Composite Tooling

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February 2020

stratasys

AGENDA

Composite Tooling Today
FDM Applications & Solutions
Use Cases


Composite Tooling Today
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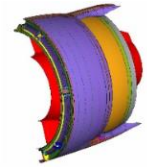
Composite Tooling Today

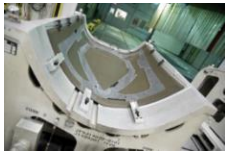
Metal Tooling - ~75% of market

Model



Mold
$300-600K
6-12 months

Machining Fixture
$100-200K
3-4 months



Part Fabrication

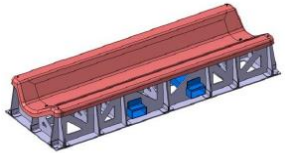
FRP Tooling - ~25% of market

Model

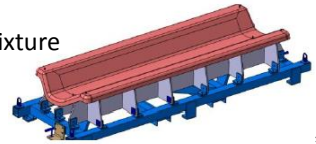
Master
$40-60K
7-8 weeks

Hand Lay-Up + Machining

Mold
$40-60K
9-11 weeks



Machining Fixture
$40-60K
9-11 weeks



Current Pain Points

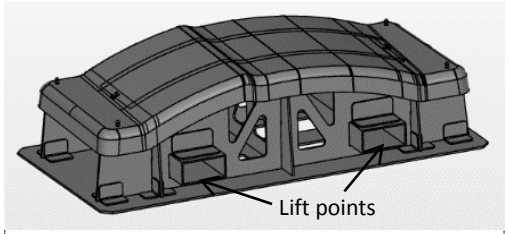
- High costs and long lead times
- High levels of touch labor.
- Costly design changes
- Large, heavy tools – difficult to move and store

Benefits of FDM

- Disruptive time & cost savings
- Reduced lead times enable iteration, change, optimization
- Respond quickly to demand fluctuation
- Tailor the tool to the application vs. one-size-fits-all
- High temperature-capable materials
- Handle tools with people, not cranes and forklifts

Examples – Disruptive Cost Reduction

"Small" Tool Example (~6-ft long):



Existing FRP Tooling
Cost – 30-45K GBP (master & mold)
Lead time – 10-14 weeks

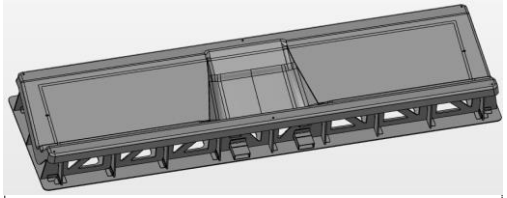
DFAM

FDM Tooling
Cost –2500 GBP
Build time – 40 hours

< 8 kg

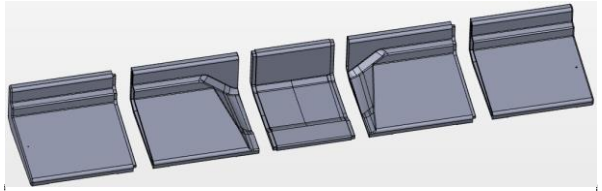
> 75% cost/time reduction

"Large" Tool Example (~15-ft) long):



Existing FRP Tooling
Cost –30-90K GBP (master & mold)
Lead time – 15-20 weeks

DFAM



FDM Tooling
Cost – < 20K GBP
Build time – < 2 weeks

> 60% cost/time reduction

FDM Applications & Solutions

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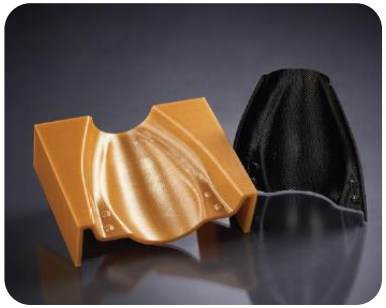
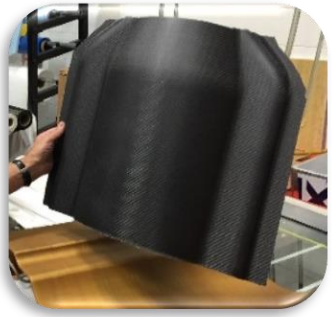
FDM Applications in Composite Tooling

