

Additive Manufacturing and certification of Aircraft Interior components



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Agenda

Inam

1. AM technology
2. Research
3. Development

Doug

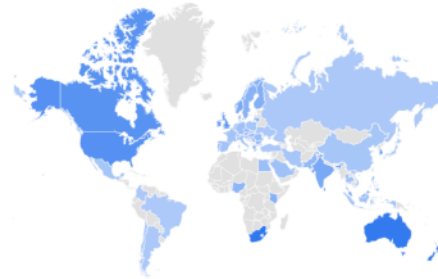
4. Applications
5. Certification
6. Future Prospects



Additive Manufacturing/ 3D Printing Trend

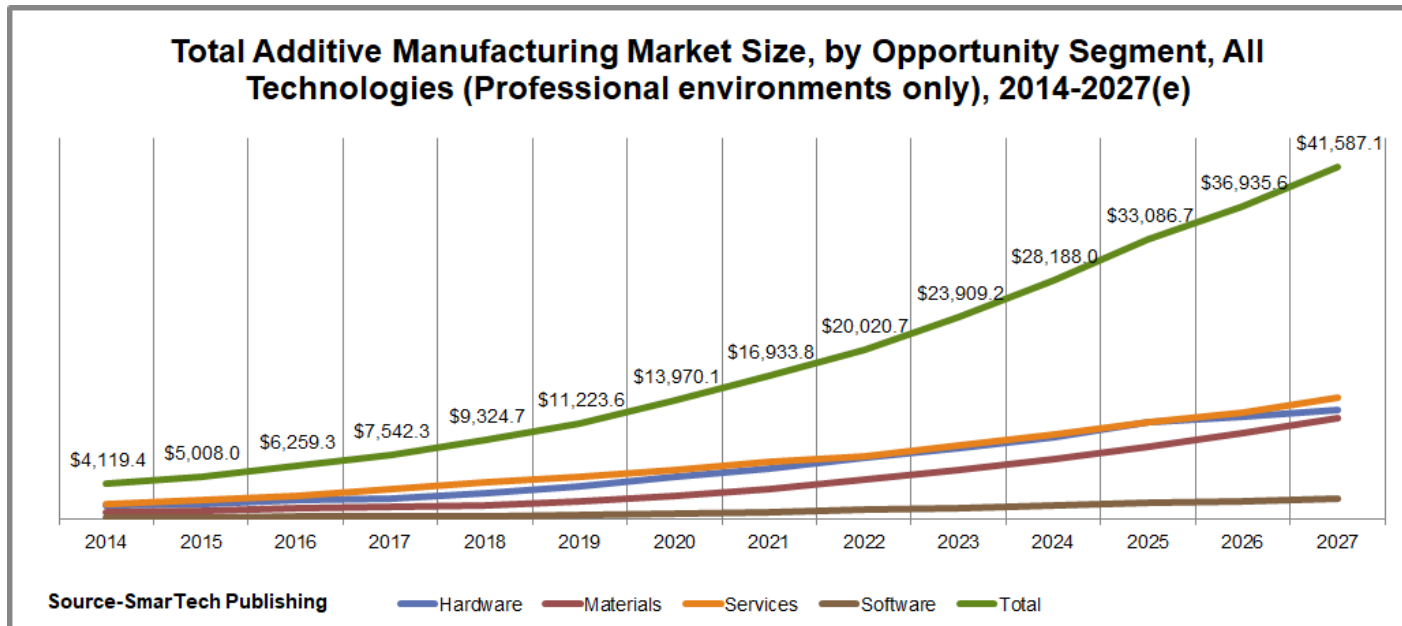


Interest by region



Region

| | | |
|---|--------------|-----|
| 1 | Singapore | 100 |
| 2 | Hong Kong | 74 |
| 3 | South Africa | 73 |
| 4 | Australia | 71 |
| 5 | New Zealand | 69 |



materialise

PRODUCTS & SERVICES INDUSTRIES ABOUT MATERIALISE

Home / Manufacturing / Materials / Design Guidelines

Design Guidelines

We've put together our trusted tips, tricks and best practices to get you off to a solid start. If you've been wondering whether a material allows for interlocking parts or embossing, or if you just want to avoid common design mistakes, check out our handy design guides.

Metal 3D Printing

- Aluminum (AlSi10Mg)
- Titanium (TiAl6V4)
- Stainless Steel (316L or 1.4404)
- Inconel (IN718)

Stereolithography (SLA)

- Poly1500
- TuskXC2700T
- TuskXC2700W
- Taurus
- Tusk Samos SolidGrey3000
- NeXt
- ProtoGen White
- Xtreme
- PeFDM

Fused Deposition Modeling (FDM)

- ABS
- ABS
- ABS-M30
- ABS-M30i
- PC
- ABS-ESD7
- PC-ABS
- Ultem 9085

Multi Jet Fusion (MJF)

- PA 12 (MJF)
- Ultrasint TPU 90A-01

Laser Sintering (SLS)

- Alumide
- PA 12 (SLS)
- Polypropylene (PP)

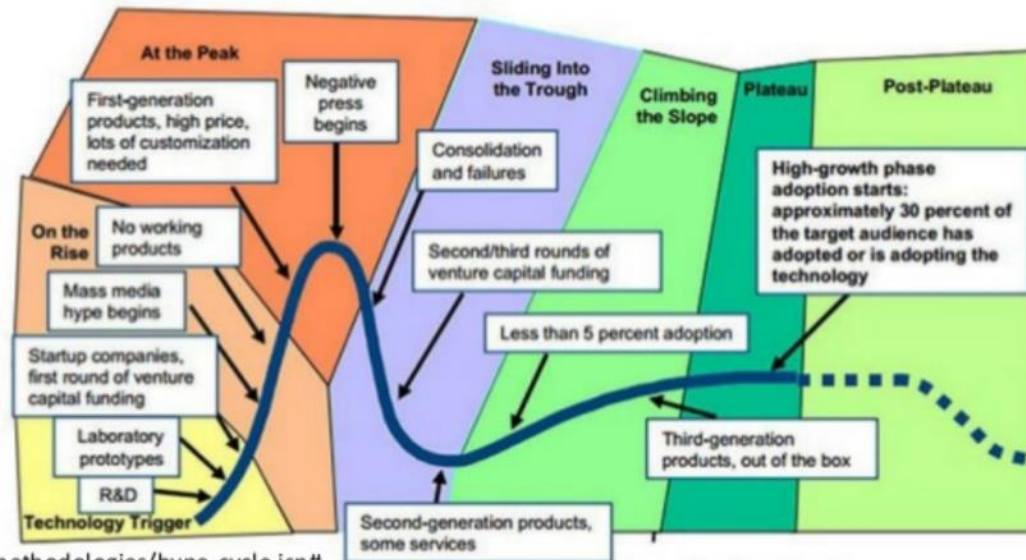
PolyJet

- Vero
- VeroClear
- Composite Materials

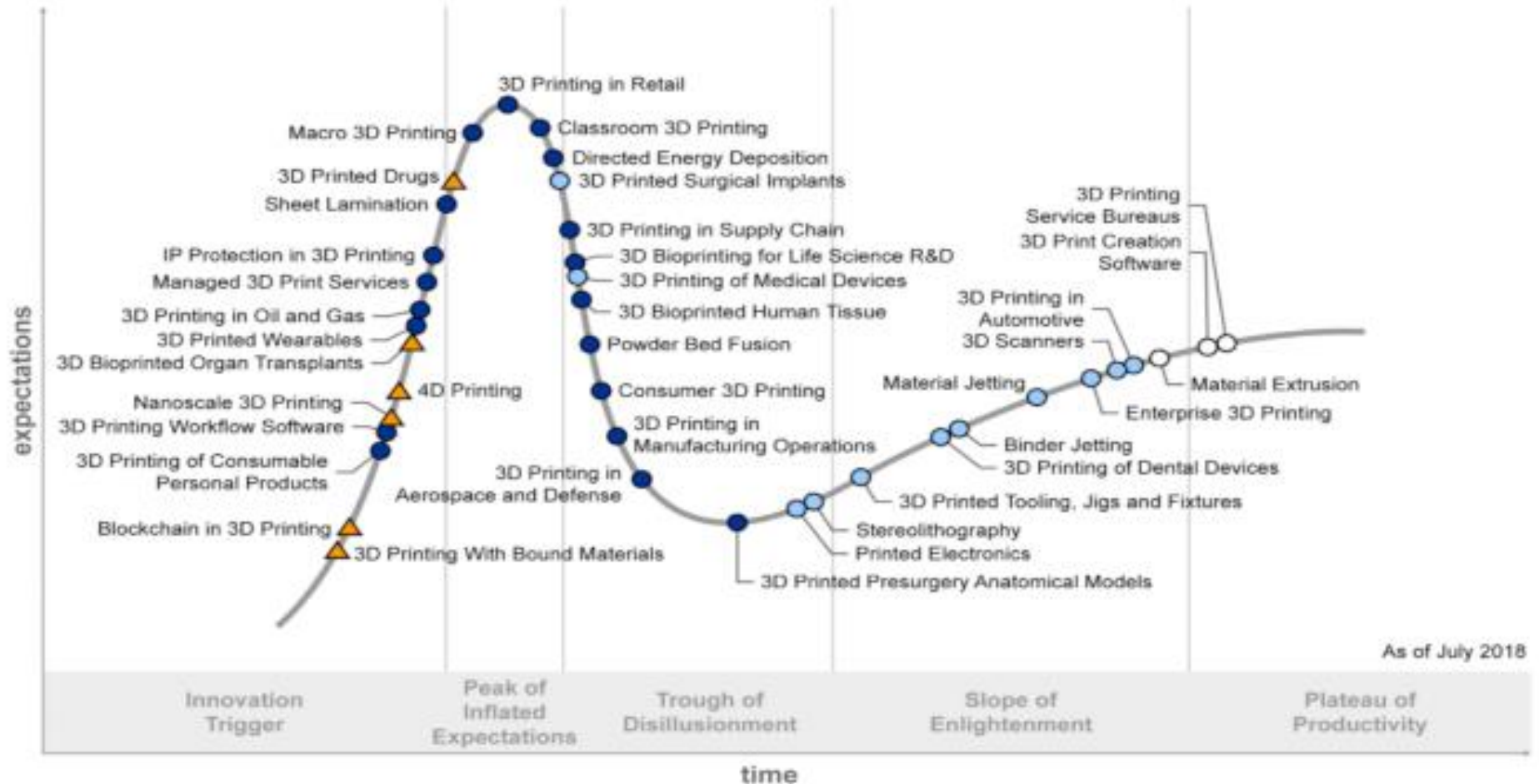


Gartner Hype Cycle

- Gartner Hype Cycles provide a graphic representation of the maturity and adoption of technologies and applications
- Gartner Hype Cycle methodology gives you a view of how a technology or application will evolve over time
- Each Hype Cycle drills down into the five key phases of a technology's life cycle.
 - Technology Trigger
 - Peak of Inflated Expectations
 - Trough of Disillusionment
 - Slope of Enlightenment
 - Plateau of Productivity



3D Printing Hype Cycle 2019



Plateau will be reached:

○ less than 2 years ● 2 to 5 years ● 5 to 10 years ▲ more than 10 years ⊗ obsolete before plateau

