Additive Manufacturing Application in Aviation – Potential and Challenge

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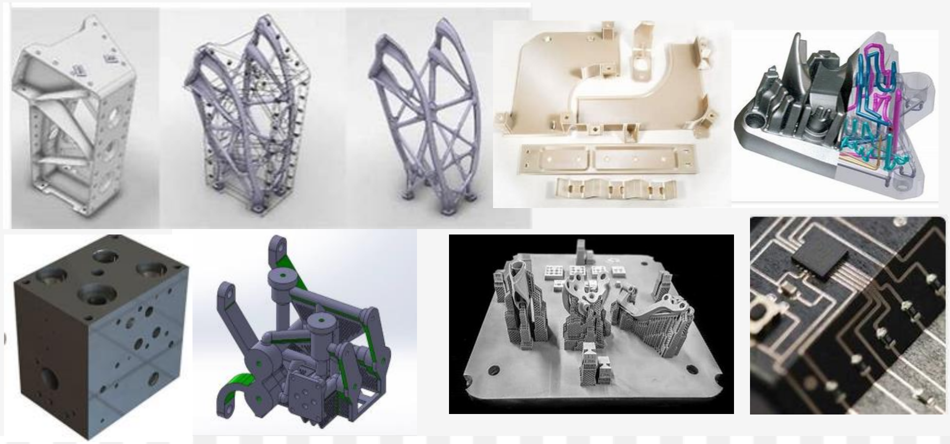
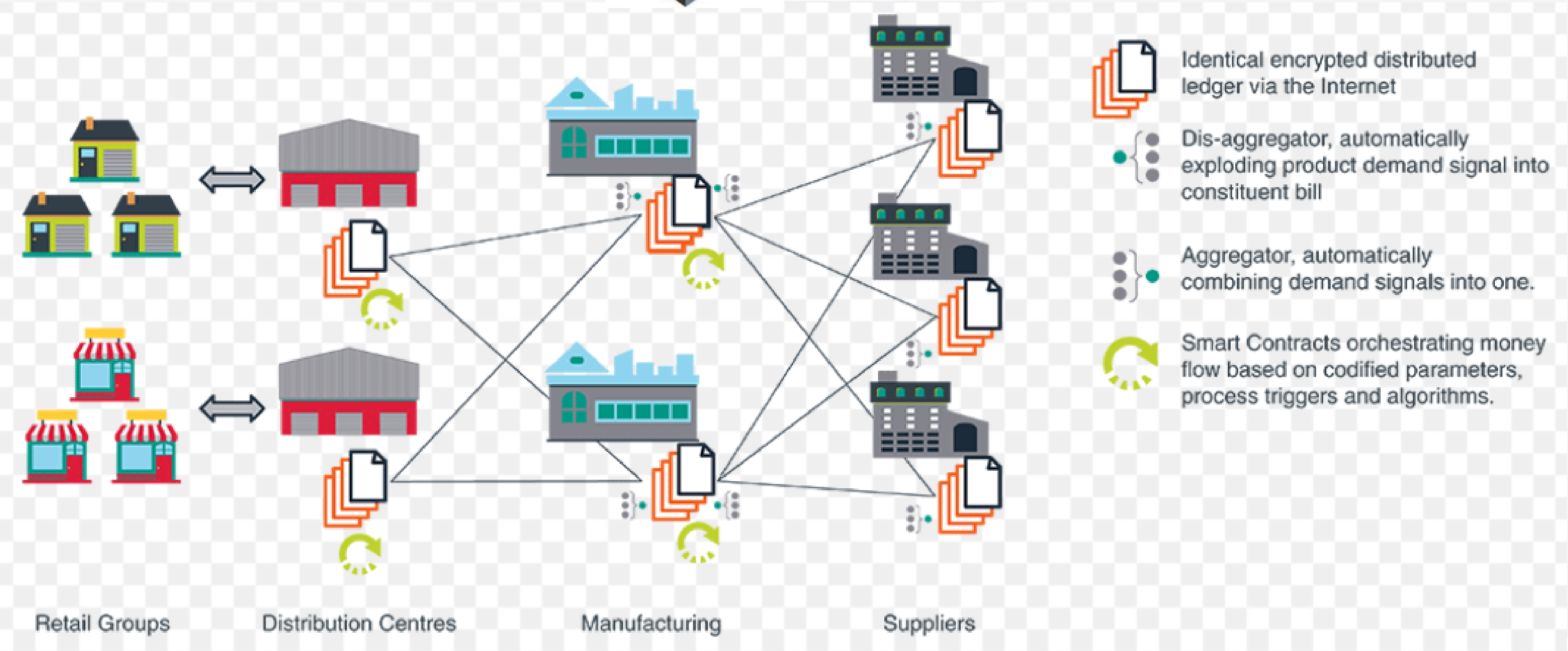
Outline

