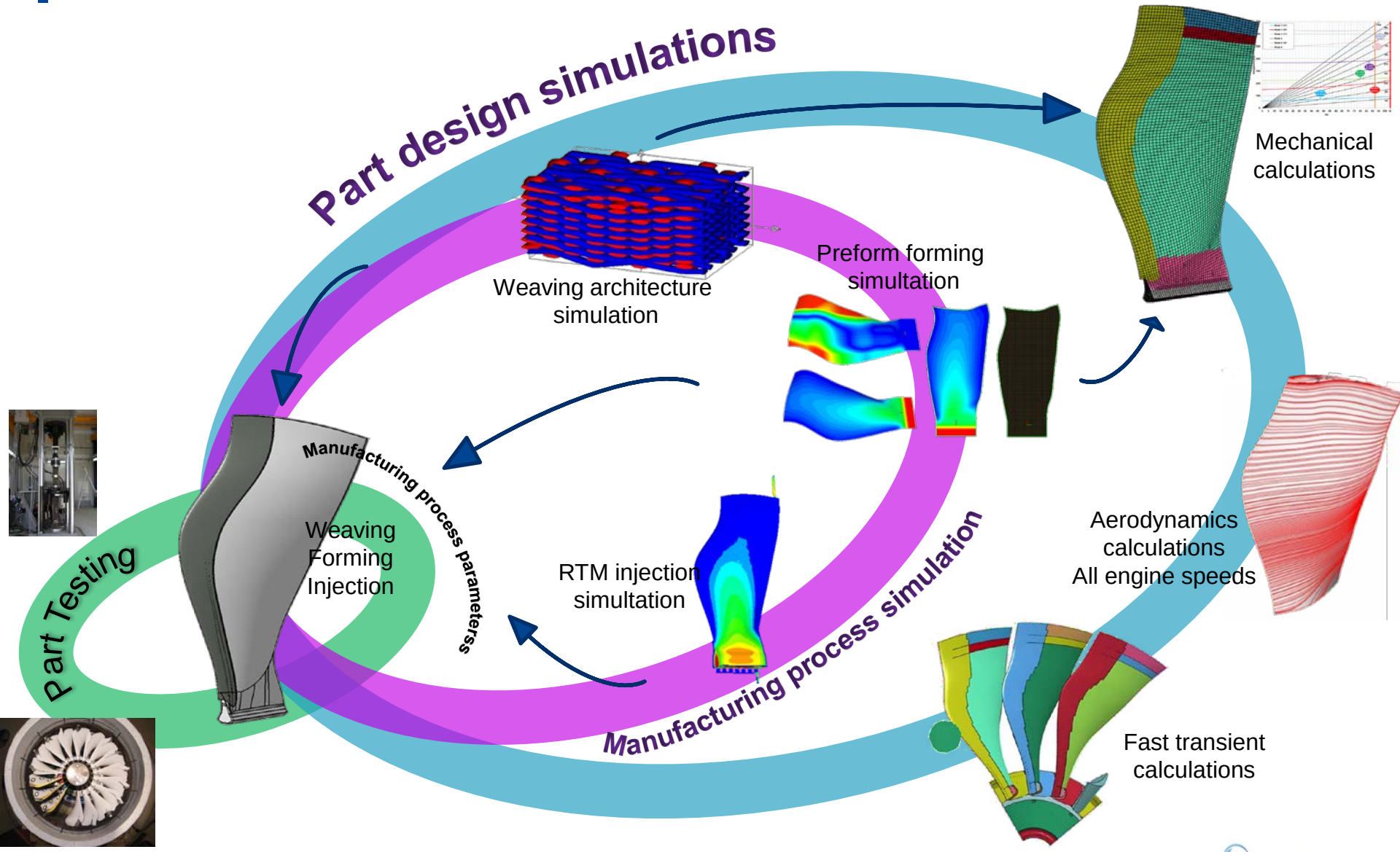
Optimisation of design using mechanical & process simulation