Lay-Up Tooling

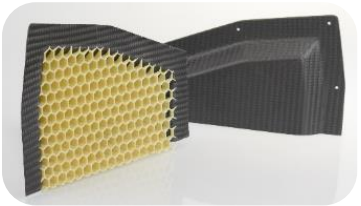


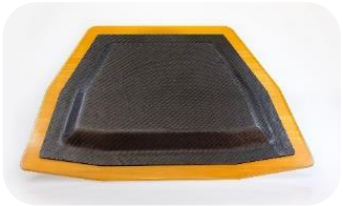


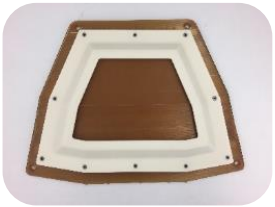
Sacrificial (Wash-Out) Tooling

Large Lay-Up Tooling

Coordinated Tool Family

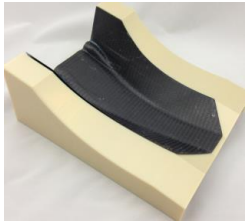


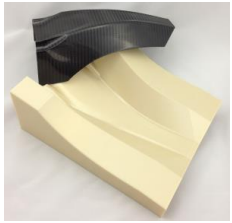


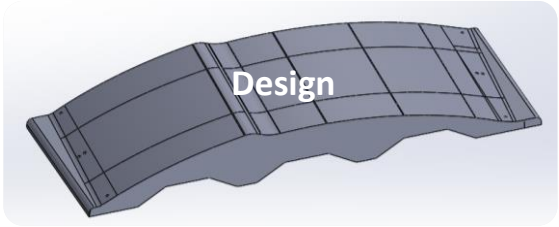


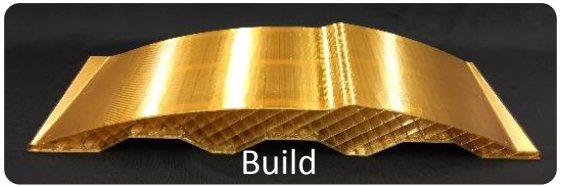
Lay-Up Tooling

- Capable, cost effective lay-up tooling
- Lay-Up Tools, High temp, Autoclave compatible
  - >180°C (350°F), 7 Bar (100 psig)
- Eliminates the need for masters, machining, and assembly
- Iterate, change and modify designs with relative ease









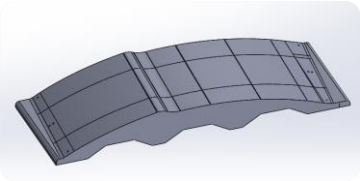
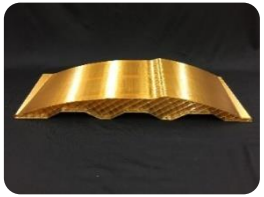
Lay-Up Tooling Considerations

Key Considerations

- Cure temperature (and pressure)
- Coefficient of thermal expansion
- Accuracy / tolerances, design features
- Build orientation / design for additive manufacturing (AM)
- Vacuum bagging, structural integrity
- Surface preparation (tool sealing)

Design Guide

Design → Build

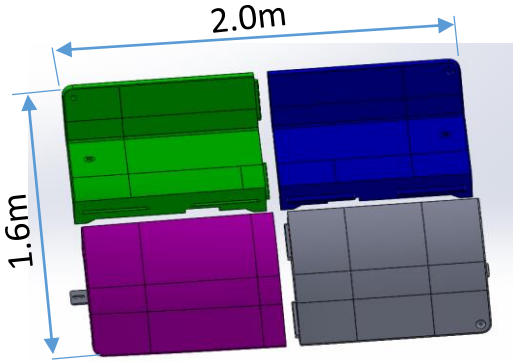



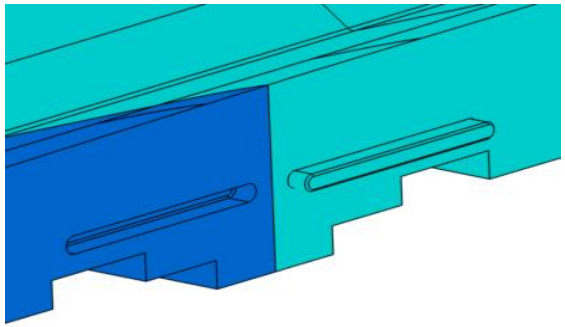
Large Lay-Up Tools

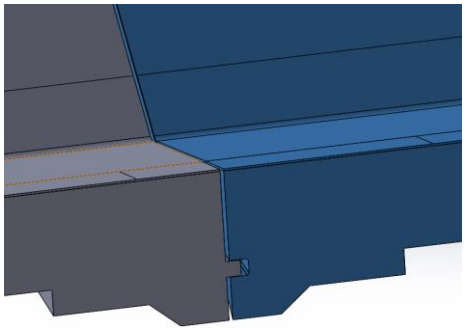
Fortus 900mc Acceleration Kit

- Available for ASA and ULTEM™ 1010
- T40 tip - 0.5mm (0.020”) slice height
- Up to 2X print speed

Enables multi-section large scale lay-up tools

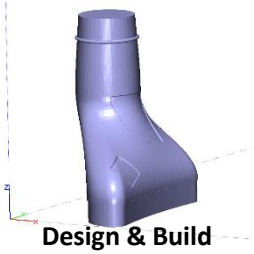






FDM Sacrificial Tooling

- Eliminates complexity of traditional trapped tooling methods
  - No casting, molding, machining…no mess
  - No material phase changes (e.g., eutectic salts)
  - No complex, multi-piece, collapsible tools or inflatable bladders
  - No steep learning curves or extensive prior expertise required
  - Wash-out solutions capable up to **120°C**
  - Break-away solutions capable up to **210°C**
- Tools available in hours, not weeks or months
- Iterate, change and modify designs with relative ease