- Review of AM and its application in flight operation
- Guidelines and Standards
- Challenges & trend
- AM In ST Engineering Aerospace

Attraction of AM
– Expectation

- Disruptive technologies
- Huge potential
- Environmental effect





AM Parts in Flight Operation

– Published examples for new products

GE additively manufactured single part fuel nozzles, which were formerly composed of 20 different parts. Used in GE's LEAP engines, these nozzles are five times more durable than those produced with conventional methods. It is also the first FAA approved 3D printed component in jet engine.

2015, GE Additive certified fuel nozzle

2017, Boeing uses first FAA –approved 3D-printed parts

AM Parts in Flight Operation
– Published examples for MRO sector

First Airbus retrofitted part (Apr 2018)

The panel has been finished to meet Airbus aesthetic requirements and, as such, will look like any other component to Finnair passengers. (Image courtesy of Materialise.)

End User : Airlines

Aviation certification lead : Airbus

AM manufacturer : Materialise

First components for Etihad passenger planes (Nov 2018)

A look inside the cabin: The interior of an Etihad Boeing 777-300.

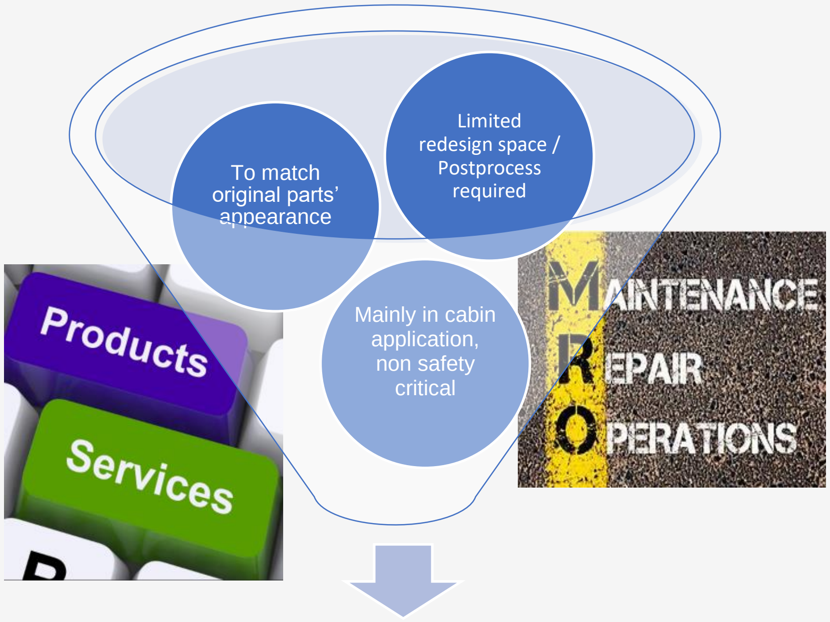
End User : Etihad

Aviation certification lead : Strata

AM manufacturer : Siemens

Observation

to realize AM benefit - performance/cost & weight

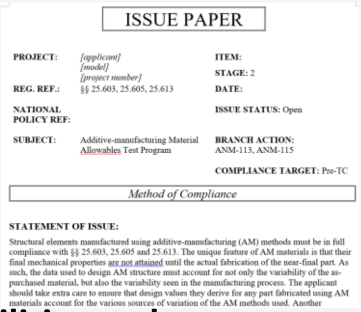


to realize parts availability - on time operation support

Guide from FAA, EASA

Jan 2016, FAA **Issue Paper on Method of Compliance**: -

- Basic Materials Requirements: (§25.603)
- Basic Process Requirements: (§ 25.605)
- Inspection Methods
- Development of Strength and Design Values: (§25.613)
- Application of Special Factors: (§ 25.619)