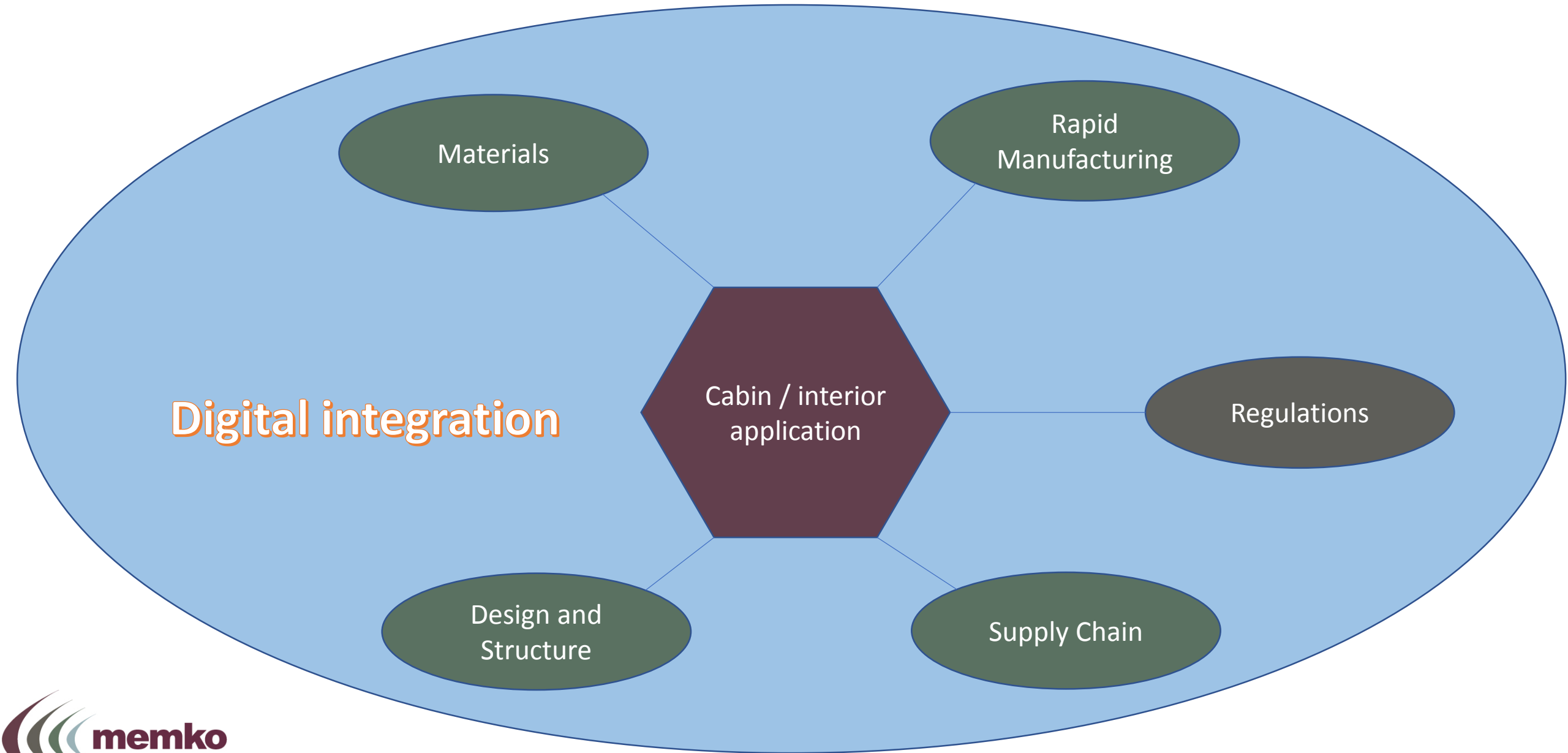
Characteristics of aircraft interiors

Demand Perspective

- Aesthetics
 - Ergonomics
 - Durability
 - Maintainability
 - Safety
- Innovation and Trends
- Multipurpose components
 - Integrated parts
 - Custom components
 - Just in time availability for replacement



Supply Perspective



Materials: Plastics in A/C Interiors

- Freedom in Design
- User Interaction
 - Surface finishes
 - Feel
 - Look
- Lightweight
 - Lesser fuel per flight
- Stability against:
 - Fire-flammability
 - Radiation
 - Corrosion
 - Low temperature
- Environmentally Friendly
 - Durable
 - Recyclable



Plastics in aerospace applications

- PEEK - Polyether ether ketone
- PEI – Polyetherimide
- PPSU – Polyphenylsulfone
- PI - Polyimide

PLEXIGLAS® Exterior Applications

- 1 Aircraft Canopy/View Windshield
- 2 Cockpit Instrument Panel
- 3 Wingtip Lens

PLEXIGLAS® Interior Application

- 4 Dust Covers

EUROPLEX® Interior Applications

- 5 Cockpit Instrument Panels
- 6 Window Shades and Dust Covers
- 7 Galleys, Partitions, Lavatories, Sidewalls, Seats & Tray Tables

POLYIMIDE P84® Interior Applications

- 8 Anti-friction/Insulating Coatings Electronics
- 9 Sealing Materials

POLYIMIDE P84® NT Powder Exterior Applications

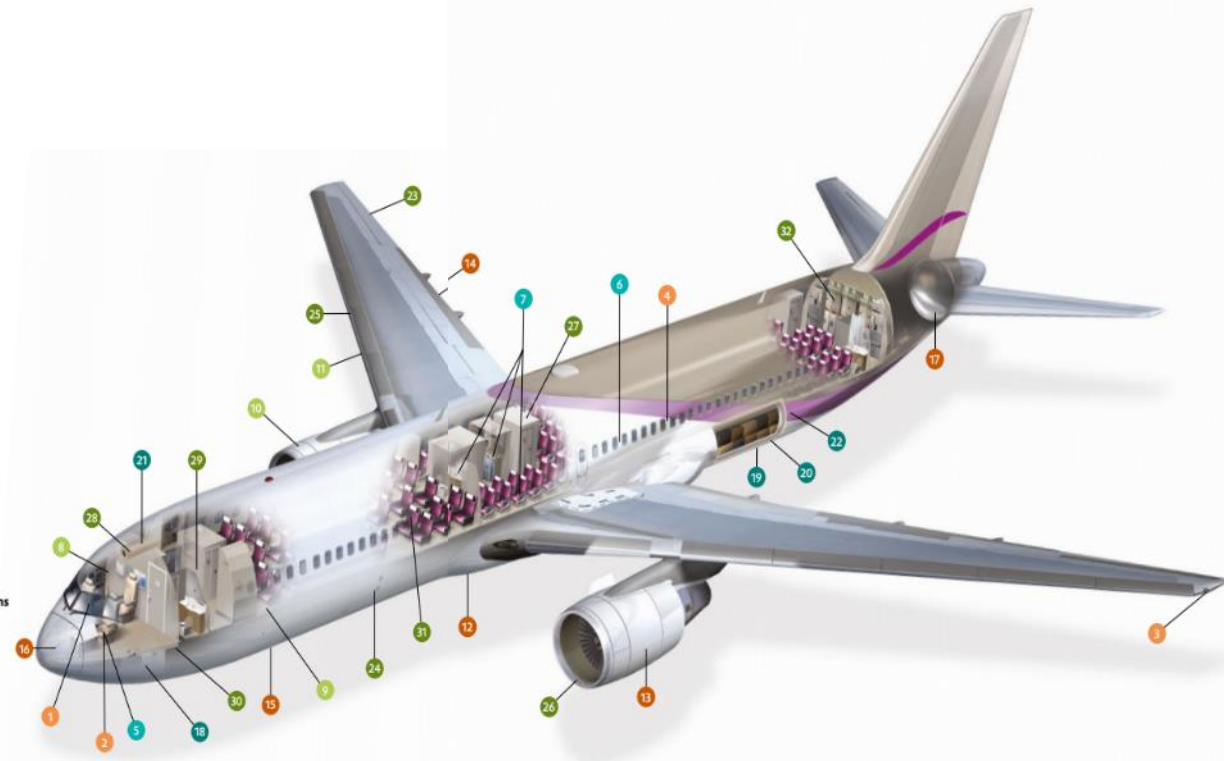
- 10 Sealings, Bearings, Bushings & Guidances
- 11 Toughening Agent for Composites

ROHACELL® Exterior Applications

- 12 Belly Fairing
- 13 Engine Cowling Doors
- 14 Flaps
- 15 Landing Gear Doors
- 16 Radome

ROHACELL® Interior Applications

- 17 Air Pressure Bulkhead



SOLIMIDE® Foams Interior Applications

- 18 Avionics Bays
- 19 Bilge Insulation
- 20 Cargo Liners
- 21 Duct Insulation
- 22 Fuselage Insulation

Suitable VESTAKEEP® Exterior Component Applications

- 23 Aileron
- 24 Fuselage
- 25 Leading Edge/J-Nose
- 26 Nacelle

Suitable VESTAKEEP® Interior Component Applications

- 27 Additive Manufacturing for High Temperature Applications
- 28 Ducting, Cable Ties & Sheathing
- 29 Hinges, Latches, Handles & Mechanical Parts
- 30 Secondary Floor Structures

VESTAMID® Interior Application

- 31 Interior Profiles/Rub Strips

Suitable VESTOSINT® Interior Application

- 32 Additive Manufacturing: Brackets, Clips & Ducts

Commercial Products



Technical Data Sheet

Radel® R-7159 polyphenylsulfone

Radel® R-7159 polyphenylsulfone (PPSU) was developed specifically for aircraft interior applications. The product complies with the FAA regulation 14CFR Part 25 Appendix F, offering vertical burn resistance, very low smoke generation and, through the use of proprietary additives, low heat release values in the Ohio State University (OSU) rate of heat release method. It also generates low flaming-mode toxic gas emissions.

match OEM color standards and in a natural-color grade that is designed to accept aircraft paint systems for aesthetic parts. Painting enhances the chemical resistance of the polymer and provides the final step in color coordination.