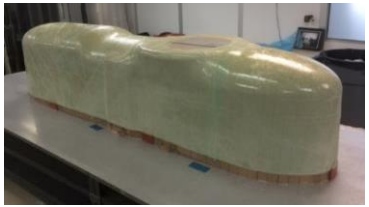
Composite Tooling Segment Definition

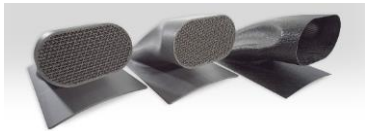
Mid Requirement

Tooling that is critical to creating a composite part that will cure at room or low temperature

Examples

- Low temp lay-up molds
- Washout mandrels for complex shapes



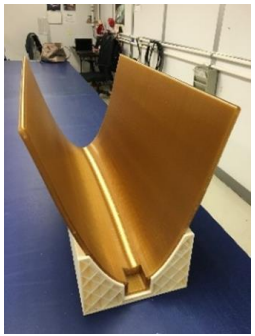


High Requirement

Tooling that needs to withstand the temperatures and pressures of an autoclave cure cycle, demonstrate sufficient tool life and other key mechanical properties

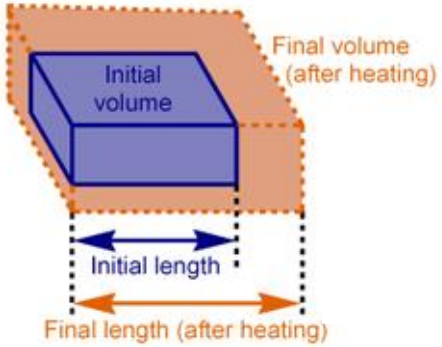
Examples

- Autoclavable hand lay-up molds and AFP mandrels



Coefficient of Thermal Expansion

- Best Practice – account for CTE in the tool design
- Use the relatively high CTE as an advantage
  Ex. increased compaction for a male mandrel with easier tool removal



FDM Materials	µm/(m·C°)	µin/(in·F°)
ST-130 (soluble)	106	59
PC	79	45
ULTEM 9085	65	37
ULTEM 1010	**47**	**26**
Conventional Tooling Materials		
Tooling Boards	36 - 72	20 - 40
AL 6061 alloy	25	14
Tool Steel	11	6
Invar	1.2	0.7

Approximately 2X the CTE of aluminum tooling

Design and Build Considerations

Tolerances

- Fortus 900mc™: ± 0.1 mm or 0.004 mm/mm

Build orientation impacts

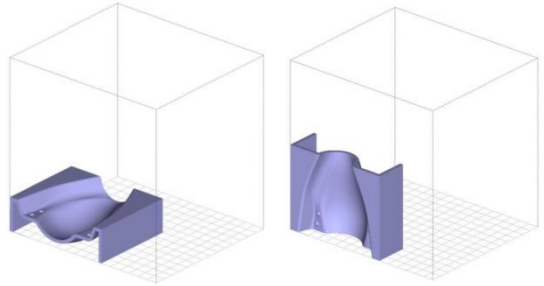
- Surface finish, mechanical properties, build time

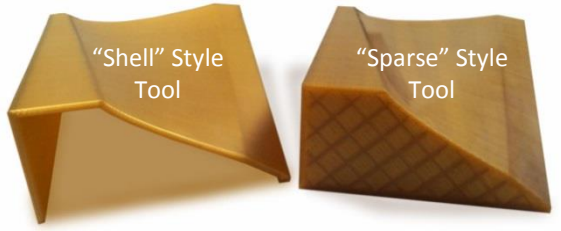
Build style impacts

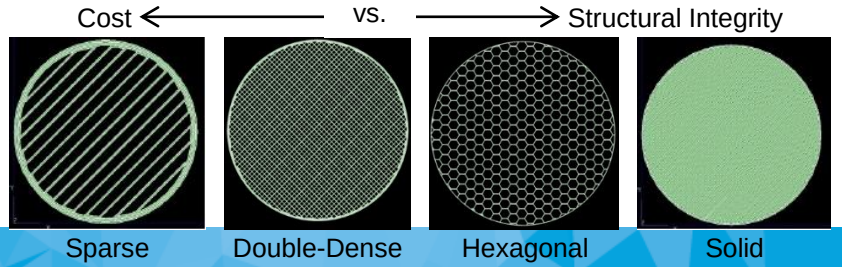
- Material usage, build time, mechanical properties

Design for AM (DFAM)

- Design for cost and function
- Tailor the tool design to the application







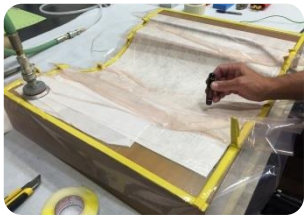
Vacuum Bagging and Structural Integrity

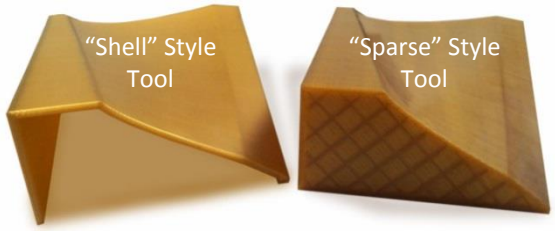
Envelope bag when possible

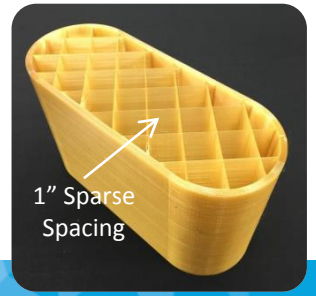
Surface bagging also effective with sealed tools