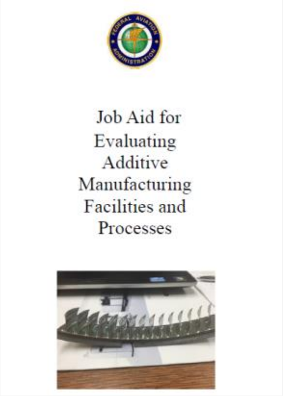
ISSUE PAPER

PROJECT:	*[applicant]* *[model]* *[project number]*	**ITEM:** **STAGE:** 2
REG. REF.:	§§ 25.603, 25.605, 25.613	**DATE:**
NATIONAL POLICY REF:		**ISSUE STATUS:** Open
SUBJECT:	Additive-manufacturing Material Allowables Test Program	**BRANCH ACTION:** ANM-113, ANM-115
		COMPLIANCE TARGET: Pre-TC

Method of Compliance

STATEMENT OF ISSUE:

Structural elements manufactured using additive-manufacturing (AM) methods must be in full compliance with §§ 25.603, 25.605 and 25.613. The unique feature of AM materials is that their final mechanical properties are not attained until the actual fabrication of the near-final part. As such, the data used to design AM structure must account for not only the variability of the as-purchased material, but also the variability seen in the manufacturing process. The applicant should take extra care to ensure that design values they derive for any part fabricated using AM materials account for the various sources of variation of the AM methods used. Another



Aug 2016, FAA "**Job Aid for Evaluating Additive Manufacturing Facilities and Processes**": -
"a tool that aviation safety inspectors (ASI) can use to evaluate additive manufacturing of certificated aeronautical products."

EASA CM No.: CM-S-008 Issue 01

EASA European Aviation Safety Agency

Certification Memorandum

Additive Manufacturing

EASA CM No.: CM–S-008 Issue 01 issued 04 April 2017

Regulatory requirement(s): CS X.571, CS X.603, CS X.605, CS X.613, 25 X.853, CS E 70, CS E 100 (a), CS P 170, CS P 240, CS APU 60, 21.A.20, 21.A.31, GM 21.A.91, 21.A.101, 21.A.131, 21.A.133, 21.A.147, 21.A.247, 21.A.433, GM 21.A.435(a), 21.A.437, 21.A.447, 21.A.805, AMC 145.A.42(c)

EASA Certification Memoranda clarify the European Aviation Safety Agency's general course of action on specific certification items. They are intended to provide guidance on a particular subject and, as non-binding material, may provide complementary information and guidance for compliance demonstration with current standards. Certification Memoranda are provided for information purposes only and must not be misconstrued as formally adopted Acceptable Means of Compliance (AMC) or as Guidance Material (GM). Certification Memoranda are not intended to introduce new certification requirements or to modify existing certification requirements and do not constitute any legal obligation.

EASA Certification Memoranda are living documents into which either additional criteria or additional issues can be incorporated as soon as a need is identified by EASA.

April 2017, EASA "Certification Memorandum, Additive Manufacturing": -

- CS X.603 Materials
- CS X.571 Fatigue & Damage Tolerance
- CS X.605 Fabrication Methods
- CS X.613 Material Strength Properties and Material design Values
- CS X.853 Compartment Interiors

Standards / Other Guidelines

– **ISO/ASTM52900,** Standard Terminology for Additive Manufacturing – General Principles – Terminology
– **ISO/ASTM52901,** Standard Guide for Additive Manufacturing – General Principles – Requirements for Purchased AM Parts
– **ISO/ASTM52910,** Standard Guidelines for Design for Additive Manufacturing
– **ISO/ASTM52915,** Standard Specification for Additive Manufacturing File Format (AMF) Version 1.2
– **ISO/ASTM52921,** Standard Terminology for Additive Manufacturing-Coordinate Systems and Test Methodologies