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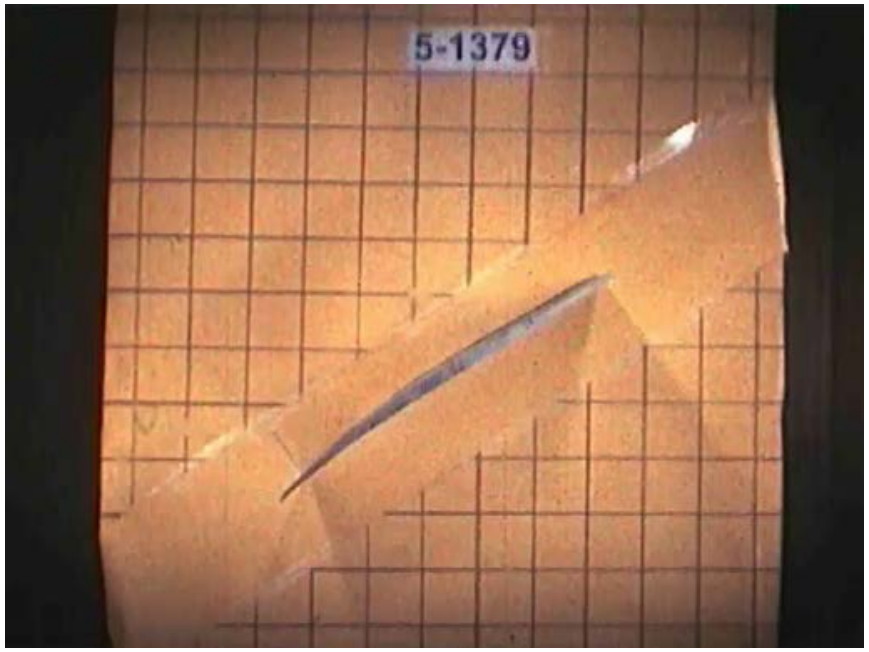
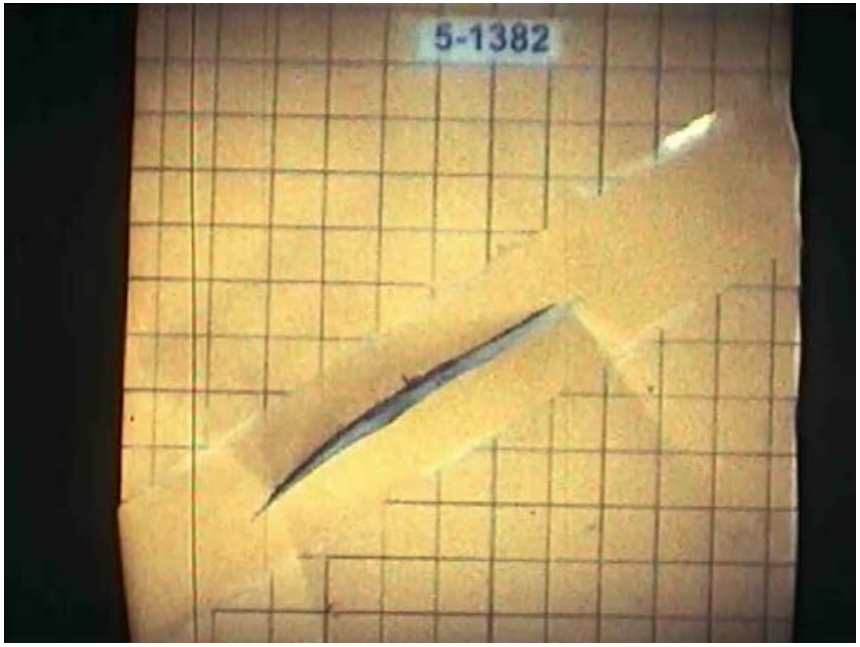
Understanding Technology Behavior