- Natural: Radel® R-7159 NT 50
- Black: Radel® R-7159 BK 937



INNOVATIVE PLASTICS PRODUCT LINE GUIDE: ULTEM™ RESINS PORTFOLIO



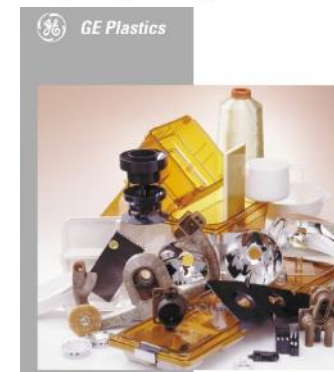
MVR: 360°C/5kg, cm³/10min; Flexural Modus, 2mm/min, MPa; IZOD Impact, unnotched, +23°C kJ/m²; VICAT Softening Temp., Rate B/120°C; UL94 Flame Class Rating

| | MVR | Flex Mod. | Vicat | IZOD | UL94* |
|---|-----|-----------|-------|------|----------|
| ULTEM 1000 resin series | | | | | |
| General Purpose, Unreinforced | | | | | |
| 1000 (R,F,E,EF,P) Standard, Extrusion | 13 | 3300 | 212 | 6 | V-0/0.75 |
| 1010 (F,R) Easy flow | 25 | 3300 | 212 | 5 | V-0/1.5 |
| ULTEM 2000 resin series | | | | | |
| Glass reinforced, greater rigidity | | | | | |
| 2100 (R,F) Standard, 10% glass reinforced | 9 | 4500 | 217 | 30 | V-0/0.41 |
| 2200 (R,F) Standard, 20% glass reinforced | 7 | 6500 | 218 | 30 | V-0/0.41 |
| 2300 (R,F) Standard, 30% glass reinforced | 6 | 8500 | 220 | 40 | V-0/0.25 |
| ULTEM 4000 resin series | | | | | |
| Wear Resistant, reduced coefficient of friction | | | | | |
| 4000 Reinforced, 25% glass reinforced | 5 | 7000 | 220 | 15 | V-0/0.84 |
| 4001 Unreinforced | 13 | 3000 | 210 | 10 | V-1/1.6 |
| ULTEM CRS5000 resin series | | | | | |
| Superior chemical resistance | | | | | |
| CRS5001 (R) Unreinforced | 7 | 2500 | 222 | - | V-0/1.5 |
| CRS5311 30% glass reinforced | 7 | 8200 | 220 | 35 | V-0/1.5 |
| ULTEM 9000 resin series | | | | | |
| Fulfills aircraft regulations (ABD, FAR, OSU, NBS), delivered with individual lot certification | | | | | |
| 9075 OSU 65/65, unreinforced, injection molding | 15 | 3200 | 200 | 7 | V-0/1.6 |
| 9085 OSU 55/55, unreinforced, high flow | 65 | 2750 | 173 | 13 | - |

ULTEM® resin is chosen because it offers:

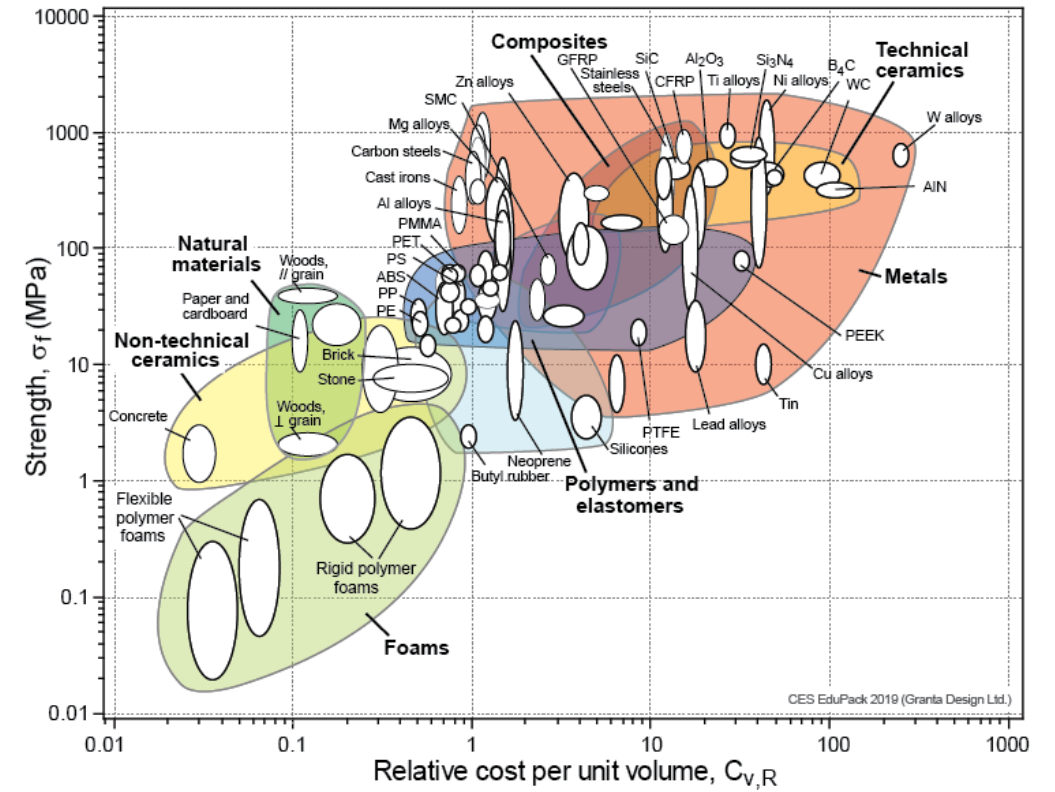
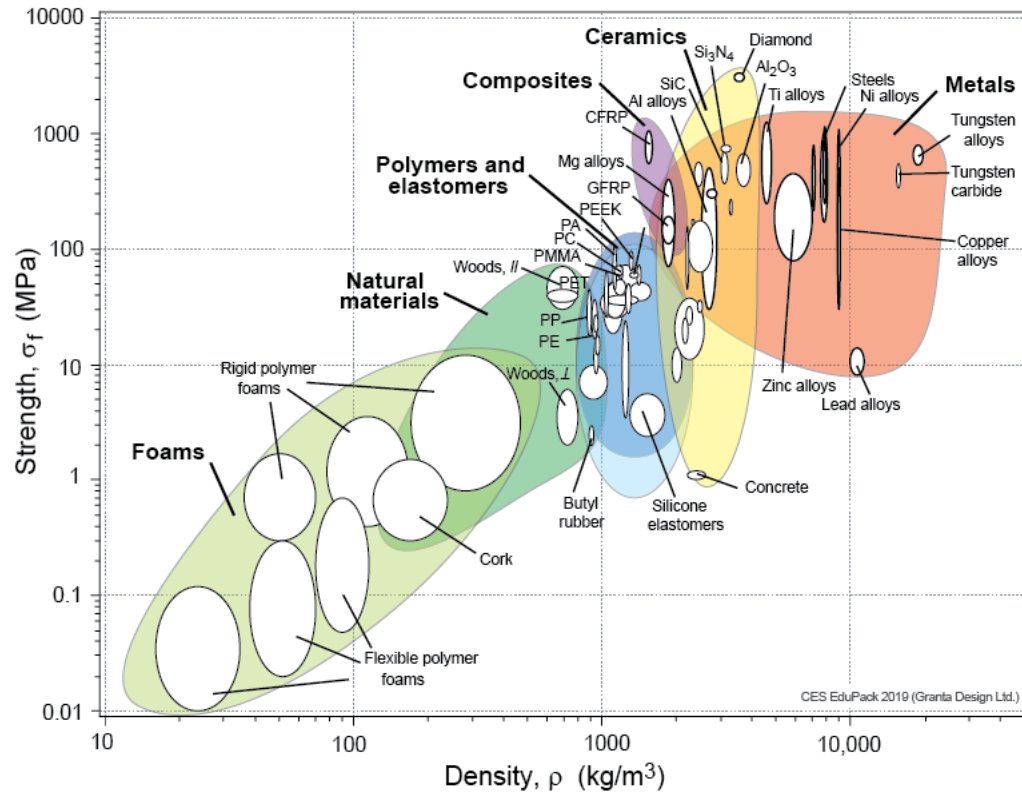
- The ULTEM® 9000 resin series for full compliance with aircraft industry regulations for aircraft interiors including ABD 0031, FAR 25.853, OSU 65/65 heat release tests and NBS smoke density tests
- The ULTEM® 1000, 2000, CRS 5000, 6000 and 7000 resin series for compliance with aircraft industry regulations such as ABD 0031, FAR 25.853, OSU 100/100 heat release tests and NBS smoke density tests
- Very low smoke and toxic gas emission, which makes it a material of choice for aircraft interiors
- Chemical resistance against most fuels and fluids
- Excellent processibility with a very good part reproducibility
- ULTEM® CRS 5000 resin series for better resistance against hydraulic aircraft fluids, such as Skydrol, compared to ULTEM® 1000 resin

- Ability to manufacture ULTEM® resin based thermoplastic composites which allow increased productivity in component manufacturing over traditional composite materials
- Ability to manufacture ULTEM® foam cores for tough, light-weight sandwich panels



ULTEM®
PEI Resin

Materials: Plastics in A/C Interiors

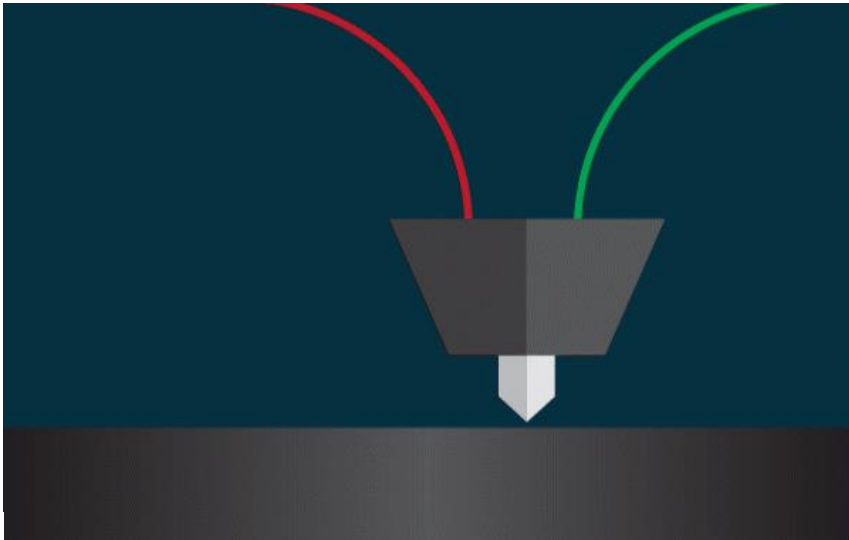


Fire Smoke Toxicity

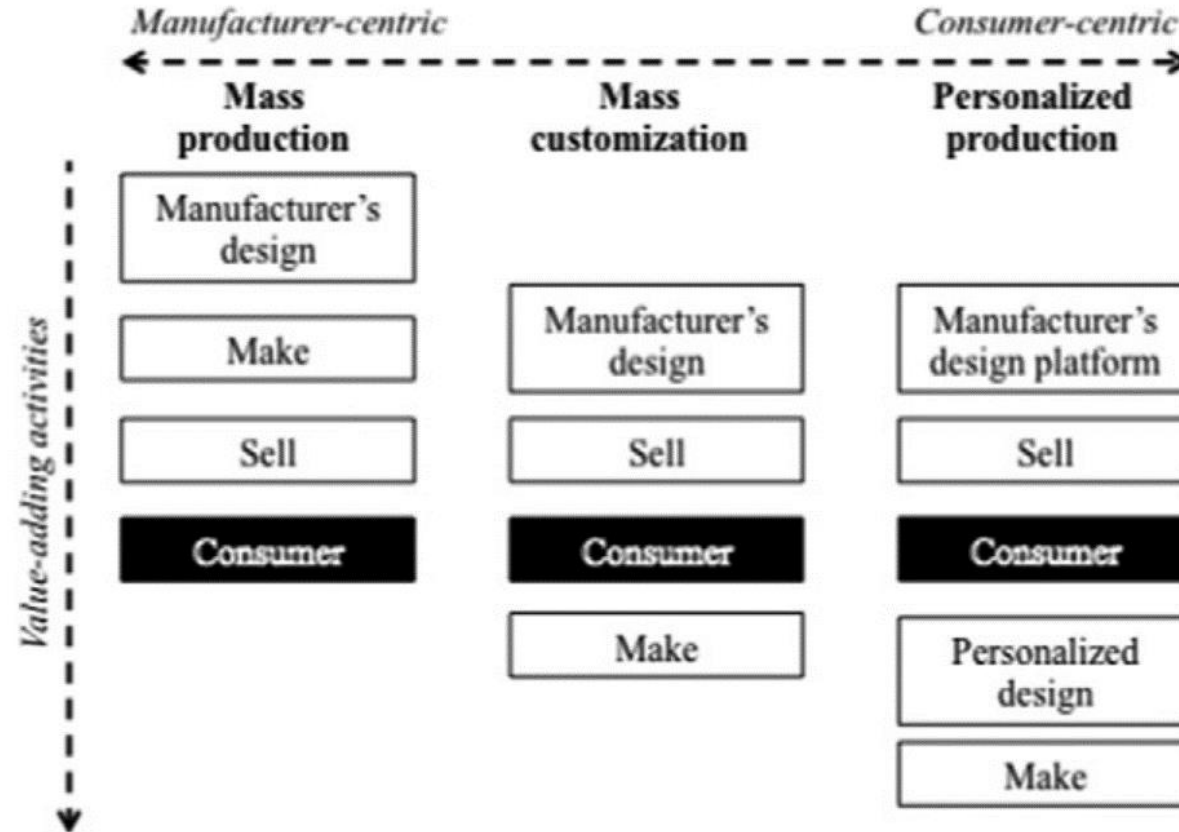
- FAR 25.853, (a) i & ii, (d)
- Flame: spread-speed, heat generated
- Smoke: density
- Toxicity: ppm of carbon monoxide (CO), hydrogen fluoride (HF), hydrogen chloride (HCl), hydrogen cyanide (HCN), nitrogen oxides (NO_x), sulfur dioxide (SO₂), carbon dioxide (CO₂) and hydrogen bromide (HBr)
- Improvement: halogen based resins, phenolics, alumina trihydrate (ATH, Al[OH]₃)