The four SAE aerospace additive manufacturing technical standards are:

- AMS7000: Laser-Powder Bed Fusion (L-PBF) Produced Parts, Nickel Alloy, Corrosion and Heat-Resistant, 62Ni - 21.5Cr - 9.0Mo - 3.65Nb Stress Relieved, Hot Isostatic Pressed and Solution Annealed
- AMS7001: Nickel Alloy, Corrosion and Heat-Resistant, Powder for Additive Manufacturing, 62Ni - 21.5Cr - 9.0Mo - 3.65Nb
- AMS7002: Process Requirements for Production of Metal Powder Feedstock for Use in Additive Manufacturing of Aerospace Parts
- AMS7003: Laser Powder Bed Fusion Process

1. ASTM F3055-14a Standard Specification for Additive Manufacturing Nickel Alloy (UNS N07718) with Powder Bed Fusion
2. ASTM F3056-14e1 Standard Specification for Additive Manufacturing Nickel Alloy (UNS N06625) with Powder Bed Fusion
3. ASTM F3049-14 Standard Guide for Characterizing Properties of Metal Powders Used for Additive Manufacturing Processes
4. ASTM F2924-14 Standard Specification for Additive Manufacturing Titanium-6 Aluminum-4 Vanadium with Powder Bed Fusion
5. ASTM F3184-16 Standard Specification for Additive Manufacturing Stainless Steel Alloy (UNS S31603) with Powder Bed Fusion
6. ASTM F3122-14 Standard Guide for Evaluating Mechanical Properties of Metal Materials Made via Additive Manufacturing Processes
7. ASTM F3001-14 Standard Specification for Additive Manufacturing Titanium-6 Aluminum-4 Vanadium ELI (Extra Low Interstitial) with Powder Bed Fusion
8. ASTM F3302-18 Standard for Additive Manufacturing — Finished Part Properties — Standard Specification for Titanium Alloys via Powder Bed Fusion
9. ASTM F3318-18 Standard for Additive Manufacturing — Finished Part Properties — Specification for AlSi10Mg with Powder Bed Fusion — Laser Beam
10. ASTM F3213-17 Standard for Additive Manufacturing — Finished Part Properties — Standard Specification for Cobalt-28 Chromium-6 Molybdenum via Powder Bed Fusion
11. ASTM F3303-18 Standard for Additive Manufacturing — Process Characteristics and Performance: Practice for Metal Powder Bed Fusion Process to Meet Critical Applications
12. ASTM F3301-18a Standard for Additive Manufacturing — Post Processing Methods — Standard Specification for Thermal Post-Processing Metal Parts Made Via Powder Bed Fusion1, 2
13. ASTM F2971-13 Standard Practice for Reporting Data for Test Specimens Prepared by Additive Manufacturing