Weave pattern optimization





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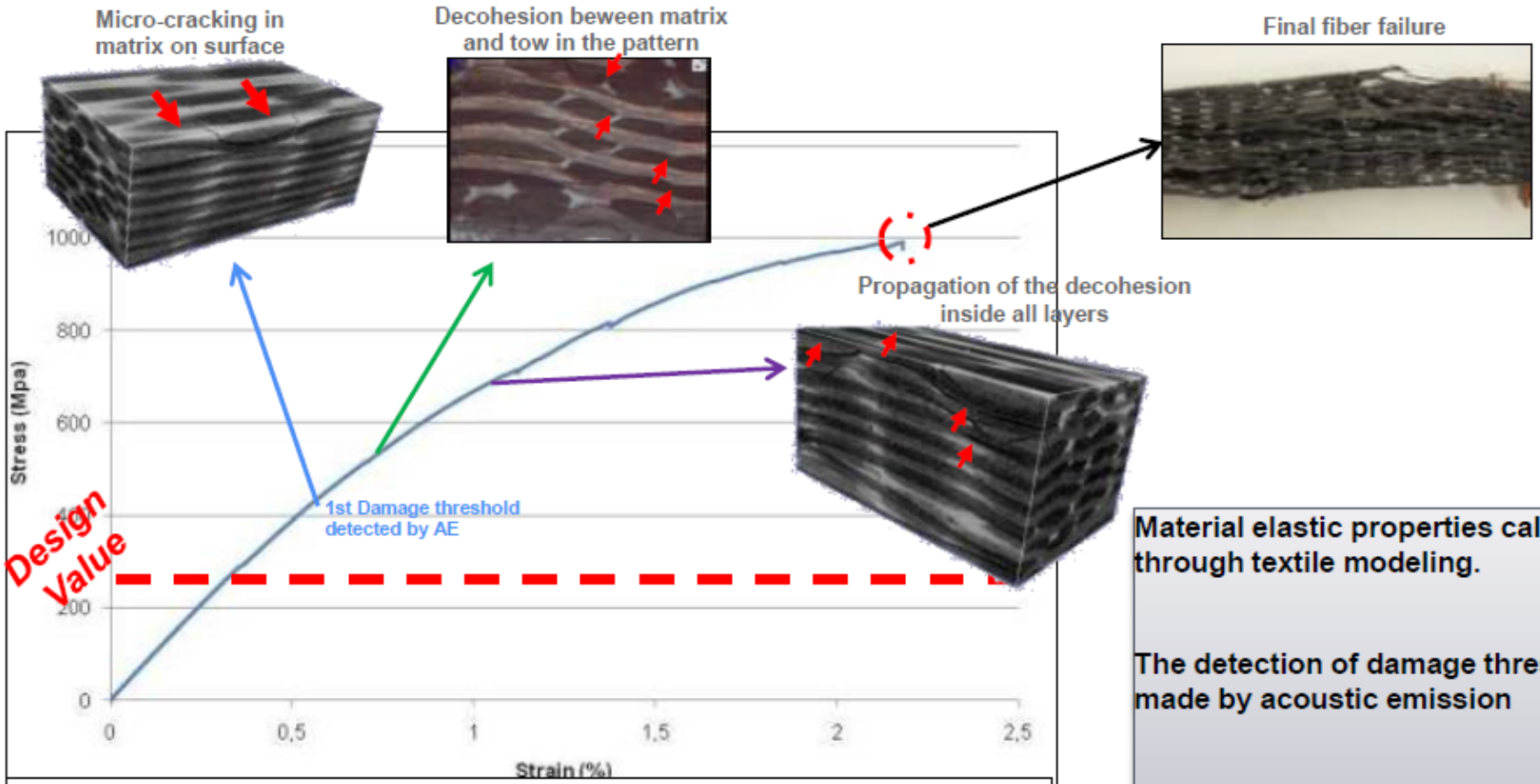
Understanding Damage Scenario



Airfoil material warp tensile

Material elastic properties calculated through textile modeling.