Additive Manufacturing

- Additive manufacturing, also known as 3D printing, is a transformative approach to industrial production that creates a physical object from a digital design which enables the creation of lighter, stronger parts and systems. (GE Additive)

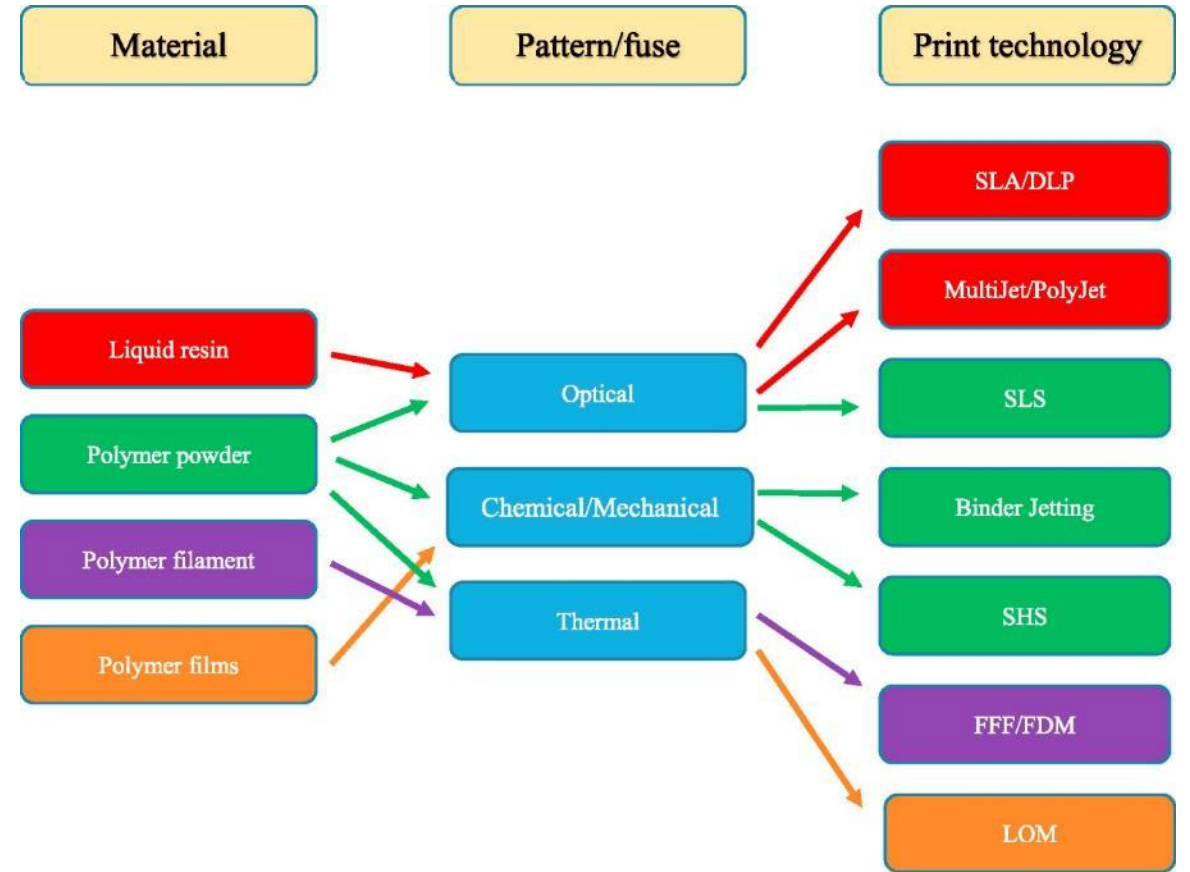


Paradigm shift



Additive Manufacturing Method of Production

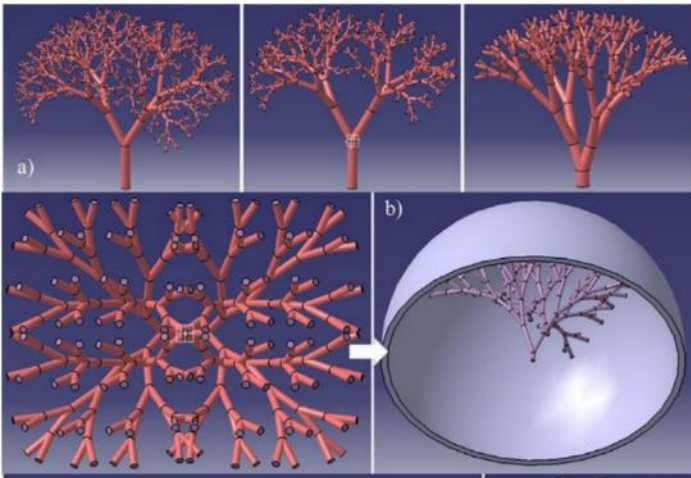
| | |
|----------------|---|
| SLA | Stereolithography apparatus |
| DLP | Digital light projection |
| CLIP | Continuous liquid interface production |
| SLS | Selective laser sintering |
| SHS | Selective heat sintering |
| BAAM | Big area additive manufacturing |
| FFF/FDM | Fused filament fabrication/fused deposition modelling |
| LOM | Laminated object manufacturing |