Tool Construction impacts bagging approach

- “Shell” style tools
  - Works well for both, easily handles 6.8+ bar
- “Sparse” style tools
  - Envelope bagging – must be sized appropriately
  - Surface bagging eliminates crushing concerns (pressure evenly distributed on all sides)







Use Cases

Customer Success Story – Sacrificial Tooling

Automotive performance part manufacturer combines 3D printing and composite tooling to create a winning formula

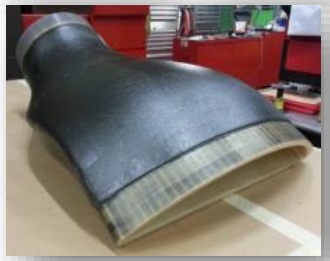
FDM sacrificial tooling allowed for:

- Consolidation of multi-piece tools.
- Design of complex geometry.
- Reduction in production time.
- Reduction in production cost.

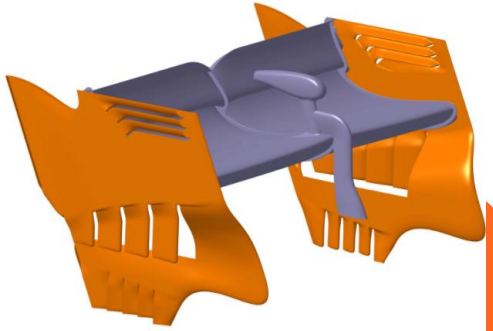
High Temp Sacrificial Tooling Demonstrator

Northrop Grumman inlet duct demonstrator as part of Air Force Research Lab (AFRL) ManTech Program

- Tool printed in ULTEM S1 break-away support material
- 180°C OoA composite (carbon/epoxy) material system
- Cured at 130°C initially / plus 180°C free-standing post-cure
- Tool removed after post-cure
- Tool build time < 8 days
- Reduced lead time to < 2 weeks
- Tool maintained better than ± 0.1 mm accuracy