The detection of damage threshold is made by acoustic emission

Damage of samples is controled by µCT

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3

VALIDATION OF TECHNOLOGY USING BUILDING BLOCK APPROACH

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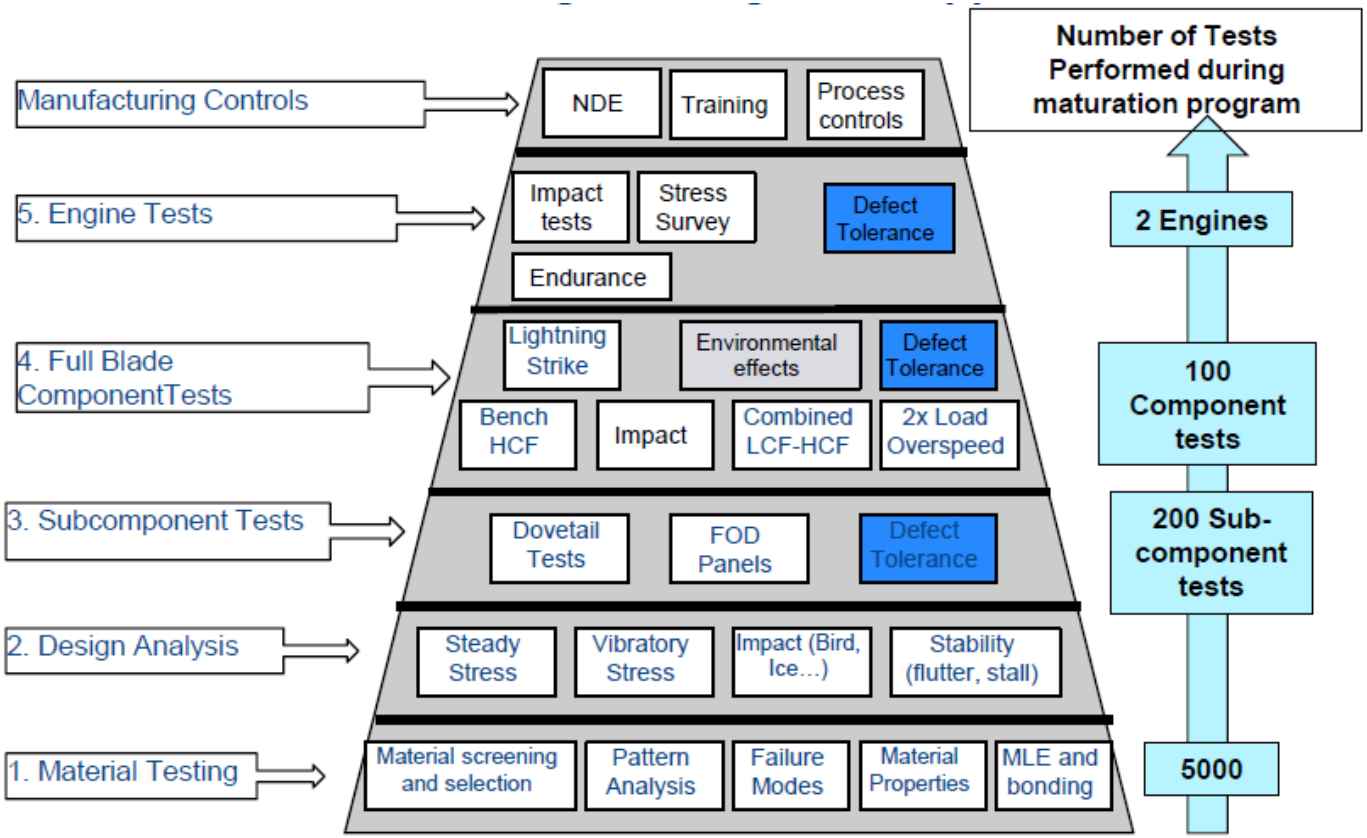
Validation Process using Building Block Approach



*Using AC-20-107B / AMC 20-29 (Composite Aircraft Structures) Building Block Approach

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Basics to Develop Composites Structures

1. **Start from structural need to identify the best composite technology available (type of fiber, type of reinforcement, type of resin system)**

2. **Work on development of structure in the same time as the work on the manufacturing process**

3. **Identify failure modes and validate through the steps of the pyramide (coupon test, subcomponent tests and component tests)**