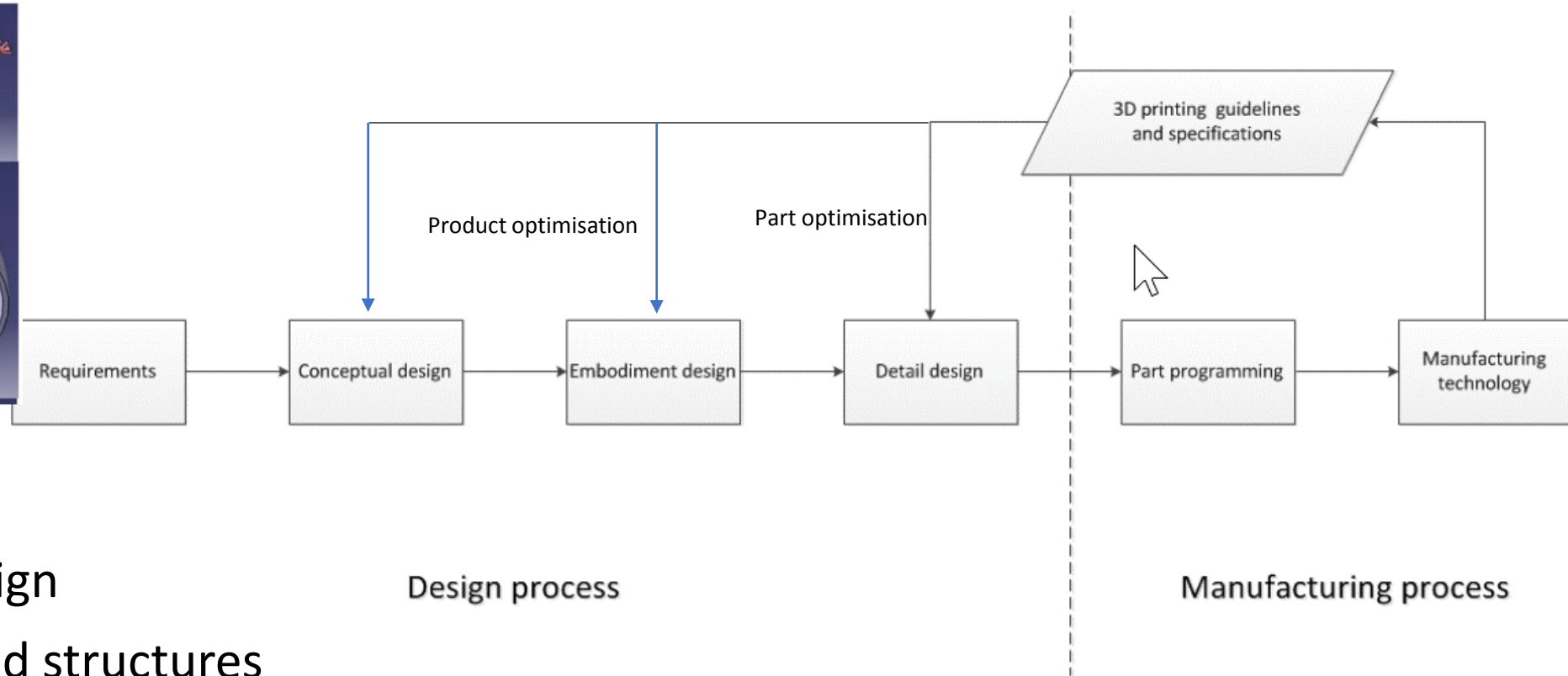
Material selection for Makers

| |  ABS |  Flexible |  PLA |  HIPS |  PETG |  Nylon |  Carbon Fiber Filled |  ASA |  Polycarbonate |  Polypropylene |  Metal Filled |  Wood Filled |  PVA |
|----------------------------------|---|--|---|--|--|---|---|---|---|---|--|---|---|
| | Learn More | Learn More | Learn More | Learn More | Learn More | Learn More | Learn More | Learn More | Learn More | Learn More | Learn More | Learn More | Learn More |
| Compare Selected | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Ultimate Strength | 40 MPa | 26 - 43 MPa | 65 MPa | 32 MPa | 53 MPa | 40 - 85 MPa | 45 - 48 MPa | 55 MPa | 72 MPa | 32 MPa | 20 - 30 MPa | 46 MPa | 78 MPa |
| Stiffness | 5 / 10 | 1 / 10 | 7.5 / 10 | 10 / 10 | 5 / 10 | 5 / 10 | 10 / 10 | 5 / 10 | 6 / 10 | 4 / 10 | 10 / 10 | 8 / 10 | 3 / 10 |
| Durability | 8 / 10 | 9 / 10 | 4 / 10 | 7 / 10 | 8 / 10 | 10 / 10 | 3 / 10 | 10 / 10 | 10 / 10 | 9 / 10 | 4 / 10 | 3 / 10 | 7 / 10 |
| Maximum Service Temperature | 98 °C | 60 - 74 °C | 52 °C | 100 °C | 73 °C | 80 - 95 °C | 52 °C | 95 °C | 121 °C | 100 °C | 52 °C | 52 °C | 75 °C |
| Coefficient of Thermal Expansion | 90 $\mu\text{m/m}^\circ\text{C}$ | 157 $\mu\text{m/m}^\circ\text{C}$ | 68 $\mu\text{m/m}^\circ\text{C}$ | 80 $\mu\text{m/m}^\circ\text{C}$ | 60 $\mu\text{m/m}^\circ\text{C}$ | 95 $\mu\text{m/m}^\circ\text{C}$ | 57.5 $\mu\text{m/m}^\circ\text{C}$ | 98 $\mu\text{m/m}^\circ\text{C}$ | 69 $\mu\text{m/m}^\circ\text{C}$ | 150 $\mu\text{m/m}^\circ\text{C}$ | 33.75 $\mu\text{m/m}^\circ\text{C}$ | 30.5 $\mu\text{m/m}^\circ\text{C}$ | 85 $\mu\text{m/m}^\circ\text{C}$ |
| Density | 1.04 g/cm ³ | 1.19 - 1.23 g/cm ³ | 1.24 g/cm ³ | 1.03 - 1.04 g/cm ³ | 1.23 g/cm ³ | 1.06 - 1.14 g/cm ³ | 1.3 g/cm ³ | 1.07 g/cm ³ | 1.2 g/cm ³ | 0.9 g/cm ³ | 2 - 4 g/cm ³ | 1.15 - 1.25 g/cm ³ | 1.23 g/cm ³ |
| Price (per kg) | \$10 - \$40 | \$30 - \$70 | \$10 - \$40 | \$24 - \$32 | \$20 - \$60 | \$25 - \$65 | \$30 - \$80 | \$38 - \$40 | \$40 - \$75 | \$60 - \$120 | \$50 - \$120 | \$25 - \$55 | \$40 - \$110 |
| Printability | 8 / 10 | 6 / 10 | 9 / 10 | 6 / 10 | 9 / 10 | 8 / 10 | 8 / 10 | 7 / 10 | 6 / 10 | 4 / 10 | 7 / 10 | 8 / 10 | 5 / 10 |
| Extruder Temperature | 220 - 250 °C | 225 - 245 °C | 190 - 220 °C | 230 - 245 °C | 230 - 250 °C | 220 - 270 °C | 200 - 230 °C | 235 - 255 °C | 260 - 310 °C | 220 - 250 °C | 190 - 220 °C | 190 - 220 °C | 185 - 200 °C |
| Bed temperature | 95 - 110 °C | 45 - 60 °C | 45 - 60 °C | 100 - 115 °C | 75 - 90 °C | 70 - 90 °C | 45 - 60 °C | 90 - 110 °C | 80 - 120 °C | 85 - 100 °C | 45 - 60 °C | 45 - 60 °C | 45 - 60 °C |
| Heated Bed | Required | Optional | Optional | Required | Required | Required | Optional | Required | Required | Required | Optional | Optional | Required |
| Recommended Build Surfaces | Kapton Tape, ABS Slurry | PEI, Painter's Tape | Painter's Tape, Glue Stick, Glass Plate, PEI | Glass Plate, Glue Stick, Kapton Tape | Glue Stick, Painter's Tape | Glue Stick, PEI | Painter's Tape, Glue Stick, Glass Plate, PEI | Glue Stick, PEI | PEI, Commercial Adhesive, Glue Stick | Packing Tape, Polypropylene Sheet | Painter's Tape, Glue Stick, PEI | Painter's Tape, Glue Stick, PEI | PEI, Painter's Tape |
| Other Hardware Requirements | Heated Bed, Enclosure Recommended | Part Cooling Fan | Part Cooling Fan | Heated Bed, Enclosure Recommended | Heated Bed, Part Cooling Fan | Heated Bed, Enclosure Recommended, May Require All Metal Hotend | Part Cooling Fan | Heated Bed | Heated Bed, Enclosure Recommended, All Metal Hotend | Heated Bed, Enclosure Recommended, Part Cooling Fan | Wear Resistant or Stainless Steel Nozzle, Part Cooling Fan | Part Cooling Fan | Heated Bed, Part Cooling Fan |

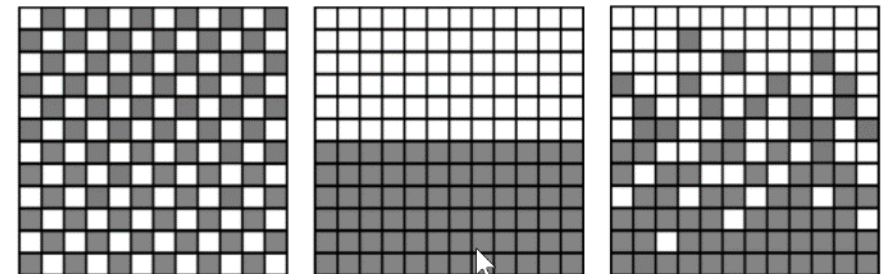
Design for Additive Manufacturing



Lantada et al. 2017

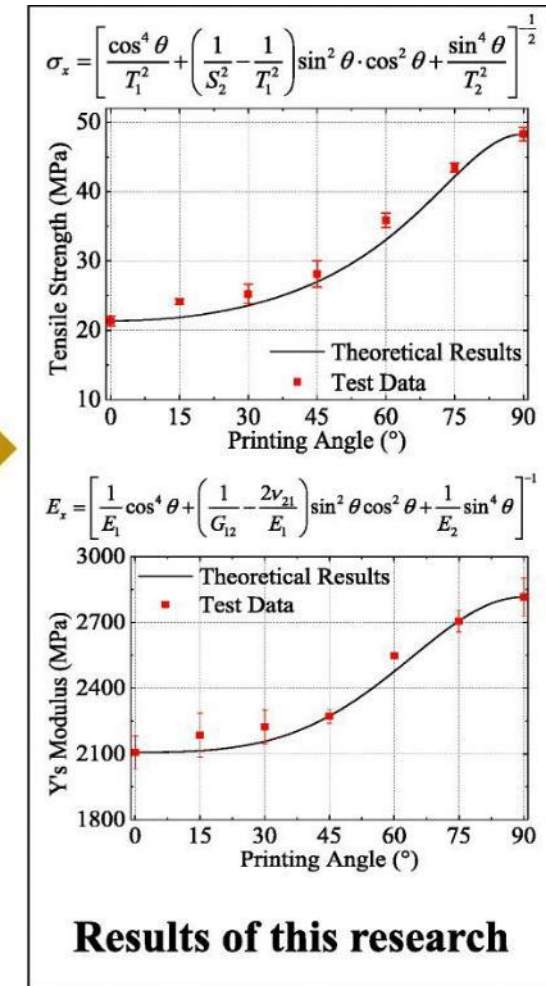
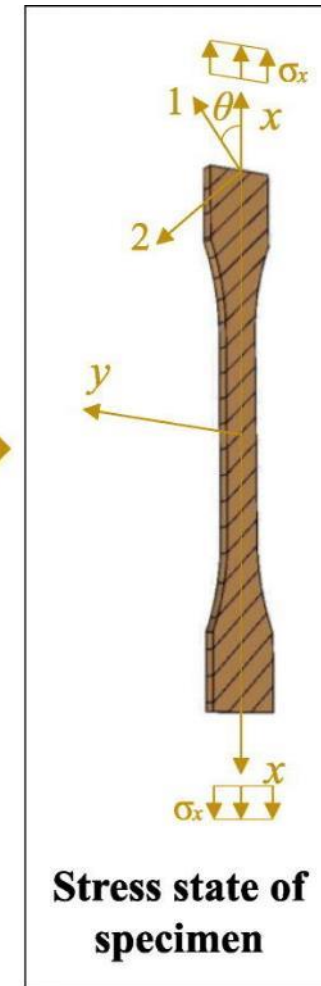
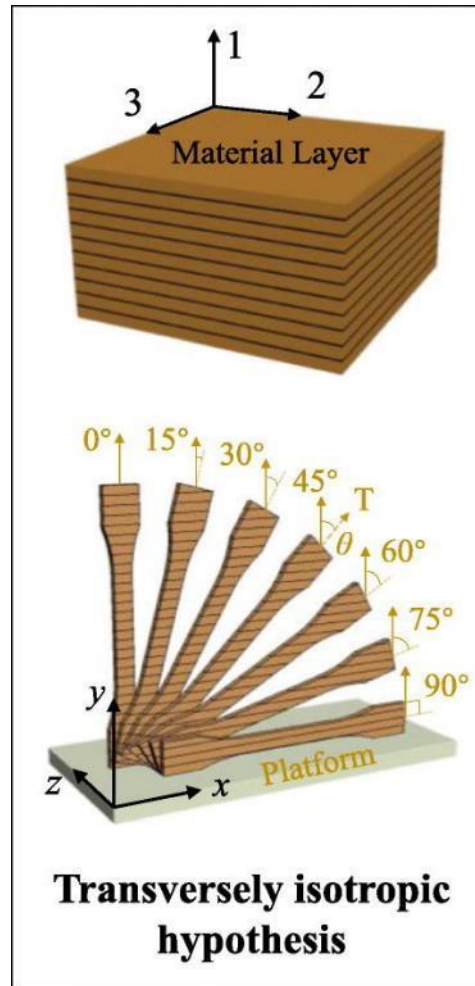
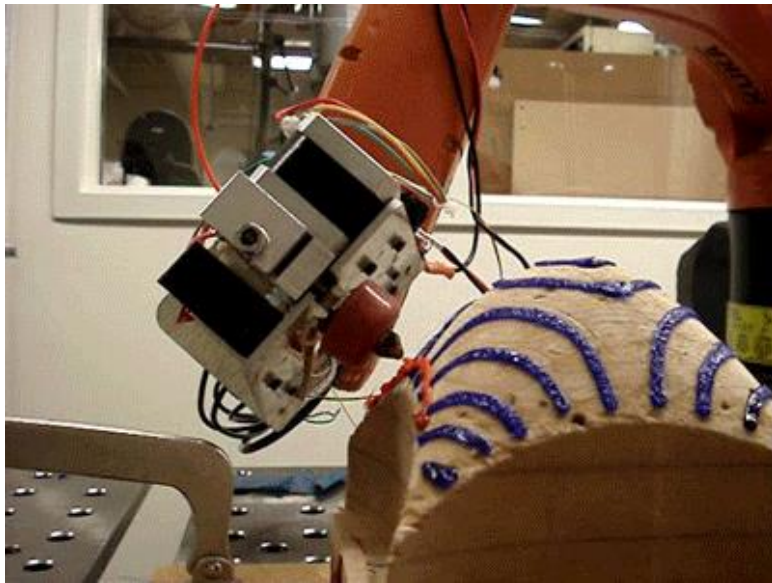
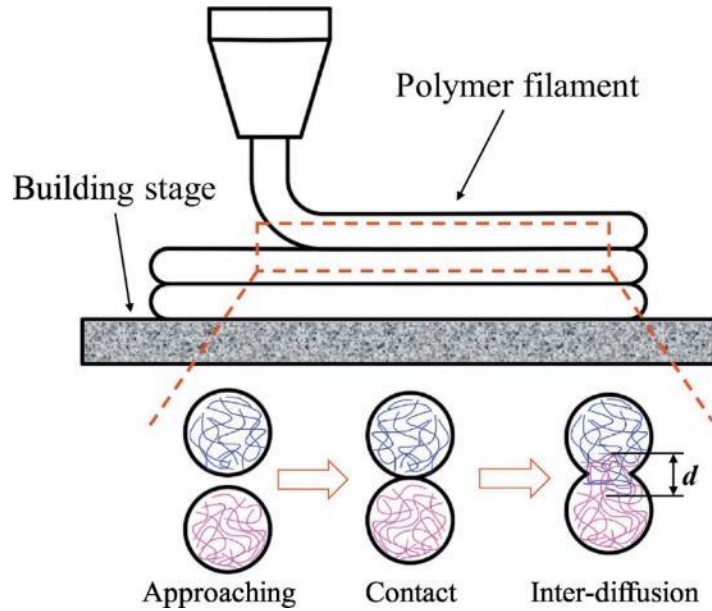