McLaren Racing - Rear Wing Main plane



Car Concept

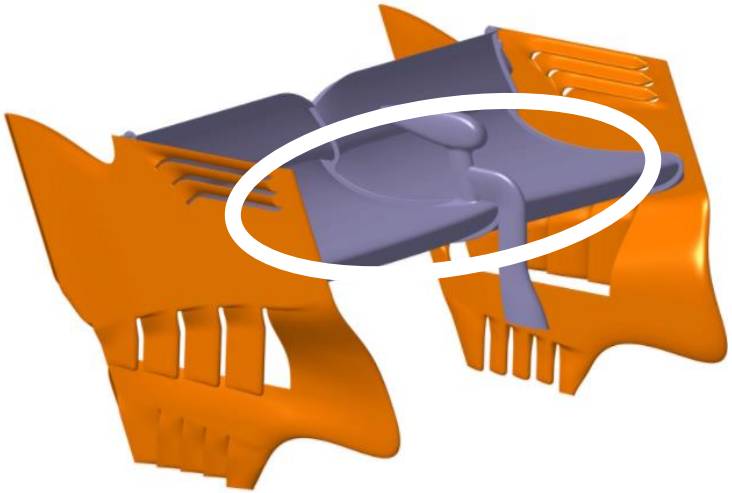
Car Engineering

Car Production

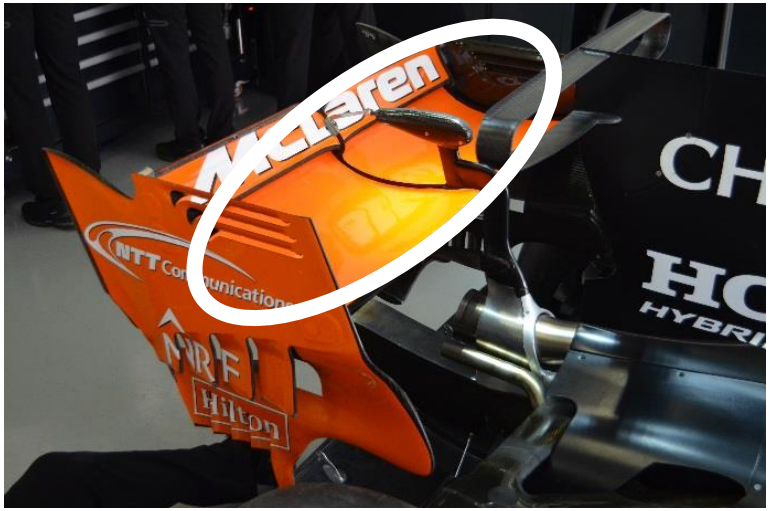
Race Execution

2017 Formula 1 Heineken Chinese Grand Prix

McLaren Racing - Rear Wing Main plane



7 DAYS



WOKING, UK

DESIGN STUDIO

TUESDAY 29th MARCH

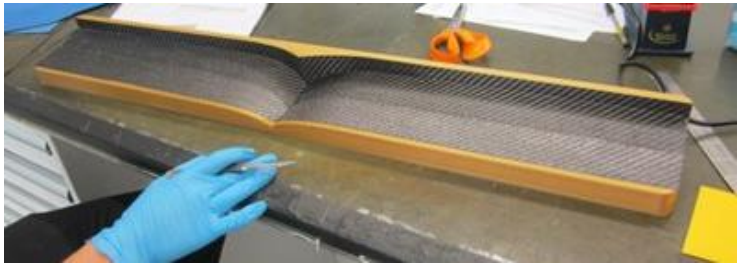
SHANGHAI INTERNATIONAL CIRCUIT, CHINA

TRACKSIDE FOR PRACTICE SESSION 1

WEDNESDAY 5th APRIL

McLaren Racing – DRS Wing Flap

McLaren Racing – DRS Wing Flap

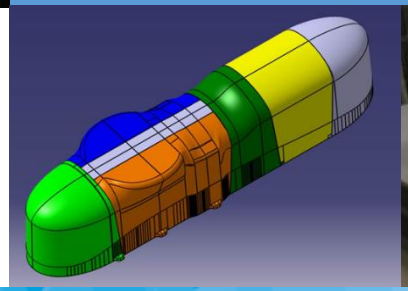


3 DAYS

AFS addressed a critical customer need for a 3 meter composite “belly pod” fairing tool

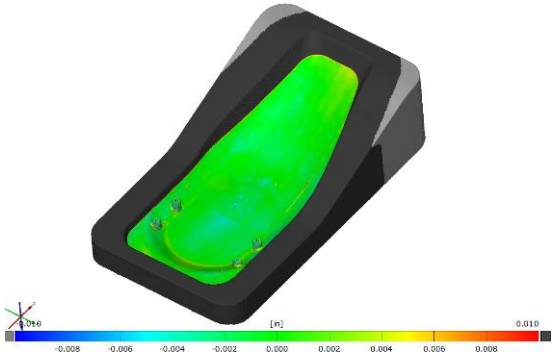
Reduced lead time from 2-3 months to 2 weeks

Featured in June 2015 *Composites World* article



Customer Success Story – HANS

Increasing Safety On The Track.