4. **Develop dedicated models for finite element analysis and prediction of non-linear behaviour, as well as process simulation**

5. **Engage early discussion with regulation agencies to consolidate validation process**

➔ For 3D printing, Safran is following the same steps to qualify and demonstrate confidence in those new technologies

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Additive Layer Manufacturing

2016 EASA Safety Conference
New Technologies & Business Models

N Mantle

Head of Additive Manufacturing, Rolls-Royce Plc

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DRIVERS

SPECIALIST PROVIDERS

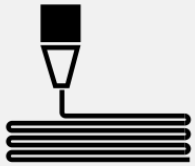
CIRCULAR ECONOMY

DRIVING VALUE

PACE OF CHANGE

AGILE RECONFIGURABLE MANUFACTURING

INTELLIGENT MANUFACTURING



DISRUPTIVE PROCESSES

DIGITAL DATA & SYSTEMS

COLLABORATION

SKILLS & CAPABILITIES

ENABLERS

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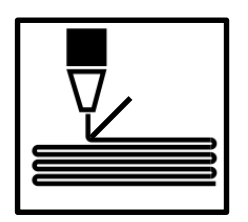
Disruptive Processes – Additive Manufacturing

Directed Energy Deposition of Metals

Energy Sources
Laser
Plasma Arc
Electron Beam

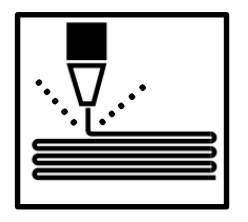


Feed Stock

Metal Wire

Difference

Larger Scale

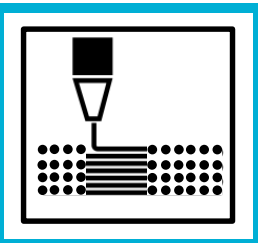


Metal Powder

Fine Scale

Powder Bed Fusion of Metals

Energy Sources
Laser
Electron Beam



Feed Stock
Metallic Powder

Difference
constrained volume

Digitally enabled 3D freeform deposition

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What are the key benefits?

- The opportunity to quickly make highly complex shapes
- In difficult and expensive materials
- Creating unique geometries and functionality – impossible using conventional design and manufacturing techniques

- Fast, adaptive with less waste and almost instant results
- Reduces number of processes and part count
- Reduces product development lead times
- Expands the art of the possible in terms of designs and shapes
- Shortens process chains and creates unique business models

Typical complex aerospace 3D printed nickel part

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We insist on comprehensive demonstration

And for ALM, it is no different….

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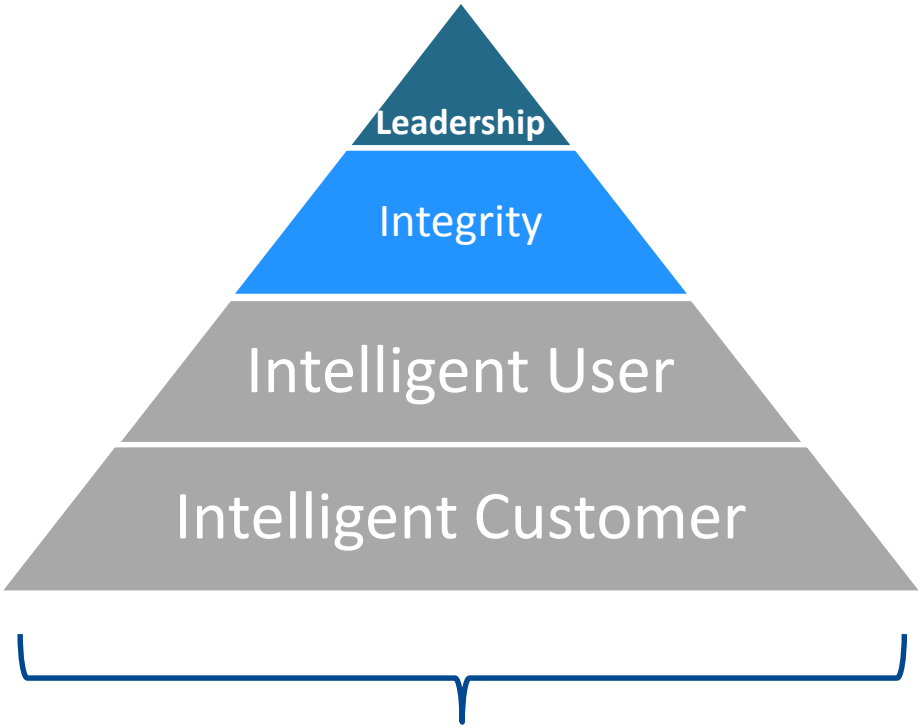
Our Approach