- Bio-Inspired Design
- Functional graded structures
- Hierarchical micro structure

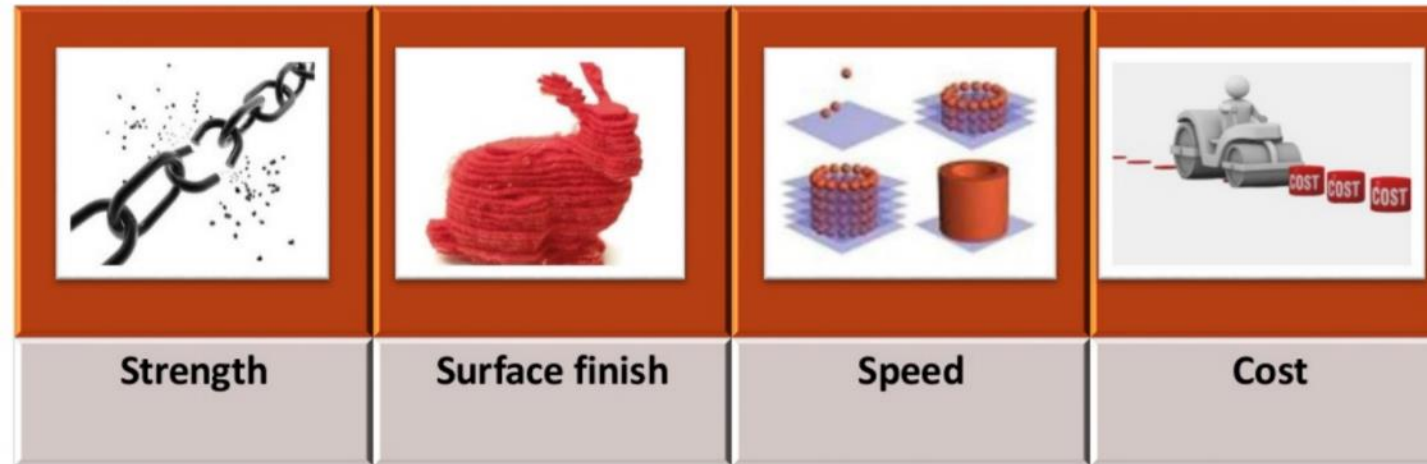


Mognol et al. 2011

Mechanical Properties



Limitations & Quality of AM Products



IMPROVEMENTS

1. Improvements in **surface fineness**
2. Increase in detail rendition by thinner layers
3. Improvements of material properties and range
4. Cut down of construction time
5. Elimination of rework
6. Reduce cost

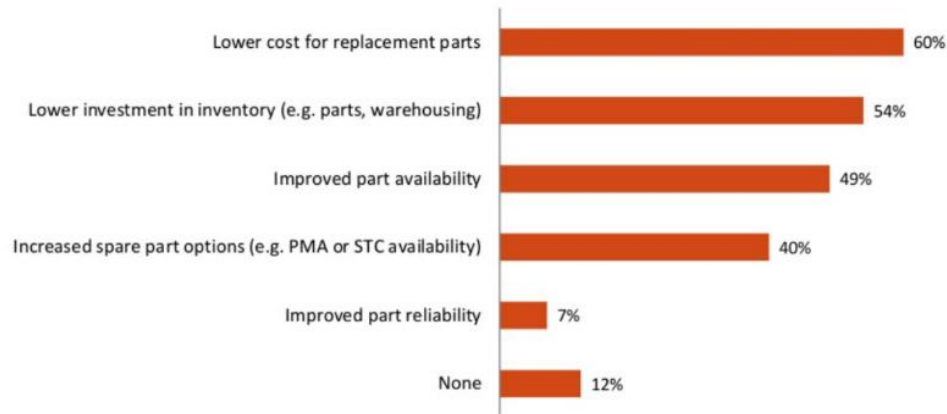
Funk J. 2015

Challenges in Supply for Maintenance Parts

- Time – when a component is needed – available when needed
- Location – need to be available near critical locations

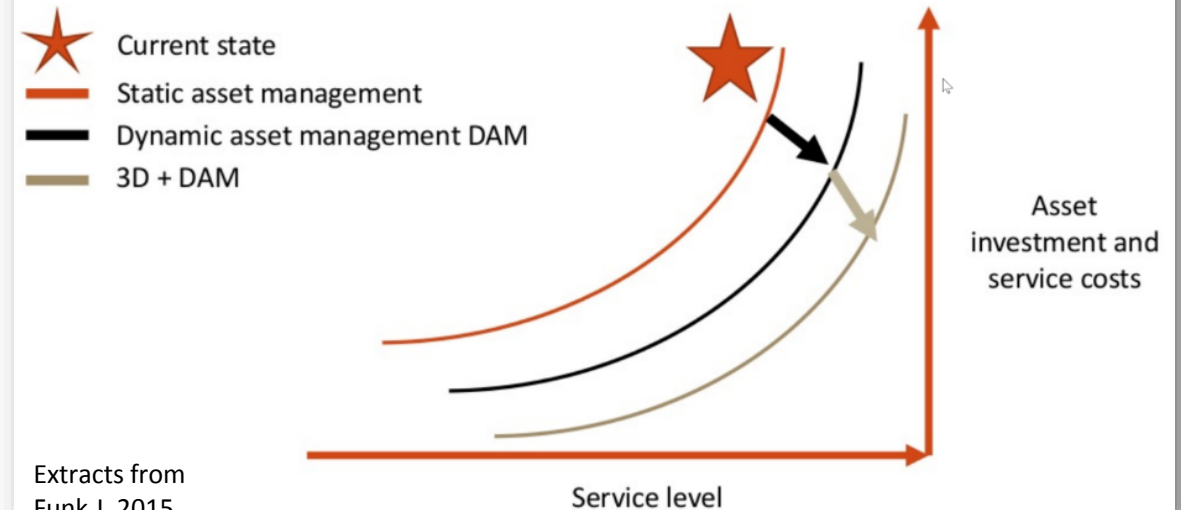
3D Printing point of view from OEM and MRO

What benefits might the successful deployment of 3D printing technology bring to airline?



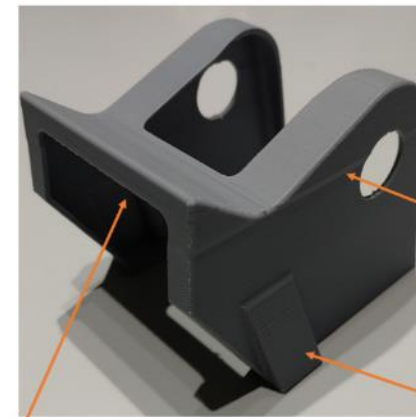
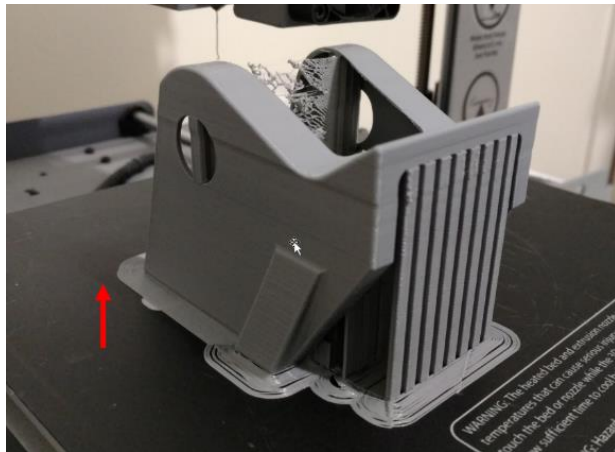
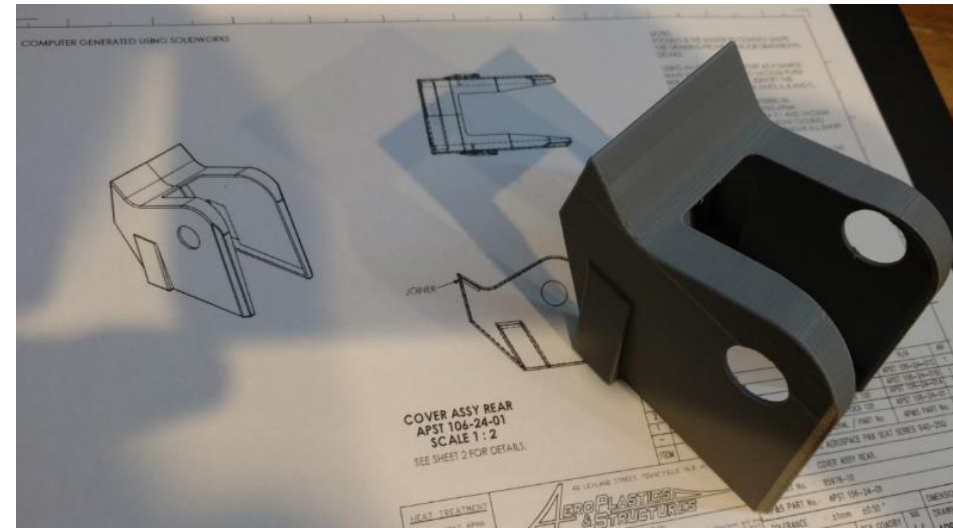
Oliver Wyman, MRO Survey 2014

Tradeoffs between Revenue, Cost and Performance



Extracts from
Funk J. 2015

Armrest cover



finishing of flatter down facing surfaces have some unremoved support pieces, a finer tool can be used to clean them

Other concepts in AM supply chain:

- Decentralized supply chain
- Reduce material inputs for leaner manufacturing
- Simplify production processes, reducing costs
- Lower risk by providing a contingency plan
- Improve process flexibility, reacting faster to demand
- Reduce the capital cost of entry into new markets



Case study: Tray Table

- Materials in tray tables
- General specs of
- Potential damage in tray tables
- General replacement procedure + supply chain +time line
- Proposed rapid maintenance solution:
 - Reverse engineering / OEM data
 - Supply chain
 - Material
 - Replacement method
 - Lifespan/ temporary AW approval