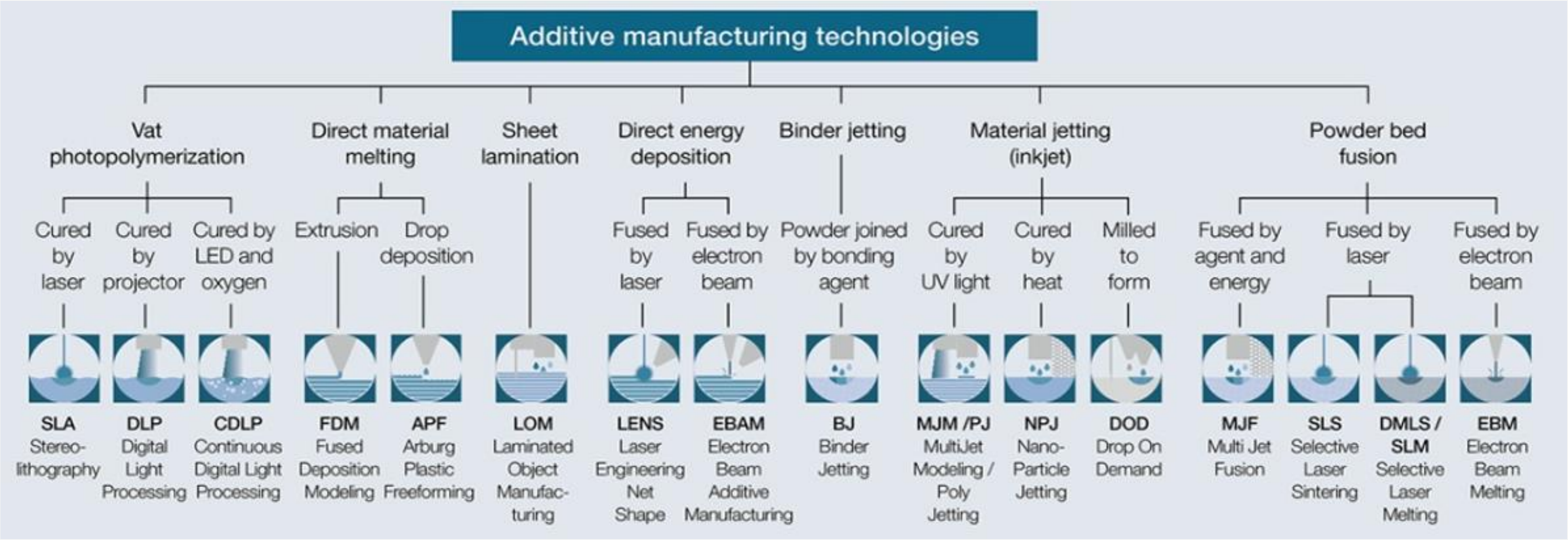
2017 Garner Hype Cycle

- Projection of AM adoption

Challenges

“Job Aid for Evaluating Additive Manufacturing Facilities and Processes” states: -

The term Additive Manufacturing itself does not describe ***one manufacturing method, but a wide range of methods, each with its own set of concerns and requirements*****.**



Challenges

Process qualification and parts certification

- Complexity and verity
- Different level of maturity
- Pre-process and post-process

long lead time

End user acceptance

- Limited applications to over perform conventional manufacturing methods in cost
- Yet to be established for entire product cycle
- Lack of in service experience/data