Large Tooling Projects in Development

DASSAULT FALCON

Aurora FLIGHT SCIENCES

NASA

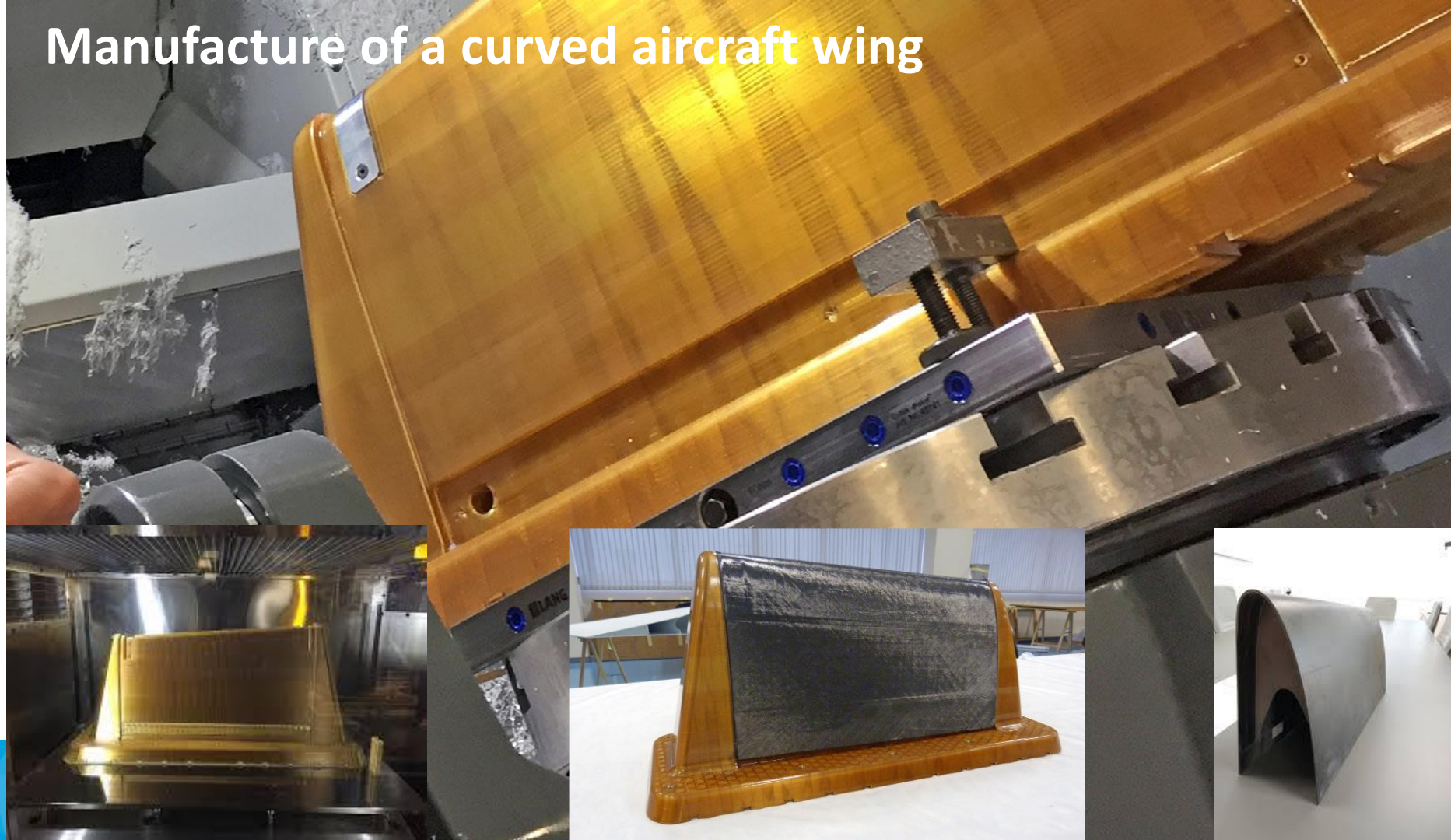
“

Responsive tooling for the most demanding development efforts

Reduced lead time from months to 2 weeks

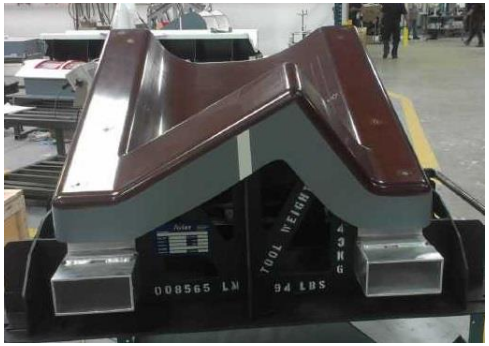
Aurora FLIGHT SCIENCES

Manufacture of a curved aircraft wing

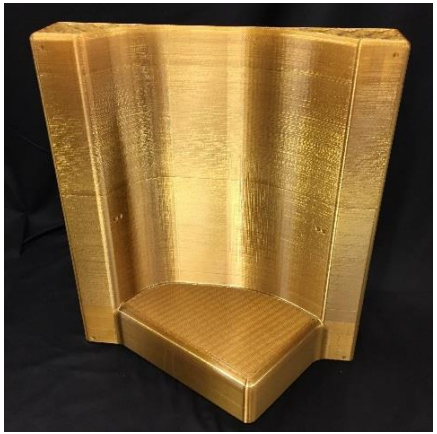


Dassault Falcon Jet Tools

DFAM

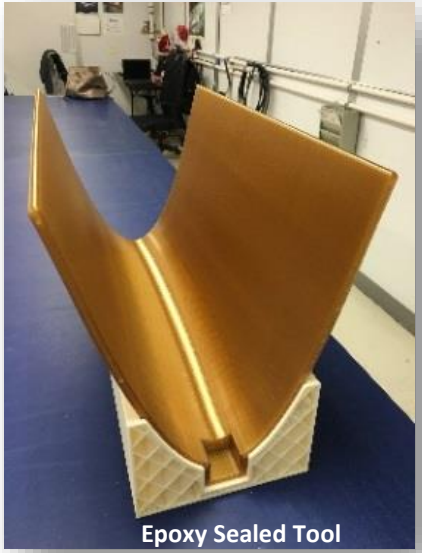


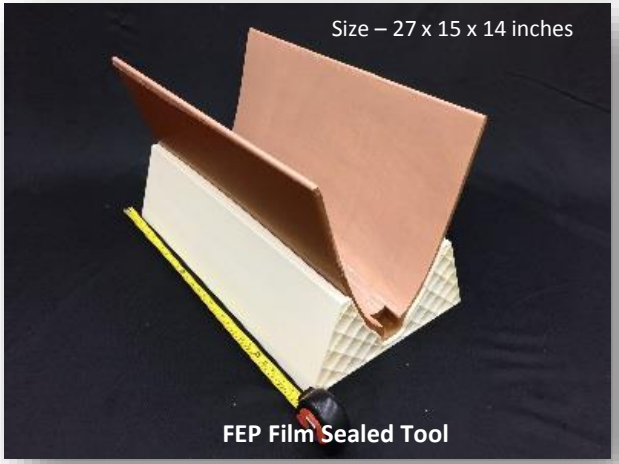
DFAM



Air Force LCAAT UAV Demonstrator

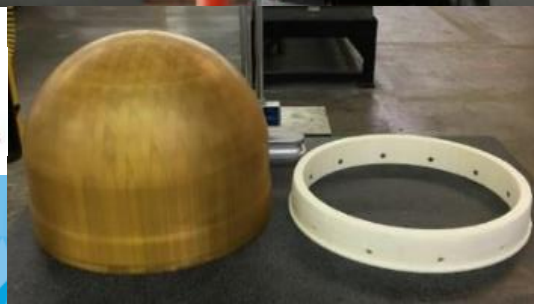
Aurora Flight Sciences / Stratasys leading edge demonstrator as part of the Air Force Research Lab (AFRL) Low-Cost Attritable Aircraft Technology (LCAAT) program