The Digital Enterprise powered by 3DEXPERIENCE

INDUSTRY SOLUTION EXPERIENCES



Model Connectors

MCAD

NX SOLID EDGE creo
 AUTODESK INVENTOR AUTOCAD

ECAD/ EDA/ SW

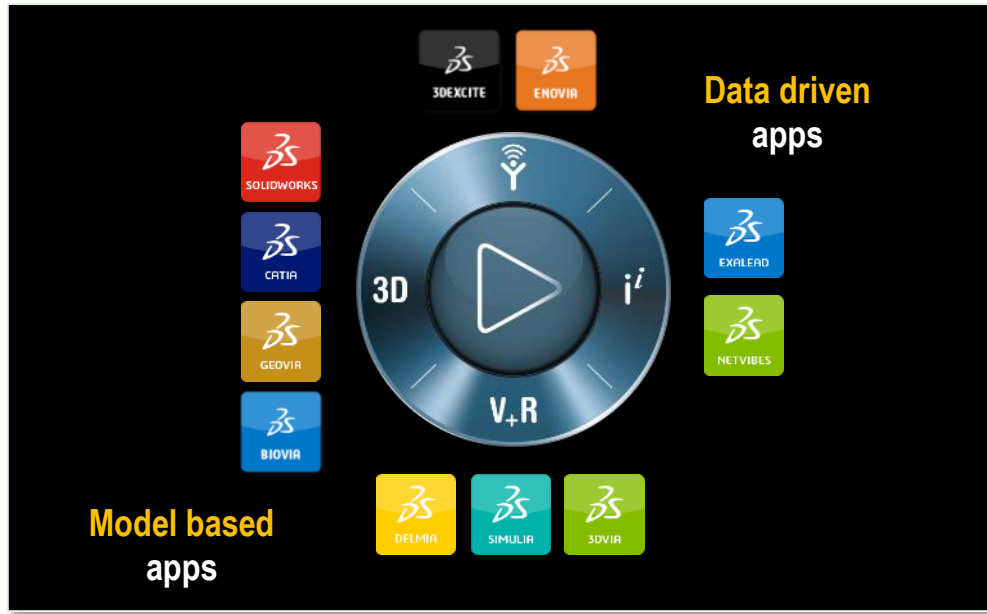
cadence ZUKEN Mentor Graphics
 SYNOPSYS eclipse

CAE/ Systems

MATLAB MSC Nastran
 fmi FUNCTIONAL MOCKUP INTERFACE MODELICA

Office

Office Ai



Data Connectors

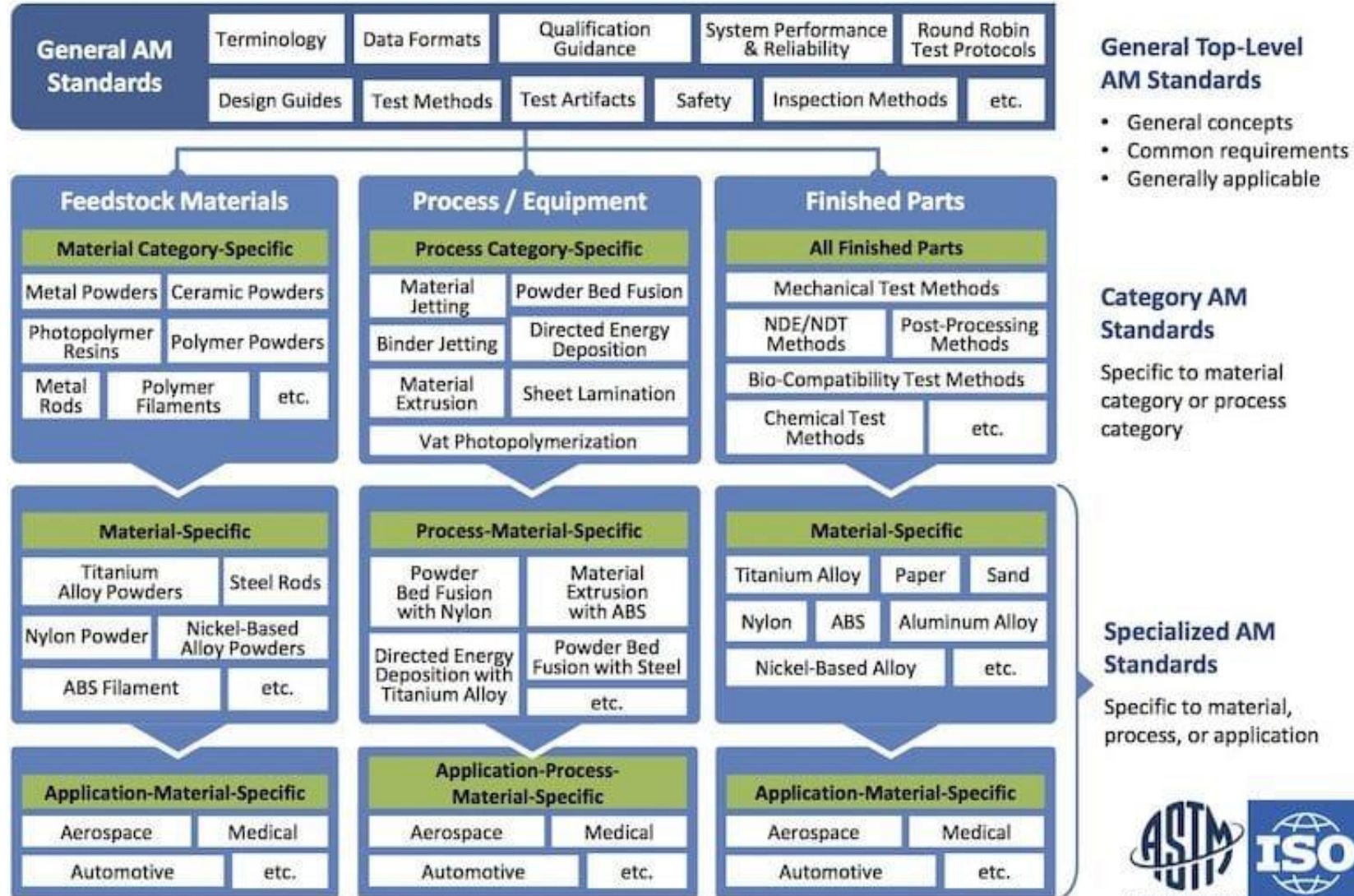
HOFS documentum by EMC
 SharePoint IBM WebSphere
 Lotus Notes OPEN TEXT The Content Experts
 FILENET An IBM Company AUTODESK VAULT
 salesforce SMARTTEAM Microsoft Exchange Server
 SOLIDWORKS PDM Livelink

SAP Windchill PTC Process Connectors ORACLE SIEMENS Teamcenter

Specialized Apps and Connectors



Additive Manufacturing Standards Structure



Aviation Context - Australia

Safety
Regulated

- Large Aircraft – minimal new design, extensive international, domestic and regional airline fleets - FAA & EASA
- Military aircraft – minimal new design fleet of ADF aircraft – F-35
- Small aircraft – some new design FAR23 Amdt 64.

Innovative
– Self
regulated

- LSA (electric), experimental – some new design
- UAV – significant new design



Graduates– to have an understanding of the role of technology for local Industry
Rapid Prototyping – Stereo Lithography

What is the Aviation context for value add AM technologies

Multi-faceted Usage in Aviation

- Out of production spare and replacement parts
Colour printing ?



- Manufacturing – natural optimisation rather than limitations of existing machining and fabrication processes.



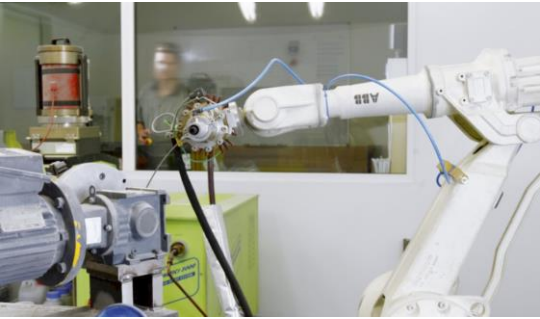
- Maintenance – Logistics and Lead time



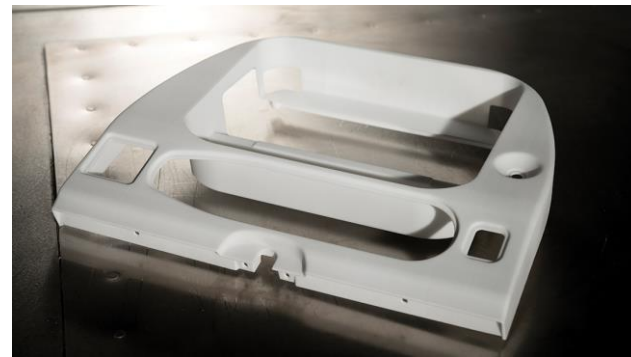
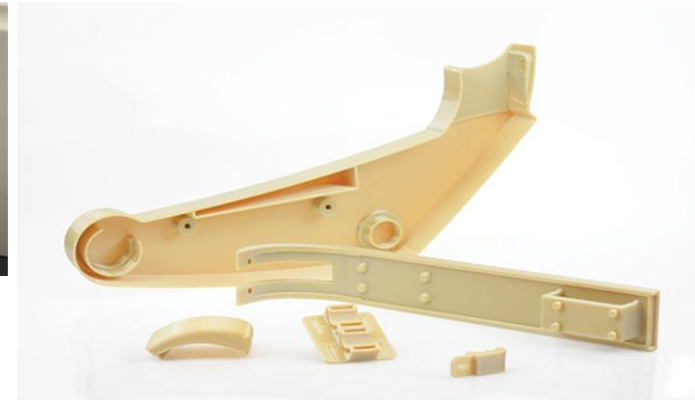
- Repairs



Australia AM context vs the Rest of the world



Australia - RUAG, Quickstep, Titomic



Globally - Airlines

Aviation Maintenance Logistics

The screenshot displays the VeriPart™ web application interface for an aviation maintenance order. The top navigation bar includes 'VeriPart™', 'Dashboard', 'Catalog', and 'Orders'. A search bar is located on the right. The main content area shows an order for a 'PROTECTOR BLOCK LEFT HAND (NON-RECESSED)' by 'AIR NEW ZEALAND'. A progress bar indicates the order status: Order Created, Transfer Request Successful, Transfer Complete, Manufacturing In Progress, and Order Complete. A 'Print Traveler Document' button is visible. A 3D model of the part is shown on the left, with a 'DOWNLOAD AND VERIFY' button below it. A world map highlights the location of the part. The order details include the name, manufacturer, part number, revision, and customer ID. The description is 'Business Premier Class Seat Monitor Left Hand Non-Recessed Protector Block. Technical Data Package is for production'. The order is split into two items, both with 'Serial #: TBD' and 'EDIT' buttons. The interface also shows fields for 'Operator:', 'Material:', and 'Comments:' for each item.

VeriPart™
Support Moog Urgent Sign Out

Dashboard Catalog **Orders**

Order 0x37785fb Print Traveler Document

Order Created **Transfer Request Successful** **Transfer Complete** **Manufacturing In Progress** **Order Complete**

Name: PROTECTOR BLOCK LEFT HAND (NON-RECESSED)
Manufacturer: AIR NEW ZEALAND
Manufacturer's Part Number: F2306-419-601-M00G
Revision: -
Customer PO: 916197444

DOWNLOAD AND VERIFY →

Description: Business Premier Class Seat Monitor Left Hand Non-Recessed Protector Block. Technical Data Package is for production

Details (2)

Serial #: TBD **EDIT** **2** **Serial #: TBD** **EDIT**

Operator:
Material:
Comments:

Operator:
Material:
Comments:

www.3dprintingmedia.network

Air New Zealand – AM Innovators



AM Certification



Australian Government
Civil Aviation Safety Authority

Conditions and Limitations:

This authorisation does not constitute approval to manufacture aeronautical products using “Additive manufacturing (3D Printing)”

The regulator seldom approves materials & processes as standalone entities.

-material & process approvals are implied when a particular design has been certificated regardless of whether this design is a component, an engine or an aircraft

User Responsibility

Ensure AM material and process determines design allowables which are reliable and have a statistical basis of derivation

Note: To manufacture AM parts you need design data and a controlled process, therefore you should have design & build capability.