low demand

Adoption issues

- High cost
- Limitations
- Violation of copyrights - counterfeit products

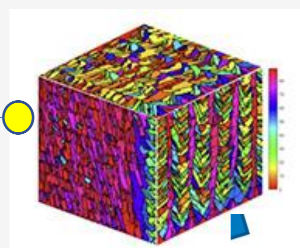
high investment, limitations and risks

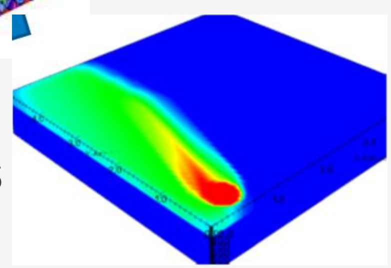
Trend

Collaboration

can achieve 10 times more productivity and up to 50% less cost per part

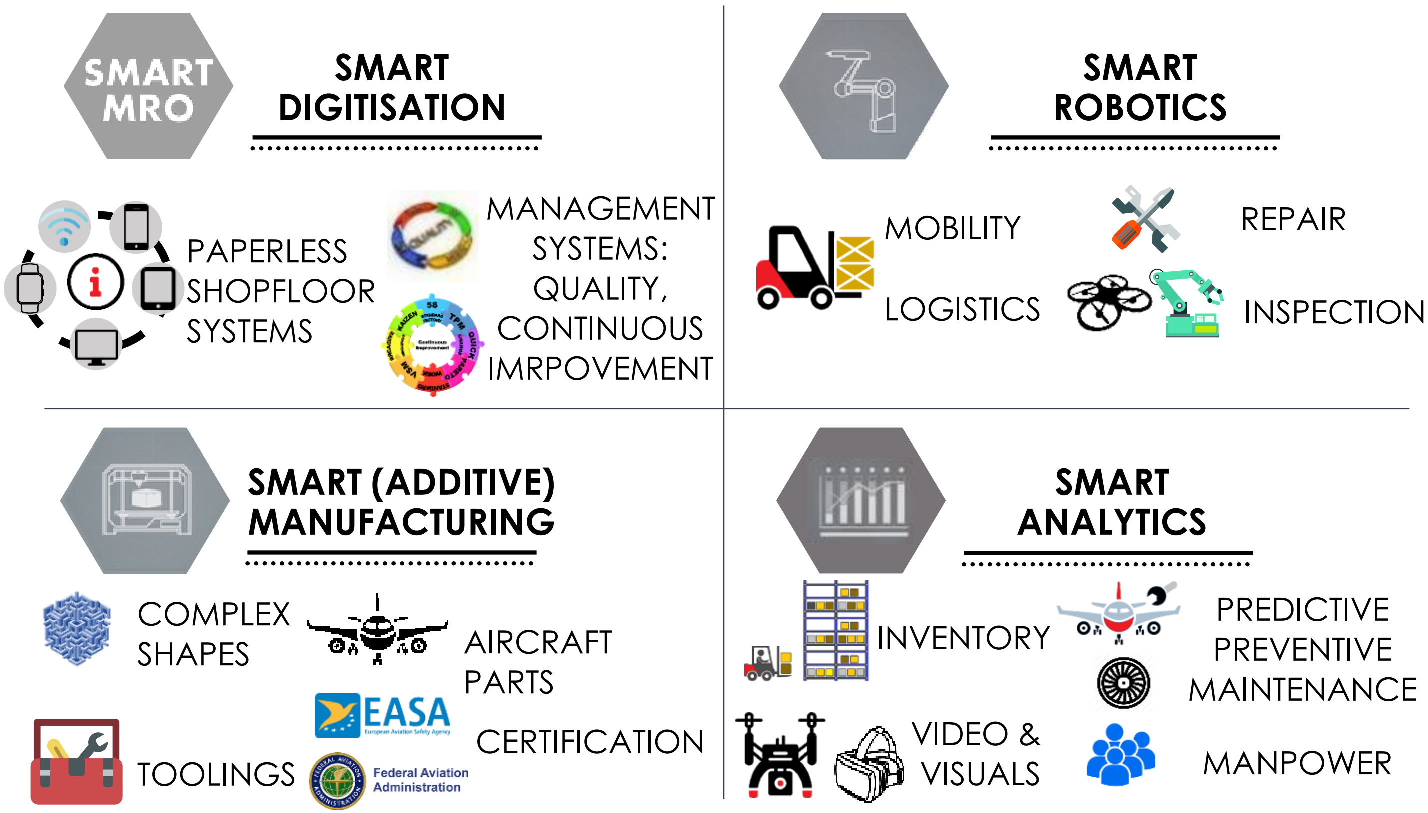
Promise of performance progression



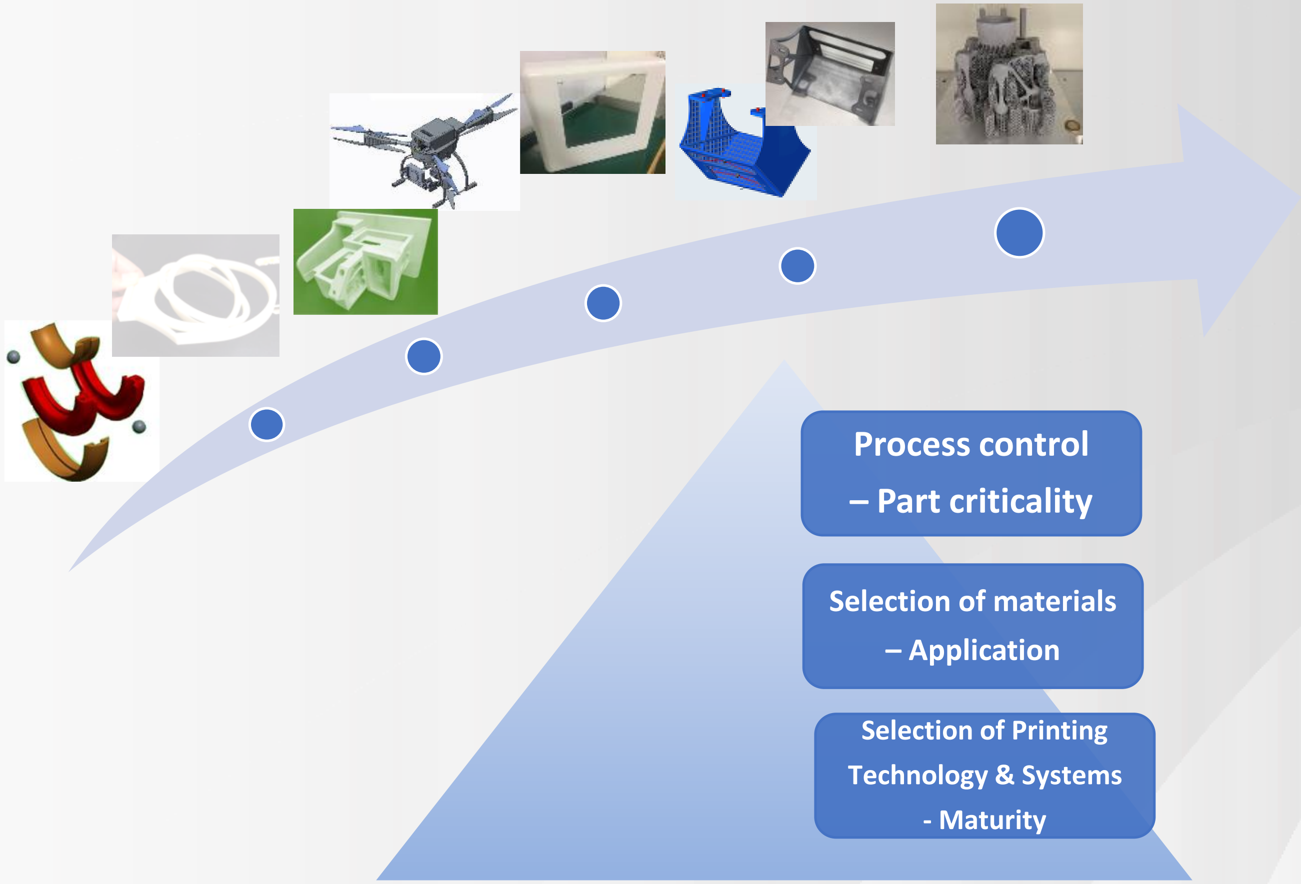


Prediction by analysts

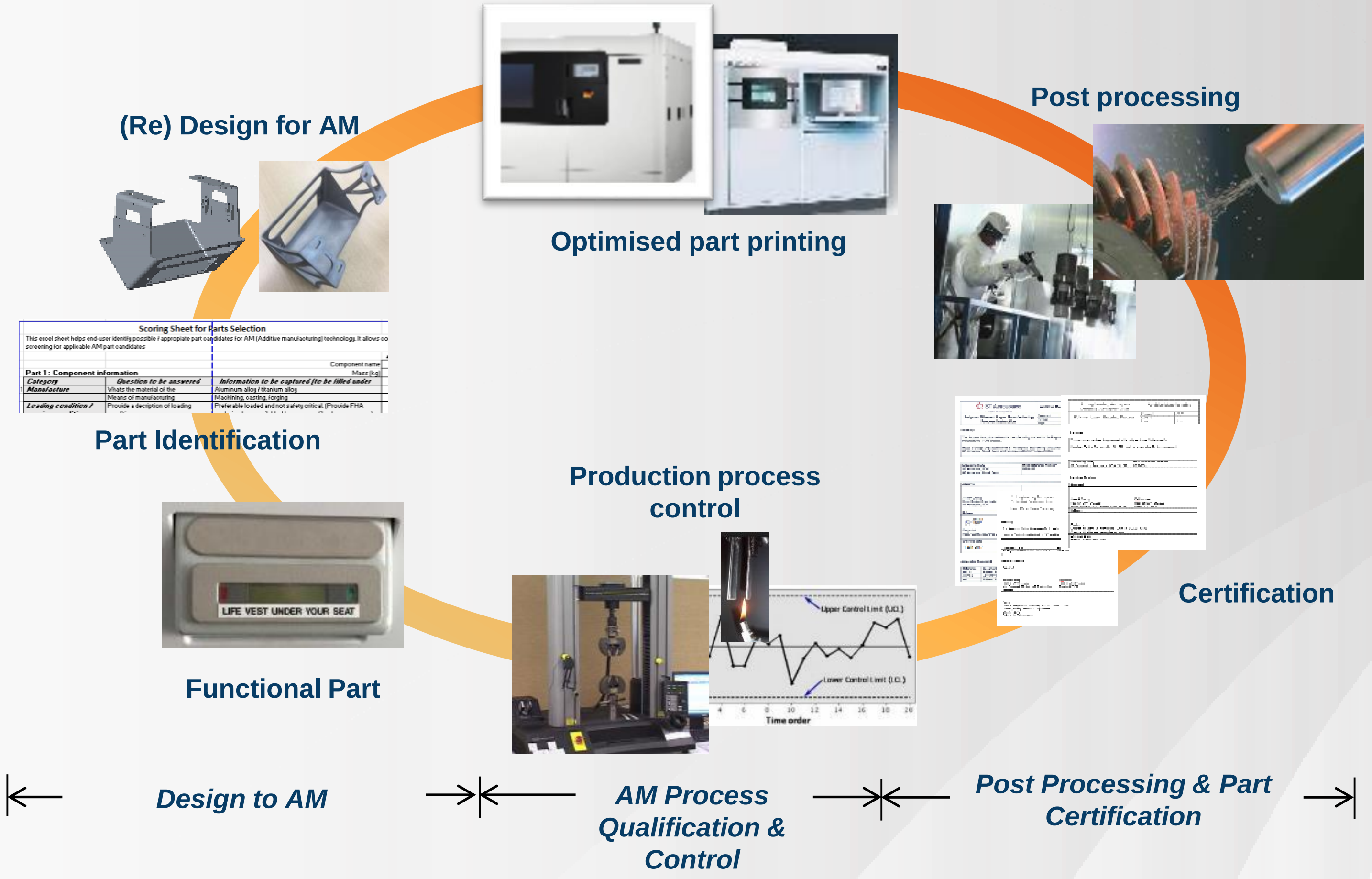
Smart MRO


SMART MRO
SMART DIGITISATION
PAPERLESS SHOPFLOOR SYSTEMS