- Leadership through a Centre of Competence
- Integrity
- Intelligent User
- Intelligent Customer



"Licence to Operate"

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“Licence to Operate” … Integrity & Assurance

Manufacturing

Consistency of Fabrication Methods

Materials

Suitability & Durability

Design

Materials Strength Properties & Materials Design Values

Licence to operate can only be achieved when all 3 disciplines are working in combination (DOA & POA)

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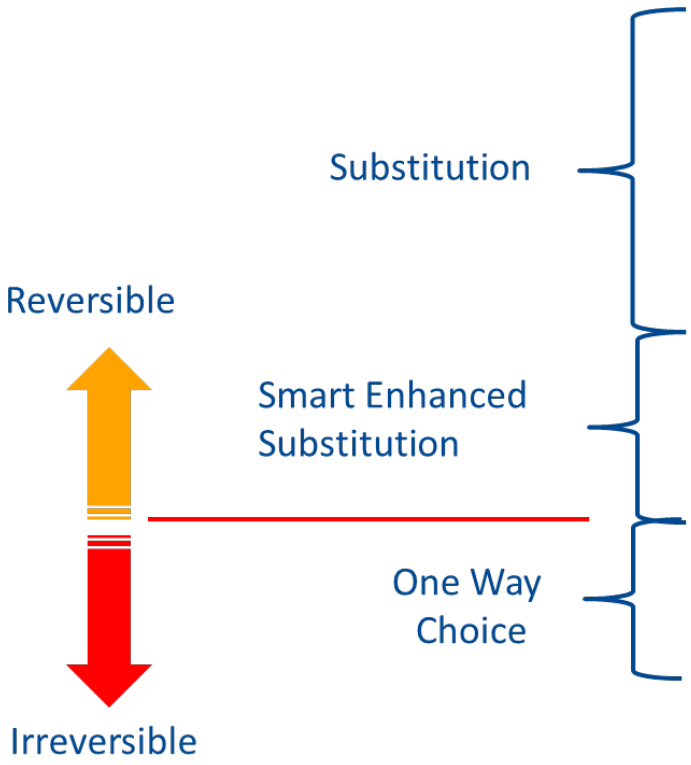
ALM – A Stepping Stone based approach



- **Maximum benefit from one way choice design for ALM**
- **Stepping stone introduction is foreseen and used to manage risk**
- **We are actively developing Additive Solutions in all phases**

Rolls-Royce proprietary information

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World Leading Demonstrator

XWB-97 Front Bearing Housing

Flown in 2015

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XWB-97 Front Bearing Housing

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XWB-97 Front Bearing Housing

- Programme Duration ~ 5 years
  - From initial technology test samples to the worlds first significant load bearing engine structure to fly using additive manufactured components

- Pre component manufacturing materials characterisation - Baseline
  - Over 200 test data points (Design and Materials)

- Intra Engine Component Development Program - Extended Baseline
  - Over 500 test data points (Design, Materials & Manufacturing)
  - Parts manufacturing under full R-R aerospace controls
  - Multiple machine cells under full R-R 24-7 control
  - Intelligent user