Production Limitation Record

The holder of Production Certificate No.

is authorised to produce

Class III Aeronautical Products

on a one-off basis, manufactured in accordance with the following design data:

| Description of Aeronautical Products | Manufacturing Location/s | Design Data | Date Production Authorised |
|---|--------------------------|--|----------------------------|
| Machined Metal Aeronautical Products Machined Plastic Aeronautical Products Sheet Metal Aeronautical Products Welded Metal Aeronautical Products Soft furnishings: Limited to covering of sidewalls and bulkheads, bags and stowage's for role equipment and loose articles. Composites: Limited to Cutting and potting of honeycomb sandwich panels Forming of metal tubing "non-fluid carrying" | | Design Data approved by: <ul style="list-style-type: none">CASA, orCASR 21.132A Authorised Person or approved design organisation; orSTC or Foreign STC approved design data; orCASR 21.437 Authorised Person or approved design organisation; orForeign modification/repair designs (see CASR 21.470); orCAR (1988) 35 Authorised person (for data approved before 27 June 2011); orCAR (1988) 36 Authorised person (for data approved before 27 June 2011); orCAR (1988) 36A Authorised person (for data approved before 27 June 2011). | 08 June 2018 |
| Curtains Carpets Seat Covers | | | |

Conditions and Limitations:
This authorisation does not constitute approval to manufacture aeronautical products using "Additive Manufacturing (3D Printing)"

Revision History:
Initial Issue: 08 June 2018

Date Issued: 08 June 2018

Certification– the questions

- A Part produced by AM is both a material and a process.

§25.603 Materials.

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

- (a) Be established on the basis of experience or tests;
- (b) Conform to approved specifications (such as industry or military specifications, or Technical Standard Orders) that ensure their having the strength and other properties assumed in the design data; and
- (c) Take into account the effects of environmental conditions, such as temperature and humidity, expected in service.

§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 program.

§25.853 Compartment interiors.

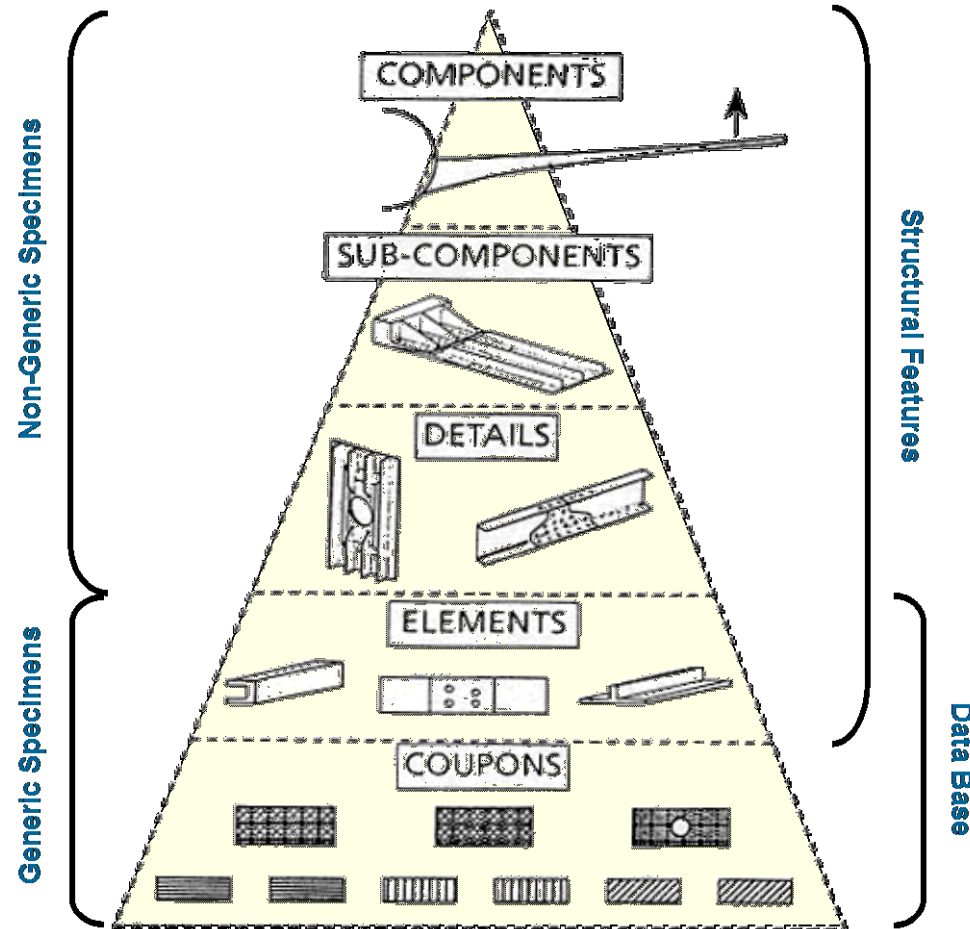
For each compartment occupied by the crew or passengers, the following apply:

- (a) Materials (including finishes or decorative surfaces applied to the materials) must meet the applicable test criteria prescribed in part I of appendix F of this part, or other approved equivalent methods, regardless of the passenger capacity of the airplane.

Certification - the process

§25.613 Material strength properties and material design values.

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



General Aviation AM implementation



Image: Piper Aircraft

Piper has produced its first production part using additive manufacturing—more commonly known as 3D printing — according to a company announcement last week. The part, a climate control system component, was printed using an HP Multi Jet Fusion 4200 3D printer. Piper says it is currently focusing on creating and testing non-flight-critical components with the goal of achieving FAA approval and expanding the use of 3D printing in aircraft manufacturing.



Image: Russian Helicopters Holding Company

Russian Helicopter Holding Company will launch serial production of 30 different helicopter parts using 3D printing from next year. This entails construction redesign, strength testing and other tests in an effort to ensure the part made by AM is equivalent to or superior in its characteristics to the original version.

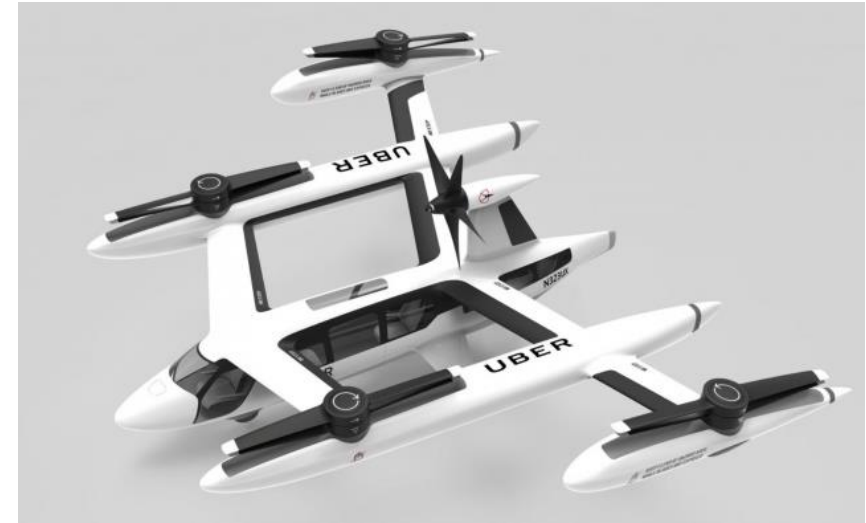
UAV - AM implementation



Systems Engineering
Capability
Mission
Performance



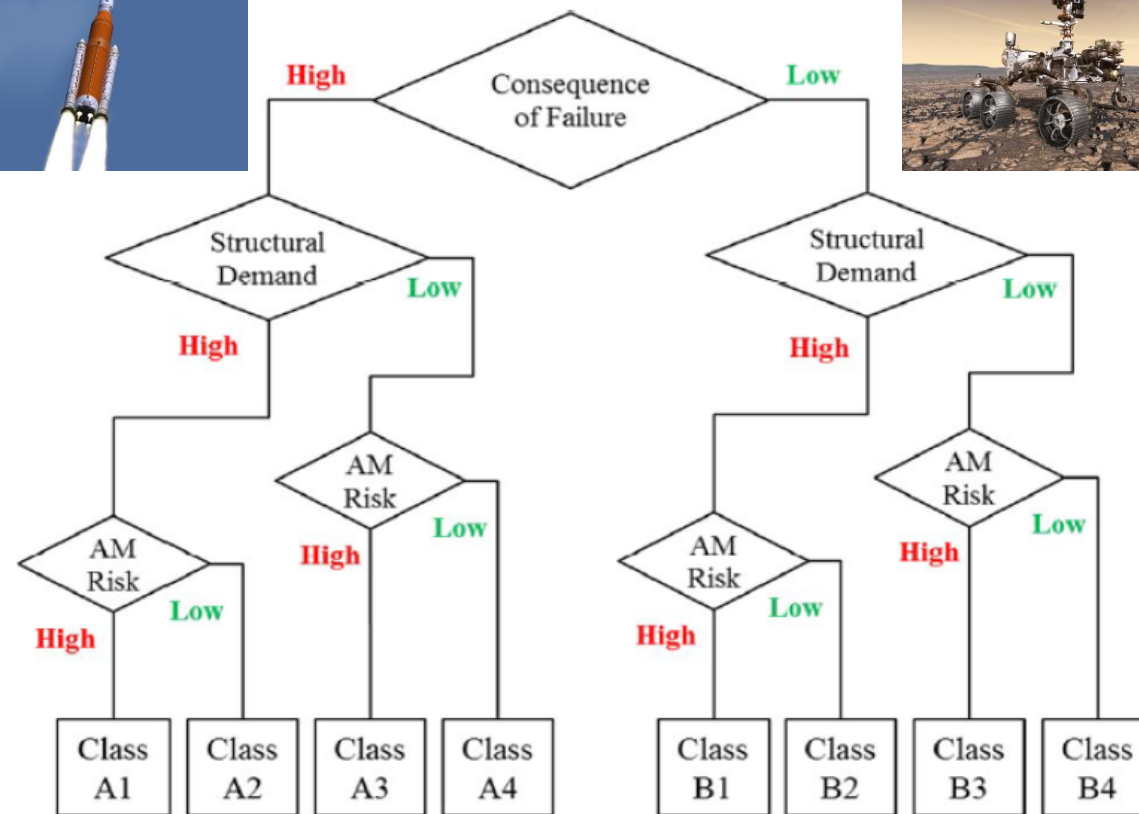
Aircraft Engineering
Safety
Cost
Reliability



Space – NASA Standards

There are currently no NASA standards providing specific design and construction requirements for certification of additively manufactured parts. Several international standards organizations are developing standards for additive manufacturing; however, NASA mission schedules preclude the Agency from relying on these organizations to develop standards that are both timely and applicable.

- The MSFC-STD-3716 classification system was used as the starting point
- This system is risk-based and stems from the three primary questions typically asked when evaluating part risk:
 - Consequence of failure (What happens if the part fails?)
 - Structural demand (How severe is the stress environment?)
 - AM Risk (How challenging is part design and can the part be reliably inspected?)
- Part Classification in 3716 is primarily a communication tool, and does not directly inform most M&P requirements



Future direction of Memko in AM

- AM Multi-Faceted
- Polymer 3D printing tertiary structure interiors
Recently, the 3D printing company Stratasys developed a version of ULTEM 9085 resin specifically tailored for certified aircraft parts, which includes material and process specifications, test plan samples and material properties at safe levels for aircraft interiors.
- Maintenance logistics & response time
- Spares and replacement parts
- Is AM an answer looking for a problem. Where does the application of the technology make sense?

Thank You



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