Rock West Composites prints lay-up molds and drill guides for **Honeywell** to meet aggressive schedules

Shortened lead time from 8 weeks to 3 days



Rock West COMPOSITES

Additional Processes

Coordinated Tooling

Coordinated Tools and Parts

- Layup mold defined by solid model
- Net shaped core defined by same
- Trim and drill tool mastered to same model

Lay-up Mold

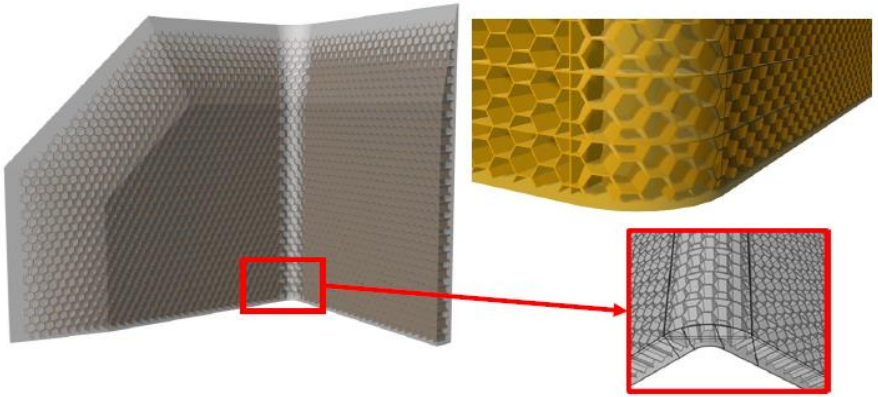
Net Shaped Core

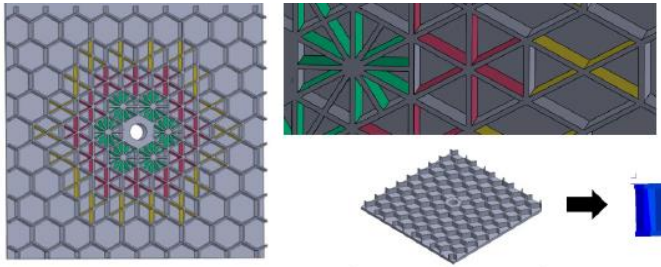
Trim Tool

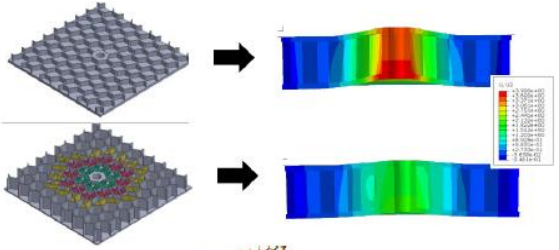
Final Part

HIGH-PERFORMANCE SANDWICH STRUCTURES WITH AM CORES

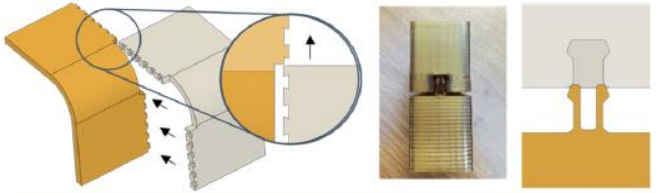
NATIONAL CENTRE ADDITIVE MANUFACTURING



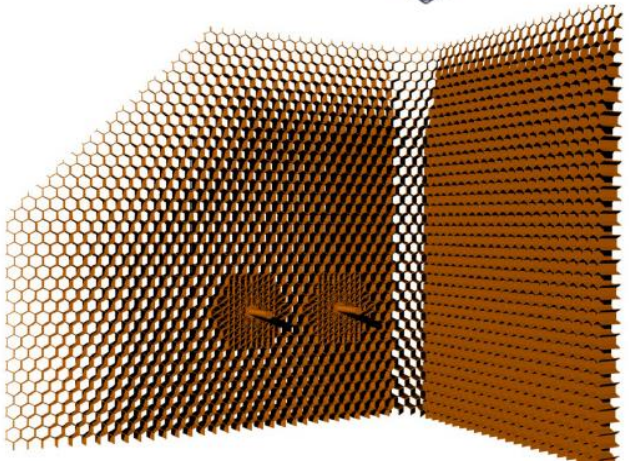




Fastening

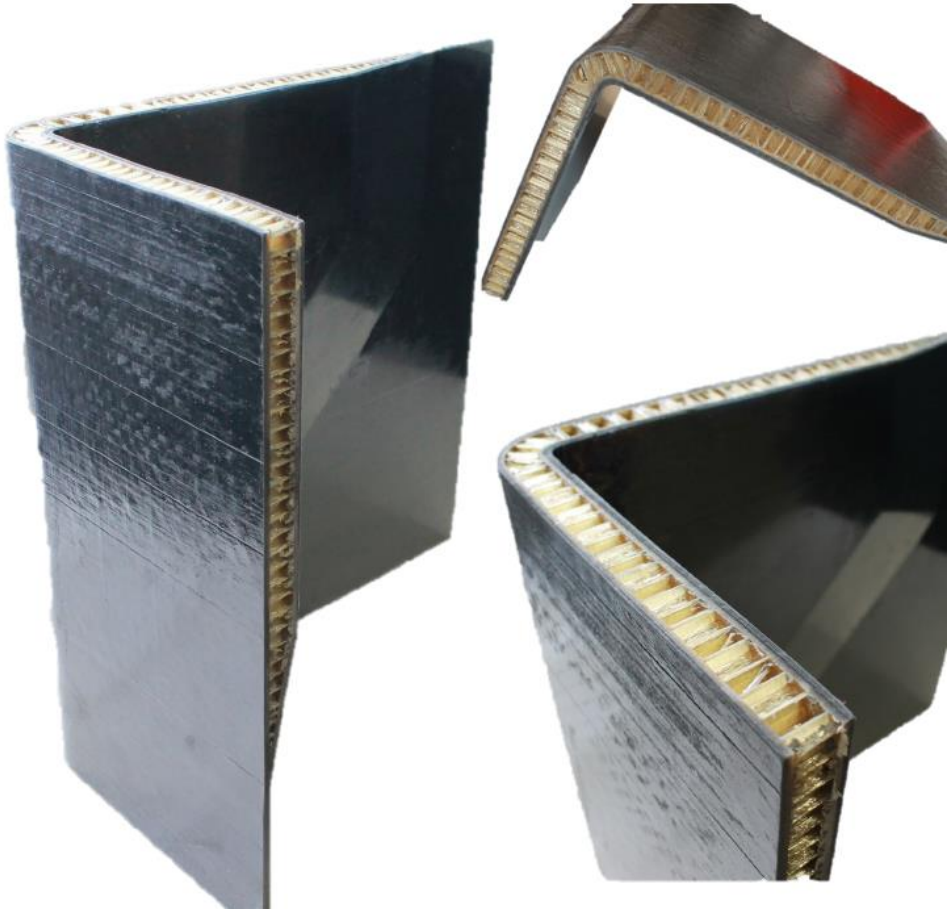


Joining



HIGH-PERFORMANCE SANDWICH STRUCTURES WITH AM CORES

- Bespoke core manufactured eliminating key challenges