Materials, Manufacturing & Design in combination

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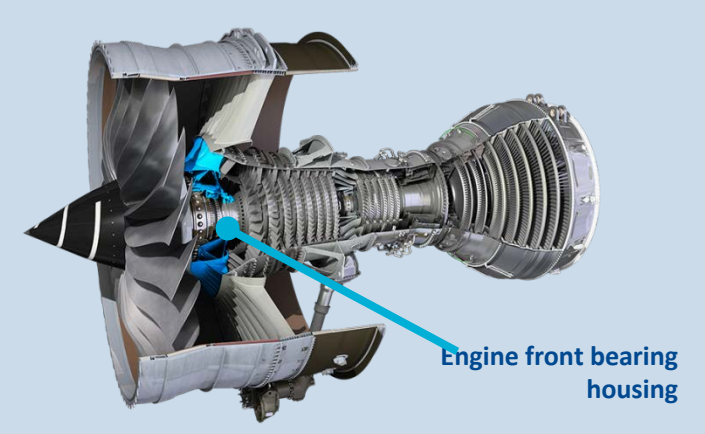
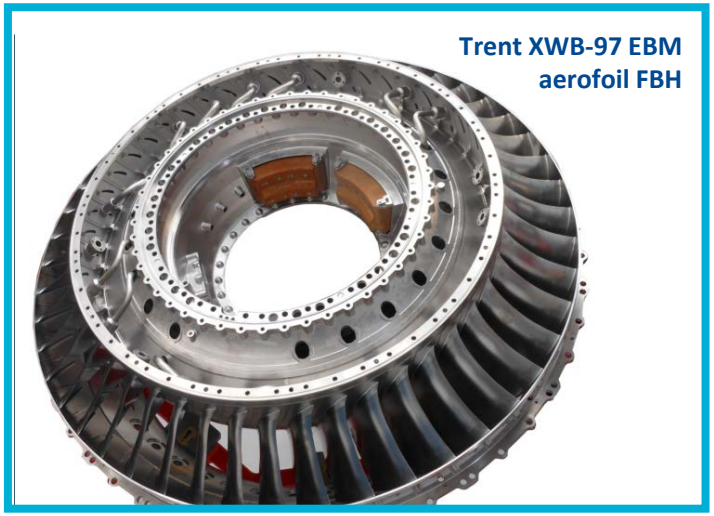
XWB-97 Front Bearing Housing





- Significant load bearing engine structure
  - **48 titanium printed aerofoils**
  - **1.5m diameter, 0.5m long**
- Successful ground testing in multiple Trent XWB-97 engines
- Demonstrated a 30% ‘like for like’ reduction in manufacturing lead time
- Faster and more cost-effective design iterations
- 100s of exacting aero quality parts made
- Tens of 1000s of hour of printing experience under full Rolls-Royce production conditions
- **Pioneered use of the world’s largest EBM titanium 3D machines**
- **Flight tested in 2015**

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Trusted to deliver excellence

Rolls-Royce

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EASA
European Aviation Safety Agency

Panel 2: Digital Transformation of Production – challenges and opportunities for industry and regulators

Enabling Technology – An Agency Perspective

Bratislava

October 2016

S.Waite: Senior Expert – Materials – EASA Certification Directorate

M. Mercy: Project Certification Manager – Propulsion - EASA Certification Directorate

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➢ 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.

egulatory Framework (moving towards **performance based regulations**)

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 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

Certification Specification Examples (design production interface):

- 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**

*Similar intent in CS-E 70 Materials and Manufacturing Methods (Engines)

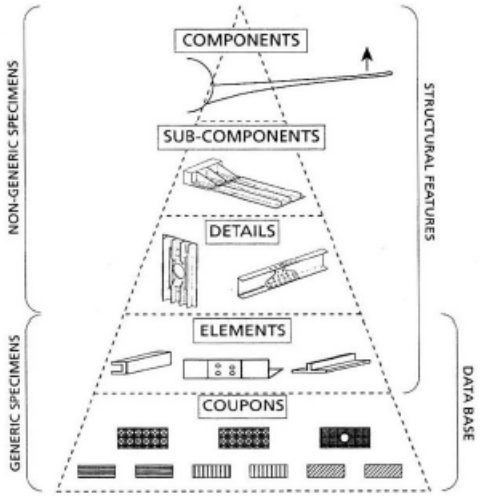

Figure 1 - Schematic diagram of building block tests for a fixed wing.