MANAGEMENT SYSTEMS: QUALITY, CONTINUOUS IMRPOVEMENT
SMART ROBOTICS
MOBILITY
LOGISTICS
REPAIR
INSPECTION
SMART (ADDITIVE) MANUFACTURING
COMPLEX SHAPES
AIRCRAFT PARTS
TOOLINGS
EASA
Federal Aviation Administration
CERTIFICATION
SMART ANALYTICS
INVENTORY
PREDICTIVE PREVENTIVE MAINTENANCE
VIDEO & VISUALS
MANPOWER

A Progressive Approach



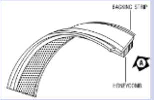
Build AM Value Chain - Collaboration



ST Engineering Aerospace

Continued Innovation & Embrace the Future

- Professional activities
  - SAE /ASTM /ISO
  - EASA /CAAS
  - Research/Industrial updates
  - CTP (Capability Transfer Program) - training
- SC3DP – Industrial Postgraduate Program
- HLIs collaborations - A*Star, Nanyang Polytechnic, National University of Singapore
- Printing System OEMs – EOS, Stratasys, etc
- Post process development
  - Coating systems
  - Surface treatment processes
  - Supply chain development tap into JIP (Jointed Industry Program)

R&D collaboration	
	**Design and print UAV wings with optimised design**
    	**Optimised design and printing processes, new material and new ss**
	**New system using wire direct deposition technology**

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Thank You