- Competitive mechanical properties achieved
- Adhesion challenges solved
- Fasteners and joining concepts investigated

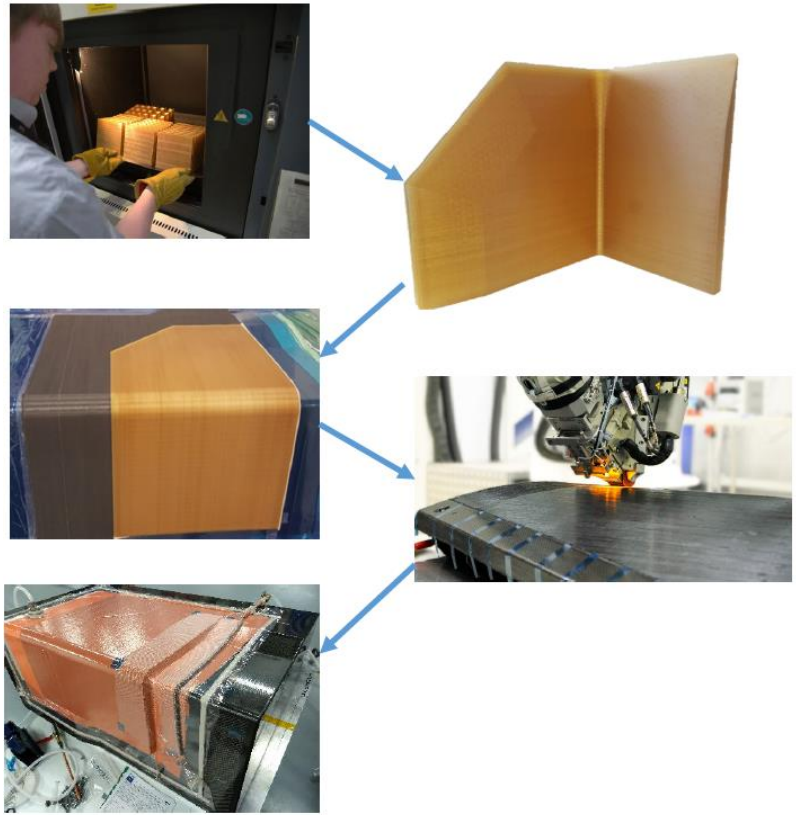


mtc Manufacturing Technology Centre

NATIONAL COMPOSITES CENTRE

Repair of existing tooling

NATIONAL CENTRE ADDITIVE MANUFACTURING



- **ULTEM 1010 (PEI) -> Superior thermal properties of most AM polymers**
- **AFPTX1100 (Solvay) dry fibre carbon**
- **Liquid resin infusion RTM-6 (Hexcel) 180 ℃cure Vacuum-assisted**

FDM Composite Tooling Summary

- Disruptive cost and time savings
- High temperature, autoclave-cure-compatible solutions
- Robust, user-friendly sacrificial tooling solutions
- Highly effective for ancillary tooling – machining, inspection and bonding fixtures, drill jigs, low-temperature masters and more

➢ Comprehensive Design Guides are available to ensure success

THANK YOU

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