Appropriate substantiation of the technology change is necessary using the **test** and analysis pyramid, e.g. new material and/or process and/or application…

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- 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
- production
- in-service

Note: 80-90% of in-service inspections are visual

Does not need to be an 'inspection' … process control, Structural Health Monitoring (SHM)?

  - *'(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'

Notes:

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

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- Opportunities arising from changing to more integrated process driven technologies… closer regulator engagement with industry…
- EASA approach to new technology*:

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

- *note, regulatory developments include:
- 1/ EASA – Composites Safety Strategy (draft)
- 2/ National Airworthiness Authorities (NAA) Materials Network formed

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- EASA AM Working Group:
- Cross directorate – certification and standardisation
- Addresses all product types in a coordinated manner - representation from:
  - AM WG Lead – R. Minter - richard.minter@easa.europa.eu
  - AM WG chair - S. Waite – simon.waite@easa.europ.eu
  - Aircraft Structures - W. Hoffmann - wolfgang.hoffmann@easa.europa.eu
  - Propulsion (Engines, Propellers & APU) - M. Mercy - matthew.mercy@easa.europa.eu
  - Cabin Safety - T. Ohnimus - thomas.ohnimus@easa.europa.eu
  - Design Organisation Approvals - A. Enache - alexandru.enache@easa.europa.eu
  - Production Organisation Approvals - D. Lamothe - dominique.lamothe@easa.europa.eu
  - Maintenance & 145 - R. Tajas - rosa.tajes@easa.europa.eu
- Risk and Mitigation Matrix
- Certification Memo (regulatory tool… encourage early appropriate engagement with industry)
- Workshops (first meeting - September 2016)
- Regular communication with other regulators

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- CM: EASA Certification Policy and Guidance for DOA and POA Holders regarding use of AM applicable to all products
- EASA CM memo is the starting point for discussion with applicants
  - Follows a performance based approach
    - Set's the stage for any future policy which may emerge with AM implementation and increasing criticality.
      - Base requirements CS-25, CS-E adequate to accommodate AM
- The main messages of the CM on AM are:
  - Encourage design organisations to engage with EASA during the implementation of AM
  - Encourage production organisations to engage with NAA's
  - Highlight the importance of DOA – POA coordination
  - Focus on process and material qualification –objective not prescriptive

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- **Example New Technology Implementation : AM workshop**
- Industry welcome performance based approach within the current requirements
- Need for understanding of failure drivers within complex process driven production and their effects on the product integrity
  - Manufacture needs to be controlled within design assumptions
    - Eliminate flaws or features (including process variation)
    - Demonstrate how the design can accommodate
  - Accommodating the unknowns
- Know your design space, validating your design space – process monitor to stay within it
  - Closed loop : engineering plan < - > manufacturing plan
    - Ensure conformity with design assumptions using approved specifications
  - Importance of calibration, process control and change control throughout the system and over time (volume production)
- Industry and Agency knowledge base - intelligent user, intelligent customer

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- **Conclusions:**
- new technologies & applications, changes must not reduce the existing 'acceptable' level of safety
- Opportunities presented by new integrated process driven technologies, e.g. AM, include:
  - EASA strategy - Working Group formed to review and assess risk, and risk mitigation, and to work with other regulators and industry (CM, Workshops etc) to ensure safe integration of technologies into aviation
- Regulatory guidance: Some change/development expected, a function of
  - criticality
  - maturity of process (use 'lessons learned' from other technologies, e.g. composites, castings, when appropriate)
  - commonality of philosophies (work with standardisation bodies)
- R&D:
  - many AM methods …regulator **focus upon maturing methods and applications**
- Training:
  - develop appropriate staff training/experience
    - (all sectors, industry regulator, standards bodies)

EASA is working with industry to address
new integrated process driven technologies and new business models

EASA
European Aviation Safety Agency

Thank you for your attention

Questions?

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